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Original article

# Does pectoralis minor stretching provide additional benefit over an exercise program in participants with subacromial pain syndrome? A randomized controlled trial

Héctor Gutiérrez-Espinoza[a,b], Felipe Araya-Quintanilla[a,c], Rodrigo Gutiérrez-Monclus[d], Mario Ríos-Riquelme[e], Celia Álvarez-Bueno[f,g,*], Vicente Martínez-Vizcaino[f,h], Iván Cavero-Redondo[f,g]

[a] Faculty of Health, Universidad de las Américas, Santiago, Chile
[b] Physical Therapy Department, Clinical Hospital San Borja Arriarán, Santiago, Chile
[c] Faculty of Health, Universidad SEK, Santiago, Chile
[d] Orthopedic Surgeon, Instituto Traumatológico, Santiago, Chile
[e] Department Sciences in Physical Activity, Universidad de Santiago, Santiago, Chile
[f] Universidad de Castilla-La Mancha, Health and Social Research Center, Cuenca, Spain
[g] Universidad Politécnica y Artística del Paraguay, Asunción, Paraguay
[h] Facultad de Ciencias de la Salud, Universidad Autónoma de Chile, Talca, Chile

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ABSTRACT

*Background:* Adaptive shortening of the pectoralis minor is one of the biomechanical mechanisms associated with subacromial pain syndrome (SPS).
*Objective:* To compare the effects of an exercise program alone with an exercise program in combination with pectoralis minor stretching in participants with SPS.
*Design:* Randomized controlled trial.
*Methods:* Eighty adult participants with SPS were randomly allocated to two groups. The control group (n = 40) received a 12-week specific exercise program and the intervention group (n = 40) received the same program plus stretching exercises of the pectoralis minor muscle. The primary outcome measure was shoulder function assessed by a Constant−Murley questionnaire, and the secondary outcomes were the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire, visual analog scale (VAS), and pectoralis minor resting length.
*Results:* The present study shows no difference between the two interventions according to the Constant−Murley questionnaire (1.5 points; $p = 0.58$), VAS at rest (0.2 cm; $p = 0.11$), VAS at movement (0.5 cm; $p = 0.08$), and pectoralis minor resting length (0.3 cm; $p = 0.06$). The DASH questionnaire showed greater functional improvement in the control group (5.4 points; $p = 0.02$). Finally, only pectoralis minor length index showed difference statistical significant in favor of intervention group (0.3%; $p = 0.04$).
*Conclusion:* In the short-term, the addition of a program of stretching exercises of the pectoralis minor does not provide significant clinical benefit with respect to functional improvement or pain reduction in participants with SPS.
*Trial registration:* Brazilian registry of clinical trials UTN number U1111-1210-3555. Registered 5 March 2018.

## 1. Introduction

Subacromial pain syndrome (SPS) is the most prevalent disorder causing pain and dysfunction of the shoulder, accounting for 50–86% of all shoulder-related visits to primary care centers (Van der Windt et al., 1995; Ostör et al., 2005) and 36% of visits to secondary care centers (Juel and Natvig, 2014). In 1972, Neer proposed the concept and diagnosis of "impingement syndrome" based on a series of cases, and advocated anterior acromioplasty (Neer, 1972); this label was based on the mechanism of structural impingement of the subacromial space.

* Corresponding author. Universidad de Castilla-La Mancha, Edificio Melchor Cano, Centro de Estudios Sociosanitarios, Santa Teresa Jornet s/n, 16071, Cuenca, Spain.
*E-mail address:* celia.alvarezbueno@uclm.es (C. Álvarez-Bueno).

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However, diagnostic labels based on a pathoanatomic model fail to accurately classify participants into subgroups for clinical decision-making (Cools and Michener, 2017). An important point for consideration is that physiotherapists focus on movement-related impairments rather than structural anatomy (Ludewig et al., 2013, 2017).

The association between alterations in scapular kinematics and SPS has been previously established (Ludewig and Reynolds, 2009; Ludewig and Braman, 2011; Timmons et al., 2012; Lawrence et al., 2014). Scapular kinematics alterations in participants with SPS are characterized by a reduction in upward and external scapular rotation and an increase in clavicular elevation and retraction (Timmons et al., 2012). One proposed mechanism for these alterations is an adaptive shortening or tightness of the pectoralis minor muscle (Michener et al., 2003; Ludewig and Reynolds, 2009; Phadke et al., 2009; Ellenbecker and Cools, 2010; Seitz et al., 2011; Ludewig and Braman, 2011; Kibler et al., 2013; Cools et al., 2014). The pectoralis minor is the only scapulothoracic muscle with both its origin and insertion anterior to the scapula (Borstad and Ludewig, 2005; Muraki et al., 2009); therefore, the orientation of the muscle fibers favors scapular internal rotation, downward rotation, and anterior tilt motions. For this reason, it is considered an antagonist to normal scapular motions during arm elevation (Ludewig and Cook, 2000; McClure et al., 2001; Borstad and Ludewig, 2005; Phadke et al., 2009). A short pectoralis minor in healthy participants has been related to an increase in scapular internal rotation and a decrease in posterior tilt during arm elevation (Borstad and Ludewig, 2005; Borstad, 2006), similar to the alterations described in participants with SPS (Ludewig and Reynolds, 2009; Phadke et al., 2009; Ludewig and Braman, 2011; Kibler et al., 2013). These scapular kinematics alterations support a potential relationship between pectoralis minor shortening and SPS (Ludewig and Reynolds, 2009; Seitz et al., 2011; Ludewig and Braman, 2011; Kibler et al., 2013).

Previous evidence has shown that several stretching exercises are able to restore the length of the pectoralis minor muscle (Borstad and Ludewig, 2006; Muraki et al., 2009; Ellenbecker and Cools, 2010; Cools et al., 2014). Specifically, Borstad and Ludewig (2006) showed that the '*unilateral corner stretch*' is more effective than the '*seated manual stretch*' or the '*supine manual stretch*'. Nevertheless, no published studies have determined a direct effect on symptoms or function in participants with SPS.

Therefore, the aim of the present randomized controlled trial was to assess the short-term effects of pectoralis minor stretching in combination with a specific exercise program on functional improvement and pain relief in participants with SPS as compared with a specific exercise program alone.

## 2. Methods

A single-blinded, randomized controlled trial in two parallel groups was conducted. This research was registered in the Brazilian Registry of Clinical Trials with the number U1111-1210-3555. Ethical approval was obtained through the Ethics Committee of the Central Metropolitan Health Service of Chile with the reference number 048975. Recruitment was conducted between March and September 2018. All participants provided written informed consent.

### 2.1. Participants

Participants were recruited from the Physical Therapy Department of Clinical Hospital San Borja Arriaran in Santiago, Chile, and were eligible for enrollment if they were older than 18 years with SPS. The diagnosis was performed by an orthopedic surgeon based on the following clinical criteria: i) pain located on the anterolateral side of the shoulder for at least 3 months; and ii) one or more positive clinical signs of SPS, such as the Neer or Hawkins − Kennedy test, pain upon resisted external rotation, or the Empty Can test. These 3 clinical signs have shown sensitivity and specificity values above 74% for the diagnosis of SPS (Michener et al., 2009). Furthermore, to confirm the exclusion of other shoulder pathologies, the clinical diagnosis was complemented with imaging studies (Watts et al., 2017), which included: anteroposterior, axial, and outlet radiography; soft tissue echotomography; and nuclear magnetic resonance. All participants were prescribed 500 mg oral naproxen twice daily for 14 days, and after 2 weeks they were referred to the Physical Therapy Department. Conversely, participants were excluded if they presented with: i) pathologies of cervical origin (cervical radiculopathy, etc.) or other pathologies of the shoulder joint complex (osteoarthritis in the acromioclavicular or glenohumeral joints, calcific tendinitis, adhesive capsulitis, glenohumeral instability, partial or full-thickness tear of the rotator cuff, etc.); ii) a history of acute trauma, previous surgery, or previous fracture in the affected shoulder; or iii) corticoid injection in the affected shoulder in the last 12 months.

Sample size calculation was based on the minimum clinically important difference in 17 points from the Constant − Murley questionnaire (Henseler et al., 2015). The assumed mean for the calculation was 72.5, with a standard deviation of 19 points based on the results of a previous randomized controlled trial (Holmgren et al., 2012). To detect this difference between the 2 treatments with a value of $\alpha = 0.05$ and a statistical power of 95%, a minimum of 33 participants per group was needed. This minimum sample size estimate was increased by 20% after considering potential dropouts, and finally, a total of 40 participants in each group were considered.

The participants were randomly allocated to the intervention and control groups via a sequence of numbers generated by a computer program prior to beginning the selection process. The group to which each participant was assigned was kept in a sealed envelope with the objective of concealing the assignment from the researcher who decided the entry of the participants to the present study. Given the nature of the studied therapeutic interventions, physiotherapist and participant blinding was not possible; however, the evaluator and statistician were blinded to the groups to which the participants belonged.

### 2.2. Interventions

The control group received a specific exercise program based on motor training, taking the clinical decision algorithm proposed by a panel of experts as a reference (Klintberg et al., 2015). The program started with conscious control exercises to improve proprioception and normalize the scapular and glenohumeral resting position (Ellenbecker and Cools, 2010; Cools et al., 2014), then scapular control exercises were performed to improve upward rotation and posterior scapular tilt. Finally, glenohumeral control exercises were performed to restore centralization and prevent the superior translation of the humeral head (Appendix A). The general principles of the program are the following: 1) exercises should not produce pain; 2) a maximum of 4 exercises are performed per session; 3) exercises should be performed with optimal scapular positioning and control without abnormal compensatory trunk movement; 4) the participant should start with low load/low activation exercises that do not cause pain, with the arms below shoulder level, emphasizing the quality of the performance of the motor task, and the exercises should be performed slowly, consciously, and progressively; and lastly; 5) exercises should selectively activate weak muscles, such as the serratus anterior and inferior trapezius, with minimal activation of overactive muscles, such as the upper trapezius and deltoids, avoiding muscle fatigue (Klintberg et al., 2015). The criteria for exercise progression were good quality shoulder movement and minimal increases in pain during exercises. The dose was 8–10 times for each

exercise, maintaining the task for 5–10 s, with 1 min of rest between each repetition. Three sessions were performed per week over 12 weeks.

The intervention group received the same program as the control group, plus a program of stretching exercises using the '*unilateral corner stretch*' protocol, which consisted of 10 repetitions of 1-min stretches with a 30-s interval between repetitions (Folpp et al., 2006). The participants were instructed by a physiotherapist to perform a unilateral corner stretch using the wall. The starting position for this stretch was with the participant in a standing position, in 90° arm abduction and 90° elbow flexion, and with the palmar surface of the hand on the wall. The contralateral leg to the shoulder being stretched was positioned forward of the other leg. To apply the stretch, the trunk was shifted forward and rotated opposite to the side being stretched (Borstad and Ludewig, 2006).

Both interventions were delivered by two physiotherapists with a master's degree in manual therapy and more than 10 year's experience in musculoskeletal physiotherapy. The interventions were standardized through one seminar, videos, and lecture sessions for the physiotherapists' treatment prior to the study. Furthermore, participants from both groups received advice and an exercise program to perform at home, which consisted of 6 exercises for the neck and shoulder without any external load. Pain-free active movements of shoulder elevation, shoulder retraction, shoulder abduction in the scapular plane, and neck retraction were performed. Passive stretching of the upper trapezius and posterior capsule were performed. Each movement exercise was repeated 10 times, and each stretching exercise 3 times, twice daily at home. To monitor the adherence at home, the participants reviewed the exercise program with the physiotherapist once a week, addressing questions regarding the exercises.

### 2.3. Outcome measures

Two blinded evaluators performed outcome assessments at baseline and at the end of the 12-week intervention. Both physiotherapists evaluated the same proportion of participants in each group.

#### 2.3.1. Primary outcome measure

The Constant−Murley questionnaire was used to assess shoulder function (Constant and Murley, 1987; Constant et al., 2008). Scores range from 0 to 100, with lower scores indicating a worse condition. This questionnaire presents a high correlation with other scales and shoulder-specific questionnaires, also showing high reliability and sensitivity for the detection of post-intervention changes in a wide variety of shoulder pathologies (Roy et al., 2010). A previous study has shown that an increase of 17 points in the Constant−Murley questionnaire can be considered a minimal clinically important difference (Henseler et al., 2015).

#### 2.3.2. Secondary outcomes measure

The Spanish version of the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire was used to assess the function of the upper limb (Hervás et al., 2006). Scores range from 0 to 100, with higher scores indicating a worse condition. This version of the DASH questionnaire has been shown to be a reliable, valid, and responsive instrument that can provide a standardized measure in Spanish participants with upper-extremity musculoskeletal disorders (Hervás et al., 2006). A previous study has shown that a decrease of 10 points in the DASH questionnaire can be considered a clinically important improvement (Franchignoni et al., 2014).

Pain intensity at rest and during movement were assessed using a visual analog scale (VAS), with scores ranging from 0 ('*no pain*') to 10 ('*the worst imaginable pain*'). The VAS has been shown to be a reliable and valid instrument for the assessment of changes in pain intensity (McCormack et al., 1988). A previous study has shown that a decrease of 1.4 cm on the VAS can be considered a minimal clinically important difference in participants with rotator cuff disease (Tashjian et al., 2009).

Pectoralis minor muscle length is defined as the distance between 2 bony landmarks: the coracoid process and the inferior medial aspect of the fourth rib adjacent to the sternocostal junction (Borstad and Ludewig, 2005). The assessment was performed using a flexible tape measure, with the participant in a standing and relaxed posture and the arms at the sides in a neutral position, avoiding postural correction, and immediately after exhalation. The pectoralis minor length index was used to determine the relative pectoralis minor length and was calculated by dividing the resting length (cm) by the participant's height (cm) and multiplying by 100 (Borstad and Ludewig, 2005). This method has been shown to have good validity and reliability (Borstad, 2008; Morais and Cruz, 2016; Rosa et al., 2016). A previous study has shown that an increase of 1.14 cm can be considered a minimal clinically important difference (Rosa et al., 2016).

### 2.4. Statistical analysis

Descriptive statistics of demographic and clinical characteristics were used for baseline results of outcome measures and other potentially confounding variables in both groups. The continuous variables are presented as the mean and standard deviation, and the categorical variables as number and percentage. To determine the statistical tests for use in data analysis, we first evaluated the normal distribution of the data using the Shapiro−Wilk test. The chi-square test was used to compare the initial baseline data regarding the variables, gender and education level, and a Student's *t*-test was used for the remaining variables.

We used analysis of covariance (ANCOVA) for differences in primary and secondary outcomes between the groups at 12 weeks using continuous scales, with adjustment for baseline levels of outcomes, using group differences in the mean change from baseline to 12 weeks as the dependent variable. This analysis was performed to avoid imbalances between groups, since participants with low scores at baseline tend to improve more than those with high scores, a phenomenon known as regression to the mean (Vickers and Altman, 2001). A significance level of 0.05 was set. After considering the sample size, the 95% confidence intervals for the differences in means between the two groups were calculated. Prior to conducting the study, the researchers decided to conduct an intention-to-treat statistical analysis; if data were lost or participants discontinued their treatment. Statistical analyses were performed using the Stata SE software, version 14 (StataCorp, College Station, Texas, USA).

## 3. Results

Eighty participants, including 40 in the control group and 40 in the intervention group, were recruited as described in the CONSORT flow chart (Fig. 1). The results for the baseline characteristics of each group are presented in Table 1. When the two groups were compared, none of the variables evaluated at the beginning showed statistically significant differences (all *P* values were higher than 0.05). With regard to adherence to treatment, in the control group, 3 participants (7.5%) did not attend 2 sessions and 2 (5%) did not attend 1 session, and in the intervention group, 4 participants (10%) did not attend 2 sessions and 2 (5%) did not attend 1 session of treatment. All the nonattendances were due to health problems not directly related to SPS. With regard to complications associated with both treatments, 2 participants (5%) in the control group reported increased pain at the end of the 6th week of

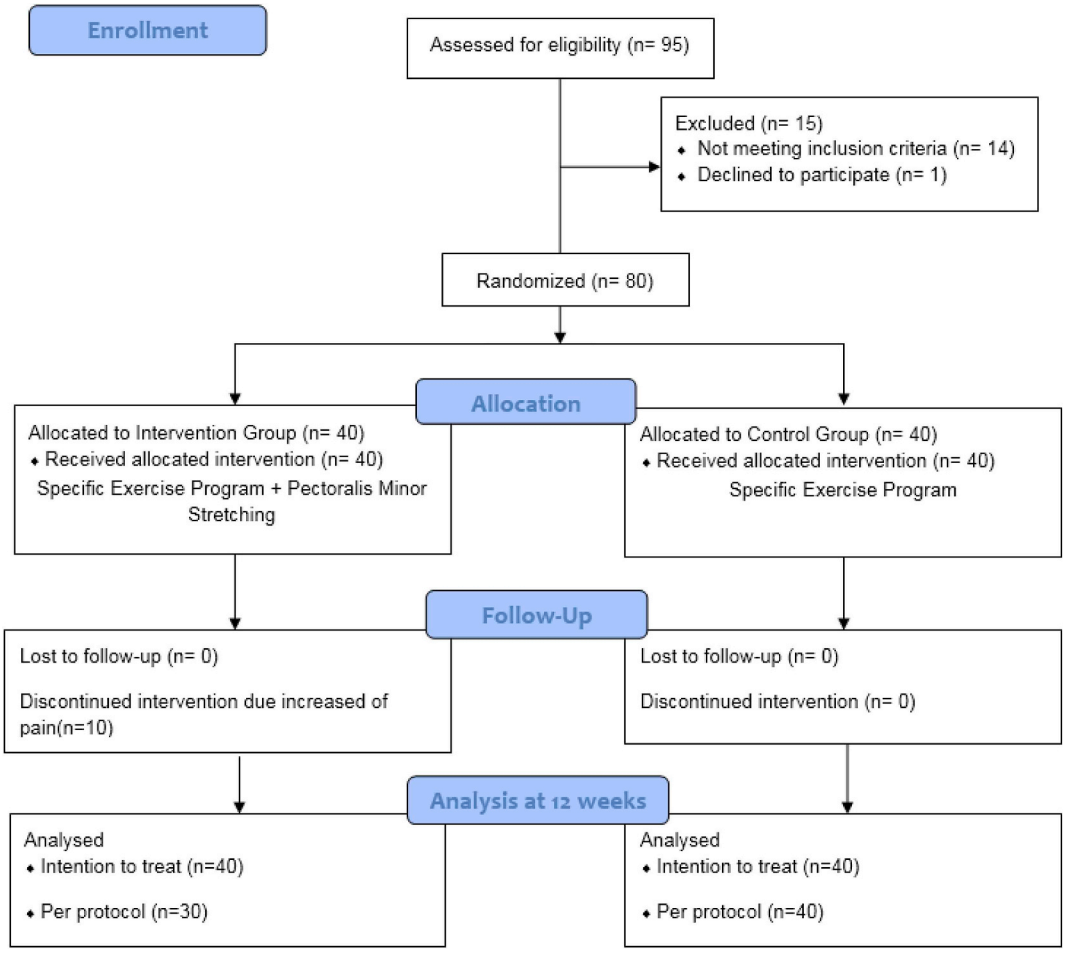


**Fig. 1.** Flow diagram of participants through phases of clinical study.

**Table 1**
Participants characteristics at baseline. Values are presented in means ± SD.

| Characteristics | Intervention Group (n = 40) | Control Group (n = 40) | pvalue |
|---|---|---|---|
| Gender male, number (%) | 27 (67.5) | 25 (62.5) | 0.74 [a] |
| Age (years) | 45.2 ± 4.3 | 44.5 ± 5.4 | 0.54 [b] |
| Duration of symptoms (months) | 3.9 ± 1.1 | 3.8 ± 1.1 | 0.91 [b] |
| Education level, number (%) | | | |
| Primary | 9 (22.5) | 9 (22.5) | 0.69 [a] |
| Middle | 21 (52.5) | 24 (60) | |
| University | 10 (25) | 7 (17.5) | |
| Height (m) | 1.6 ± 0.8 | 1.6 ± 0.7 | 0.55 [b] |
| Weight (kg) | 76.5 ± 7.1 | 75.8 ± 7.7 | 0.71 [b] |
| BMI (kg/m$^2$) | 27.4 ± 2.3 | 27.5 ± 2.4 | 0.88 [b] |
| Constant-Murley | 39.1 ± 6.6 | 41.2 ± 6.5 | 0.14 [b] |
| DASH | 42.2 ± 6.4 | 40.3 ± 6.7 | 0.19 [b] |
| VAS at rest (cm) | 1.9 ± 0.7 | 1.7 ± 0.7 | 0.35 [b] |
| VAS at movement (cm) | 6.1 ± 0.8 | 5.7 ± 1.3 | 0.21 [b] |
| Pm resting length (cm) | 13.5 ± 0.9 | 13.6 ± 1.1 | 0.62 [b] |
| PMI (%) | 8.0 ± 0.7 | 8.1 ± 0.9 | 0.59 [b] |

SD: Standard deviation.
BMI: Body mass index.
DASH: Disabilities of the Arm, Shoulder and Hand questionnaire.
VAS: Visual Analog Scale.
PMI: Pectoralis minor index.
[a] P value: obtained with the Chi-square test.
[b] P value: obtained with the *t*-test.

treatment. In the case of the intervention group, 10 participants (25%) reported increased pain at the end of the sessions during the first 2 weeks of treatment, requiring a visit to the orthopedic surgeon for re-evaluation of the clinical condition. Analgesics were prescribed for 1 week and rest for 48–72 h; therefore, these participants discontinued the originally assigned treatment.

The differences within groups from baseline to 12 weeks are presented in Table 2.

The comparison of the results between the two treatments at the end of the 12th week are presented in Table 3, according to the intention-to-treat and per-protocol analysis the changes in Constant-Murley questionnaire, VAS at rest, VAS during movement, and pectoralis minor resting length occurred similarly in both groups, and the minimal differences were not statistically significant. The DASH questionnaire showed greater functional improvement in the control group. Finally, only pectoralis minor length index showed difference statistical significant in favor of intervention group.

## 4. Discussion

The present study aimed to compare the effects of pectoralis minor stretching in addition to a specific exercise program with those of a specific exercise program alone in participants with SPS. Our results show that in the short-term, addition of '*unilateral corner stretch*' exercise does not result in a significant clinical benefit with respect to functional improvement or pain reduction in these participants.

**Table 2**
Mean change within groups from baseline to 12 weeks adjusted for baseline scores. Values are presented in means ± SD.

| Outcome | Intention to treat analysis | | | | Per protocol analysis | | | |
|---|---|---|---|---|---|---|---|---|
| | Δ Intervention group (n = 40) | pvalue [a] | Δ Control group (n = 40) | pvalue [a] | Δ Intervention group (n = 30) | pvalue [a] | Δ Control group (n = 40) | pvalue [a] |
| Constant-Murley, 0 to 100 points | 31.6 ± 11.1 | 0.00 | 30.2 ± 11.1 | 0.00 | 32.2 ± 11.5 | 0.00 | 30.6 ± 11.5 | 0.00 |
| DASH, 0 to 100 points | −18.5 ± 7.3 | 0.00 | −23.9 ± 7.3 | 0.00 | −17.5 ± 6.9 | 0.00 | −24.2 ± 6.9 | 0.00 |
| VAS at rest, 0–10 cm | 0.1 ± 0.5 | 0.19 | −0.1 ± 0.5 | 0.14 | −0.02 ± 0.5 | 0.74 | −0.1 ± 0.5 | 0.14 |
| VAS at movement, 0–10 cm | −2.9 ± 1.1 | 0.00 | −3.3 ± 1.1 | 0.00 | −2.9 ± 1.1 | 0.00 | −3.4 ± 1.1 | 0.00 |
| Pm resting length, cm | 0.9 ± 0.6 | 0.00 | 0.6 ± 0.6 | 0.00 | 0.8 ± 0.6 | 0.00 | 0.6 ± 0.6 | 0.00 |
| PMI, (%) | 0.7 ± 0.5 | 0.00 | 0.3 ± 0.5 | 0.00 | 0.7 ± 0.5 | 0.00 | 0.4 ± 0.5 | 0.00 |

Pm: Pectoralis minor.
SD: Standard deviation.
DASH: Disabilities of the Arm, Shoulder and Hand questionnaire.
VAS: Visual Analog Scale.
PMI: Pectoralis minor index.
[a] Pvalue obtained with ANCOVA.

Based on biomechanical fundamentals, several investigations have established that loss of flexibility of the pectoralis minor alters the normal kinematics of the scapula (Michener et al., 2003; Borstad, 2006; Ludewig and Reynolds, 2009; Seitz et al., 2011; Ludewig and Braman, 2011; Rosa et al., 2017). Although the studies that support this association were conducted in a healthy, young population (Borstad and Ludewig, 2005, 2006; Borstad, 2008), several authors recommend including pectoralis minor stretching in the rehabilitation of participants with SPS (Ludewig and Reynolds, 2009; Phadke and Camargo, 2009; Ellenbecker and Cools, 2010; Ludewig and Braman, 2011; Seitz et al., 2011; Kibler et al., 2013; Cools et al., 2014).

Several studies that have included self-stretching exercises of the pectoralis minor in home treatment programs have shown a decrease in symptoms and functional improvement in participants with SPS (Wang et al., 1999; Ludewig and Borstad, 2003; McClure et al., 2004; Rosa et al., 2017). However, these positive clinical effects do not correlate with changes in the length of the pectoralis minor or scapular kinematics (McClure et al., 2004; Rosa et al., 2017). Some randomized controlled trials have studied pectoralis minor stretching together with an exercise program and manual therapy for the treatment of participants with SPS. A previous study has shown significant benefits with respect to pain reduction and functional improvement (Bang and Deyle., 2000); nevertheless, another study found no significant benefits in terms of pain reduction, functional improvement, or scapular kinematics when manual therapy was added to an exercise program that included stretching of the pectoralis minor (Camargo et al., 2015). However, although pectoralis minor stretching is one of the most often used techniques in clinical practice, it is difficult to determine its direct beneficial effect on movement, function, and symptoms in participants with SPS (Rosa et al., 2017).

One of the main strengths of our study is that due to its methodological structure, we could determine the direct clinical effect of the stretching program using the '*unilateral corner stretch*'. This is the most frequently used exercise in the literature for this purpose (Wang et al., 1999; Bang and Deyle, 2000; Ludewig and Borstad, 2003; McClure et al., 2004; Rosa et al., 2017), since it has the advantage of being self-applied by the participant and being more effective than other types of stretching exercises (Borstad and Ludewig, 2006). However, this exercise places the participant's shoulder into a position that can possibly cause pain in the case of subacromial or internal impingement (Ellenbecker and Cools, 2010; Kibler et al., 2013; Cools and Struyf, 2014). Ten participants in the intervention group reported complications consistent with previous findings, identifying the '*unilateral corner stretch*' as the factor triggering increased pain. These participants were evaluated by an orthopedic surgeon who prescribed analgesics and rest during 48–72 h; thus, the exercise program characteristics were modified according to their tolerance.

Currently, no consensus exists regarding the best procedure for the assessment of pectoralis minor tightness (Morais and Cruz, 2016). We used a direct method to assess the pectoralis minor resting length

**Table 3**
Mean differences between groups at 12-weeks adjusted for baseline scores. Values are presented in 95% confidence interval.

| Outcome | Intention to treat analysis | | Per protocol analysis | |
|---|---|---|---|---|
| | Treatment effect [a] mean (CI 95%) | pvalue | Treatment effect [a] mean (CI 95%) | pvalue |
| Constant-Murley, 0 to 100 points | 1.5 (3.8–6.6) | 0.58 | 1.6 (−4.3 to 7.5) | 0.59 |
| DASH, 0 to 100 points | 5.4 (1.9–8.8) | 0.02 | 6.8 (3.3–10.4) | 0.00 |
| VAS at rest, 0–10 cm | 0.2 (−0.04 to 0.4) | 0.11 | 0.1 (−0.1 to 0.3) | 0.44 |
| VAS at movement, 0–10 cm | 0.5 (−0.1 to 1.1) | 0.08 | 0.4 (−0.2 to 1.0) | 0.13 |
| Pm resting length, cm | 0.3 (−0.02 to 0.5) | 0.06 | 0.2 (−0.1 to 0.5) | 0.20 |
| PMI, (%) | 0.3 (0.1–0.6) | 0.04 | 0.3 (0.05–0.5) | 0.02 |

Pm: Pectoralis minor.
CI 95%: Confidence Intervals 95%.
DASH: Disabilities of the Arm, Shoulder and Hand questionnaire.
VAS: Visual Analog Scale.
PMI: Pectoralis minor index.
[a] Difference between groups adjusted for baseline scores analyzed with ANCOVA.

(Borstad and Ludewig, 2005), with the mean change after treatment in the intervention group being 0.9 cm, with a small effect size. Since the mean change of 0.9 cm is smaller than the minimum detectable change (1.14 cm), the increase in pectoralis minor length measured at the end of the treatment does not represent a real alteration in muscle length after stretching (Rosa et al., 2016). In comparison with the control group, this difference in favor of the intervention group was not statistically significant. For clinical purposes, direct measurement of pectoralis minor muscle length should be normalized to an individual's anthropometrics. Originally, height was used to normalize pectoralis minor length, and the pectoralis minor length index was calculated according to the method proposed by Borstad and Ludewig (2005). This was the only statistically significant difference in favor of the intervention group.

The efficacy of stretching techniques depends on the force and duration (dosage) applied (Morais and Cruz, 2016); however, the best dosage for an effective stretch has not yet been determined (Weppler and Magnusson, 2010). A shorter stretching duration may reduce the perception of pain or increase the tolerance of connective tissue to lengthening, so the muscle can stretch further; however, this effect is due to a modified perception of sensation and not to an increment in extensibility as such (Weppler and Magnusson, 2010). Nevertheless, a minimum of 10 min per session appears to be necessary to achieve a greater improvement in muscle flexibility and passive stiffness over time, likely due to a more permanent deformation of the connective tissue (Guissard and Duchateau, 2004; Morais and Cruz, 2016). Regarding the duration of treatment, the minimum period required to achieve a decrease in passive muscular resistance has been described as at least 4 weeks (McHugh and Cosgrave, 2010; Weppler and Magnusson, 2010).

Some limitations should be addressed in this research. A recognized limitation is that linear measurements, such as the one used to quantitate pectoralis minor length in this study, cannot represent real structural changes in muscle after a stretching protocol. An additional limitation is the absence of follow-up once both treatments were finalized, which does not allow establishment of the effectiveness of the therapeutic intervention in the long-term. Moreover, blinding of the physiotherapists and participants was not achievable given the nature of the studied interventions. Finally, all these considerations must be examined when attempting to extrapolate the results of our study to the treatment of participants with SPS.

## 5. Conclusions

In the short-term, addition of '*unilateral corner stretch*' exercise does not provide a significant clinical benefit in terms of functional improvement or pain reduction in participants with SPS. Thus, our study has important clinical implications, since it demonstrates that adding this stretching exercise program to the regular treatment for SPS is not an effective therapeutic strategy. Further studies are needed to support the clinical effectiveness of pectoralis minor stretching in these participants.

## Ethics aspects

The study protocol was approved on 14 September 2015 by the Ethics Committee of the Central Metropolitan Health Service in Santiago of Chile.

## Declaration of funding

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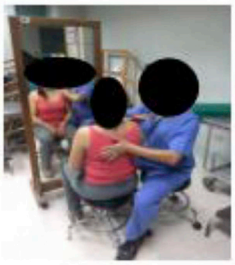
## Declaration of conflict of interests

The authors declare they do not have any potential conflict of interest with regard to the investigation, authorship, and/or publication of this article.

## Appendix A. Detailed description of the specific exercises program

Fig. a Scapular orientation exercise with conscious control

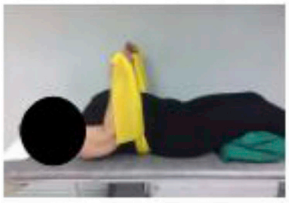


Active movements of the scapula in front of a mirror assisted by the therapist.

Progression

Scapular retraction exercise in side-lying with conscious control in front of a mirror

Fig. b Scapular control exercise in flexion

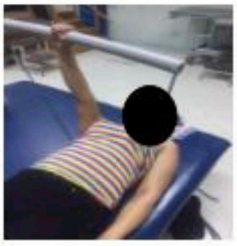


Supine patient performs shoulder flexion up to 60 degrees

Progression

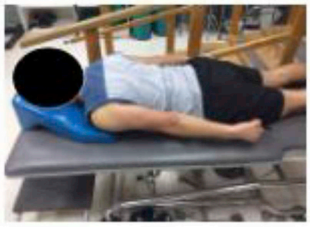
Sitting patient performs shoulder flexion up to 90 degrees.

Fig. c Scapular control exercise in closed kinetic chain



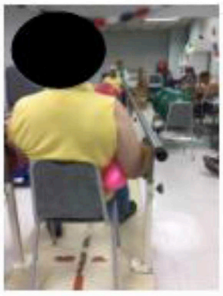
"Unilateral Bench Press", the patient performs a protraction with the full-extended arm.

Fig. d Scapular control exercise extension prone



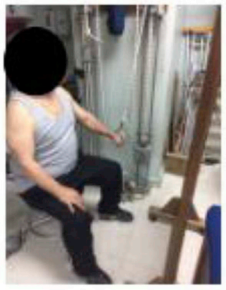
The patient performs a shoulder extension with the full arm extended.

Fig. e Glenohumeral control exercise



The patients perform an isometric adduction with a pillow under the arm, with isometric external rotation.

Fig. f Glenohumeral control exercise



The patient perform an isometric adduction at 30 to 60 ° glenohumeral abduction

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