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Review article

Effects of home or community-based strength training on muscle, walking, mobility, and balance performances in patients with multiple sclerosis: A systematic review and meta-analysis

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A R T I C L E I N F O

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A B S T R A C T

Introduction: Multiple sclerosis (MS) is a chronic disabling disorder with several features affecting muscle, mobility, gait, and balance performance. Home or community-based strength training (HCBST), alone or combined with other types of training, can be used to improve the aforementioned outcomes of interest. This systematic review and meta-analysis assessed the scientific evidence regarding the effects of HCBST on muscle, walking, mobility, and balance performances in patients with MS.

Methods: The Cochrane library, EMBASE, PEDro, Web of Science, and PubMed databases were searched. Randomized controlled trials were retrieved, and their risk of bias and methodological quality were evaluated using the Cochrane risk-of-bias tool and PEDro scale respectively. Qualitative and quantitative syntheses were used for data analysis.

Results: The results revealed that, in patients with multiple sclerosis, HCBST combined with balance training significantly improved balance performance (standardized mean difference [SMD]= 1.08, $P < 0.0001$), postural sway (mean difference [MD] = −29.40, $P < 0.\ 00001$), physiologic fall risk ($P = 0.02$), physical activity ($P < 0.00001$), psychological impact of MS ($P = 0.01$), and satisfaction with life ($P < 0.0001$) compared with the control condition. Additionally, strength training (ST) alone significantly improved leg strength (SMD = 0.42, 95 % CI:0.01 to 0.84, $P = 0.05$), functional mobility (MD = −8.20, $P = 0.01$), waking speed ($P < 0.00001$), walking ability ($p = 0.01$) and physical fatigue ($P = 0.03$) compared with comparison groups.

Conclusions: In patients with MS, HCBST significantly improves leg strength, walking, mobility and physical fatigue; while HCBST combined with balance training significantly improved walking, balance, fall, physical activity and quality of life.

1. Introduction

Multiple sclerosis (MS) is a chronic neurodegenerative disorder with a variable clinical course, and the key impairments associated with it are a loss of walking ability and balance, which cause a loss of independence and an increase in disease severity and sense of fatigue (Grazioli et al., 2019). Balance problems, fatigue, and muscle weakness lead to the decrease in daily activities in patients with MS (Cakt et al., Jun 2010), whose commonest complaints are fatigue and muscle weakness (Manca et al., 2017). The decreased muscle strength in these patients is associated with resulting functional limitation, which affect balance, gait, movement, and coordination (Cano-Sánchez et al., 2024). Deficits in gait and balance are frequent in patients with MS (Kalron et al., 2017), and abnormal gait or immobility have negative effects on daily activities (DeBolt and McCubbin, 2004).

Functional interventions and exercises development could enhance everyday functioning abilities and cognitive impairment in patients with MS (Ghahfarrokhi et al., 2022). Resistance training signifies an approach for maintaining, preserving, or enhancing skeletal muscular strength and structural features in patients with MS, but the impact of the resistance training on patients' functional ability is not yet clear (Felipe et al., 2018). Lower limb muscle strength, postural control, and core stability influence the functionality of each other (Güngör et al., 2022). Getting an effective exercises that can be safely carried out at home or in a community setting on a long-term basis is a crucial consideration for patient with MS (Rodriques et al., 2016). In particular,

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due to the disabling impacts of MS, rehabilitation strategies with a physiological basis are needed (Dalgas et al., 2009). In that regard, progressive resistance training (PRT) is advantageous as it can easily be performed at home for persons with mobility limitations, and the amount/intensity of resistance applied can be modified all through without difficulty (Akbar et al., 2018).

Implementation of various types of training, e.g., Pilates, yoga, aerobic training, and resistance training, can influence different physiological parameters (Andreu-Caravaca et al., 2022). Emerging evidence indicates the possibility of improving endurance, gait speed, and balance with functional exercises that involve the performance of function-based activities such as sit-to-stand (Williams et al., 2021). It is probable that extended interventions with more training intensities will have more reliable impact on functional capacity (Kjølhede et al., 2015). However, the advantage of strengthening exercises on functional ability is required to be established (Romberg et al., 2004). Because the execution of daily activities can be affected by muscle weakness in patients with MS, and increase in muscle strength due to PRT may cause further permanent changes in daily physical activities, and consequently may lead to preservation of strength and other useful outcomes without the need to continue training (Dodd et al., 2011).

There is an urgent need to synthesize scientific evidence regarding the effects of home or community-based strength training on the functional abilities of patients with MS. Such evidence might guide the recommendation of practicable, accessible, cost-effective, and unsupervised strength training strategies to promote the recovery of functional independence in patients with MS. To the best of our information, no systematic review and meta-analysis has been conducted on the effects of home or community-based strength training on muscle, walking, mobility, and balance outcomes. Thus, the objective of this systematic review and meta-analysis was to assess the available scientific evidence on the effects of home or community-based strength training on muscle, walking, mobility, and balance performances in patients with MS.

2. Methods

The PROSPERO has this review registered (registration number: CRD42024576595); and was carried out using the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines (Fig. 1). The PICOS method was used to construct the following research question: What are the effects of home or community-based strength training (I = intervention) on muscle, walking, mobility, and balance performances (O = outcome) in patients with MS (P = population) when compared with other exercises, standard/regular care, usual/routine care, or no intervention (C = comparison) in randomized clinical trials (RCTs) (S = study design)?

2.1. Data sources and search method

The Cochrane library, EMBASE, PEDro, Web of Science, and PubMed databases were searched for relevant studies from inception. The PICOS technique was used to formulate the search strategy for the databases. The search of each database was conducted in line with its specifications. Details of the search strategy are provided in Supplementary Material 1. Additionally, a general literature search and a manual search of the reference lists of the retrieved studies and reviews were performed. The relevant studies were exported to a reference manager, duplicates were expunged, and the articles left were screened further. The search was performed independently by an author (JSU) and verified by the other two authors (TWLW and SSMN).

2.2. Criteria for selection

The review included Studies that fulfilled the following inclusion

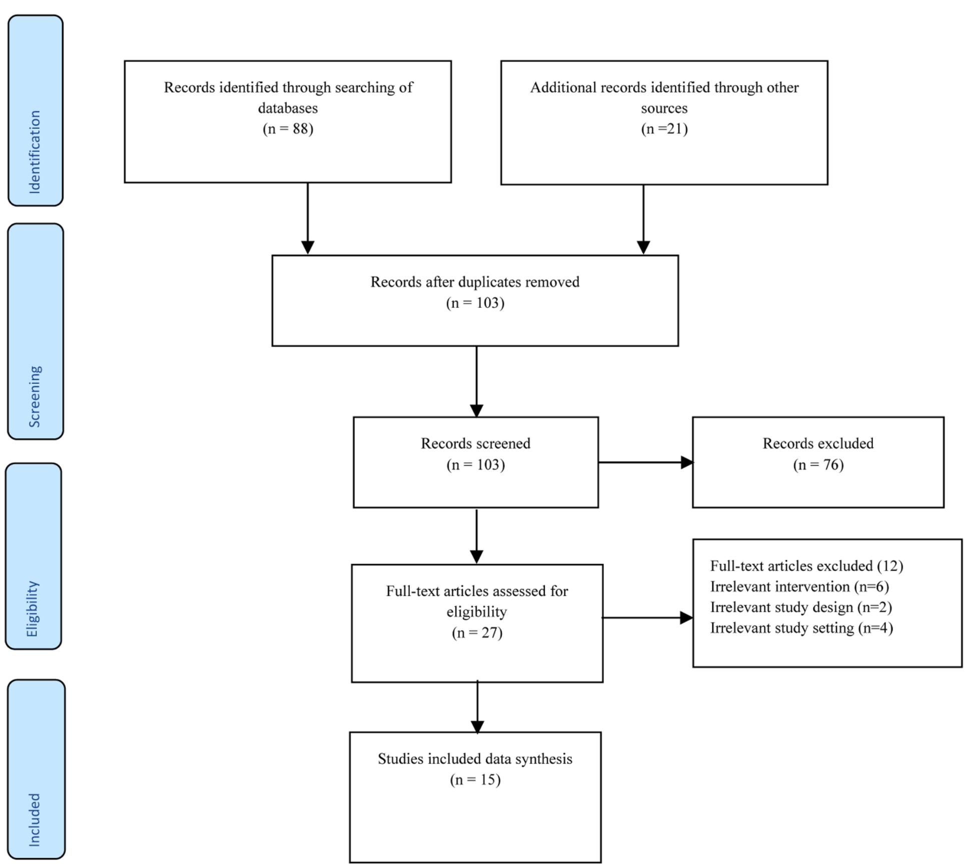

Fig. 1. PRISMA flowchart of the review process.

criteria: studies (i) that reported the effects of home or community-based or non-hospital-based lower-limb strength training alone or in combination with lower extremity balance, aerobic, gait or mobility training; (ii) that had a parallel or cross-over RCT design with full-text available; and (iii) that involved patients with MS and published in peer-reviewed journals in English. Conference abstracts, theses, and review studies were not included.

2.3. Study selection and extraction of data

Subsequent to the removal of duplicates, the titles and abstracts of the rest of the studies were screened independently by two authors (JSU and TWLW) using the criteria for selection. By involving the third author (SSMN), all differences between the two authors about the eligibility of a study were addressed. Subsequently, the full-texts of qualified studies were saved, and the following information were extracted from each study: Author and year of publication, study design and main exercise (s) involved, sample size, sex, ambulatory status, age and duration of MS, disability level/status of MS, intervention groups, nature of intervention setting/location, exercise protocols, outcomes and assessment periods, and the findings and conclusions. The extracted data and the characteristics of the studies were documented in a Microsoft Excel sheet.

2.4. Evaluation of methodological quality and risk of bias

The methodological qualities (MQ) of the included studies were judged using the PEDro scale. This scale is consists of 11-items (Maher et al., 2003) that assess the statistical reporting and internal validity of the studies, except the first item, that has to with the eligibility criteria and is not used in computing the overall score (Paci et al., 2022). The 10 items for Internal validity have a score of either 1 or 0, representing Yes (present) or No (absent), respectively (Paci et al., 2022). The total score attained is used to classify MQ as poor (0–3), fair (4–5), good (6–8), and excellent (9–10) (Foley et al., 2003; Gonzalez et al., 2018).

The risk of bias (ROB) of the relevant studies was determined with the Cochrane ROB tool (Fig. 2a and b). This tool assesses the ROB of items in the following domains: reporting bias, performance bias, other bias, selection bias, detection bias, and attrition bias (Higgins et al., 2011). The ROB level for each domain is rated as unclear, high, or low. For each study, an overall score is calculated using the total scores of all domains. The ROB determination was independently performed by two authors (JSU and TWLW). All differences were addressed by communicating with the third author (SSMN).

2.5. Analysis of the data

The extracted data were analyzed using qualitative and quantitative syntheses. In the qualitative synthesis, the MQ, ROB, and characteristics of the relevant studies were summarized and described. A random-effects meta-analysis was used in the quantitative synthesis using mean and standard deviation values. The mean and standard deviation values were also used to calculate the effect size for outcomes for which meta-analyses were not possible, for example, because they were reported by fewer than two studies. The degree of evidence certainty was evaluated using the Cochrane GRADE criteria.

3. Results

3.1. Qualitative synthesis of the results

All of the data extracted from the included studies were subjected to a qualitative synthesis.

3.2. Selection of relevant studies

In total, 109 relevant articles were found through databases and other sources searches. After removing duplicates (six studies), 103 articles remained. A screening of titles and abstracts resulted in the removal of 76 studies as they did not fulfil the criteria for selection. The full-texts of the final 27 studies were accessed and reviewed according to the criteria for selection. Twelve studies were excluded for not meeting

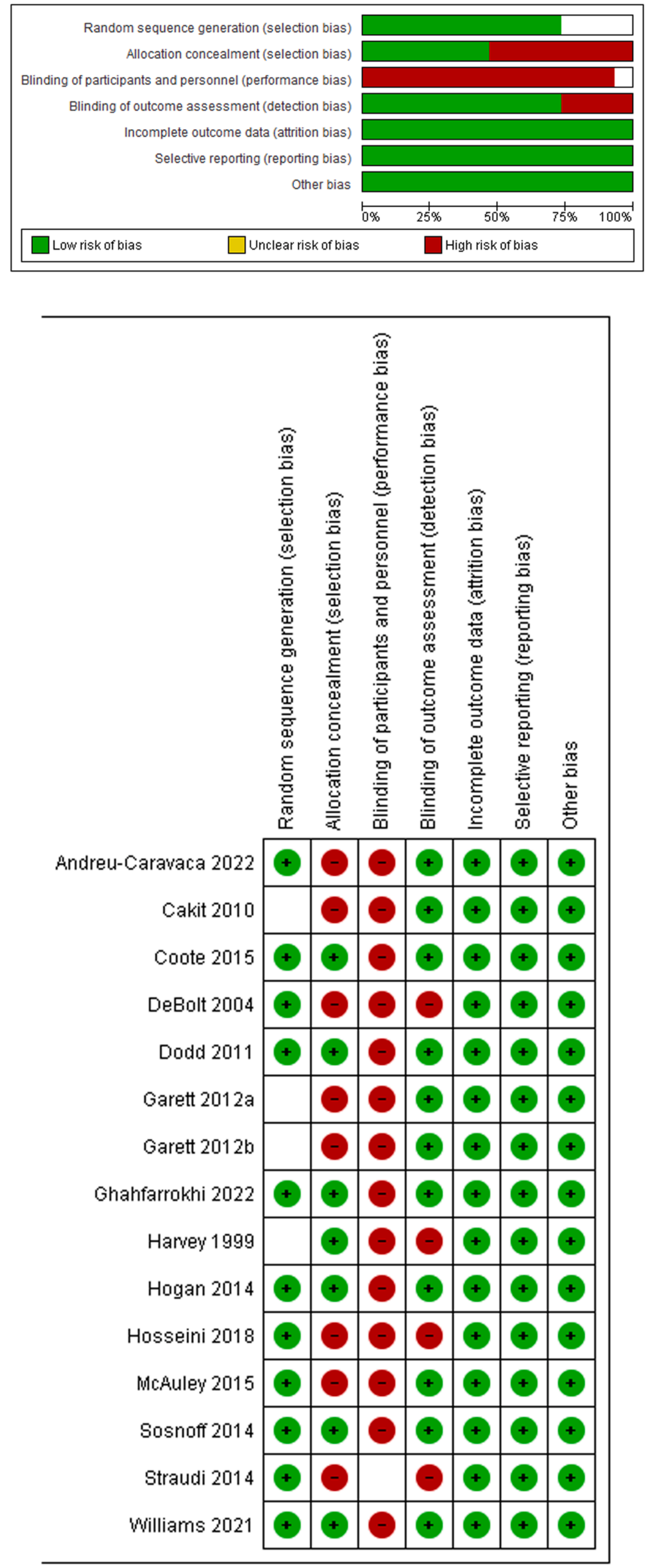

Fig. 2. a. Risk of bias in the included studies. b. Risk of bias summary for the included studies.

the criteria for selection (Supplementary Material 2). Fifteen eligible studies were found and included in the final review. Each study that was included was a parallel design RCT. The selection of studies in conformity with the PRISMA guidelines is shown in Fig. 1.

3.3. Methodological quality of the relevant studies

Out of the 15 studies, eleven had good MQ and four had fair MQ. In terms of the PEDro scale domains, all of the included studies specified the eligibility criteria, used random allocation, had groups that were similar at baseline in terms of important prognostic indicators, reported between-group comparisons for outcomes, and reported point measures and measures of variability for key outcomes. Nearly half of the studies reported allocation concealment, and had all participants whose outcome measures were available received intervention as allocated. In most of the studies, there was measurement of key outcomes in the majority of participants initially allocated to the groups. All but one study lacked experimenter blinding, and all but four studies reported outcome assessor blinding. No study reported blinding of participants. Table 1 contains the methodological details of the included studies.

3.4. Risk of bias in the relevant studies

All of the included studies had a low ROB in the domains of reporting, attrition, and other biases, and all except four studies (high risk) had a low ROB in the domain of detection bias. Seven studies had a low ROB and eight had a high ROB in the domain of selection bias (allocation concealment). All but four studies (unclear ROB) had a low ROB in the domain of selection bias (random sequence generation). All but one study (unclear ROB) had a high ROB in performance bias. Fig. 2a and b contained the ROB details of the relevant studies.

3.5. Characteristics of the studies included

The included studies involved a total of 1013 participants, 374 of whom were males. The mean ages of the participants ranged from 32.4 to 60.07 years. The mean duration of MS ranged from 7.3 to 15.8 years. The types of exercise used in the studies were strengthening exercises/ resistance trainings (DeBolt and McCubbin, 2004; Ghahfarrokhi et al., 2022; Andreu-Caravaca et al., 2022; Dodd et al., 2011; Coote et al., 2015; Harvey et al., 1999; Hosseini et al., 2018), strength training combined with balance exercise (Cakt et al., Jun 2010; Williams et al., 2021; Hogan et al., 2014; Sosnoff et al., 2014; McAuley et al., Jan-Dec 2015), strength training combined with gait training (Straudi et al., 2014), and resistance training combined with aerobic exercise (M Garrett et al., May 2013; M Garrett et al., May 2013). Phone calls were used to monitor the exercises in nine of the studies (Cakt et al., Jun 2010; DeBolt and McCubbin, 2004; Ghahfarrokhi et al., 2022; Williams et al., 2021; Coote et al., 2015; Harvey et al., 1999; Hosseini et al., 2018; McAuley et al., Jan-Dec 2015; Straudi et al., 2014), physical monitoring was used in eight studies (DeBolt and McCubbin, 2004; Ghahfarrokhi et al., 2022; Williams et al., 2021; Dodd et al., 2011; Hogan et al., 2014; Sosnoff et al., 2014; M Garrett et al., May 2013; M Garrett et al., May 2013); diary was used in three studies (Andreu-Caravaca et al., 2022; Sosnoff et al., 2014; Straudi et al., 2014), and one study each used daily checklist (Hosseini et al., 2018) and exercise log send by mail (McAuley et al., Jan-Dec 2015). All studies used a parallel RCT design. In nearly all the studies, majority of the participants suffered from relapsing-remitting MS. Five studies included participants who can walk independently (Cakt et al., Jun 2010; Ghahfarrokhi et al., 2022; Andreu-Caravaca et al., 2022; Hosseini et al., 2018; Straudi et al., 2014), seven involved participants who can walk with or without aid (DeBolt and McCubbin, 2004; Williams et al., 2021; Harvey et al., 1999; Sosnoff et al., 2014; McAuley et al., Jan-Dec 2015; M Garrett et al., May 2013; M Garrett et al., May 2013), one included those with mild to moderate walking disabilities (Dodd et al., 2011) and two involved those who can walk but require more support for gait (Coote et al., 2015; Hogan et al., 2014). About the disability level/MS status, majority of the studies involved participants with mild to moderate MS. Home-based exercise was used in ten studies (Cakt et al., Jun 2010; DeBolt and McCubbin, 2004; Ghahfarrokhi et al., 2022; Williams et al., 2021; Coote et al., 2015; Harvey et al., 1999; Hosseini et al., 2018; Sosnoff et al., 2014; McAuley et al., Jan-Dec 2015; Straudi et al., 2014) and community-based exercise was used in six studies (Andreu-Caravaca et al., 2022; Williams et al., 2021; Dodd et al., 2011; Hogan et al., 2014; M Garrett et al., May 2013; M Garrett et al., May 2013). Regarding outcome assessments, all the included studies conducted outcome measurements at pre- and post-intervention, and three studies also included follow up assessments. Table 2 contains the characteristics of the included studies.

Table 1
Methodological quality of the included studies according PEdro criteria.

Study/Author (year)	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9	Item 10	Item 11	Total Score	Overall quality assessment
Andreu-Caravaca (2022)	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes	7	Good quality
Cakit (2010)	Yes	Yes	No	Yes	No	No	Yes	No	No	Yes	Yes	5	Fair quality
Coote (2015)	Yes	Yes	Yes	Yes	No	No	Yes	No	No	Yes	Yes	6	Good quality
Debolt (2004)	Yes	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes	5	Fair quality
Dodd (2011)	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	8	Good quality
Garrett (2012a)	Yes	Yes	No	Yes	No	No	Yes	No	No	Yes	Yes	5	Fair quality
Garrett (2012b)	Yes	Yes	No	Yes	No	No	Yes	No	No	Yes	Yes	5	Fair quality
Ghahfarrokhi (2022)	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	8	Good quality
Harvey (1999)	Yes	Yes	Yes	Yes	No	No	No	Yes	No	Yes	Yes	6	Good quality
Hogan (2014)	Yes	Yes	Yes	Yes	No	No	Yes	No	No	Yes	Yes	6	Good quality
Hosseini (2018)	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	6	Good quality
McAuley (2015)	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes	7	Good quality
Sosnoff (2014)	Yes	Yes	Yes	Yes	No	No	Yes	No	No	Yes	Yes	6	Good quality
Straudi (2014)	Yes	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	7	Good quality
Willaims (2021)	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	8	Good quality

Item 1: eligibility criteria specified; **Item 2**: subjects were randomly allocated to groups(in a crossover study, subjects were randomly allocated an order in which treatments were received); **Item 3**: Allocation was concealed; **Item 4**: the groups were similar at baseline regarding the most important prognostic indicators; **Item 5**: there was blinding of all subjects; **Item 6**: there was blinding of all therapists who administered the therapy; **Item 7**: there was blinding of all assessors who measured at least one key outcome; **Item 8**: Measures of at least one key outcome were obtained from more than 85 % of the subjects initially allocated to groups; **Item 9**: all subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analyzed by "intention to treat"; **Item 10**: the results of between-group statistical comparisons are reported for at least one key outcome; **Item 11**: The study provides both point measures and measures of variability for at least one key outcome.

Table 2
Characteristics of included studies.

Author (Year)	Design Main exercise (s) involved	N(Sex) MS type Ambulatory status of participants	Age (Years) Duration of MS/Time since diagnosis (Y) Disability level/MS status	Intervention(s)/ Groups/type Nature of Intervention setting/location Exercise monitoring	Exercise protocols	Outcomes Assessment Period	Findings	Conclusion
Andreu-Caravaca (2022)	RCT-P Resistance training	30 (15 M, 15F) RR: 27; SP: 3 Participants can walk independently for > 100 m	46.21±10.43 NR *Av.* EDSS score: 3.22 Mild to Moderate MS	EG: Lower-limb Fast-velocity concentric resistance training (FVCRT) CG: No intervention Sport Centre Diary was used to monitor the exercise	10 weeks of home-based lower-limb FVCRT, three times per week on alternate days Control group: Participants did not perform any intervention	Strength, mobility, quality of life (QOL) Pre training; and post training.	10 weeks of FVCRT can be efficient in improving early RFD and mobility in patient with MS. Also, QOL increased following finishing the training program.	The 10-week FVCRT has possibility of improving early RFD and mobility. Also, FVCRT offers advantage to self-perceived QOL in patients with MS.
Cakit (2010)	RCT-P Strengthening and balance exercise	33 10 M, 23F RR or SP Participants can walk	G1: 36.4 ± 10.5 G2: 43.0 ± 10.2 G3: 35.5 ± 10.9 G1: 9.2 ± 5.0 G2: 6.2 ± 2.2 G3: 6.6 ± 2.4 EDSS score: ≤ 6 Mild to Moderate MS	G1: Progressive resistance training (PRT) on a bicycle ergometer and balance exercise G2: Home-based lower-limb strengthening and balance exercise G3: Control group Home-based Monitoring of exercises via twice a month phone calls	G1: PRT on a static bicycle ergometer two times a week on non-consecutive days during the 2-month periods. G2: Received home-based exercise with goal of enhancing LE muscle strength and balance, the same exercises received as GI excluding the cycling PRT. G3: No exercises, instead, participants were instructed to continue with their normal living	Dynamic balance/mobility, gait, static balance, fear of falling, walking speed, fatigue, depression and quality of life. Initially; and at 8 weeks	Combined cycling PRT and balance exercise have positive effects on walking speed, balance, FOF, fatigue and depression. Even though less effective than exercises in group 1, it impacts positively on DE, TMW, FOF, and physical functioning scale of SF-36.	The result revealed specific exercise program, including cycling PRT, can enhance balance, fatigue, and depression, and decrease FOF in patients with MS.
Coote (2015)	RCT-P Progressive resistance training	25 8 M, 17F RR: 12; PP: 7; SP: 3; BN: 1; UK:2 Participants used walking aid mostly and can walk at least 10 m unaided.	PRT: 51.8 ± 12.1 PRT + NMES: 51.8 ± 12.6 PRT: 12.2 ± 4 PRT + NMES: 11.8 ± 5.5 Significant disability	PRT: Progressive resistance training consisting of 6 home-based lower-limb exercises PRT and NMES: PRT and neuromuscular electrical stimulation (using kneehab device) Home-based Weekly phone calls to monitor the exercises.	PRT: 12-week PRT two times a week for the first 6 weeks, and 3 times a week from week 7 to 12. PRT and NMES: Same program augmented by NMES	Strength, quadriceps muscle endurance, lower limb spasticity, mobility, walking ability, balance, participation/ impact of MS, and fatigue. Baseline; and post intervention	The NMES group significantly enhanced quadriceps endurance, balance, physical impact of MS, and impact of fatigue. Only change in MFIS score was significantly larger in the NMES group compared with the PRT group.	Home PRT program with NMES is feasible, and only decrease in fatigue impact was larger in the NMES compared with the PRT group.
DeBolt (2004)	RCT-P Resistance training	37 8 M, 29F RR: 17; P: 3; CP: 15; BN: 2 Participants have ability to walk with or without assistive devices at least 20 m with no rest.	50.7 14.10 *Av.* EDSS score: 3.99	EG: Home-based resistance training (lower extremity resistance training), focused on functional activities and increase strength and power in the lower-limbs. CG: Control group Home-based	EG: The exercise instructional sessions were for 3 sessions a week, on alternate days, for two weeks. The 8-week resistance training started after the instructional phase. Participants carried out 5 to 10	Balance, postural sway (AP and ML sway), and sway velocity, leg power (using leg extensor power rig), functional mobility (using TUG)	The home-based resistance exercise significantly improved leg extensor power, but mobility and balance did not change.	Participant found the home-based resistance training to be well tolerated, and it provided a practical way to rapidly improve leg extensor power.

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Table 2 (*continued*)

Author (Year)	Design Main exercise (s) involved	N(Sex) MS type Ambulatory status of participants	Age (Years) Duration of MS/Time since diagnosis (Y) Disability level/MS status	Intervention(s)/ Groups/type Nature of Intervention setting/location Exercise monitoring	Exercise protocols	Outcomes Assessment Period	Findings	Conclusion
				Bimonthly home visits and weekly phone contact to monitor the exercises.	min of warm up, 25–30 min of strengthening exercises (walking) and stretches, and 5 to 10 min of whole-body stretching, 3 times a week. CG: After the 2-week instructional phase 3 times per week for around an hour. Participants were given the home exercise video at the start of training or at post testing.			
Dodd (2011)	RCT-P Progressive resistance training	71 19 M,52F RR: 71 Mild to Moderate walking disabilities.	EG: 47.7 ± 10.8 CG: 50.4 ± 9.6 Mild to Moderate walking disabilities	EG (PRT): Progressive resistance strength training group CG: Usual care and Education and low activity program Community based (Community gymnasium) Exercises were physically monitored/ supervised by PTs and personal sports trainers.	PRT: 10-week, twice per week PRT program targeting the key lower-limb muscles for supporting weight of the body and for generating and absorbing power while walking. CG: 10 weeks of usual care/ habitual exercise and education and low activity program/ attention and social program.	Walking performance (walking speed and walking endurance), muscle performance (leg press), fatigue and QOL. Baseline, end of intervention, and follow up	Compared with comparison group, PRT showed increased: leg press strength, reverse leg press strength, muscular endurance of the reverse leg press, also there was improved physical fatigue, and physical health domain of QOL in favor of PRT. PRT did not improve walking performance.	PRT is comparatively safe intervention that could have short-term effects on decreasing physical fatigue, increasing muscle endurance, and could result to slight enhancements in muscle strength and QOL in patients with relapsing-remitting MS.
Garrett (2012a)	RCT-P Resistance exercise/ progressive resistance training and aerobic exercise	242 67 M, 175F RR: 135 PP: 25 SP: 34 BN:07 UK:41 Many participants had unaffected gait or were unsteady but does not use aid. Some uses at most unilateral aid outdoors.	50.05 10.4	PT-led exercise group Yoga group FI-led exercise group Control group Community based/setting (group classes) Supervision/ monitoring by PTs, FIs and YIs	PT-led exercise group: comprised of a circuit style form of exercise resisted by body weight or through adding free weights. FI-led exercise group: Comprised of a combined progressive resistance and aerobic exercise Yoga group: Started with relaxation/ centering and then followed by a combined "joint freeing series" of range of motion and stretching exercises, and weight bearing postures. Control group:	Fatigue, physical and psychological impacts of MS, and walking endurance Baseline, end of intervention, and follow up	The MFIS improved significantly from week 1 to week 12. PT-led and FI-led groups improved after intervention, and then dis-improved at follow-up stage. Yoga group deteriorated over the treatment phase and improved during follow-up.	Although the findings recommends that the useful effects of exercise on the physical impact of MS are not preserved three months post intervention, the ↓in the psychological impact of MS and the ↓in the impact of fatigue remained improved significantly from baseline.

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Table 2 (*continued*)

Author (Year)	Design Main exercise (s) involved	N(Sex) MS type Ambulatory status of participants	Age (Years) Duration of MS/Time since diagnosis (Y) Disability level/MS status	Intervention(s)/ Groups/type Nature of Intervention setting/location Exercise monitoring	Exercise protocols	Outcomes Assessment Period	Findings	Conclusion
					They were instructed not to change their exercise habits.			
Garrett (2012b)	RCT-P Resistance exercise/ progressive resistance training and aerobic exercise	242 60 M, 182F RR: 133 PP: 25 SP: 39 BN:05 UK:40 Many participants had unaffected gait or were unsteady but does not use aid. Some uses at most unilateral aid outdoors.	50.1 10.625	PT-led exercise group Yoga group FI-led exercise group Control group Community based/setting (group classes) Supervision/ monitoring by PTs, FIs and YIs	PT-led exercise group: comprised of a circuit style form of exercise that were resisted by body weight or by adding free weights. FI-led exercise group: Consisted of a combined progressive resistance and aerobic exercise Yoga group: Began with breathing exercises, relaxation or body centering and were followed by joint freeing series, range of motion exercises or stretching exercises, and weight bearing poses. Control group: They were instructed not to change their exercise habits.	Fatigue, physical and cognitive components of fatigue, physical and psychological impacts of MS, and walking endurance Pre, and post intervention	The MSIS-29 physical component statistically significant improvement in all three of the exercise interventions groups over time. All three exercise interventions caused a significant improvement on the MSIS-29 psychological component and both the MFIS total and physical subscales better than control. Only PT-led and FI-led interventions cause significant improvement in MSIS-29 physical and 6MWT better than the control.	All three exercise groups caused significant positive effects in the MSIS-29v2 psychological component, MFIS total and physical subscale. PT-led and FI-led had positive effects on the MSIS-29 physical aspect and 6MWT.
Ghahfarrokhi (2022)	RCT-P Resistance training	30 25 M,5F RR: 30 Participants can be able to walk for not <100 m without continuous aid needed.	38.85 ± 8.76 9.07 ± 5.81 EDSS score: < 6	Home-based resistance training (HBRT) Home-based neuro-functional training (HBNFT) Home-based For the HBRT, there was monitoring via phone calls and WhatsApp video calls, instructors supervised 1 week resistance training at home. HBNFT was supervised by instructors and sports center and exercise physiologist at home	In both HBRT and HBNFT, exercise was performed at home 3 times per week for 8 weeks.	Gait speed, walking endurance, walking ability, functional mobility, balance, strength and self-reported feasibility.	HBNFT significantly enhanced 6MWT and tandem walk test, but no significant differences were found in other outcomes. When administered remotely, eight weeks of both HBFT and HBRT approaches were safe and feasible for a small population with MS patients with moderate cognitive and mobility impairments.	The findings of the pilot trial offered preliminary evidence that HBNFT is a safe and viable means of enhancing certain ambulatory aspects in individuals with MS who have cognitive impairment.
Harvey (1999)	RCT-P Strength training	17 3 M,14F RR: 17 Participants can walk with or with no walking aid.	43.33 6.67	Group A: No exercise Group B: Mobility exercise Group C: Weighted leg exercise	Mobility exercise group: stretching, and general balance and mobility exercises, swimming and	Muscle strength, functional activities such as walking and transferring, timed transfer, perceived social	There was a trend of improvement for the participants undertaking either exercise prescribed by a	There is no evidence from this limited study that suitably utilized conventional strengthening

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Table 2 (*continued*)

Author (Year)	Design Main exercise (s) involved	N(Sex) MS type Ambulatory status of participants	Age (Years) Duration of MS/Time since diagnosis (Y) Disability level/MS status	Intervention(s)/Groups/type Nature of Intervention setting/location Exercise monitoring	Exercise protocols	Outcomes Assessment Period	Findings	Conclusion
				Home-based Biweekly phone calls to monitor the exercises.	exercise sessions on exercise bike. Weighted leg exercise group: This group was instructed to carry out seated leg extension exercises at an angle of 45 °, with ankle weights graded based on their strength. After demonstration and trial, the exercise was performed on both legs, twice per day at home. No exercise group: Participants were instructed not to change their normal activity patterns, only to document the exercise they performed or any uncommon activity they engaged in.	support, Initial and follow up	physiotherapist or leg raising exercises, whereas those who perform nothing revealed little or no improvement.	exercise such as weighted leg extensions caused worsening of function in patients with MS and they might lead to some improvements.
Hogan (2014)	RCT-P Strengthening and balance exercises	111 40 M, 71F RR: 29 PP: 26 SP: 46 UK:10 Participants need bilateral support for gait.	Age (SIQR) GP: 57 (10) IP: 52 (11) Yoga: 58(8) Control:49 (6) GP: 18 (9) IP: 13 (8) Yoga: 15 (8) Control:10 (3) Significant disability	Group physiotherapy group Individual physiotherapy group Yoga group Control group Community-based (group and individual intervention) Supervision by PTs and YIs	All interventions were performed for an hour a week, for 10 weeks. The physiotherapy group intervention was a circuit class exercise that was self-paced that was aimed at balance and strength with a goal of increasing mobility and balance. Participants in the individual physiotherapy group received individual therapy based on the problem list and objectives set by the treating physiotherapist. In the Yoga group, every week, participants attended a yoga class that lasted roughly an hour. Control group: Participants were	Fatigue, physical and psychological components of fatigue, balance and walking endurance Pre, and post intervention	There were significant time effects for physical component of MSIS-29v2 and MFIS. No significant difference in BBS between GP and IP groups. There was improvement in 6MWT for IP group, and MSIS-9v2 psychological score for GP group.	There was preliminary evidence that 10-week interventions comprising of strengthening and balance exercises improve balance.

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Table 2 (*continued*)

Author (Year)	Design Main exercise (s) involved	N(Sex) MS type Ambulatory status of participants	Age (Years) Duration of MS/Time since diagnosis (Y) Disability level/MS status	Intervention(s)/ Groups/type Nature of Intervention setting/location Exercise monitoring	Exercise protocols	Outcomes Assessment Period	Findings	Conclusion
					instructed not to change their exercise habits			
Hosseini (2018)	RCT-P Resistance training	26 12 M, 14F Participants can walk.	Home strength G: 32.9 ± 8.13 Home Hatha yoga exercise G: 31.3 ± 7.09 Control G: 33.0 ± 9.74 EDSS score range: 1–6	HRTG: Home-based resistance training Control group HHEG: Home-based Hatha Yoga exercises Control group Home-based Daily checklist and weekly telephone calls to monitor the training.	HRT: 8-week (3 times a week) RT program started. The training program focused on exercises planned for increasing strength HHEG:8-week Hatha yoga training program was started. The training program involved three sessions per week of 60–70 min beginning with stretching exercises in standing, prone and sitting positions. Control group: Participants were instructed not to change their routine physical activity habits	Muscle strength, disability, balance, and walking time. Pre, and post intervention	YT had no significant effect on muscle strength of leg extensor, however, the home RT increased it. Either YT and RT did not affect functional capacity, however, the balance changed specially with YT.	RT and Hatha yoga training can positively affect the lower limbs strength and some level of balance improvement in patients with MS.
McAuley (2015)	RCT-P Strengthening, balance and flexibility exercises	48 12 M, 36F RR: 32 PP: 1 SP: 5 UK:3 NR: 7 Participants can walk with little help (capable of walking independently or with a cane).	FlexToBa (FTB) G: 5 9.62 ± 1.43 CG: 59.78 ±1.50 EDSS score: < 6.5	FTB group: FlexToBs DVD exercise CG: Control group Home-based Participants received a daily exercise log to fill up and submit back by mail once a month. For the first two months, all FlexToBa participants received a brief support phone call every two weeks along with an exercise "tip of the day." After that, they received a call every month.	FTB G: The FlexToBa intervention consist of progressive exercise sessions, and safety principles, the exercises focus on strength, balance and flexibility. Participants were urged to exercise with the FlexToBa DVDs three times a week on nonconsecutive days, and to advance to the next session every four weeks. CG: Participants received healthy ageing DVD and watch 85-minute documentary and carry on with their regular daily activities.	Physical function, physical performance, physical activity, balance, gait speed, lower extremity strength, upper body strength and endurance, upper and lower body flexibility, quality of life and satisfaction.	At program end, there was no significant difference in the physical function of the two conditions. The intervention condition had a better outcome of Short Physical Performance Battery scores than the control condition, better lower and upper body flexibility, larger grip strength for the right and left hands, improved balance for the right-leg hand but not the left. Compared to the control condition, the FlexToBa condition reported significantly higher levels of overall leisure time physical activity. Individuals in the exercise training condition	With a DVD-delivered exercise training intervention, there were modest improvements in physical activity, flexibility, strength, and balance as well as in QOL.

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Table 2 (*continued*)

Author (Year)	Design Main exercise (s) involved	N(Sex) MS type Ambulatory status of participants	Age (Years) Duration of MS/Time since diagnosis (Y) Disability level/MS status	Intervention(s)/ Groups/type Nature of Intervention setting/location Exercise monitoring	Exercise protocols	Outcomes Assessment Period	Findings	Conclusion
							reported higher scores on the MSIS's psychological and physical subscales and expressed a higher level of life satisfaction.	
Sosnoff (2014)	RCT-P Strengthening and balance exercises	27 21 M, 6F RR: 20 PP: 3 SP: 4 Participants can be able to walk 25 feet independently or with a walking aid.	60.07 15.8 (9.1) Median EDSS score: 5.0	Home exercises group Control group Home-based Exercise monitored by a certified exercise leader at the initial weeks of training, and diaries were used to assess the home exercise compliance. Participants were called through phone every two weeks during the intervention period to inquire about the incidence of falls and any other unfavorable events.	Home exercises group: Participants carry out the exercises three times a week at home for 12 weeks. Exercises include balance exercises, lower limb and core muscle strengthening exercises, and stretching exercises. The exercises focused on lower muscle strength and balance. Control group: Participants in the wait list control group continued their normal activity, and only received intervention after the completion of the study.	Proprioception, strength, reaction time, postural sway. Fall risk, physiological profile, mobility, balance, falls, timed walk, walking endurance, and contrast sensitivity function. Baseline, and post-intervention	Home-based exercises decreased the risk of falls, there were subtle but significant group differences in balance confidence, and walking speed after the exercise program.	12-wek home-based exercise program aiming at lower limb strength and balance is safe and decreases physiological fall risk in older adults with MS compared with a control.
Straudi (2014)	RCT-P Strengthening exercises, Gait training, and stretching exercises.	24 7 M, 17F RR: 6 PP: 10 SP: 8 Participants can be able to walk for not <100 m without continuous aid needed.	52.58 ± 11.21 15.21 ± 8.68 EDSS score: between 4 and 5.5. Mild to Moderate gait impairments	EG: Task-oriented circuit training (TOCT) and home exercise program CG: Usual care Home-based Diary and calls were used to document and monitor the exercise respectively.	EG: Ten TOCT sessions spanning 2 weeks (2 h per session, 5 days per week) followed by home-exercise program for 3 months. Home based training program: Following the 2 weeks exercises which was supervised, the home-based exercises included gait training (overground or treadmill), stretching and strengthening exercises. Home -based exercises were performed 3 times/week (60 min/each session) for 3 months Control group: The usual care group did not receive any	Gait speed, walking endurance, mobility, balance, fatigue, health-related quality of life, and walking ability. Pre, at end of TOCT, and at the end of 3 months home-based training program	There was significant improvement in walking ability and health-related quality of life with minor retention after 3 months. The control group revealed no significant changes in any variable.	Two weeks TOCT of high-intensity followed by three months home-based exercise program is safe and well tolerated in patients with MS having moderate gait and mobility impairments. Also, there might be some positive impacts on walking ability.

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Table 2 (*continued*)

Author (Year)	Design Main exercise (s) involved	N(Sex) MS type Ambulatory status of participants	Age (Years) Duration of MS/Time since diagnosis (Y) Disability level/MS status	Intervention(s)/ Groups/type Nature of Intervention setting/location Exercise monitoring	Exercise protocols	Outcomes Assessment Period	Findings	Conclusion
					particular rehabilitation intervention aimed at gait and mobility improvement.			
Willaims (2021)	RCT-P Functional strengthening and balance exercises.	50 12 M, 38F RR: 31 PP: 7 SP: 6 BN:3 UK:3 Participants can be able to walk 10 m with or with no assistance in two minutes.	Home-based individual intervention G (HIIG):51.3 ± 8.9 5.6 ± 5.9 Centre-based group intervention G (CGIG): 52.7 ± 11.9 12.4 ± 10.2	In both HIIG and CGIG, the interventions focused on functional strengthening, body weight, functional task performance and balance exercises. Home and center based (local community center) Supervision by one center-based PT at the start of the intervention, and biweekly telephone support to monitor the home exercises.	Exercises for both groups involved two 60 min session per week, performed at least two days apart for 8 weeks.	Gait speed, walking endurance, and balance Pre, post 8 weeks of intervention, and follow up at week 16	There was no significant difference in gait or balance between groups or over time; but, the mean difference in gait speed attained in both groups, and mean gait endurance attained in center-based group was similar or higher than the ones previously described in studies as statistically significant.	Either home-based or center-based exercise did not statistically significantly improve balance, gait speed, and endurance in patients with MS; but, changes in gait speed met minimally important differences.

AP: Anterio-posterior; *Av.*: Average; BBS: Berg balance scale; BN: Benign; CG: Control group; CP: Chronic progressive; DE: Duration of exercise; EDSS: Expanded disability status sclae; EG: Experimental group; F: Female; FIs: Fitness instructors; FOF: Fear of falling; FVCRT: Fast-velocity concentric resistance training; G: Group; GP: group physiotherapy; HHE: Home-based Hatha yoga; HRT: Home-based resistance training; IP: Individual physiotherapy; LE: lower-extremity; M: Male; Mean ± SD; MFIS: Modified fatigue impact scale; ML: Medio-lateral; MS: Multiple sclerosis; N: Total sample size; NMES: Neuromuscular electrical stimulation; P: Progressive; PRT: Progressive resistance training, PP: primary progressive; PTs: Physiotherapists; QOL: Quality of life; RCT-P: Parallel Randomize controlled trial; RFD: Rate of force development; RR: Relapsing remitting; RT: Resistance training; SD: Standard deviation; SIQR: semi-interquartile range, SP: Secondary progressive; TMW: Tolerated maximum workload; TOCT: task oriented circuit training; UK: Unknown; UC: Usual care; Y: Years; YIs: Yoga instructors; YT: Yoga training; 10M: Ten meters.

3.6. Outcomes described

Muscle performance parameters: Eight studies reported on muscle strength (Ghahfarrokhi et al., 2022; Andreu-Caravaca et al., 2022; Dodd et al., 2011; Coote et al., 2015; Harvey et al., 1999; Hosseini et al., 2018; Sosnoff et al., 2014; McAuley et al., Jan-Dec 2015), three reported on muscle endurance (Dodd et al., 2011; Coote et al., 2015; McAuley et al., Jan-Dec 2015), and one reported on leg power (DeBolt and McCubbin, 2004).

Mobility: Seven studies reported on functional mobility (Cakt et al., Jun 2010; DeBolt and McCubbin, 2004; Ghahfarrokhi et al., 2022; Andreu-Caravaca et al., 2022; Coote et al., 2015; Sosnoff et al., 2014; Straudi et al., 2014).

Walking performance parameters: Eight studies reported on walking speed (Cakt et al., Jun 2010; Ghahfarrokhi et al., 2022; Williams et al., 2021; Dodd et al., 2011; Harvey et al., 1999; Hosseini et al., 2018; McAuley et al., Jan-Dec 2015; Straudi et al., 2014), eight reported on walking endurance (Ghahfarrokhi et al., 2022; Williams et al., 2021; Dodd et al., 2011; Hogan et al., 2014; Sosnoff et al., 2014; Straudi et al., 2014; M Garrett et al., May 2013; M Garrett et al., May 2013), three reported on walking ability (Ghahfarrokhi et al., 2022; Coote et al., 2015; Straudi et al., 2014), and three reported on timed walking (Harvey et al., 1999; Hosseini et al., 2018; Sosnoff et al., 2014).

Balance performance and fall parameters: Ten studies reported on balance (Cakt et al., Jun 2010; DeBolt and McCubbin, 2004; Ghahfarrokhi et al., 2022; Williams et al., 2021; Coote et al., 2015; Hosseini et al., 2018; Hogan et al., 2014; Sosnoff et al., 2014; McAuley et al., Jan-Dec 2015; Straudi et al., 2014), two studies reported on postural sway (DeBolt and McCubbin, 2004; Sosnoff et al., 2014), and two studies reported on fear of fall/ risk of fall (Cakt et al., Jun 2010; Sosnoff et al., 2014)

Fatigue: Seven studies reported on fatigue (Cakt et al., Jun 2010; Dodd et al., 2011; Coote et al., 2015; Hogan et al., 2014; Straudi et al., 2014; M Garrett et al., May 2013; M Garrett et al., May 2013).

Participation, satisfaction and quality of life (including Impact of MS): Four studies reported on the quality of life (Cakt et al., Jun 2010; Andreu-Caravaca et al., 2022; Dodd et al., 2011; Straudi et al., 2014), and one study reported on participation (Coote et al., 2015). Three studies reported on the physical and psychological impacts of MS (McAuley et al., Jan-Dec 2015; M Garrett et al., May 2013; M Garrett et al., May 2013). One study reported on satisfaction with life (McAuley et al., Jan-Dec 2015)

Other parameters: One study each reported on depression (Cakt et al., Jun 2010), disability (Hosseini et al., 2018), and lower limb spasticity (Coote et al., 2015), and one study reported on the physiological profile, contrast sensitivity function, proprioception, and reaction time (Sosnoff et al., 2014). Also, physical function, physical performance and physical activity were reported in one study (McAuley et al., Jan-Dec 2015).

Effects of home or community based strength training (narrative

synthesis): Findings from the studies revealed positive effects of home or community based strength training on muscle-related parameters (leg strength, leg power, endurance and flexibility); walking-related parameters (walking speed, walking endurance and walking ability); mobility, balance and falls-related parameters (balance performance, balance confidence postural sway and fear/risk of falling); fatigue, depression, quality of life and impact of MS. Table 2 contain the details.

3.7. Quantitative synthesis and meta-analysis

3.7.1. Effects of the interventions on patients with MS

Effects on muscle performance: The result of random effects meta-analysis (REMA) of studies that evaluated the effects of home or community-based strength training on leg strength is as follows: the results revealed a significant difference in leg strength (standardized mean difference [SMD]= 0.42, 95 % confidence interval [CI] −0.01 to 0.84, P = 0.05) post-intervention between the strength training and control groups (Fig. 3) (low certainty of evidence downgraded due to imprecision and a high ROB). The calculated effect size (ES) revealed no significant difference in muscle endurance (mean difference [MD]= 0.38, 95 % CI: −0.09 to 0.85, P = 0.11) (Dodd et al., 2011), leg extensor power (MD = 0.27, P = 0.50) (DeBolt and McCubbin, 2004); quadriceps maximum voluntary contraction for better leg (MD = 3.90, P = 0.53) and for worst leg (MD = −2.77, P = 0.53) post-intervention between the strength training and control groups (Harvey et al., 1999).

Effects on mobility: Strength training combined with balance training caused no significant difference in improving the functional mobility (SMD = −0.63, 95 % CI: −2.48 to 1.21, P = 0.50) compared with control group (Fig. 4) (low certainty of evidence downgraded due to imprecision and a high ROB), as shown in the meta-analysis result. However, the calculated ES from another study (Andreu-Caravaca et al., 2022) revealed a significant improvement in functional mobility in favor of strength training group (MD = −8.20, 95 % CI: −14.48 to −1.92, P = 0.01) compared with the control group. Also, the calculated ESs from other studies shows no significant difference in improving functional mobility between resistance training and control (MD = −1.93, P = 0.15) (DeBolt and McCubbin, 2004), and between resistance training and neurofunctional training (MD = −0.94, P = 0.73) (Ghahfarrokhi et al., 2022).

Effects on walking performance: Strength training caused no significant difference in improving the walking speed (SMD = 0.25, 95 % CI: −0.17 to 0.67, P = 0.25) compared with the control group (Fig. 5) (low certainty of evidence downgraded due to imprecision and a high ROB), as shown in the meta-analysis result. From the calculated ES from other studies, strength training combined with balance training also caused no significant difference in improving the walking speed (MD = −0.13, P = 0.93) and dynamic gait index (MD = −1.80, P = 0.49) (Cakt et al., Jun 2010), as well as walking impairment (MD = −8.80, P = 0.39), walking function/ability (MD = −1.80, P = 0.13) and walking endurance (MD = 296.90, P = 0.07) (Sosnoff et al., 2014) compared with the control group. Also, the calculated ESs from two studies revealed no significant difference in walking endurance (P > 0.05) between the strength training group (Ghahfarrokhi et al., 2022) or strength training combined with balance training group (Williams et al., 2021) and the comparison groups. However, compared with comparison groups, there was a significant improvement in walking ability (MD = 3.21, 95 % CI: 0.55 to 5.87, P = 0.01) following strength training (Ghahfarrokhi et al., 2022), walking speed following strength training combined with balance training (MD = 0.24, 95 % CI: 0.02 to 0.46, P = 0.04) (Williams et al., 2021), and following strength training (MD = 13.84, 95 % CI: 7.94 to 19.74, P < 0.00001) (Ghahfarrokhi et al., 2022).

Effects on balance performance and fall: Strength training combined with balance training led to a significant improvement in balance performance (SMD = 1.08, 95 % CI: 0.57 to 1.59, P < 0.0001) (Fig. 6) (low certainty of evidence downgraded due to imprecision and a high ROB), as shown in the result of meta-analysis. Also, the ES calculated from another study (Sosnoff et al., 2014) revealed significant improvement in physiological fall risk in favor of strength training combined with balance training group (MD = −1.17, 95 % CI: −2.12 to −0.22, P = 0.02), but no significant difference with the control group in improving fear of fall/risk of fall (MD = 12.20, 95 % CI: −7.69 to 32.09, P = 0.23) was observed from the ES calculated from one other study (Cakt et al., Jun 2010). The calculated effect sizes from other studies showed no significant difference in improvement in functional reach (MD = −3.40, P = 0.44) (Cakt et al., Jun 2010) or balance confidence/self-efficacy (MD = 5.7, P = 0.51) (Sosnoff et al., 2014), but a significant improvement in postural sway (MD = −29.40, 95 % CI: −39.60 to −19.20, P < 0.00001) (Sosnoff et al., 2014) was observed in the strength training combined with balance training group compared with the control group. Additionally, the calculated ESs from a study (Hosseini et al., 2018) revealed no significant difference in two-leg open-eye balance test (MD = 0.20, P = 0.87), two-leg close-eye balance test (MD = −1.40, P = 0.21), or single-leg open-eye balance test (MD = −0.40, P = 0.73) performance between the strength training and control groups. Strength training combined with balance training also caused no significant difference in improving proprioception (MD = −0.30, P = 0.53) compared with the control group, as shown in the result of ES calculated from a study (Sosnoff et al., 2014). However, home based individual strength training combined with balance training significantly improved balance performance (MD = 7.20, 95 % CI: 0.42 to 13.98, P = 0.04) (Williams et al., 2021).

Effects on fatigue: The meta-analysis results showed that, compared with the control groups, no significant difference in improving the overall fatigue in the strength training combined with balance training group (SMD = 0.02, 95 % CI: −0.99 to 1.04, P = 0.96) (Fig. 7) (low certainty of evidence downgraded due to imprecision and a high ROB) was observed. The calculated effect size from another study (Dodd et al., 2011) revealed no significant difference in improving fatigue (MD= −5.30, P = 0.12) or cognitive fatigue (MD = −1.10, P = 0.56) following the strength training compared with the control group, but a significant improvement in physical fatigue (MD = −3.60, 95 % CI: −6.82 to −0.38, P = 0.03) was observed. Also, from ES calculated from one other study (M Garrett et al., May 2013), strength training combined with aerobic training group did not significantly differ from control group (p > 0.05) in improving overall fatigue as well as physical and cognitive aspects of it.

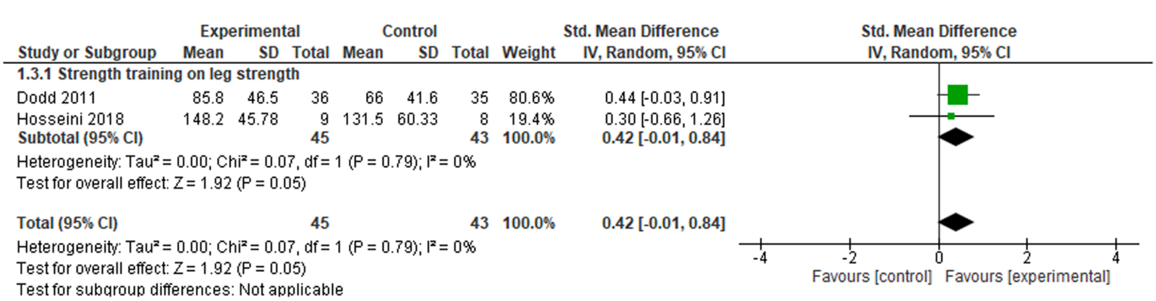

Fig. 3. Effects of home or community-based strength training on leg strength.

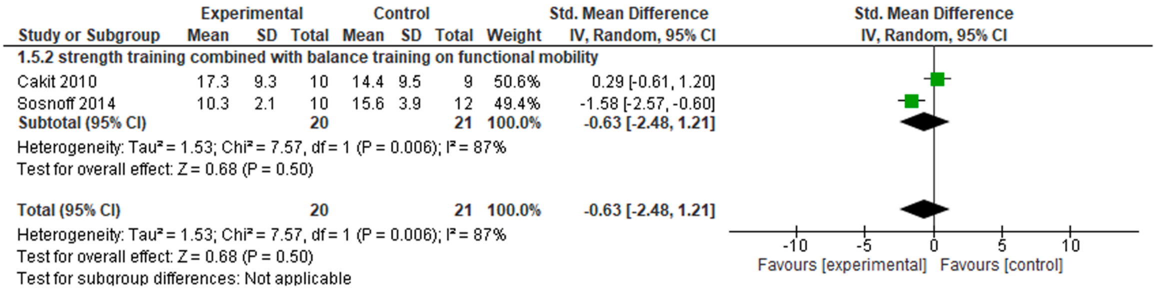

Fig. 4. Effects of home or community-based strength training combined with balance training on functional mobility.

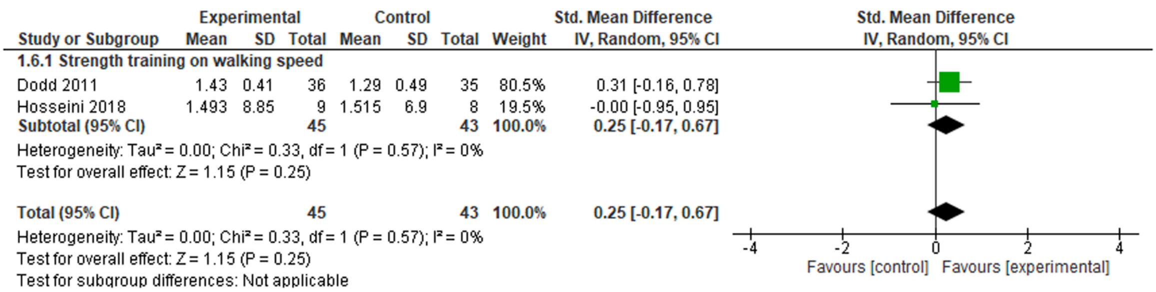

Fig. 5. Effects of home or community-based strength training on walking speed.

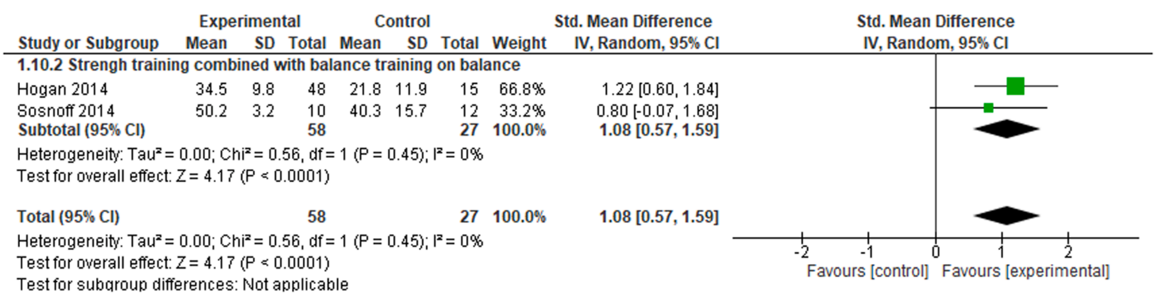

Fig. 6. Effects of home or community-based strength training combined with balance training on balance.

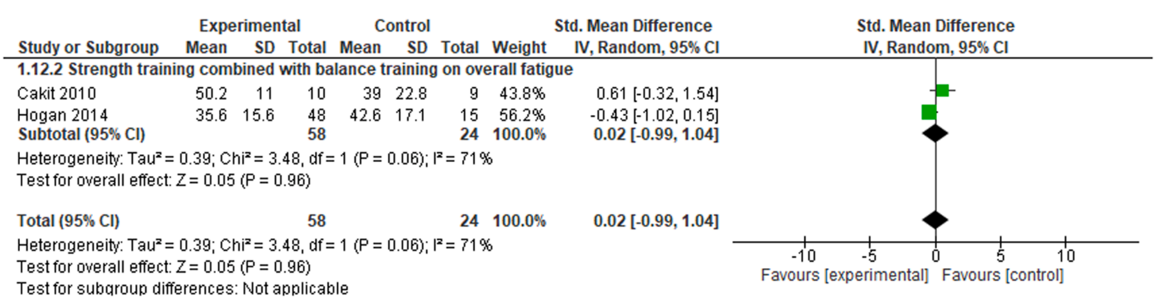

Fig. 7. Effects of home or community-based strength training combined with balance training on overall fatigue.

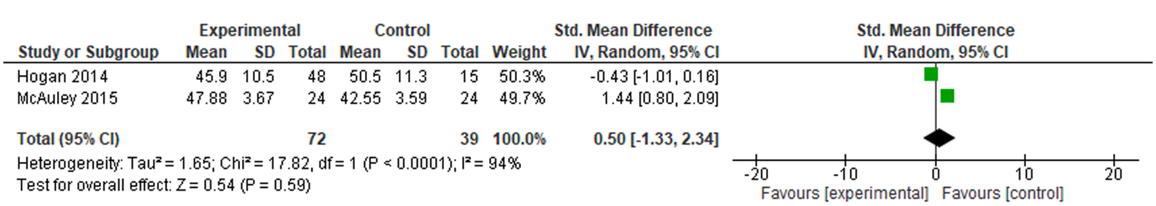

Fig. 8. Effects of home-based strength training combined with aerobic training on the physical impact of multiple sclerosis.

Effects on the impact of MS: The result of meta-analysis revealed that strength training combined with balance training caused no significant difference in improvement on physical impact of MS (SMD = 0.50, 95 % CI: −1.33 to 2.34, P = 0.59) (Fig. 8) (low certainty of evidence downgraded due to imprecision and a high ROB), but the ES calculated from another study (McAuley et al., Jan-Dec 2015) showed significant improvement in psychological impact of MS (MD= −1.09, 95 % CI −1.96 to −0.22, P = 0.01) compared with the control group. However, the calculated effect size from one other study (M Garrett et al., May 2013) revealed no significant difference in the physical impact of MS between the strength training combined with aerobic training group (MD = −0.40, 95 % CI: −7.90 to 7.10, P = 0.92) and the control group.

Effects on other parameters: From the calculated ESs of a study (McAuley et al., Jan-Dec 2015), the result showed that, compared with the control group, strength training combined with balance training significantly improved total leisure physical activity (MD = 8.93, 95 % CI: 7.26 to 10.60, $P < 0.00001$), moderate to vigorous activity (MD = 5.54, 95 % CI: 4.26 to 6.82, $P < 0.00001$) and satisfaction with life (MD = 2.02, 95 % CI: 1.05 to 2.99, $P < 0.0001$). However, the calculated ESs from other studies revealed no significant differences in reaction time (MD = −22.40, P = 029) (Sosnoff et al., 2014), or depression (MD = 16.40, P = 0.09) (Cakt et al., Jun 2010) between the strength training combined with balance training group and the control group.

4. Discussion

The purpose of this systematic review and meta-analysis was to evaluate the scientific evidence regarding the effects of home or community-based strength training alone or in combination with other types of training on muscle, walking, mobility, and balance performances in patients with MS. Both quantitative and qualitative syntheses were used to analyzed the data. The main results revealed that home-based strength training alone or combined with balance training positively improved leg strength, functional mobility, walking speed and ability, balance performance, postural sway, physical fatigue, physical activity, psychological impact of MS, quality of life and satisfaction with life in patients with MS.

4.1. Qualitative synthesis findings

The findings of the studies included in the review show positive effect of the interventions on some parameters related to muscle performance, walking function, mobility, balance, falls, fatigue, physical activity, quality of life and impact of MS. Overall, the findings showed that home or community-based strength training alone or in combination with balance training was effective in improving such parameters in patients with MS, particularly those with mild to moderate MS. This indicates the significance and benefits of home or community-based strength training for such patients. It is thus suggested that such interventions may be considered as options for managing patients with MS presenting with challenges related to those outcomes of interest.

4.2. Quantitative synthesis findings

Home or community-based strength training significantly improved leg strength, functional mobility, walking speed, walking ability and physical fatigue. The finding is consistent with the statement that strength training has a positive effect on mobility parameters, which underscores the relevance of involving such kinds of physical exercise for patients with MS (Andreu-Caravaca et al., 2022). This is further supported by a previous assertion that increase in muscle strength due to PRT may result to further permanent changes in daily physical activities, and consequently may lead to preservation of strength and other benefits without the need to continue exercising (Dodd et al., 2011). It could be deduced from the findings that, when the aiming for better strength and mobility related elements in patients with MS, home or community-based strength training could be a treatment of choice.

The findings that home or community-based strength training combined with balance training significantly improved walking speed, balance performance, postural sway, physiologic fall risk, physical activity, psychological impact of MS, and satisfaction with life, indicate that this combined training modality is valuable for patients with MS. Because improvements in such parameters can go a long way in aiding and enabling the patients to partake in daily activities without difficulties. These findings are in line with the report that functional strength and balance program have trends of likely affecting gait speed and endurance (Williams et al., 2021). This may be because balance control abnormalities are among the findings commonly found in patients with MS (Cakt et al., 2010). Such is vital, because one key issue that must be addressed to avoid falls is identification of particular factors responsible for increased risk of fall that can be changed with intervention, with a suggestion that improvements in balance might play a role in decreasing incidence of fall after home-based interventions (Sosnoff et al., 2014). In the studies included in this review, the tasks involved in the training interventions may have led to improvements in balance and mobility parameters, which could have had a direct impact on the improved parameters of patients with MS. Thus, home or community-based strength training combined with balance training may be an ideal treatment strategy when focusing on management of balance, mobility and falls in patients with MS.

The positive effect of the interventions observed may be linked to some factors, for example, nearly all the studies administered the exercise interventions in an organized manner with dosage and progression of the exercises, also the duration of the exercises across nearly all the studies was at least 8 weeks. Furthermore, majority of the participants across the studies suffered from relapsing-remitting MS, and in terms of disability level, most of the studies involved participants with mild to moderate MS. Such point to the specific type and characteristics of MS involved in the studies, thus, the findings may be more attributed to such class of patients with MS. Moreover, despite that the exercises were performed in a non-hospital setting, such as home or community center/gymnasium, the initial demonstration and instruction by the health professionals/physiotherapists may have impacted on the training and the outcomes. Also, the continuous monitoring of the exercises via physical supervision, home visits, phone calls, use of diaries, checklist and exercise log across the studies, may have enhance adherence to the exercises and impacted on the treatment outcomes. Therefore, it is suggested that prior instructions as well as monitoring of the home or community-based exercise interventions may be of crucial significance in enhancing the interventions outcomes.

The non-significant differences observed in other parameters may be related to several factors such as the nature of the interventions implemented, dosage of the interventions, MQ of the studies involved. This is consistent with the findings of a previous study of Sosnoff et al. (2014) which stated that training of higher duration; and/or intensity may possibly be needed to observe an improvement in muscle strength. Hence, future studies should consider addressing these factors. Additionally, the non-significant difference obtained in some walking related variables may be linked with the ambulatory and mobility characteristics of the participants included in some of the studies. Because, while some included participants with independent walking ability, a good number included those with or without independent walking ability, and few included those who require more aid to walk.

The results of this review may be influenced by the limitations of the included studies. For instance, home-based training is limited by the lack of adequate supervision and guidance a patient may need while performing the exercise. Additionally, the inconsistencies across non-hospital settings and other needs of the patients, may have affected the outcomes of some of the studies. The number of studies that assessed various outcomes were not many, and some of these had small sample sizes, therefore, conclusions from a some of them were drawn based on the calculated effect sizes and qualitative synthesis, which may have limited the review results. Most of the included studies in the review and meta-analysis were of good MQ, and few were of fair MQ. This enhanced the strength of the synthesized evidence. Nevertheless, future studies are required to address the abovementioned limitations.

5. Strengths and limitations

The primary strengths of this review and meta-analysis are that it involved a search of online databases, evaluation of the certainty of evidence, MQ and ROB using appropriate evaluation tools/procedures, and it was conducted in line with the PRISMA guidelines. In terms of limitations, nearly all of the included studies had a high ROB in the domains of performance bias, and many of the studies had a high ROB in allocation concealment, and there is a likelihood of bias might be increased due to the inclusion of only studies published in English. Future studies are needed to address these limitations.

6. Conclusions

In patients with mild to moderate MS, especially the relapsing-remitting type, home or community-based strength training significantly improves leg strength, walking, mobility and physical fatigue; whereas home or community-based strength training combined with balance training significantly improves walking, balance, fall, physical activity and quality of life.

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CRediT authorship contribution statement

Jibrin Sammani Usman: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Thomson Wai-Lung Wong:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Formal analysis, Data curation, Conceptualization. **Shamay Sheung Mei Ng:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Statement

Data is available from the corresponding author on reasonable request

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.msard.2025.106413.

References

Akbar, N., Sandroff, B.M., Wylie, G.R., et al., 2018. Progressive resistance exercise training and changes in resting-state functional connectivity of the caudate in persons with multiple sclerosis and severe fatigue: a proof-of-concept study. Neuropsychol. Rehabil.

Andreu-Caravaca, L., Ramos-Campo, D.J., Chung, L.H., Manonelles, P., Boas, J.P.V., Rubio-Arias, J., 2022. Fast-velocity resistance training improves force development and mobility in multiple sclerosis. Int. J. Sports Med. 43 (7), 593–599. https://doi.org/10.1055/a-1710-1492.

Cakt, B.D., Nacir, B., Genç, H., et al., Jun 2010. Cycling progressive resistance training for people with multiple sclerosis: a randomized controlled study. Am. J. Phys. Med. Rehabil. 89 (6), 446–457. https://doi.org/10.1097/PHM.0b013e3181d3e71f.

Cano-Sánchez, J., Aibar-Almazán, A., Hita-Contreras, F., et al., 2024. Is resistance training an option to improve functionality and muscle strength in middle-aged people with Multiple sclerosis? A systematic review and meta-analysis. J. Clin. Med. 13 (5), 1378.

Coote, S., Hughes, L., Rainsford, G., Minogue, C., Donnelly, A., 2015. Pilot randomized trial of progressive resistance exercise augmented by neuromuscular electrical stimulation for people with multiple sclerosis who use walking aids. Arch. Phys. Med. Rehabil. 96 (2), 197–204. https://doi.org/10.1016/j.apmr.2014.09.021.

Dalgas, U., Stenager, E., Jakobsen, J., et al., 2009. Resistance training improves muscle strength and functional capacity in multiple sclerosis. Neurology 73 (18), 1478–1484.

DeBolt, L.S., McCubbin, J.A., 2004. The effects of home-based resistance exercise on balance, power, and mobility in adults with multiple sclerosis. Arch. Phys. Med. Rehabil. 85 (2), 290–297.

Dodd, K.J., Taylor, N.F., Shields, N., Prasad, D., McDonald, E., Gillon, A., 2011. Progressive resistance training did not improve walking but can improve muscle performance, quality of life and fatigue in adults with multiple sclerosis: a randomized controlled trial. Mult. Scler. 17 (11), 1362–1374. https://doi.org/10.1177/1352458511409084.

Felipe, J.A., CARNEIRO, A.L., MOREIRA, O.C., et al., 2018. Effects of resistance training on the physical condition of people with multiple sclerosis. J. Sports Med. Phys. Fitness. 58 (7–8), 1127–1134.

Foley, N.C., Teasell, R.W., Bhogal, S.K., Speechley, M.R., 2003. Stroke rehabilitation evidence-based review: methodology. Top. Stroke Rehabil. 10 (1), 1–7.

Güngör, F., Tarakci, E., Özdemir-Acar, Z., Soysal, A., 2022. The effects of supervised versus home Pilates-based core stability training on lower extremity muscle strength and postural sway in people with multiple sclerosis. Mult. Scler. J. 28 (2), 269–279.

Garrett, M., Hogan, N., Larkin, A., Saunders, J., Jakeman, P., Coote, S., 2013a. Exercise in the community for people with multiple sclerosis–a follow-up of people with minimal gait impairment. Mult. Scler. 19 (6), 790–798. https://doi.org/10.1177/1352458512461390.

Garrett, M., Hogan, N., Larkin, A., Saunders, J., Jakeman, P., Coote, S., 2013b. Exercise in the community for people with minimal gait impairment due to MS: an assessor-blind randomized controlled trial. Mult. Scler. 19 (6), 782–789. https://doi.org/10.1177/1352458512461966.

Ghahfarrokhi, M.M., Banitalebi, E., Faramarzi, M., Motl, R., 2022. Feasibility and efficacy of home-based neurofunctional exercise vs. resistance exercise programs for ambulatory disability of multiple sclerosis patients with cognitive impairment. Mult. Scler. Relat. Disord. 58, 103400.

Gonzalez, G.Z., Moseley, A.M., Maher, C.G., Nascimento, D.P., Costa, LdCM, Costa, L.O, 2018. Methodologic quality and statistical reporting of physical therapy randomized controlled trials relevant to musculoskeletal conditions. Arch. Phys. Med. Rehabil. 99 (1), 129–136.

Grazioli, E., Tranchita, E., Borriello, G., Cerulli, C., Minganti, C., Parisi, A., 2019. The effects of concurrent resistance and aerobic exercise training on functional status in patients with multiple sclerosis. Curr. Sports Med. Rep. 18 (12), 452–457.

Harvey, L., Smith, A.D., Jones, R., 1999. The effect of weighted leg raises on quadriceps strength, EMG parameters and functional activities in people with multiple sclerosis. Physiotherapy 85 (3), 154–161.

Higgins, J.P., Altman, D.G., Gøtzsche, P.C., et al., 2011. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. BMJ 343.

Hogan, N., Kehoe, M., Larkin, A., Coote, S., 2014. The effect of community exercise interventions for people with MS who use bilateral support for gait. Mult. Scler. Int. 2014 (1), 109142.

Hosseini, S.S., Rajabi, H., Sahraian, M.A., Moradi, M., Mehri, K., Abolhasani, M., 2018. Effects of 8-week home-based yoga and resistance training on muscle strength, functional capacity and balance in patients with multiple sclerosis: a randomized controlled study. Asian J. Sports Med. 9 (3).

Kalron, A., Rosenblum, U., Frid, L., Achiron, A., 2017. Pilates exercise training vs. physical therapy for improving walking and balance in people with multiple sclerosis: a randomized controlled trial. Clin. Rehabil. 31 (3), 319–328.

Kjølhede, T., Vissing, K., de Place, L., et al., 2015. Neuromuscular adaptations to long-term progressive resistance training translates to improved functional capacity for people with multiple sclerosis and is maintained at follow-up. Mult. Scler. J. 21 (5), 599–611.

Maher, C.G., Sherrington, C., Herbert, R.D., Moseley, A.M., Elkins, M., 2003. Reliability of the PEDro scale for rating quality of randomized controlled trials. Phys. Ther. 83 (8), 713–721.

Manca, A., Cabboi, M.P., Dragone, D., et al., 2017. Resistance training for muscle weakness in multiple sclerosis: direct versus contralateral approach in individuals with ankle dorsiflexors' disparity in strength. Arch. Phys. Med. Rehabil. 98 (7), 1348–1356. . e1.

McAuley, E., Wójcicki, T.R., Learmonth, Y.C., et al., 2015. Effects of a DVD-delivered exercise intervention on physical function in older adults with multiple sclerosis: a pilot randomized controlled trial. Mult. Scler. J. Exp. Transl. Clin. 1, 2055217315584838. https://doi.org/10.1177/2055217315584838.

Paci, M., Bianchini, C., Baccini, M., 2022. Reliability of the PEDro scale: comparison between trials published in predatory and non-predatory journals. Arch. Physiother. 12 (1), 1–9.

Rodriques, C., Jackson, K., Barrios, J.A., Laubach, L.L., Bigelow, K.E., 2016. Task-oriented ankle and foot training for improving gait, balance, and strength in individuals with multiple sclerosis: a pilot study. J. Exer. Med. Online 1 (1).
Romberg, A., Virtanen, A., Ruutiainen, J., et al., 2004. Effects of a 6-month exercise program on patients with multiple sclerosis: a randomized study. Neurology. 63 (11), 2034–2038.
Sosnoff, J.J., Finlayson, M., McAuley, E., Morrison, S., Motl, R.W., 2014. Home-based exercise program and fall-risk reduction in older adults with multiple sclerosis: phase 1 randomized controlled trial. Clin. Rehabil. 28 (3), 254–263.
Straudi, S., Martinuzzi, C., Pavarelli, C., et al., 2014. A task-oriented circuit training in multiple sclerosis: a feasibility study. BMC Neurol. 14, 1–9.
Williams, K.L., Low Choy, N.L., Brauer, S.G, 2021. Center-based group and home-based individual exercise programs have similar impacts on gait and balance in people with multiple sclerosis: a randomized trial. PM&R 13 (1), 9–18.