

Original Article

Effect of motor control and strengthening exercises on shoulder function in persons with impingement syndrome: A single-subject study design[☆]

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Received 4 July 2007; received in revised form 14 January 2008; accepted 21 January 2008

Abstract

The aim of the study was to evaluate the effect of an intervention including shoulder control and strengthening exercises on function in persons with shoulder impingement. Eight subjects with shoulder impingement were evaluated weekly during the nine weeks of this single-subject design study. The study was divided into three phases (A₁–B–A₂) and involved repeated measures of shoulder pain and function (Shoulder Pain And Disability Index (SPADI) questionnaire), painful arc of motion, peak torque and 3-dimensional scapular attitudes. During the intervention phase, each subject participated in 12 exercise sessions supervised by a physiotherapist. Measures taken during the intervention and post-intervention phases were compared to pre-intervention values. All subjects showed significant improvement in the SPADI at the end of the study. A disappearance of a painful arc of motion in flexion and abduction ($n = 6$), an increase in isometric peak torque in lateral rotation ($n = 3$) and abduction ($n = 2$), and changes in the scapular kinematics, mainly in the sagittal plane, were also observed. The present results provide preliminary evidence to support the use of shoulder control exercises to reduce pain and improve function of persons with shoulder impingement.

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Keywords: Rehabilitation; Kinematics; Exercise

1. Introduction

More than a third of painful shoulder diagnoses are related to disorders of the rotator cuff that are often associated with a clinical entity called shoulder impingement syndrome (SIS) (Matsen and Arntz, 1990). SIS has been described as a repeated mechanical compression of the subacromial structures under the coracoacromial arch during arm elevation (Matsen and Arntz, 1990). In a systemic review, Michener et al. (2004) concluded from limited evidence that exercises and joint mobilization are efficacious for people with SIS. Many other studies have also reported a positive effect of exercises,

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such as strengthening, stretching, and motor control exercises, on shoulder function (Brox et al., 1993; Bang and Deyle, 2000; Ludewig and Borstad, 2003; McClure et al., 2004; Walther et al., 2004; Ginn and Cohen, 2005). However, the duration of the proposed exercise programs (three weeks–six months), as well as their intensity and level of subject's supervision diverged widely across studies.

Several studies have identified impairments associated with SIS. They have reported that people with SIS present weakness of scapulohumeral muscles (Warner et al., 1990; Leroux et al., 1994) and improper control of the glenohumeral (G/H) and scapulothoracic (S/T) movements during arm elevation. Improper control is characterized by changes in muscle activation levels. More specifically, lower activity of the serratus anterior, higher activity of the upper and lower trapezius (Ludewig and Cook, 2000), and lack of coordination between the different parts of the trapezius have been observed (Wadsworth and Bullock-Saxton, 1997; Cools et al., 2003). This inadequate muscle control is believed to contribute to a reduction of amplitude in posterior tilting and lateral rotation of the scapula during arm elevation (Ludewig and Cook, 2000; Borstad and Ludewig, 2002). Lower activity of the infraspinatus and subscapularis (Reddy et al., 2000) as well as inadequate coactivation of the scapulohumeral muscles (Myers et al., 2003) have also been reported. This abnormal muscle control is most likely associated with a reduction of the subacromial space (Graichen et al., 1999; Hébert et al., 2003b) leading to impingement.

The hypothesis that can be derived from these studies is that an improper control of G/H and S/T joint movements and strength deficits in the scapulohumeral and scapulothoracic muscles seem to be partly responsible for the level of shoulder disability in patients with SIS. Hence, this highlights the importance of assessing a comprehensive rehabilitation program that combines two types of exercises used in rehabilitation for SIS: supervised motor control exercises to correct the abnormal G/H and S/T movements and strengthening exercises. As a first step to assess the potential benefit of such a program, the individual responses to this type of rehabilitation intervention must be evaluated. The aim of this study was to evaluate, using a single-subject design, the effects of a 4-week supervised rehabilitation intervention based on a combination of shoulder control and strengthening exercises on shoulder function in persons with SIS.

2. Methods

2.1. Subject selection

Eight subjects with unilateral SIS, diagnosed by an orthopaedic surgeon, were recruited (Table 1). The subjects were included if they had at least one positive

finding in each of these categories (Hébert et al., 2003b): (1) painful arc of movement during flexion or abduction, (2) positive Neer or Kennedy–Hawkins impingement signs, or (3) pain on resisted lateral rotation, abduction or Jobe test. Exclusion criteria were type III acromion, calcification or fracture; shoulder instability; previous shoulder surgery; and cervicobrachialgia or shoulder pain during neck movement. All subjects signed an informed consent form. This study was approved by the Ethics Committee of the Quebec Rehabilitation Institute.

2.2. Study design

An A_1 – B – A_2 single-subject design was used (Backman et al., 1997). The study was divided into three phases over a 9-week period. Within the first two weeks, three evaluations of the outcome measures were performed (phase A_1). During the following four weeks (phase B), each subject participated in 12 supervised exercise sessions and the immediate effect of the intervention was assessed at the end of each week. The last three weeks consisted of the post-intervention phase (phase A_2) during which the short-term effects of the intervention were assessed once a week. The subjects were assessed and treated by the same physiotherapist.

2.3. Outcome measures

The main outcome was the pain and disability level, which was evaluated at the beginning of the study and each week thereafter using the Shoulder Pain And Disability Index (SPADI). The SPADI is a valid and reliable self-administered questionnaire (Roach et al., 1991). Higher scores indicate a greater level of pain and disability (0–100).

Secondary outcomes were the presence of a painful arc of motion, assessed at the same time period as the SPADI, the isometric peak torque, the pain intensity during strength tests and the 3-dimensional scapular attitudes (3DSA), assessed at the beginning of the study and the end of A_1 , B and A_2 phases.

In a seated position, the presence of a painful arc of shoulder motion during flexion and abduction was evaluated. If pain was present during one of the two trials performed in each plane of movement, the subject was considered having a painful arc of motion in that plane.

In a supine position, the maximal isometric strength of shoulder abductors (shoulder at 10° of abduction; elbow at 0°) and lateral rotators (shoulder at 0° of abduction; elbow at 90°) was assessed with a dynamometer (Chatillon CSD 300, Greensboro, NC). The mean torque ($n = 2$) in Newton-meters was calculated. The intensity of pain during these tests was measured with a visual analogue scale (VAS). The VAS scores for each muscle

Table 1
Subjects' characteristics at the initial evaluation.

Subject	Age (years)	Gender	Dominant side	Impaired side	Weight (kg)	Height (m)	Duration (month) ^b	Mean SPADI ^c
S1	53	F	Right	Right	57	1.61	12	69.6
S2	40	M	Left	Right	96	1.80	26	27.0
S3	32	F	Right	Right	85	1.74	3	28.1
S4	49	F	Right	Left	93	1.51	16	67.9
S5	60	F	Right	Right	69	1.62	3	47.1
S6	29	F	Left	Right	62	1.61	5	38.2
S7	56	F	Right	Left	79	1.69	8	42.0
S8	50	F	Left	Left	63	1.70	48	26.5
Total	46 ^a (± 11)	1 male 7 female	5 right 3 left	5 right 3 left	75.5 ^a (± 14.9)	1.66 ^a (± 0.09)	15.1 ^a (± 15.4)	43.3 ^a (± 17.4)

^a Mean (± 1 standard deviation).

^b Time between the appearance of the symptoms and the initial evaluation.

^c Mean of the three SPADI scores during phase A₁.

group were averaged ($n = 2$) to calculate the final outcome (0–100).

The 3DSA were calculated at two shoulder positions, 90° of abduction and 70° of flexion, with the Optotrak Probing System (Northern Digital Inc., Waterloo, Ontario, Canada) (Hébert et al., 2000; Roy et al., 2007). These positions were chosen because it has been shown that a reduced posterior tilting at those two positions along with five other variables could explain 91% of the variance of the pain and disability level experienced by subjects with SIS (Hébert et al., 2003a). Two trials were recorded at each position and the mean ($n = 2$) was used for the analysis. For each trial, six body landmarks were digitized: three on the scapula (acromial angle, inferior angle, root of the spine), and three on the trunk (C7 spinous process, right and left posterosuperior iliac spines). The position of the scapula was calculated relative to the trunk. The three scapular rotations used to describe the 3DSA were lateral/medial rotation, anterior/posterior tilting, and protraction/retraction (Fig. 1). The coordinate system and Euler angle sequence of rotations were defined in accordance with ISB recommendations (Wu et al., 2005).

2.4. Phase A₁: pre-intervention

At the first evaluation visit, the outcomes were all evaluated and the participants were taught a standardized home exercise program. This program, performed daily, was comprised of submaximal isometric contraction exercises in abduction and lateral and medial rotations against a wall. This program was prescribed for ethical reasons since it was not possible to leave the subjects without any intervention for two weeks. Participants were evaluated at the end of each week during this 2-week phase. At the last evaluation, a standardized physical examination was performed (shoulder range of motion [ROM], evaluation of scapular movements during arm elevation). The results of this examination were used to determine the intensity of the exercises performed in phase B.

2.5. Phase B: intervention

Before developing the intervention program, a review of the literature on SIS and motor learning principles was conducted and a focus group of physiotherapists was held. Thereafter, the aims of the intervention were determined. It was firstly to promote proper scapula kinematic during arm elevation against gravity and secondly, to strengthen the scapulohumeral and scapulothoracic muscles with an external resistance. The decision to introduce strengthening exercises with an external resistance only when proper shoulder control has been observed was taken to ensure a gradual loading of the muscle-tendon-bone units without any setback in the pain level. It resulted that during the intervention more emphasis was put on shoulder control.

The subjects participated in three exercise sessions per week. Exercises of increasing difficulty in terms of movement plane, ROM, number of repetitions, speed and resistance were performed. Two indicators were used to determine the level of difficulty of the exercises: quality

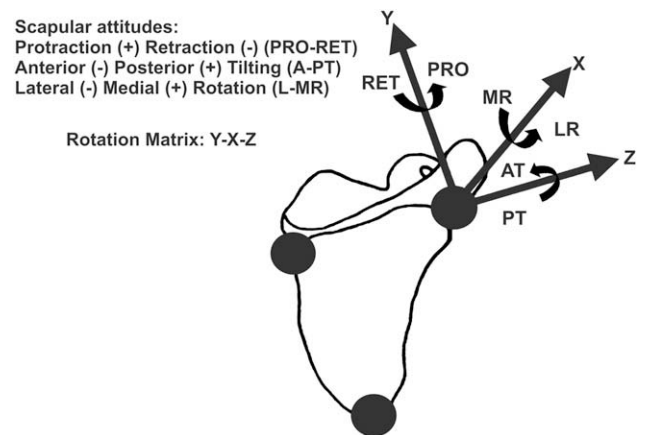


Fig. 1. Representation of the scapular rotations around the Y, X and Z axes. The scapular rotations are defined in accordance with the ISB recommendations. The sequence of rotations used is YsXsZs.

of shoulder motion and perceived intensity of pain. The intervention started with shoulder control exercises during arm elevation in the frontal, sagittal and scapular planes. These exercises were progressed following a 6-phase retraining program and began under the close supervision of the physiotherapist, who directed the retraining with feedback (Table 2). The retraining phases were graded according to: (1) the level of resistance applied on the shoulder during arm elevation (no resistance/passive movement; active assisted; active with or without external resistance); and (2) the use or non use of feedback during the movement. The phases ranged from no resistance with feedback to active movement with external resistance without feedback. In each retraining phase, the ROM was gradually increased as shoulder control improved until proper control was achieved for the full ROM in each vertical plane. When the subject was able to perform a series of 10 repetitions with proper control, series were added to reach three. Then, the subject moved up the next phase. At the end of each session, exercises in diagonal planes were performed. Subjects had to touch targets in a determined sequence, which took into account the maximum ROM they were able to reach in each vertical plane. Once abduction up to a range of 90° was properly controlled, humeral lateral rotation at 90° of abduction was performed. When a proper control was achieved with supervision, the exercise was practiced alone as home exercise.

The criterion to start strengthening exercises was to be able to perform pain-free arm elevations with a resistance of 0.45 kg. Humeral medial and lateral rotation at 0° of shoulder abduction using Thera-Bands (red to blue level), push-ups with a progression from vertical wall to

standard horizontal push-ups, and horizontal arm abduction in supine performed with a dumbbell (starting with 0.45 kg) were the exercises performed. The number of repetitions was increased from one to three series of 10. When three series were easily performed, resistance was progressively increased.

2.6. Phase A₂: post-intervention

At the end of phase B, an individualized home exercise program was given. The content of this program was determined according to the level of shoulder control and strength reached at the end of phase B and was reviewed at the two subsequent visits.

2.7. Data analysis

Outcome values obtained in phases B and A₂ were compared to the pre-intervention values using two standard deviations above and below the pre-intervention mean (A₁-interval). For the outcomes measured on a weekly basis (SPADI; painful arc of motion), two consecutive SPADI scores outside the A₁-interval or an absence of a painful arc of motion for two consecutive evaluations were necessary to conclude to a significant change in the corresponding B and A₂ phases. For the outcomes measured less frequently (peak torque; pain during peak torque), one measurement outside the A₁-interval was necessary to conclude to a significant change in phases B and A₂. Finally, the differences between 3DSA of phase A₁ and 3DSA of phases B and A₂ were calculated and illustrated graphically to describe the direction of changes during the study.

Table 2
Phases for retraining of shoulder control and manual feedback given according to scapular dyskinesia.

Phases	Steps for retraining of shoulder control			
	1	2	3	4
1 ^a	Passive elevation	Final position actively kept for 5 sec	Active return with manual feedback if needed	Verbal feedback
2 ^a	Active assisted elevation ^b	Final position actively kept for 5 sec	Active return with manual feedback if needed	Verbal feedback
3 ^a	Active elevation with manual feedback if needed	Final position actively kept for 5 sec	Active return with manual feedback if needed	Verbal feedback
4 ^a	Phase 3, but without manual feedback			
5	Phase 4, but without visual feedback.			
6	Phase 5, but with the elevation performed faster, and then with a load.			
Types of dyskinesia	Description of the scapular dyskinesia	Manual feedback		
1	Decrease of the scapular lateral rotation	Guidance of lateral rotation with a lateral pressure on the inferior angle of the scapula		
2	Tilt of the scapular inferior angle	Restriction of the tilt with a anterior pressure on the inferior angle of the scapula		
3	Elevation of the superior border of the scapula	Restriction of the scapular elevation with a inferior pressure on the acromion		
4	Tilt of the medial scapular border	Restriction of the tilt with a anterior pressure on the medial border of the scapula		

^a In front of a mirror.

^b Movement assisted by the physiotherapist to reduce the load on the shoulder.

3. Results

Seven of the eight subjects showed significant improvement in the SPADI during phase B. For five subjects, the improvement started following the first intervention week, whereas for two subjects, the improvement started following the second week. All eight subjects showed significant improvement during phase A₂ (Fig. 2).

In flexion, one subject (subject 5 [S5]) did not experience a painful arc of motion, while the seven other subjects presented a painful arc of motion during phase A₁. During phase B, only one subject (S8) presented significant improvement with disappearance of pain during flexion for two consecutive evaluations. In phase A₂,

five subjects (S1, S2, S3, S4, S8) presented significant improvement. At the last evaluation, only one subject (S7) had a painful arc of motion. In abduction, all eight subjects presented a painful arc during phase A₁. Two subjects showed significant improvement during phase B (S2, S5) and six during phase A₂ (S2, S3, S4, S5, S7, S8). Two subjects (S6, S7) still presented a painful arc in abduction at the last evaluation.

Significant increase in isometric abduction peak torque was seen at the end of phases B and A₂ for one subject and at the end of phase B for two subjects (Fig. 3). In lateral rotation, a significant increase in peak torque was found in only one subject following phase B, and in three subjects following phase A₂ (Fig. 3). Six of the eight subjects (S1, S3, S4, S5, S6 and S8) exhibited significant

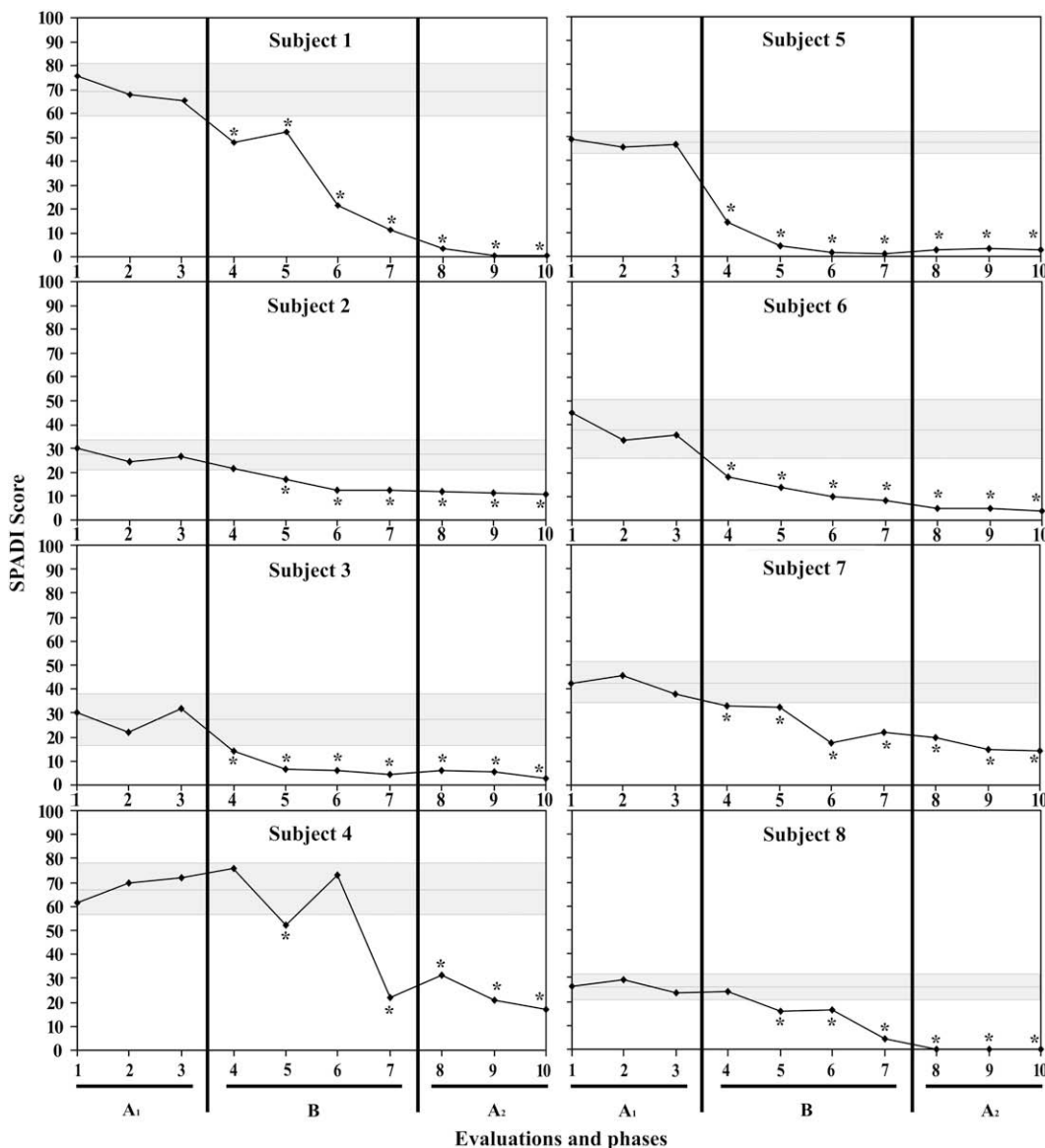


Fig. 2. Profile of the SPADI scores. Profiles of the SPADI scores over the three phases of the study (pre-intervention [A₁], intervention [B] and post-intervention [A₂]). The grey band represents two standard deviations above and below the pre-intervention mean and the line in the middle of this band indicates the mean (n = 3) value during phase A₁. The * indicates significant changes in the SPADI during phases B and A₂.

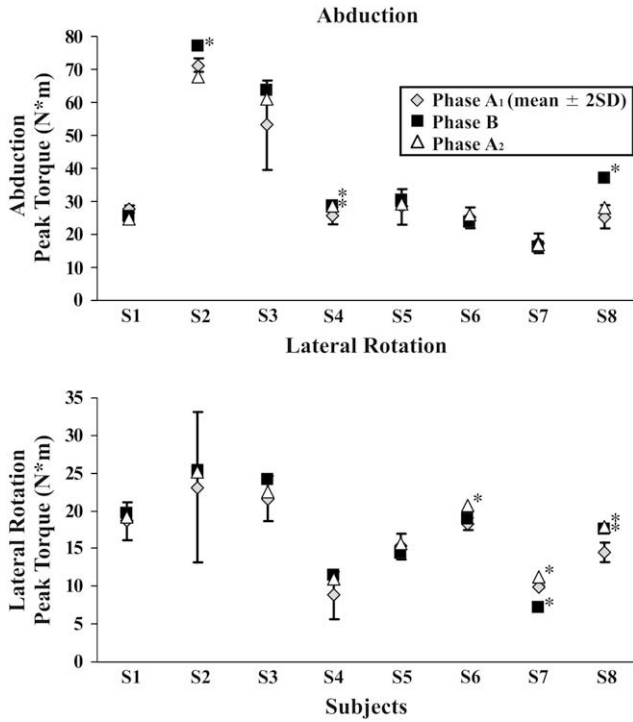


Fig. 3. Isometric peak torque in abduction and lateral rotation. The * indicates significant changes in the peak torque during phases B and A₂.

reduction of pain intensity during strength testing following phase A₂ in abduction and lateral rotation.

For the 3DSA in abduction, posterior tilting was increased for seven subjects following phase B and was still increased for five subjects at the end of phase A₂; lateral rotation was increased for five subjects following phase B and for six subjects following phase A₂; finally, protraction was increased for seven subjects following phases B and A₂ (Fig. 4).

In flexion, posterior tilting was increased for five subjects following phase B and for six subjects following phase A₂; lateral rotation was increased for four subjects at the end of phases B and A₂; finally, protraction was increased for four subjects following phases B and A₂ (Fig. 5).

3.1. Compliance with the intervention

All eight subjects participated in the 12 supervised sessions and performed both shoulder control and strengthening exercises (Table 3). The shoulder control exercises were progressed for all subjects from exercises in the vertical and diagonal planes, to exercises in lateral rotation at 90° of abduction. Strengthening exercises were begun between the third and seventh session with strengthening in medial and lateral rotations. Two subjects had to stop these exercises after three days because of an increased level of pain. Only S4 did not perform push-ups because of pain during its execution. Finally, four subjects performed the horizontal abduction

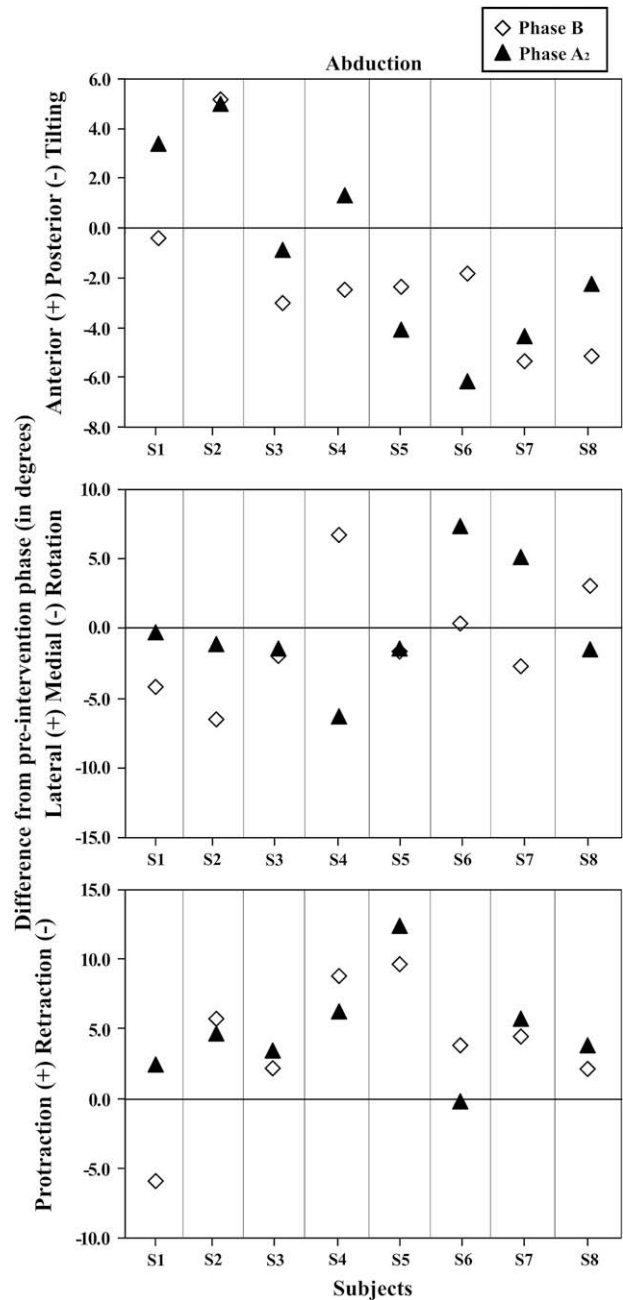


Fig. 4. Three-dimensional scapular attitude at 90° of abduction. Phases B (white diamonds) and A₂ (black triangles) 3DSA differences established in comparison with the mean pre-intervention (A₁) phase 3DSA.

strengthening exercise. The four other subjects did not perform horizontal abduction since they had pain during its execution with a dumbbell of 0.45 kg.

4. Discussion

The present results suggest that a rehabilitation program based on motor control and strengthening exercises is effective to reduce shoulder pain and

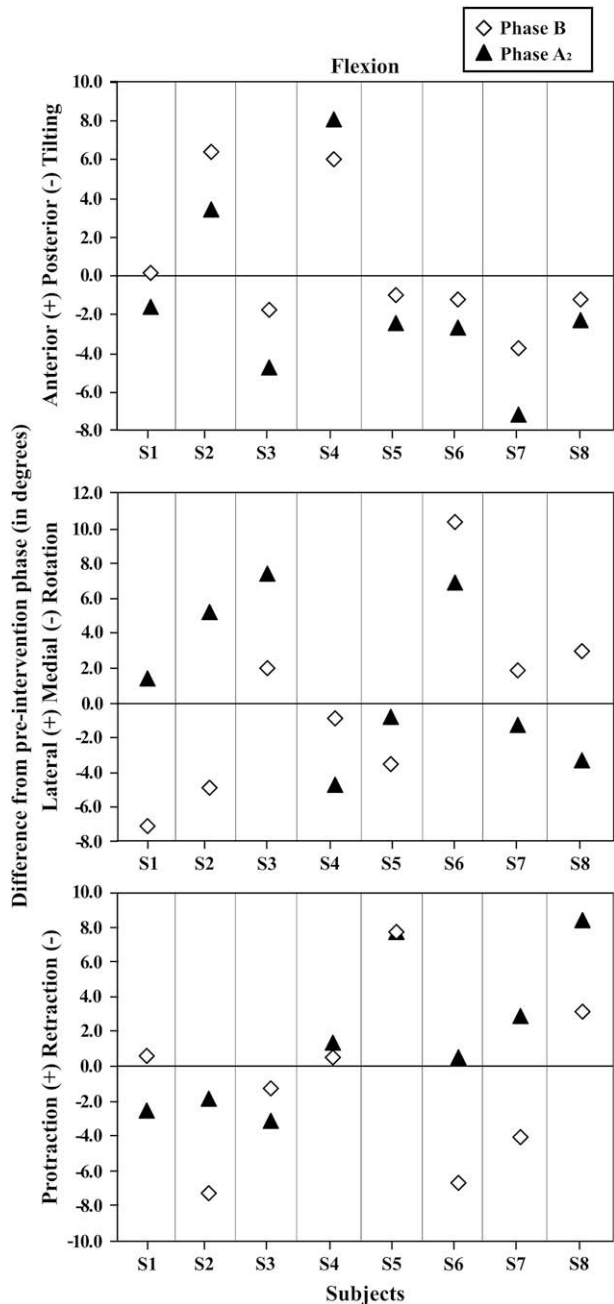


Fig. 5. Three-dimensional scapular attitude at 70° of flexion. Phases B (white diamonds) and A₂ (black triangles) 3DSA differences established in comparison with the mean pre-intervention (A₁) phase 3DSA.

promote better function in persons with SIS. These improvements were accompanied, for most subjects, by reduction in pain during maximal contractions and disappearance of the painful arc of motion. Interestingly, the improvement persisted after the end of the supervised intervention, suggesting that home exercises were sufficient to maintain or even enhance the benefits of the intervention. Our results support the findings of other studies that have shown the positive effects of rehabilitation in persons with SIS (Brox et al., 1999;

Bang and Deyle, 2000; Ludewig and Borstad, 2003; McClure et al., 2004; Walther et al., 2004; Ginn and Cohen, 2005).

The main contribution of this study is to propose a 4-week exercise program, based mainly on motor control principles, that provides a fast improvement in shoulder pain and function. In comparison to previous studies in which exercises have been used to improve shoulder control in individuals with SIS, our results seem promising. Indeed, Conroy and Hayes (1998) reported no difference in pain following a supervised exercise program of similar duration (three weeks) but composed of other types of exercises (stretching and isometric strengthening). The addition of joint mobilization to their program led, however, to a better functional outcome. As in the present study, Ludewig and Borstad (2003) also observed a significant improvement in shoulder function following home exercises. However, the duration of their home exercise program was more than twice longer (10 weeks) as ours. Finally, improvement in shoulder function has also been demonstrated by Brox et al. (1999) following a much longer supervised exercise program of three–six months.

The intervention proposed in this study includes shoulder control exercises targeting the specific impairments described in patients with SIS (Ludewig and Cook, 2000; Borstad and Ludewig, 2002). More specifically, the exercises were designed, in part, to promote larger amplitude of posterior tilting and lateral rotation of the scapula during arm elevation. Such changes in scapular rotations were not consistently found among subjects. Variability in the response to the intervention in a relatively small sample of subjects may explain this result. One can also argue that the measure used to quantify scapular rotations was not sensitive enough to capture changes that are relevant to function. When looking at individual data, changes of small magnitudes were observed following intervention for some subjects. They were mostly found in the sagittal plane with larger posterior tilting amplitude. It is known that posterior tilting elevates the anterior part of the acromion and that the acromiohumeral distance in people with SIS is decreased by only 1.2–1.3 mm around 90° and 110° of arm elevation (Hébert et al., 2003b). Therefore such small increases in posterior tilting could have resulted in less compression of the subacromial structures (Ludewig and Cook, 2000), which may have had an impact on overall shoulder pain and function.

Only small changes were observed in the isometric peak torques following the intervention. In the present study, more emphasis was put on exercises promoting better shoulder control in the first weeks of the intervention. Strengthening exercises were only introduced when proper shoulder control was achieved. Once started, strengthening exercises were progressed in order to gradually load the muscle–tendon–bone units without any

Table 3
Description of the exercises performed during phase B.

Subjects	Vertical planes		Diagonal planes		Lateral rotation at 90° of abduction		Medial and lateral rotation with Thera-Band		Push-ups		Horizontal abduction in supine	
	From	For	From	For	From	For	From	For	From	For	From	For
S1	1 (4) ^a	12	2 (7) ^a	11	7 (7) ^a	3	4	9	6	7	9	4
S2	1 (3)	12	2 (4)	8	5 (11)	5	3	10	4	4	12	1
S3	1 (4)	12	4 (8)	7	6 (7)	3	4	9	5	8	8	5
S4	1 (6)	12	4	7	7	2	7	2 ^b	NP	NP	NP	NP
S5	1 (4)	12	2 (11)	11	2	11	4	9	6	7	NP	NP
S6	1 (5)	12	3 (8)	8	4 (7)	9	5	8	8	5	NP	NP
S7	1 (4)	12	2 (9)	8	2	11	7	3 ^b	8	5	NP	NP
S8	1 (3)	12	1 (8)	11	2 (5)	10	3	10	4	9	7	6

Abbreviations: From, session where the exercise was first performed; For, the total number of sessions where the exercise was performed; NP, exercise not performed.

^a The number in brackets represents the session where the exercise was first performed with a dumbbell.

^b The exercise had to be stopped because of an increased level of pain.

setback in the pain level. In some subjects who experienced pain during strengthening exercises, these exercises had to be stopped or progressed more slowly than expected. One can hypothesize that tension or compression of the degenerated rotator cuff tendons may have been responsible for the enhancement of shoulder pain. Hence, the number of weeks during which they were performed was probably not large enough to bring about changes in shoulder strength. In comparison, McClure et al. (2004) observed significant gains in the isometric strength of the rotators and abductors of the shoulder following a 6-week program composed of more intense strengthening exercises. Undoubtedly, strengthening exercises help improve function in subjects with SIS. They should, however, be introduced at a proper stage during recovery to avoid pain recurrence and performed at a sufficient intensity to promote functional changes.

Although all the subjects showed improvement in shoulder pain and function, they did not reach normal level at the last evaluation. A longer follow-up evaluation could have provided more information of the long term outcomes and guided us on the need for some subjects to have a longer duration of supervised intervention. The home exercises performed during the pre-intervention phase may have introduced an additional source of variability on measurements, potentially leading to larger 95% confidence intervals and a reduction in our capacity to detect changes. The use of a single-study design limits the generalizability of the results and, by performing repeated measurements of outcomes, bias may have been introduced. Finally, the effect of not having an independent evaluator may have reduced the strength of our conclusions. The use of a self-administered questionnaire as the primary outcome, as well as standardized measurement procedures and valid outcomes enhance, however, the confidence in our results. This study has brought a deeper understanding of the mechanisms that led to the changes observed following

the proposed program. However, a randomised controlled trial is needed to confirm the present findings.

5. Conclusions

Results of this study suggest that a 4-week program including motor control and strengthening exercises reduces shoulder pain and improves function in persons with SIS. To better understand how shoulder control is modified, further studies need to evaluate changes in muscle and interjoint coordination using electromyography and motion analysis systems. Nonetheless, this study provides preliminary evidence to support the use of shoulder control exercises to promote better function in people with SIS.

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