Does the addition of motor control or strengthening exercises to education result in better outcomes for rotator cuff-related shoulder pain? A multiarm randomised controlled trial

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ABSTRACT

Objective To compare the short-term, mid-term and long-term effects between three interventions (education only, education and strengthening exercises, education and motor control exercises) for rotator cuff-related shoulder pain (RCRSP) on symptoms and function.

Methods 123 adults presenting with RCRSP took part in a 12-week intervention. They were randomly assigned to 1 of 3 intervention groups. Symptoms and function were evaluated at baseline and at 3 weeks, 6 weeks, 12 weeks and 24 weeks using the Disability of Arm, Shoulder and Hand Questionnaire (*Quick*DASH) (primary outcome) and Western Ontario Rotator Cuff Index (WORC). Linear mixed modelling was used to compare the effects of the three programmes on the outcomes.

Results After 24 weeks, between-group differences were −2.1 (-7.7 to 3.5) (motor control vs education), 1.2 (-4.9 to 7.4) (strengthening vs education) and −3.3 (-9.5 to 2.8) (motor control vs strengthening) for the *Quick*DASH and 9.3 (1.5 to 17.1) (motor control vs education), 1.3 (−7.6 to 10.2) (strengthening vs education) and 8.0 (−0.5 to 16.5) (motor control vs strengthening) for the WORC. There was a significant group-by-time interaction (p=0.04) with *Quick*DASH, but follow-up analyses did not reveal any clinically meaningful between-group differences. There was no significant group-by-time interaction (p=0.39) for the WORC. Between-group differences never exceeded the minimal clinically important difference of *Quick*DASH or WORC.

Conclusion In people with RCRSP, the addition of motor control or strengthening exercises to education did not lead to larger improvements in symptoms and function compared with education alone. Further research should investigate the value of providing stepped care by identifying individuals who may only need education and those who would benefit from the addition of motor control or strengthening exercises.

Trial registration number NCT03892603.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Rotator cuff-related shoulder pain (RCRSP) accounts for approximately 70% of shoulder pain consultations and it may lead to pain, reduced function, decreased muscle performance, altered shoulder kinematics, and maladaptive pain behaviours like kinesiophobia and catastrophisation.
⇒ Education and exercises are two of the most frequently used interventions for RCRSP with evidence supporting their effectiveness.
⇒ No study has directly compared education, strengthening exercises and motor control exercises for the management of RCRSP to better highlight recovery over time as well as the choice of intervention provided.

WHAT THIS STUDY ADDS

⇒ All three interventions (education only; education and motor control exercises; education and strengthening exercises) were effective in improving symptoms and functional limitations in individuals with RCRSP, but the addition of motor control or strengthening exercises did not lead to significantly better outcomes than education alone.
⇒ A high load/low repetition strengthening exercises regimen did not lead to additional strength improvement compared with education alone or education combined with motor control exercises.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Clinicians could consider using education as a stand-alone intervention for the management of patients with RCRSP, as the addition of exercise to education did not improve outcomes.
⇒ More research is needed to determine when including motor control or strengthening exercises in the rehabilitation of RCRSP will provide the most benefit.

INTRODUCTION

Rotator cuff-related shoulder pain (RCRSP) accounts for approximately 70% of shoulder pain consultations.[1] It is associated with reduced function, decreased muscle performance, altered shoulder kinematics, and maladaptive pain behaviours such as kinesiophobia and catastrophisation.[2–4] Management commonly involves education, exercise,[5 6] medication, injections[7] and surgery.[8 9] However, 30% of individuals do not report significant improvement.[10]

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Education is used to increase knowledge of the condition and present pain management options and their anticipated benefits.[11] Education is also used to reassure, improve adherence, confidence and self-efficacy, and reduce kinesiophobia and pain catastrophising.[12] However, education alone may not help improve the impaired movement and muscle performance observed in individuals with RCRSP, and resolve pain and functional limitations.[3 4] Thus, exercises may be indicated to address such impairments.[3 4]

Two of the most widely recommended types of exercises for RCRSP are strengthening and motor control exercises (MCE).[13] Strengthening aims to increase a muscle force production and the capacity of its tendon to sustain load.[14] In contrast, MCE are used to facilitate movement that may be impeded by pain inhibition, central nervous system reorganisation, muscle guarding and kinesiophobia.[15] Both strengthening and MCE have been shown to be effective for decreasing pain and disability in individuals with RCRSP,[16–18] although some uncertainty remains as to the added value of exercise compared with placebo.[19]

Education, combined with exercise therapy should be prioritised as the initial management for people seeking care with RCRSP.[20–22] No specific exercise intervention has demonstrated superiority over another.[13] The aim of this randomised clinical trial (RCT) is to compare the short-term, mid-term and long-term effects between three different interventions (education only, education and strengthening exercises, and education and MCE; comparing all three groups at once[23]) for people diagnosed with RCRSP on symptoms and functional limitations. The hypotheses were that both exercises groups would demonstrate a better outcome in pain and function compared with the education only group, with the MCE leading to greater improvement in the short term.[13]

METHODS

This RCT adheres to the Consolidated Standards of Reporting Trials (CONSORT) multiarm extension[23 24] and the Consensus on Exercise Reporting Template (CERT)[25] guidelines (online supplemental file 1) and its protocol has been published.[26] All participants provided written consent.

Participants

Adults presenting with RCRSP were recruited through the electronic mailing list of *Université Laval* (convenience sampling out of >52 000 individuals) using the criteria presented in table 1. A positive cluster of criteria 3, 4 and 5 was required for inclusion, which is similar, although not identical, to the one proposed by Michener *et al*.[27]

Table 1 Eligibility criteria

Including criteria	Excluding criteria
1. 18–75 years of age 2. Symptoms >3 months 3. Presence of a painful arc 4. Presence of a positive Neer sign or Hawkin's Kennedy test 5. Presence of pain when resisting humeral external rotation or abduction, or positive Jobe test	1. Clinical signs of massive rotator cuff tears (gross weakness in the absence of pain (positive lag sign))[58] 2. Other shoulder disorders, for example, frozen shoulder, severe osteoarthritis, fracture and dislocation 3. Symptomatic cervical spine pathology 4. Presence of significant comorbidity, for example, neurological disorders, rheumatoid arthritis 5. Previous shoulder surgery 6. Corticosteroid injection in the past 6 weeks

Study design

This multiarm RCT included five evaluation sessions over 24 weeks (T_0, T_3, T_6, T_{12}, T_{24}), six intervention sessions over 12 weeks for both exercise groups and two education sessions over 12 weeks for the education group. During baseline evaluation, participants answered questions on sociodemographics and symptomatology, and completed self-administered questionnaires on pain, functional limitations, kinesiophobia and pain catastrophising. Then, ultrasonographic measurements of the acromiohumeral distance (AHD) were conducted[28] and isometric strength (peak force) was assessed. Thereafter, participants were randomly assigned to one of three groups: education, education and strengthening, education and motor control. All study outcomes (self-administered questionnaires, ultrasonographic and strength measurements) were re-evaluated at T_{12}, while only the self-administered questionnaires were completed at T_3, T_6 and T_{24} using internet-based questionnaires. Participants were instructed to declare to the assessors the use of any co-intervention and adverse events (eg, pain exacerbation for more than 48 hours following exercises).

Randomisation and blinding

A randomisation list was generated by an independent research assistant using a random number generator. Allocation was concealed in sealed and opaque envelopes that were sequentially numbered. Randomisation was stratified for gender (male/female) and age groups (18–55/55–75 years), and blocked randomisation was used to obtain three equal groups of 41 participants (random blocks of 3, 6 or 9). Only the assessors and statistician were blinded to group allocation.

Interventions

1. Education group (see online supplemental file 2): During two education sessions, participants were provided with information by a physiotherapist pertaining to shoulder (anatomy and function), basic pain science, advice on pain management (night and day) and activity modification (when to increase and decrease),[29–31] and were directed to watch a series of six educational videos on shoulder pain and function, persistent pain, stress, and the importance of physical activity, sleep and healthy eating habits. After watching each video, participants were asked two questions: (1) What was the most important message you took from the video? (2) Was there anything you did not understand in the video? During the second education session, responses were reviewed, and all additional questions raised by the participants regarding the videos were answered.
2. Strengthening group:[26] In addition to same advice and education the education group received, participants were given a progressive shoulder strengthening exercises programme based on the maximum number of repetitions at 90% of 1 repetition maximum (RM) that involved concentric and eccentric contractions with free weights and resistance elastic tubes. To determine 90% of 1 RM, the treating physiotherapist first determined the 1 RM by finding the weight with which the participant could only complete one repetition of the exercise. Then, the weight was adjusted to 90% 1 RM. Exercises targeted humeral internal/external rotators, abductors and the scapular muscles. Number of repetitions was one set of the maximum number of repetitions until muscular fatigue. If the pain level reached 3/10 or more at rest, participants were asked to start with a lower number of repetitions and increase or decrease depending on their pain

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behaviour in the following hours and the next day. At each of the six supervised intervention sessions spread over the 12 weeks (every 1 week or 2 weeks), shoulder strength was reassessed, and the programme was progressed accordingly.

3. Motor control group:[26] Participants received the same advice and education as the other groups as well as a MCE programme. Each of the six supervised intervention sessions spread over the 12 weeks (every 1 week or 2 weeks) started with different shoulder symptom modification procedures[32] to alleviate symptoms during upper limb movements. A series of clinical tests were performed in a sequential format through three key areas: thoracic 'finger on sternum technique', scapular procedures, 'humeral head' procedures. If a technique reduced pain, that technique was then used during elevation exercises in three planes (flexion, abduction, scaption) and incorporated into the participant's everyday functional movements. MCE during arm elevation were progressed through a standardised six-phase retraining sequence, where external feedback was progressively decreased and external load was slowly increased (without the load exceeding 50% of 1 RM (>15 reps)).[33] Once participants had reached pain free execution, the programme was progressed into exercises involving the whole body and mirroring the different functions performed by the shoulder. Number of repetitions varied from one to three sets of 15 repetitions.

   Participants in both exercise groups were asked to complete the exercises at home every day and completed a daily diary of their exercise adherence (see online supplemental file 1 for the CERT table). Participants were asked to report any adverse events in the exercise diary.

Outcomes

A blinded assessor performed all evaluations according to standardised procedures. Symptoms and functional limitations were evaluated using the Disability of Arm, Shoulder and Hand Questionnaire (*Quick*DASH) (minimal detectable change (MDC): 11; minimal clinically important difference (MCID): 11),[34] the primary outcome, as well as with two other validated self-reported questionnaires: Western Ontario Rotator Cuff Index (WORC) (MDC: 12; MCID: 12)[35] and short form of Brief Pain Inventory (BPI-SF).[36] Pain-related fear and catastrophising were evaluated using the Tampa Scale of Kinesiophobia (TSK) and the Pain Catastrophizing Scale (PCS), respectively.[37 38]

Since one intervention targeted motor control, ultrasonographic measurements of AHD at rest and at 60° of active abduction were performed to estimate the humeral head position in relation to the acromion using a 12-MHz linear array probe (Logic e9, GE Healthcare, USA).[39] For each position, three measurements were taken (intraclass correlation coefficient (ICC): 0.98; MDC: 0.7 mm).[28]

Since one intervention targeted strengthening, maximum voluntary isometric contraction was assessed for shoulder abductors and external rotators using a handheld dynamometer (Atlas-Medic, Canada) as per validated methods (online supplemental file 3),[40] which are similar to the ones suggested by Cools *et al* (ICC: 0.93–0.99).[41] The peak force value (N) from three trials was used and normalised to lever arm length (Nm).

Sample size

Based on our sample size calculation, calculated for a between-group difference for our primary outcome, 41 participants were required per group (G*Power 3.1.9; effect size: 0.80, α=0.05, power=0.90, SD=13 *Quick*DASH points, MCID=11 *Quick*DASH points, expected lost at follow-up=15%).[34 42]

Data analysis

Analyses were performed using linear mixed models (LMMs) with a random effect by participants to account for the correlation present in repeated measures within individuals (R V.4.1.1). These models allowed us to analyse and compare (all three groups at once) the effects of the three programmes on symptoms and function, kinesiophobia and catastrophising (three interventions X 5 Time (T_0, T_3, T_6, T_{12}, T_{24})), as well as on isometric strength and ultrasonograph-based outcomes (three interventions X 2 Time (T_0, T_{12})). The two-sided alpha level (0.05) was not adjusted for the various analyses. Overall interaction values of p were the primary focus of our analyses. If interactions were revealed during analyses, post hoc analyses were used to identify where the differences were. Using LMM allowed us to include baseline values in the model and adjust for age and gender.[43] All available measurements were included in the model. LMM does not require a complete case approach and only needs to assume that missing values are missing at random. Effect sizes derived from the model are presented as the mean weekly improvement in questionnaire score over 12 weeks and 24 weeks for all participants.

Deviations from trial registration and protocol

Strength measurements were not included in trial registration and protocol. They were added to determine if a high load/low repetitions strengthening programme led to greater increases in strength than the other interventions of interest. Second, our choice of statistical analyses differed from the initial trial registration and protocol. To adopt a more robust statistical model and to control for potential baseline confounders,

Table 2 Baseline participant characteristics (n=123)

	Education (n=41)	Motor control exercises (n=41)	Strengthening exercises (n=41)	Total (n=123)
Demographics				
Gender (F/M; % of F)	20/21; 48.8	22/19; 53.7	21/20; 51.2	63/60; 51.2
Age (years)	47.9±15.3	46.9±15.7	48.4±14.6	47.7±15.1
BMI (kg/m^2)	26.6±4.2	26.5±5.6	25.9±4.7	26.3±4.8
Dominance (L/R; % of L)	6/35; 14.6	3/38; 7.3	3/38; 7.3	12/111; 8.1
Symptoms related to shoulder				
Symptomatic side (L/R; % of L)	13/28; 31.7	18/23; 43.9	17/24; 41.5	48/75; 39.0
Dominant symptomatic side (%; *n*/41)	68.3 (28/41)	53.7 (22/41)	61.0 (25/41)	61.0 (75/123)
Duration of symptoms (months) (median; IQR)	24.0; 54.0	18.0; 47.0	24.0; 32.5	24.0; 40.0

BMI, body mass index; F, female; L, left; M, male; R, right.

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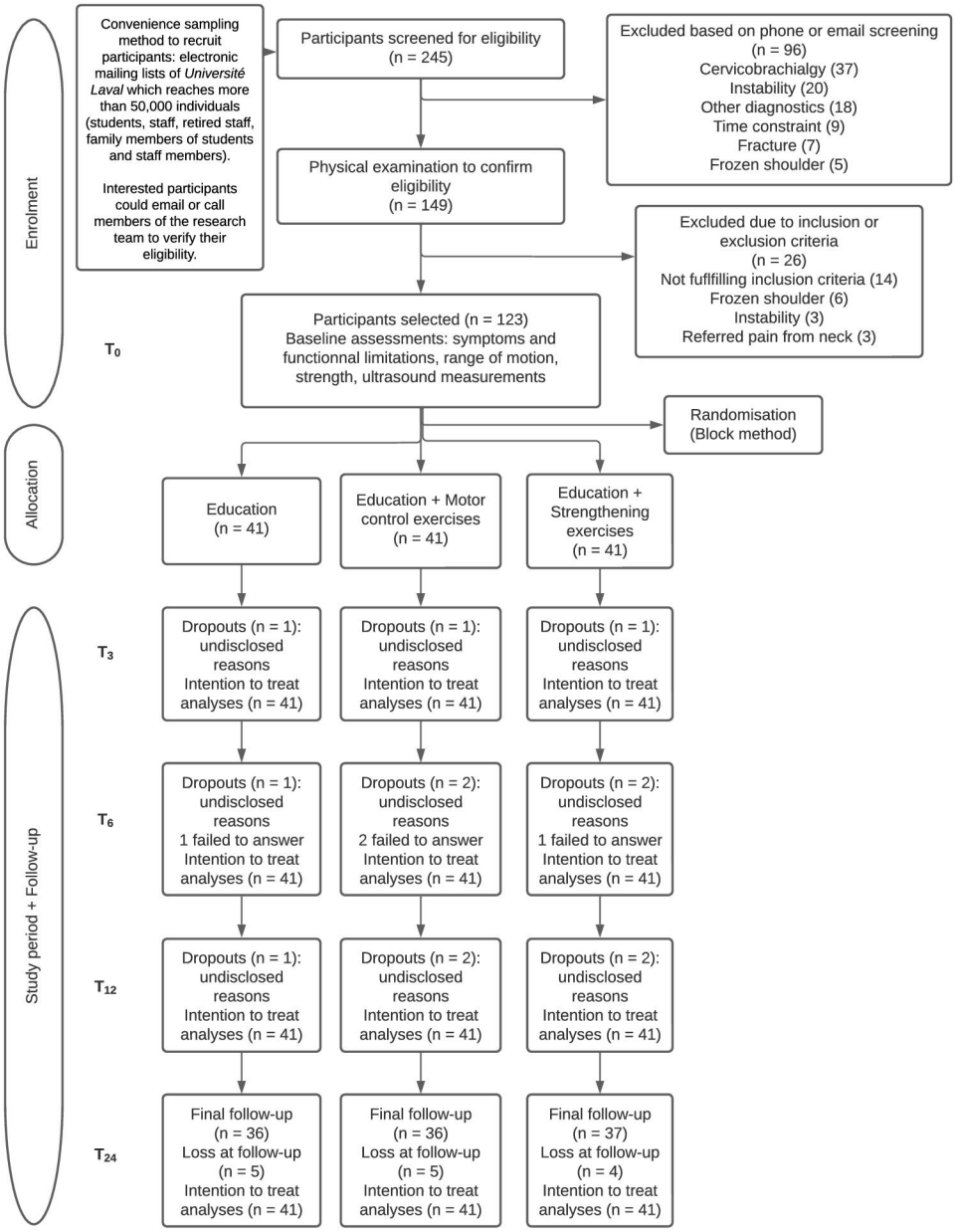


Figure 1 Flow of participants through study.

including stratification variables in the randomisation, we used a LMM approach. Results of the originally planned analyses are presented in online supplemental file 4.

RESULTS

Participants

Between May 2019 and November 2020, 123 individuals with RCRSP (table 2) were recruited out of 245 potential participants (figure 1). Five participants dropped out before T_{12}, and eight additional participants failed to return their questionnaire at T_{24} (follow-up rate=89.4 %). Sixty-three appointments were missed (attendance rate: 89%) with half of those related to COVID-19. At week 12, self-declared adherence to the MCE and strengthening exercises was 86% and 82%, respectively. No participant declared the use of a co-intervention (ie, injection, surgery, concomitant management by a health professional) and there were no adverse events reported. Assessors declared not knowing group allocation for any participant.

Main outcomes

There was a significant group-by-time interaction (p=0.04) for *Quick*DASH, but follow-up analyses did not reveal clinically meaningful between-group differences at any individual time point. There was no significant group-by-time interaction (p=0.39) for WORC. Although some of the pairwise group comparisons at individual time points were statistically significant, none of them exceeded the clinically important thresholds of 11% (*Quick*DASH) or 12% (WORC), and these group differences were not observed across the entire study period (tables 3 and 4, figure 2).

Secondary outcomes

There were significant time effects (p<0.001) for *Quick*DASH and WORC. According to our model, participants presented an overall mean weekly improvement of 0.8 and 1.2 points on the *Quick*DASH and the WORC over the 24-week follow-up period. When calculated for the 12-week intervention period,

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Table 3 Groups scores for all outcomes presented as mean (95% CI)

	Education	Motor control exercises	Strengthening exercises
*Quick*DASH (0–100)			
T_0	34.0 (29.6 to 38.3)	37.4 (32.6 to 42.1)	31.9 (27.8 to 36.0)
T_3	26.5 (22.7 to 30.4)	22.5 (18.4 to 26.6)	23.5 (19.8 to 27.1)
T_6	21.3 (17.0 to 25.7)	19.6 (15.0 to 24.2)	22.7 (18.7 to 26.6)
T_{12}	17.8 (13.5 to 22.1)	12.1 (8.3 to 15.8)	15.6 (11.6 to 19.6)
T_{24}	14.9 (11.0 to 18.7)	12.8 (8.4 to 17.1)	16.1 (11.6 to 20.6)
WORC (0–100)			
T_0	50.4 (44.0 to 56.7)	53.0 (48.1 to 58.0)	51.8 (46.2 to 57.3)
T_3	65.0 (58.9 to 71.2)	72.8 (67.6 to 78.0)	67.9 (62.6 to 73.1)
T_6	71.9 (64.9 to 79.0)	80.9 (75.6 to 86.2)	71.9 (66.4 to 77.4)
T_{12}	77.1 (70.1 to 84.0)	88.9 (84.8 to 92.9)	79.8 (73.7 to 85.8)
T_{24}	79.4 (72.8 to 85.9)	88.7 (84.0 to 93.3)	80.7 (74.3 to 87.1)
BPI (0–40)			
T_0	13.2 (11.3 to 15.1)	12.7 (10.5 to 14.8)	13.4 (11.5 to 15.4)
T_3	9.5 (7.7 to 11.3)	8.3 (6.3 to 10.4)	9.5 (7.6 to 11.4)
T_6	8.2 (5.8 to 10.6)	6.8 (4.8 to 8.8)	9.8 (7.5 to 12.0)
T_{12}	7.5 (5.2 to 9.8)	4.5 (2.7 to 6.2)	7.6 (5.6 to 9.5)
T_{24}	5.9 (3.8 to 7.8)	5.4 (3.3 to 7.6)	7.0 (4.9 to 9.1)
TSK (17–68)			
T_0	36.8 (34.5 to 39.2)	37.2 (34.9 to 39.5)	38.1 (36.0 to 40.2)
T_3	33.4 (31.2 to 35.6)	31.8 (29.7 to 33.8)	32.2 (30.2 to 34.2)
T_6	29.9 (27.4 to 32.3)	29.8 (27.8 to 31.7)	30.8 (28.8 to 32.7)
T_{12}	30.2 (28.0 to 32.5)	28.4 (26.5 to 30.2)	29.1 (26.8 to 31.3)
T_{24}	29.1 (26.6 to 31.5)	27.7 (25.7 to 29.6)	29.9 (27.5 to 32.3)
PCS (0–52)			
T_0	13.4 (10.3 to 16.4)	13.4 (10.6 to 16.1)	13.3 (10.5 to 16.1)
T_3	9.7 (6.9 to 12.6)	8.0 (5.8 to 10.1)	7.4 (5.4 to 9.4)
T_6	7.1 (4.7 to 9.6)	6.0 (3.9 to 8.1)	7.0 (4.7 to 9.2)
T_{12}	5.8 (3.3. to 8.2)	3.6 (2.3 to 4.9)	6.8 (4.6 to 9.0)
T_{24}	5.3 (2.9 to 7.7)	4.2 (2.4 to 6.0)	7.9 (5.0 to 10.7)
Peak isometric strength—shoulder abductors (Nm)			
T_0	62.7 (50.7 to 74.8)	58.8 (50.4 to 67.2)	47.0 (39.8 to 54.2)
T_{12}	72.0 (57.9 to 86.2)	68.1 (57.4 to 78.7)	58.8 (50.5 to 67.0)
Peak isometric strength—shoulder external rotators (Nm)			
T_0	24.2 (19.9 to 28.5)	23.1 (19.4 to 26.8)	19.2 (16.3 to 22.0)
T_{12}	25.4 (20.9 to 29.9)	25.2 (21.6 to 28.9)	21.5 (18.5 to 24.4)
US measurements—AHD 0° (cm)			
T_0	1.09 (1.02 to 1.15)	1.11 (1.05 to 1.17)	1.08 (1.02 to 1.14)
T_{12}	1.08 (1.03 to 1.14)	1.15 (1.07 to 1.22)	1.07 (1.01 to 1.13)
US measurements—AHD 60° (cm)			
T_0	0.89 (0.83 to 0.95)	0.90 (0.82 to 0.98)	0.85 (0.80 to 0.91)
T_{12}	0.87 (0.81 to 0.94)	0.96 (0.87 to 1.05)	0.84 (0.80 to 0.89)

AHD, acromiohumeral distance; BPI, Brief Pain Inventory; PCS, Pain Catastrophizing Scale; QuickDASH, Disability of Arm, Shoulder and Hand Questionnaire; T_0, week 0; T_3, week 3; T_6, week 6; T_{12}, week 12; T_{24}, week 24; TSK, Tampa Scale of Kinesiophobia; US, ultrasound; WORC, Western Ontario Rotator Cuff Index.

Table 4 Group differences at each time point for all outcomes presented as mean (95% CI)

	Mean difference with education		Mean difference between exercise groups
	Motor control exercises	Strengthening exercises	
*Quick*DASH (0–100)			
T_0	3.4 (−3.1 to 9.9)	−2.1 (−7.6 to 3.4)	5.4 (−0.9 to 11.8)
T_3	−4.1 (−10.0 to 1.8)	−3.1 (−8.9 to 2.7)	−1.0 (−6.2 to 4.2)
T_6	−1.7 (−8.6 to 5.2)	1.3 (−5.0 to 7.7)	−3.1 (−8.0 to 1.9)
T_{12}	−5.7 (−11.2 to −0.2)	−2.2 (−7.9 to 3.6)	−3.5 (−8.7 to 1.6)
T_{24}	−2.1 (−7.7 to 3.5)	1.2 (−4.9 to 7.4)	−3.3 (−9.5 to 2.8)
WORC (0–100)			
T_0	2.7 (−5.7 to 11.1)	1.4 (−6.8 to 9.6)	1.3 (−6.5 to 9.1)
T_3	7.7 (−1.2 to 16.6)	2.8 (−5.7 to 11.4)	4.9 (−2.7 to 12.5)
T_6	9.0 (−0.5 to 18.4)	0.0 (−8.6 to 8.6)	9.0 (1.9 to 16.0)
T_{12}	11.8 (3.4 to 20.2)	2.7 (−6.2 to 11.6)	9.1 (1.5 to 16.8)
T_{24}	9.3 (1.5 to 17.1)	1.3 (−7.6 to 10.2)	8.0 (−0.5 to 16.5)
BPI (0–40)			
T_0	−0.6 (−3.8 to 2.6)	0.2 (−2.7 to 3.1)	−0.8 (−3.8 to 2.3)
T_3	−1.1 (−4.1 to 1.8)	0.0 (−2.7 to 2.8)	−1.2 (−4.0 to 1.7)
T_6	−1.4 (−4.5 to 1.6)	1.6 (−1.6 to 4.7)	−3.0 (−5.4 to −0.6)
T_{12}	−3.0 (−5.7 to −0.3)	0.1 (−3.0 to 3.1)	−3.1 (−5.7 to −0.5)
T_{24}	−0.4 (−2.9 to 2.2)	1.2 (−1.9 to 4.3)	−1.6 (−4.7 to 1.5)
TSK (17–68)			
T_0	0.4 (−2.9 to 3.7)	1.3 (−1.3 to 3.9)	−0.9 (−4.1 to 2.3)
T_3	−1.7 (−4.8 to 1.4)	−1.2 (−4.3 to 1.9)	−0.4 (−3.1 to 2.3)
T_6	−0.1 (−3.5 to 3.3)	0.9 (−2.4 to 4.2)	−1.0 (−3.5 to 1.5)
T_{12}	−1.9 (−4.9 to 1.1)	−1.2 (−4.4 to 2.1)	−0.7 (−3.3 to 1.9)
T_{24}	−1.4 (−4.6 to 1.8)	0.8 (−2.9 to 4.6)	−2.2 (−5.4 to 0.9)
PCS (0–52)			
T_0	0.0 (−3.9 to 4.0)	−0.1 (−4.5 to 4.4)	0.1 (−4.0 to 4.2)
T_3	−1.8 (−5.6 to 2.1)	−2.3 (−6.2 to 1.6)	0.5 (−2.7 to 3.8)
T_6	−1.1 (−4.3 to 2.1)	−0.2 (−3.8 to 3.4)	−0.9 (−4.1 to 2.3)
T_{12}	−2.2 (−4.8 to 0.4)	1.0 (−2.7 to 4.8)	−3.2 (−5.9 to −0.6)
T_{24}	−1.1 (−3.9 to 1.6)	2.6 (−1.5 to 6.7)	−3.7 (−7.2 to −0.2)
Peak isometric strength—shoulder abductors (Nm)			
T_0	−6.2 (−21.3 to 8.8)	−15.8 (−30.0 to −1.5)	11.8 (−0.9 to 24.5)
T_{12}	−5.8 (−23.9 to 12.3)	−13.3 (−27.1 to 0.5)	9.3 (−4.7 to 23.3)
Peak isometric strength—shoulder external rotators (Nm)			
T_0	−1.2 (−6.9 to 4.5)	−5.1 (−10.2 to 0.0)	3.9 (−1.3 to 9.1)
T_{12}	−0.2 (−6.3 to 5.9)	−3.9 (−8.7 to 0.9)	3.8 (−1.4 to 8.9)
US measurements—AHD 0° (cm)			
T_0	0.02 (−0.07 to 0.11)	0.02 (−0.6 to 0.10)	0.03 (−0.6 to 0.12)
T_{12}	0.06 (−0.03 to 0.15)	0.00 (−0.07 to 0.07)	0.08 (−0.2 to 0.18)
US measurements—AHD 60° (cm)			
T_0	0.0 (−0.09 to 0.10)	−0.02 (−0.10 to 0.06)	0.03 (−0.07 to 0.13)
T_{12}	0.08 (-0.02 to 0.18)	−0.02 (-0.10 to 0.05)	0.10 (0.01 to 0.20)

AHD, acromiohumeral distance; BPI, Brief Pain Inventory; PCS, Pain Catastrophizing Scale; QuickDASH, Disability of Arm, Shoulder and Hand Questionnaire; T_0, week 0; T_3, week 3; T_6, week 6; T_{12}, week 12; TSK, Tampa Scale of Kinesiophobia; US, ultrasound; WORC, Western Ontario Rotator Cuff Index.

the overall mean weekly improvement was 1.3 and 2.1 points on *Quick*DASH and WORC.

There was no significant group-by-time interaction for BPI, TSK and PCS, but significant time effects ($p<0.001$) were observed as the three groups showed statistically significant improvement in time (tables 3 and 4).

There was no significant time or group-by-time interaction for AHD at 0° or 60° of abduction (tables 3 and 4). A significant time effect was observed for shoulder abductors ($p=0.0032$) peak isometric strength, but not for external rotators ($p=0.16$). There was no significant group-by-time interaction (tables 3 and 4).

DISCUSSION

Contrary to our first hypothesis, the addition of MCE or strengthening (high load, limited repetitions) exercises did not offer additional benefits in reducing symptoms and functional limitations of individuals with RCRSP over education alone.

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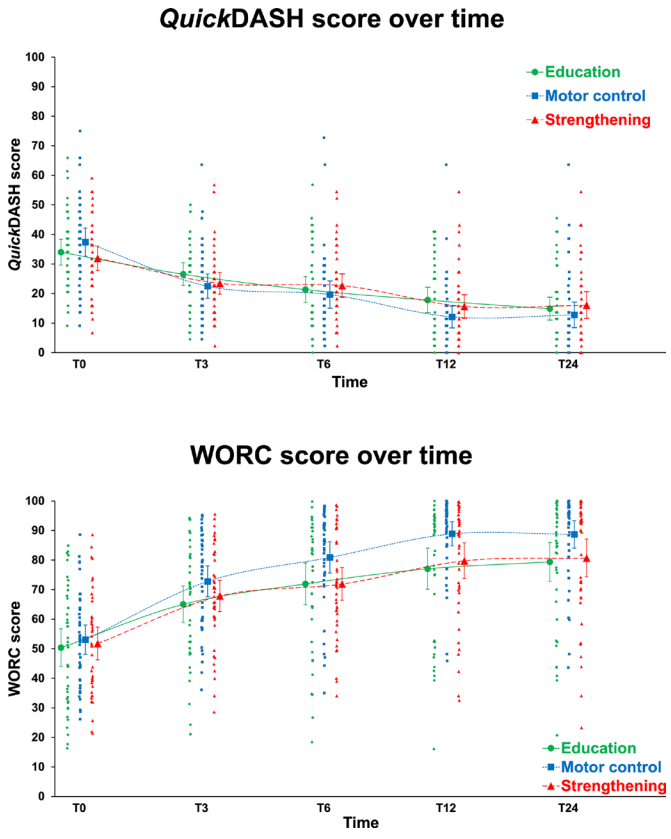


Figure 2 Mean group scores for Disability of Arm, Shoulder and Hand Questionnaire (*Quick*DASH) and Western Ontario Rotator Cuff Index (WORC). Error bars show 95% CI.

Education and advice related to pain and activity management could represent an interesting stand-alone intervention for individuals with RCRSP and this needs to be further investigated by comparing education to an actual control group. In the context of a crying need for access to high-value rehabilitation services, an education and advice session could lay a good foundation for low-cost care that is accessible to all, regardless of socioeconomic background.[44] In a qualitative study, Cridland *et al* reported that for patients with RCRSP, adequate individualised education was an important component in the management of their condition and patients felt it was best delivered by a trusted source, such as a healthcare professional.[30] Still, we cannot confirm that the statistically and clinically significant improvement in symptoms and limitations observed in our study was solely due to education since there was no control group.

In a systematic review Lafrance *et al* concluded that MCE probably led to a small but greater, positive short-term effect compared with strengthening exercises.[13] However, in the current study, neither education and MCE nor education and strengthening exercises outperformed the other, and neither outperformed education by itself. This finding led to the rejection of our second hypothesis. In addition to not providing additional benefits on symptoms and functional limitations, the combination of either MCE or strengthening with education did not lead to significant biomechanical changes regarding AHD compared with education alone. MCE and education may operate on similar mechanisms, and like education, MCE might decrease kinesiophobia and increase pain self-efficacy because of the progressive nature of the exercises preventing pain flare-ups. For many patients, education may therefore be sufficient to promote those changes.[45 46]

While our strengthening exercise parameters were different than those usually prescribed in the literature, there is currently no consensus on the best parameters for exercise prescription. Fundamentally, strengthening aims to improve muscle strength by inducing neuromuscular adaptations.[47] As the effectiveness of lower loads to produce physiological changes has been questioned,[48] we targeted higher loads to ensure that the physiological loads applied to the musculotendinous unit were sufficient to promote physiological adaptations.[48] Our results should therefore only be generalised to the exercises prescribed as other parameters (ie, repetitions, resistance) may have led to different results. The 1 RM obtained with our sample of participants could have been skewed by the presence of pain or kinesiophobia. Thus, 90% of 1 RM might not have been as high as 90% of 1 RM in the same individual without pain. Our results are similar to those obtained by Hopewell *et al* where the addition of progressive resisted/strengthening exercises of varying loads did not result in additional benefits when compared with best practice advice.[49] Recent systematic reviews reported uncertain clinical benefits associated with higher-dose and higher-volume exercises as well as progressively loaded exercises.[50 51]

Both of our exercise groups included an external load component. However, we believe that the difference in load between the two is sufficient to distinguish them, as one group had a high load/low repetitions strategy, and another had a strategy with a much lower load (ie, <50% of 1 RM) and focused mainly on movement quality. High load/low repetitions strengthening exercises did not lead to significantly greater strength improvement as all three groups improved their peak abduction force value. This overall strength improvement is most likely explained by a decrease in inhibition, initially caused by pain.[52–54] These lower-than-expected improvements following strengthening exercises have also been observed in other trials.[55] Recently, Clausen *et al* concluded that adding a large dose of shoulder strengthening to usual care does not lead to better results in disability and strength after 4 months, compared with usual care alone, in individuals with persistent RCRSP.[55] Strengthening exercises still remain an important component to include towards the end of rehabilitation to optimise long-term physical capacities.[56 57]

Limitations

First, we used a convenience sample where participants volunteered to take part in the study after seeing advertisements. Participants may have believed that the interventions proposed may help their symptoms, which may impact the external validity of our study. We did not consider the longitudinal design of our study or the presence of three groups in sample size calculation. For the longitudinal design, we would have needed to provide the variance and the correlation within repeated measurements. These are often difficult to obtain or estimate. This might have led us to overpower our study, which is not ideal but arguably better than underpower. As for the presence of three groups and of multiple comparisons, we believed that the approach used to calculate the sample size was one of the best in the absence of a single calculation that could have included all three groups and reflect our primary analysis of a single global test. The study was thus designed to be sufficiently powered for pairwise comparisons, without adjusting for the various possible analyses. Also,

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there was no control group to compare natural history, so, in theory, we cannot make any claims about efficacy of education alone. However, patients' symptoms duration (median: 24 months) and the improvement observed during the 12-week intervention period could lead us to speculate that some changes could be explained by the educational intervention and not only by time and contextual effects.

CONCLUSION

Results from this study indicate that MCE or strengthening exercises did not offer additional benefits in reducing symptoms and functional limitations of individuals with RCRSP over education alone. Future research could look at the potential value of providing stepped care where education and advice could be delivered to patients before deciding if they truly need the addition of an exercise programme.

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Competing interests JSL conceptualised the SSMP concept, which was part of the movement or motor control program used in this study.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants and was approved by the Research Ethics Committee of *Centre intégré universitaire de santé et de services sociaux de la Capitale-Nationale* (CIUSSS-CN) (#2019-1762). Participants gave informed consent to participate in the study before taking part.

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