Commentary on: Strength training for people with multiple sclerosis and the current recommendations.

ABSTRACT

Recent guidelines recommend strength and conditioning training for patients with multiple sclerosis (MS). This article evaluates and summarises four systematic reviews examining strength training for people with MS and examines if these reviews substantiate these current guidelines.

Papers being reviewed

- Cruickshank TM, Reyes AR, Ziman MR. A systematic review and meta-analysis of strength training in individuals with multiple sclerosis or Parkinson disease. *Medicine*. 2015;*94*(4):1-15. https://doi.org/10.1097/MD.0000000000000411
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- Manca A, Dvir Z, Deriu F. Meta-analytic and Scoping Study on Strength Training in People With Multiple Sclerosis. **J Strength Cond Res**. 2019;*33*(3):874–889. https://doi.org/10.1519/JSC.0000000000002381

Background to the reviews

Multiple sclerosis (MS) is estimated to affect 2.8 million individuals worldwide (Walton et al, 2020), with 105780 individuals living with the condition in England (Public Health England (PHE), 2020). People with MS (PwMS) can experience a variety of symptoms, including physical impairments, fatigue, pain and cognitive deficits, which often result in a progressive limitation of function (Amatya et al, 2019) and have a negative impact on quality of life (Jones et al, 2008). MS also has a substantial economic impact on health care services (Kobelt et al,, 2017), especially as diagnosis is frequently in early-to-middle adulthood (Walton et al, 2020) and life expectancy is only reduced by around 7 years (Lunde et al, 2017).

Exercise and physical activity are reported as a key component of the management strategies of PwMS and has been shown to improve functional outcomes, improve quality of life and reduce fatigue (Amatya et al, 2019). However, PwMS participate in significantly lower levels of exercise and activity compared to those without a long-term condition or disability (Kinnett-Hopkins et al, 2017). The updated UK physical activity guidelines (PHE, 2019) have, for the first time, included guidelines for disabled adults, supported by a rapid evidence review (PHE, 2018), evaluating physical activity for a broad range of impairments.

However, it is important that clinicians use these guidelines in the context of condition specific recommendations (Latimer-Cheung et al, 2013).

The updated UK physical activity guidelines also place an increased focus on the benefits of strength training (PHE, 2019). Strength training has been shown to improve muscle strength in PwMS, although its impact on balance, functional outcomes and quality of life is less clear (Kjølhede et al, 2012). Over the last decade, two guidelines have been developed that facilitate the implementation of strength training specifically for PwMS (Latimer-Cheung et al, 2013a; Kim et al, 2019). The guideline produced by Latimer-Cheung et al, (2013a) was informed by a systematic review and descriptive data analysis (Latimer-Cheung et al, 2013b), alongside an expert and stakeholder review. It identified that there was adequate evidence to formulate a guideline to achieve fitness benefits; however, the evidence was insufficient to formulate guidelines to inform improvements in mobility, fatigue or quality of life. Kim et al, (2019) developed a guideline through a synthesis of nine previous guidelines, dated between 1999 and 2017, including the guideline by Latimer-Cheung et al, (2013b). Many of these synthesised guidelines are based on review articles and lack evidence of a systematic approach to the guideline development. The two sets of exercise guidelines focus on adults living with mild to moderate MS and have many commonalities, providing a starting point for clinicians and PwMS to explore strength training. However, four systematic reviews (Cruickshank et al, 2015; Jørgensen et al, 2017; Mañago et al, 2019; Manca et al, 2019) relating to strength training for PwMS have been published after the Latimer-Cheung et al (2013b) guidelines and are not referenced within the guidelines by Kim et al (2019).

The aim of this commentary is to:

1. Critically appraise the methods used within these four systematic reviews and report the key findings on strength training for PwMS
2. Cross-reference the guideline recommendations against relevant studies (studies that have used similar methods as recommended in the guidelines) within the four systematic reviews in order to verify, challenge or develop the key points of the guidelines for strength training for PwMS.

Methods and quality of the reviews

The core inclusion criteria for all four reviews were studies of PwMS who had undergone strength training and were assessed with a muscle strength outcome. All four reviews included randomised controlled trials (RCTs), with two reviews also including non-randomised trials (Cruickshank et al, 2015; Jørgensen et al, 2017). Two reviews (Jørgensen et al, 2017; Manca et al, 2019) only included studies with a no exercise training control. See Table 1 for the full list of Population, Intervention, Control, Outcomes (PICO) variables.

Table 2. Population, Intervention, Control, Outcomes (PICO) characteristics

PICO	Cruickshank et al (2015)	Jørgensen et al (2017)	Manca et al (2019)	Mañago et al (2019)
Population	Diagnosis of MS	Diagnosis of MS	Diagnosis of MS	Diagnosis of MS
Intervention	Strength training	Strength training	Strength training	Strength training for lower extremities and /or trunk included in study but not necessarily primary intervention.
Control	Not specified	No training or usual care	No intervention or assigned to a waiting list	Inactive or other active intervention
Outcomes	Inclusion outcomes: Muscle strength (1RM, maximum voluntary isometric contraction, maximum voluntary dynamic contraction, power) Other outcomes: Functional Mobility, Balance, Functional Capacity, Quality of Life, Fatigue, Mood, Muscle endurance	Inclusion outcomes: Muscle strength (1RM, maximum voluntary isometric contraction, maximum voluntary dynamic contraction, power)	Inclusion outcomes: Muscle strength (1 repetition maximum [1RM], maximal voluntary isometric contraction) Other outcomes: Gait performance Balance Fatigue, Function Quality of Life	Inclusion outcomes: Muscle strength (1RM, maximal force, endurance) Gait performance

Table note: MS = multiple sclerosis

All four studies were judged to be methodologically robust, using the Joanna Briggs Institute (JBI) critical appraisal checklist for systematic reviews and research syntheses (Aromataris et al, 2015). The only areas of concern were the methods of synthesis and assessment of publication bias for Mañago et al (2019) and the data extraction and search strategy for Jørgensen et al (2017). Table 2 features quality assessment and corresponding methods for all of the systematic reviews.

Table 2. Quality assessment (JBI) and methods

Criteria	**Cruickshank et al (2015)**	**Jørgensen et al (2017)**	**Manca et al (2019)**	**Mañago et al (2019)**
1. Is the review question clearly and explicitly stated?	Yes: To examine the effects and response differences to strength training between people with Parkinson's disease or PwMS	Yes: To examine effects of progressive resistance training on muscle function for PwMS	Yes: To identify changes to muscle strength and functional outcomes after strength training in PwMS	Yes: To appraise the exercise parameters and intervention of strength training as a means to improve walking in PwMS
2. Were the inclusion criteria appropriate for the review question?	Yes: Included key aspects of PICO criteria	Yes: Included key aspects of PICO criteria	Yes: Included key aspects of PICO criteria. Only RCTs included	Yes: Included key aspects of PICO criteria. Only RCTs included
3. Was the search strategy appropriate?	Yes: Full description of the search strategy. Relevant key terms used. No additional filters were applied	No: No description given of the search strategy	Yes: Full description of the search strategy. Relevant key terms used. Limited to English language only	Yes: Full description of the search strategy. Relevant key terms used. Limited to English language only
4. Were the sources and resources used to search for studies adequate?	Yes: Multi-database search (from date of inception to July 2014). No methods of identification of additional studies were used. No description of screening process	Yes: Multi-database search (date of inception to March 2016). Reference lists of included studies were checked. Screening was conducted by one author after completing an	Yes: Multi-database search (date of inception to May 2017). Scrutiny of clinical trials registers. Reference lists of included studies were checked. Screening was conducted by two	Yes: Multi-database search (no start date to July 2017). Reference lists of included studies were checked. Screening was conducted by two authors, with a third author

		evaluation of reviewer agreement. If inclusion was unclear a second author was consulted	authors independently, with a third author utilised for consensus	utilised for consensus
5. Were the criteria for appraising studies appropriate?	Yes: PEDro scale was used	Yes: PEDro scale was used	Yes: PEDro scale & Cochrane Collaboration Risk-of- bias tool were used	Yes: PEDro scale was used
6. Was critical appraisal conducted by two or more reviewers independently?	Yes: 2 authors independently. Disagreements resolved by consensus	Yes: Validated against the score in the PEDro database. Discrepancy resolved by another reviewer	Yes: 2 reviewers independently. Disagreements resolved by consensus	Yes: 2 reviewers (unclear if independently). Validated against the score in the PEDro database
7. Were there methods to minimize errors in data extraction?	Yes: Undertaken by two reviewers independently	No: Not reported	Yes: Undertaken by two reviewers independently	Yes: Undertaken by two reviewers independently
8. Were the methods used to combine studies appropriate?	Yes: Meta-analysis using standardised effect sizes for pre- and post-test outcomes was undertaken. The exact model method was unclear. Heterogeneity was evaluated using I^2	Yes: A random effects meta-analysis using SMD was undertaken comparing intervention and control group outcomes. Heterogeneity was evaluated using I^2 but a sensitivity analysis was not reported	Yes: A random effects meta-analysis using SMD was undertaken. Pre and post-test outcomes were used to compare between group data. "Double counting" bias was corrected. Heterogeneity was evaluated using I^2 and sensitivity with a leave-one-out analysis	No: Data synthesis of between group and /or within group changes was descriptive. A meta-analysis was discounted due to assumed heterogeneity between studies rather than statistical findings
9. Was the likelihood of publication bias assessed?	Yes: Using the Eggers regression test.	N/A: Insufficient number of publications to	Yes: Using a funnel plot and Eggers regression test	No: Not reported

		carry out assessment of publication bias		
10. Were recommendations for policy and/or practice supported by the reported data?	Yes: Use of strengthening exercise to improve strength for PwMS was substantiated. Evidence to support strength training to improve fatigue, quality of life and function but not gait, balance or mood. Limited practice specific recommendations	Yes: Use of strengthening exercise to improve strength for PwMS, consistent with current guidelines, was substantiated. Limited practice specific recommendations	Yes: Use of strengthening exercise to improve strength for PwMS was substantiated. Preliminary evidence provided to support strength training to improve gait. Limited practice specific recommendations	Yes: Use of strengthening exercise to improve strength for PwMS, consistent with current guidelines, was substantiated. Data was inconclusive regarding the impact of strength training on gait. Limited practice specific recommendations
11. Were the specific directives for new research appropriate?	Yes: Recommendation for future research on the use of strength training with more severe PwMS	Yes: To investigate progressive resistance training on the upper body or power training elements for PwMS	Yes: To investigate strengthening for the ankle, trunk and upper limb muscles, if strength gains correlate with increases in function and quality of life or the use of strength training with more severe PwMS	Yes: To investigate higher intensity training /dose response, relationship of strength to gait outcomes or types of strength training interventions most relevant to improving gait for PwMS

Table note: PEDro = Physiotherapy Evidence Database; SMD = Standard Mean Difference; MS = multiple sclerosis; PwMS = people with multiple sclerosis; RCTs = randomised control trials; PICO = Population, Intervention, Control, Outcomes

Results

All systematic reviews included participants with a diagnosis of MS, presenting with mild to moderate MS equivalent to an Expanded Disability Status Scale (EDSS) of 6.5 or less (ie participants were all ambulatory).

Assessment of quality

Some 18 unique trials in total were included across the four systematic reviews (duplicate data sets used in several studies were either counted as one study or removed from the synthesis). All four review papers used the PEDro scale to assess for quality and risk of bias in the original studies. Manca et al (2019) also reported on the Cochrane Collaboration Risk-of-Bias tool (Higgins et al, 2021). The reviewers' interpretation of the PEDro scale was consistent between reviewers, except for Jørgensen et al (2017), who regularly scored differently to two or three other review papers. The PEDro scores (including discrepancies) are shown in Table 3. Taking these discrepancies into consideration, seven studies scored 6 or above (high quality), six studies scored between 5 and 6 (high/moderate quality) and five scored 4 to 5 (moderate quality). The criteria, which were not achieved by the included studies within the four systematic reviews, included the lack of blinding of therapists, participants and assessors.

Publication bias was assessed using the Eggers regression test by two reviews (Cruickshank et al, 2015; Manca et al, 2019). Only Manca et al (2019) reported a significant result supported by a funnel plot, which showed a lack of trials that were statistically non-significant.

Table 3. Individual studies utilised across the four review papers showing number of reviews the study was included in, PEDro scores and reported strength outcome changes

Study	Included in number of systematic reviews (out of four reviewed)	PEDro Scale (including any discrepancy)	Change in Strength outcome
Broekmans et al (2011)	4	6 (5: Jørgensen)	++
Dalgas et al (2009; 2010a; 2010b; 2013)	4	6 (5: Jørgensen)	++
Dodd et al (2011)	4	8 (7: Jørgensen)	++
DeBolt and McCubbin (2004)	3	6 (5: Jørgensen)	+
Fimland et al (2010)	3	4 (6: Jørgensen)	++
Kjølhede et al (2015a; 2015b)	3	6 (5: Jørgensen)	++
Medina Perez et al (2014)	2	6	++
Moradi et al (2015)	2	5	++
Romberg et al (2004)	2	6	+
Sangelaji et al (2016)	2	5/6	+

Eftekhari et al (2012)	1	5	++
Frevel and Maurer (2015)	1	6	NC
Harvey et al (1999)	1	6	NC
Hayes et al (2011)	1	5	+
Learmonth et al (2012)	1	7	NC
Manca et al (2017)	1	7	+
Medina –Perez et al (2016)	1	5	+
Sabapathy et al (2011)	1	5	NC

Table notes: + = significant improvement in one strength outcome from baseline to follow; ++ = statistical significant improvement in one strength outcome comparing intervention to control group (difference within difference); NC = no significant improvement in any comparison; PEDro = Physiotherapy Evidence Database

Strength outcomes

All four reviews reported statistically and clinically significant improvements in strength outcomes following strength training, as shown in Table 4, either through a meta-analysis or descriptive analysis. Out of the 18 individual studies, only four showed no improvement in strength outcomes (as shown in Table 4).

Table 4. Summary Findings from Review Papers on Strength Outcomes Following Strength Training

Review paper	**Synthesis Method**	
	Meta-analysis SMD (95%CI)	**Descriptive analysis (Vote Counting)**
Cruickshank et al (2015)	RCTs=5, Non RCTs=1 Data sets = 10 SMD =0.31 (0.15-0.48) Statistically significant Small effect* I^2 =0%	
Jørgensen et al (2017)	RCTs=6 Data sets =6 SMD=0.45 (0.18-0.72) Statistically significant Moderate effect* I^2 =0%	
Mañago et al (2019)		10/13 studies showed significant between groups and/or within group improvements

		6/13 studies showing significant improvement between groups.
Manca et al (2019)	RCTs=9 Data sets =14 SMD=0.37 (0.16-0.57) Statistically significant Small effect* I^2 =21%	

*Table notes: *Effect size referenced against Schünemann et al (2021)*

How findings support current guidelines

Reporting of individual study intervention characteristics was variable across the 18 studies and four reviews. Therefore, information about each guideline aspect was not available from every individual study. This commentary information is based on the information extracted from the four review papers and, as such, information has not been cross-checked back to the original studies.

There was no clear association between varying modifiable exercise factors and the increase in number of studies reporting a positive increase in strength outcomes. The majority of studies that used similar exercise recommendation variables to those discussed in the guidelines found a positive increase in strength outcomes. A descriptive evaluation, based on available information, of the strength outcomes from the individual studies in relation to the guideline recommendations is shown in Table 5.

Table 5. Evaluation of the strength outcomes from the individual studies in relation to the guideline recommendations

	Guideline Overview	Study breakdown	Strength Outcomes
Muscle group focus	Major muscle groups	18/18 studies included lower limb muscle groups with 17/18 reporting on lower limb outcomes	Lower limb: 14/17 = positive
		8/18 focused on whole body or did not specify with 1/18 reporting an upper limb outcome	Upper limb: 1/1 = no change
Number of exercises	5-10	9/18 studies included 1-4 exercises	1-4 exercises: 7/9 = positive
		7/18 studies included 5-8 exercises	5-8 exercises: 6/7 = positive
Frequency	2-3 x week	14/18 studies used a frequency between 2-3 x week	2-3 x week: 12/14= positive

		2/18 studies used a frequency between 3-5 x week	3-5x week: 2/2 = positive
Repetitions	8-15 repetitions (reps)	14/18 studies used a range which in part fell into the guideline range reporting between 5-15 reps.	5-15 reps: 11/14 = positive
		2/18 studies used a specific 4 reps	4 reps: 2/2= positive
Sets	1-3	12/18 studies used between 1-3 sets	1-3 sets: 10/12 = positive
		4/18 studies used between 3-5 sets	3-5 sets: 3/4 = positive
Resistance	Barely but safely finish 8-15 reps	4/18 studies included a range between 50-80%1RM with a further 2/18 included 35-70%1RM.	35-80%1RM: 6/6 = positive
		1/18 using 85-90% 1RM	85-90%1RM 1/1= positive
		3/18 studies included 6-15RM with 3/3 reporting a positive strength outcome.	6-15RM: 3/3=positive
		3/4 studies which did not identify a change in strength outcome did not report a resistance measure and 1/4 used the Borg scale.	
Suggested Modalities	Weight machines, free weights, resistance bands	10/18 studies used weight machines	Weight machines: 10/10= positive
		1/18 studies used body weight exercises alone and 1/18 used free weights alone	Body weight alone: 1/1= no change Free weights alone: 1/1 = no change
		5/18 studies used combined training using body weight exercises and another modality (Resistance bands, weighted vest, weight machine)	Combined training: 3/5 = positive
Rest	1-4 mins between sets and exercises.	Only 5/18 studied reported on rest with variation between 0.5-3 mins	Rest period: 4/5 = positive

Location	Not reported in the guidelines	3/18 studies were home based	Home based: 2/3= positive
		3/18 identified they were based in a gym / rehab centre with a further 9/18 not providing a location but using weight machines suggesting a centre based exercise	Assumed gym based: 11/12 = positive
		1/18 was a community class without equipment	Community class (no equipment): 1/1= no change
Supervision	Supervised exercise is advisable but not essential	7/18 were reported as supervised with a further 6 likely supervised as centre based or using machines.	Assumed supervision: 11/13 = positive
		1/18 independent with a further 2 likely independent as home based.	Assumed unsupervised: 2/3 = positive
Progression	Gradually progress duration, frequency and intensity (suggests progress intensity last)	Not evaluated from the study characteristics	
Joint aerobic and resistance training	Can be performed on the same day	Not evaluated from the study characteristics	

Note: Positive change = significant improvement in one or more strength outcomes (baseline to follow-up or between groups)

Secondary outcomes

There is some evidence that strength training, compared to no intervention/waiting list, will improve some gait outcomes, with Manca et al (2019) reporting that the pooled results from the meta-analysis show statistically significant improvements in walking speed. Mañago et al (2019) reported that six out of 13 studies demonstrated a significant improvement in gait; this is in comparison with Cruickshank et al (2015), who reported that none of the four studies evaluated reported significant improvements in functional mobility. Limited findings can be drawn regarding other outcomes, due to the small number of studies involved, although there is a suggestion that fatigue can be improved with strength training (Cruickshank et al, 2015).

Table 6. Summary Findings from Review Papers on Secondary Outcomes Following Strength Training

Review Paper	Outcome	Synthesis Method	
		Meta-analysis (SMD (95%CI)	Descriptive Analysis (Vote Counting)
Cruickshank et al (2015)	Functional mobility		0/4 found significant improvement
	Balance		1/3 found significant improvement
	Functional Capacity		1/1 found significant improvement
	Quality of Life (QoL)		2/3 found significant improvement
	Fatigue		3/3 found significant improvement
	Mood		1/2 found significant improvement
	Muscle endurance		1/2 found significant improvement
Mañago et al (2019)	Gait Outcomes		6/13 found significant improvements
Manca et al (2019)	Walking speed	RCTs=6 Data sets =6 SMD=0.35 (0.07-0.63) Small effect * I^2 =0%	
	2 Minute Walk Test	RCTs=2 Data sets=2 SMD =0.5 (-0.48-1.48) Moderate effect* I^2 =23%	
	Timed-Up-and-Go (TUG)	RCTs= 2 Data sets=2 SMD=0.38 (-0.16-0.91) Non-significant I^2 =0%	
	6 Minute Walk Test	RCTs=2 Data sets=2 SMD=-0.25 (-0.3-0.8) Non-significant I^2 =0%	

Note: *Effect size referenced against Schünemann et al (2021)

Discussion

Using the JBI critical appraisal checklist for systematic reviews and research syntheses (Aromataris et al, 2015), it was judged that the systematic reviews by Manca et al (2019) and Cruickshank et al (2015) had used appropriate methods for all 11 criteria. The review by Mañago et al (2019) met nine criteria, as it did not undertake appropriate methods of synthesis. The review classified the included studies to be heterogeneous and hence did not perform a meta-analysis. However, this heterogeneity was not evaluated statistically and, considering the other three reviews achieved a meta-analysis with at least some of the included studies, it could be argued that Mañago et al (2019) should have included a meta-analysis of some of the study information. The review by Jørgensen et al (2017) met eight criteria, due to the lack of detail around the search strategy and data extraction. Both Cruickshank et al (2015) and Manca et al (2019) made an error in including multiple outcomes measuring strength from a single study as different effect estimates from the same sample are typically correlated and assuming independence may be inappropriate (Sutton et al, 2000). Subsequently, this means that the confidence intervals presented in these reviews are questionable, although they are similar to the review by Jørgensen et al (2017), where this error did not occur. It is worth noting that, while Manca et al (2019) and Mañago et al (2019) identified a comprehensive search strategy, they did limit the search to English language studies, and Cruickshank et al (2015) did not provide detail of the study screening process. However, in the context of this work, the four reviews were considered together, which decreases the risk of reduced recall. Therefore, they can be considered to provide an adequate and comprehensive summary of evidence relating to strength training for PwMS. Additionally, It is important to acknowledge that this is a commentary and the original focus was not to identify all reviews in this area, but instead to gather a substantial number of reviews addressing the topic area to inform practice.

At a study level, all studies were assessed by the review papers as being of moderate to high quality. The main methodological concerns were around the lack of blinding of therapists, participants and assessors, which, in part, reflects the intervention being investigated. None of the four systematic reviews carried out a meta-regression or subgroup analysis for quality of evidence but, based on the evidence being judged to be of moderate to high quality, the effect estimates within the reviews are unlikely to be substantially affected by bias.

Current evidence for strength training for PwMS is focused on those living with mild to moderate disease (ie they are ambulatory). For this group of PwMS, strength training is associated with improved muscle strength and, therefore, has a clear role in both clinical practice for people presenting with muscle weakness and in general fitness. What remains less clear is the role strength training plays in other functional outcomes, such as walking, functional activity and quality of life. Muscle weakness has been shown to be associated with reduction in a variety of functional tasks (Jørgensen et al, 2017) and is commonly identified as an underlying modifiable impairment in clinical practice. These more functional outcomes may also be more relevant to PwMS than a pure strength outcome. Some weak evidence suggests that strength training can be used to improve aspects of gait performance; however, the evidence for other outcomes is too limited currently to draw conclusions for practice.

Both guidelines broadly sit within the intervention parameters of the studies documented, and these were generally associated with positive results (Latimer-Cheung et al, 2013b; Kim et al, 2019). Therefore, these recommendations should be adopted as part of standard practice where relevant. See Table 7 for full considerations for practice in relation to current guidelines.

Table 7. Considerations for practice in relation to current guidelines

Guideline overview (Latimer-Cheung et al, (2013b; Kim et al, 2019)	**Considerations for practice**
Muscle group focus = major muscle groups	Current evidence supports strength training for lower limbs rather than all major muscle groups, although this is due to a lack of studies addressing upper limb training and evaluating upper limb outcome measures
Number of exercises = 5-10	Current evidence supports between 1-8 exercises, but reflects that some of the studies were working specific muscle groups only
Frequency = 2-3 x week	Current evidence supports that the frequency of exercise should be between 2-3 times a week
Repetitions = 8-15	Current evidence supports guideline with suggestion that a larger reps range may be acceptable, eg 5-15
Sets = 1-3	Current evidence supports that 1-3 sets are adequate to produce strength improvements
Resistance = barely but safely finish 8-15 reps (8-15RM)	Current evidence difficult to interpret due to the variety of outcome measures used in the studies. Use of percentage of 1RM is difficult to translate to clinical practice
Suggested modalities = weight machines, free weights, resistance bands	The majority of evidence is for weight machines rather than other modalities, which may not be accessible in practice. It is unclear how transferable the evidence from weight machines is to other forms of resistance
Rest = 1-4 mins between sets and exercises	Poorly reported in current evidence
Location = not reported in the guidelines	Poorly reported in current evidence. Although assuming machine-based exercise is centre-based, the majority of evidence is for centre-based strength training, which may not be accessible in practice
Supervision= supervised exercise is advisable but not essential	Poorly reported in current evidence. Although assuming centre-based exercise as supervised and home exercise as independent, there is a larger evidence base for supervised exercises supporting the guidelines
Progression = gradually progress duration, frequency and intensity (suggests progress intensity last)	Poorly reported in current evidence
Joint aerobic and resistance training= Can be performed on the same day	Not reported in current evidence

Historically, PwMS were advised not to exercise (Sutherland and Andersen, 2001) and, while exercise is now an established part of MS treatment, PwMS have been predominately involved in aerobic training (Manca et al, 2019). Considering this, it is likely that both PwMS and the health and exercise professionals with whom they work with may have a knowledge gap around strength training. A recent report into strength training (Chartered Society of Physiotherapy, 2020) identified that people living with long-term conditions continue to hold the belief that their condition prevents them from engaging in strength training. This reinforces the need for education about strength training for people with long-term conditions and professionals who work with them.

Questions remain around elements of best practice for strengthening exercise for PwMS. Future research needs to further evaluate the impact of strength training with a focus on: (1) other key outcomes, such as fatigue, function and quality of life; (2) people with severe MS **(an EDSS greater than 6.5)**; and (3) upper limb strength. More pragmatic studies are also required that investigate aspects of strength training in situations relevant to PwMS when access to weight machines, centre-based exercise, identification of 1RM and supervision may be limited. Additionally, clinicians, exercise professionals and PwMS would benefit from knowledge and understanding about both the use of rest periods and exercise progression to maximise training effect for PwMS. Finally, as the most recent paper in these four reviews is from 2017, there is a growing need for these reviews to be updated to take emerging evidence into consideration.

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KEY POINTS

- **Strength training is associated with improved muscle strength in people with mild to moderate (Expanded Disability Status Scale [EDSS] of 6.5 or less) multiple sclerosis**
- **The effectiveness of strength training for functional outcomes are inconclusive**
- **Further research is required in regard to the effectiveness of strength and conditioning on functional-related outcomes.**

CPD REFLECTIVE QUESTIONS

- What are the main limitations of the for systematic reviews included in this commentary?
- What knowledge gaps do you have around strength and conditioning for people with multiple sclerosis (PwMS)?
- What current strength and conditioning training do you use with PwMS, and do you use any of the principles identified in the guidelines?

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