

ORIGINAL RESEARCH

Is the angular onset of pain during arm elevation associated to functioning in individuals with rotator cuff related shoulder pain?



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KEYWORDS

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Abstract

Background: Rotator cuff related shoulder pain (RCRSP) is the main diagnosis for shoulder pain. A painful arc during active arm elevation is a common finding in RCRSP. The angular onset of pain during arm elevation may play an important role on functioning of the upper extremities.

Objective: This study aimed to: 1) determine and characterize the association between the angular onset of pain during arm elevation and upper-limb self-reported functioning, 2) verify whether demographic and clinical characteristics contribute to this association, and 3) investigate whether these characteristics differ considering distinct ranges of angular onset of pain in individuals with RCRSP.

Methods: 252 individuals with RCRSP were divided in 3 groups based on the angular onset of pain during arm elevation in the sagittal plane: $<60^\circ$, 60° - 120° , and $>120^\circ$. The Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire was used to assess functioning of the upper limbs. Demographic and clinical characteristics were selected for the multivariable analysis.

Results: Individuals with an angular onset of pain above 120° of arm elevation presented lower DASH score (lesser disability) than individuals with an angular onset of pain between 60° - 120° . Male sex, age, dominance of the side affected, duration of symptoms, and the angular onset of pain during arm elevation explained 31% of the DASH score variance.

Conclusion: Individuals with RCRSP and angular onset of pain above 120° of arm elevation present better functioning than individuals with onset of pain between 60° - 120° , and similar functioning as those with pain below 60° . Male sex, lower age, non-dominant side being affected and longer duration of symptoms are also associated to better functioning as assessed by the DASH questionnaire.

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Introduction

The diagnostic label of subacromial impingement syndrome is a common diagnosis of shoulder pain and was introduced by Neer¹ in 1972. Subacromial impingement syndrome is an “umbrella” term that encompasses a number of pathoanatomic alterations in patients with similar clinical presentation.² Considering the aforementioned, rotator cuff related shoulder pain (RCRSP) has been proposed as a more adequate term for painful conditions attributed specifically to the rotator cuff.³ Although it is now suggested that the use of special and provocative tests for the diagnosis of RCRSP should be abandoned,⁴ these tests are still commonly used in clinical practice.⁵

Patients with RCRSP typically present with pain during active elevation of the arm. The “painful arc” is considered a hallmark sign of RCRSP, and has been classically described to occur between 60° and 120° of arm elevation.⁶ However, the presence of pain below and above the “painful arc” is often seen clinically. The source of pain during arm elevation is unknown but is often presumed to be caused by compression of the subacromial structures.⁷ Several investigations have assessed the impact of humeral elevation on subacromial proximities.⁸ Studies generally report minimal acromiohumeral distance to occur in the range of 70° to 120° of arm elevation.⁹ But, this metric does not reflect proximity to the rotator cuff tendons as it is a bone-to-bone measurement. Other studies have identified the smallest distances between the insertion of the rotator cuff tendons and the coracoacromial arch to occur at lower angles of arm elevation, between 40° and 75°.^{8–11}

This calls into question if the “painful arc” is useful to help clinicians during clinical management in patients with shoulder pain. While for some individuals most activities of daily living or work (such as cooking, making the bed, typing, driving, washing the floor, cleaning surfaces, gardening, etc.) are performed at lower ranges of arm elevation, for others, many daily professional activities (such as washing walls and windows, brick laying, painting walls and ceilings, etc.) are performed at higher levels of arm elevation. Therefore, it is possible that people who experience the onset of pain at different ranges of arm elevation may have distinct functioning of the upper limbs. Demographic characteristics (e.g. age) and clinical characteristics (e.g. chronicity of symptoms) of the condition may also impact upper extremity functioning to some extent.¹² The clinical presentation and functioning of patients with shoulder pain may be affected by several factors that occur with both aging and duration of symptoms, such as shoulder degenerative alterations,^{13,14} strength decline,¹² and high relative effort during functional tasks.¹² Information regarding other possible clinical and demographic contributors to upper extremity disability may provide a better understanding of the evaluation and decision-making processes for treating individuals with RCRSP.

The objectives of this study were to: 1) determine and characterize the association between the angular onset of pain during arm elevation and upper-limb self-reported

functioning, 2) verify whether demographic and clinical characteristics contribute to this association, and 3) investigate whether these characteristics differ considering distinct ranges of angular onset of pain in individuals with RCRSP.

Methods

Participants and study design

This is a secondary analysis of data previously collected on individuals with RCRSP. All original studies were performed at the Laboratory of Analysis and Intervention of the Shoulder Complex from the Department of Physical Therapy (Universidade Federal de São Carlos) and approved by the Human Research Ethics Committee of Universidade Federal de São Carlos. All individuals signed a written consent before study enrollment. Eligible participants had self-reported shoulder pain during flexion of the arm for at least four weeks. The diagnosis for RCRSP was based on a clinical examination and self-reported orthopedic history. To be classified as having RCRSP, potential individuals had to present atraumatic onset of shoulder pain, pain with active arm elevation, and at least 2 of the following findings: positive Neer sign,¹ positive Hawkins sign,¹⁵ positive Jobe test,¹⁶ or pain with isometric resisted shoulder external rotation.¹⁷ This combination of shoulder tests is suggested to provide better diagnostic accuracy to confirm RCRSP.^{5,17}

Individuals with a history of fracture or previous surgery in the upper limbs, recurrent glenohumeral joint dislocations in the last two years, clinical signs of adhesive capsulitis as assessed by glenohumeral external and internal rotation range of motion deficit, presence of neck-related pain determined by the Spurling and cervical quadrant tests, or shoulder pain reproduced by the upper limb neurodynamic test for the median nerve were excluded.

Angular onset of pain during arm elevation

The angular onset of pain during arm elevation was measured with a digital inclinometer (Acumar™, Lafayette Instrument Company, Lafayette, IN) with the individual in the standing position and the elbow in full extension.¹⁴ Individuals were instructed to assume a relaxed position with the arms at their side, and then raise the arm in the sagittal plane with the thumb pointing towards the ceiling until the onset of shoulder pain. The inclinometer was then placed on the distal upper arm, just proximal to the elbow to measure the elevation angle.¹⁸ Only one trial was performed. Four examiners with at least four years of experience in assessing individuals with shoulder pain were responsible for performing the measurements. The intraclass correlation coefficient for interrater reliability of shoulder flexion measurements ranges from 0.88 to 0.96 as reported in a previous study.¹⁹

Individuals were divided in 3 groups based on the angular onset during arm elevation: <60°, 60° - 120°, and >120°.

These ranges were chosen based on the classic definition of “painful arc” ($60^\circ - 120^\circ$).²⁰

Functioning

The Brazilian version of the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire was used to assess functioning of the upper limbs.¹⁵ The DASH is a self-reported questionnaire with 30 questions that assesses the individual’s ability to perform daily activities. Scores range from 0 to 100, with higher scores indicating a worse disability. This version of the DASH questionnaire has been shown to be valid and reliable.^{15,16}

Statistical analysis

Continuous data (age, height, weight, duration of symptoms, angular onset of pain, and DASH score) are presented as median [interquartile range] according to the Shapiro-Wilk test of normality. Categorical variables (sex and dominance of the affected side) are presented as counts and percentages. Comparisons between groups were performed using the Kruskal-Wallis test for continuous variables followed by a post hoc Dunn test for multiple comparisons and adjusted with the Benjamini-Hochberg method, and Pearson’s Chi-squared test with Yates’ continuity correction for categorical variables. Backward stepwise multivariable linear regression was used to investigate the relationship between the angular onset of pain during arm elevation as continuous data and DASH score. Selected demographic (sex, age, height, and weight) and clinical (dominance of the affected side, duration of symptoms, and angular onset of pain) characteristics were used for the multivariable analysis. Covariates included in the final model were chosen based on minimization of the Akaike Information Criterion.²¹ Multicollinearity was tested by examining the variance inflation factor associated with each independent variable. A variance inflation factor below 2 was considered as an absence of multicollinearity. Linear regression assumptions and potential problems were checked by producing diagnostic plots visualizing the residual errors (Residuals vs Fitted plot, Spread-location plot, QQ plot, and Residuals vs Leverage plot). Statistical significance was assessed at a two-sided p -value < 0.05 . 95% confidence intervals (95% CI) were constructed for the differences in medians between groups. All analyses were conducted using R 3.5.2 (The R Project for Statistical Computing, 2018) in R-studio 1.1.463 (RStudio Inc., Boston, MA, USA).

Results

The characteristics of the participants and between-group comparisons are presented in [Table 1](#). A total of 252 individuals were included in the study. Dunn post-hoc analysis revealed a substantial difference in age between the $60^\circ - 120^\circ$ and the $>120^\circ$ groups (median difference: -5 years; 95%CI: $-8, -1$). Majority of the individuals (65.4%) presented angular onset of pain above 120° of arm elevation, 31.7% presented angular onset of pain between $60^\circ - 120^\circ$ of arm elevation and 2.8% below 60° of arm elevation ([Fig. 1](#)).

Considering the comparison of DASH score between each category of the angular onset of pain, the score was lower in individuals with angular onset of pain above 120° of arm elevation when compared to those with the onset of pain between $60^\circ - 120^\circ$ (median difference: -10.8 points; 95%CI: $-15.0, -6.7$). There was no difference between the other categories ([Fig. 2](#)).

The relationship between the angular onset of pain and the DASH score was further analyzed using a stepwise multivariable linear regression. [Table 2](#) shows that 31% (Adjusted $R^2 = 0.30$) of the variance in the final model was explained by male sex, age, the dominant side affected, duration of symptoms, and the angular onset of pain during arm elevation.

Discussion

The results of this study demonstrated that most individuals with RCRSP presented with an angular onset of pain above 120° of arm elevation in the sagittal plane, and similar functioning as the few participants with angular onset of pain below 60° . Male sex, lower age, non-dominant side being affected, and longer duration of symptoms were found to be associated with better functioning as assessed by the DASH score. These variables were able to explain only 31% of DASH score variance.

Greater disability was observed in individuals with the angular onset of pain between $60^\circ - 120^\circ$ of arm elevation in the sagittal plane. It is worthy to highlight that most activities assessed in the DASH questionnaire and most daily activities²² are performed in this range of motion. A recent study has suggested that the DASH questionnaire may not be appropriate to assess individuals with RCRSP who have onset of pain at higher ranges of arm elevation.²³ This is because ceiling effect occurred in most individuals with the angular onset of pain above 120° of arm elevation.²³ Clinicians should be careful when interpreting the DASH in individuals with RCRSP and pain above 120° of arm elevation in the sagittal plane.

Individuals with the angular onset of pain above 120° showed similar functioning as the few individuals with the angular onset below 60° . Interestingly, those are the ranges that put the supraspinatus tendon in closer contact to the glenoid (above 120°) and coracoacromial arch (below 60°).²⁴ In our study, most individuals presented the angular onset of pain above 120° of arm elevation in the sagittal plane. Saini et al.²⁴ demonstrated that deformation of the supraspinatus tendon against the glenoid occurred more frequently than against the coracoacromial arch. This is interesting data. Although we cannot make direct comparison, as compression may not be the source of pain or related to functioning, the current study may also suggest that individuals with RCRSP are more likely experiencing internal rather than subacromial impingement. Finally, these data call into question whether the “painful arc” is not being precisely described or is not representing RCRSP.

When using a stepwise multivariable linear regression, sex and dominance of the affected side were the most associated to the DASH score. However, these results should be interpreted with caution because the contribution of each covariate to the DASH score reaches the standard error of

Table 1 Characteristics of the study participants.

	Overall (n = 252)	Angular Onset of Pain During Arm Elevation		
		< 60° (n = 7)	60° – 120° (n = 80)	> 120° (n = 165)
Sex				
Female, n (%)	115 (45.6)	2 (28.6)	36 (45.0)	77 (46.7)
Male, n (%)	137 (54.4)	5 (71.4)	44 (55.0)	88 (53.3)
Age, years*	33.0 [26.0, 47.0]	39.0 [26.5, 45.5]	39.0 [27.7, 51.2]	31.0 [26.0, 43.0]
Height, m	1.71 [1.64, 1.75]	1.73 [1.65, 1.76]	1.70 [1.62, 1.75]	1.72 [1.66, 1.76]
Weight, kg	73 [64, 80]	73 [67, 76]	74 [64, 80]	73 [64, 80]
Affected side				
Dominant, n (%)	151 (59.9)	3 (42.9)	55 (68.8)	93 (56.4)
Non-dominant, n (%)	101 (40.1)	4 (57.1)	25 (31.2)	72 (43.6)
Duration of symptoms, m	24 [6, 48]	8 [5, 72]	24 [5, 51]	24 [7, 48]
Angular onset of pain, degrees**	138 [105, 163]	38 [30, 47]	95 [80, 109]	155 [140, 170]
DASH score**	22.5 [13.1, 35.8]	18.3 [15.0, 35.0]	30.0 [19.8, 47.5]	19.2 [10.8, 30.8]

Data are reported as median [interquartile range]. DASH: Disabilities of Arm, Shoulder and Hand questionnaire.

* $p < 0.05$ in the Dunn post hoc analysis.

** $p < 0.001$ in the Dunn post hoc analysis.

the measurement (4.6 points), but does not reach the minimum detectable change (10.8 points) of the DASH for individuals with upper-extremity musculoskeletal disorders.²⁵ Being a man decreases the DASH score by 9.5 points, which means that men present better functioning than women. Cultural and occupational factors may contribute to explain this finding. One conceivable factor may be the presence of sex imbalance in domestic work.²⁶ Women are more likely to look after the house, even if they have a full-time job, performing activities such as cleaning, cooking and others, adding to their everyday jobs and possibly overloading the shoulder over time. Physiological factors may also be considered, as men are capable to produce more strength²⁷ and likely contribute to the findings.

In addition, according to the model obtained, having the non-dominant side affected also decreases the DASH

by 6.15 points. When completing the DASH individuals rate their ability to complete specific activities regardless of which arm is used to perform them.²⁸ However, many activities (e.g. opening a tight or new jar, writing, changing a light bulb overhead, etc.) are likely to be performed with the dominant side. As such, involvement of the dominant limb possibly leads to greater DASH total scores, i.e., greater disability. In contrast, Christiansen et al.²⁹ have demonstrated that the side of the symptoms does not influence the DASH total score in individuals with rotator cuff disorders, but does influence the score by about 20% for some specific activities of the 30 items of the DASH.²⁹ Therefore, clinicians are encouraged to look at individual activities of the DASH, and not only rely on the total score to seek possible influence of the affected side.

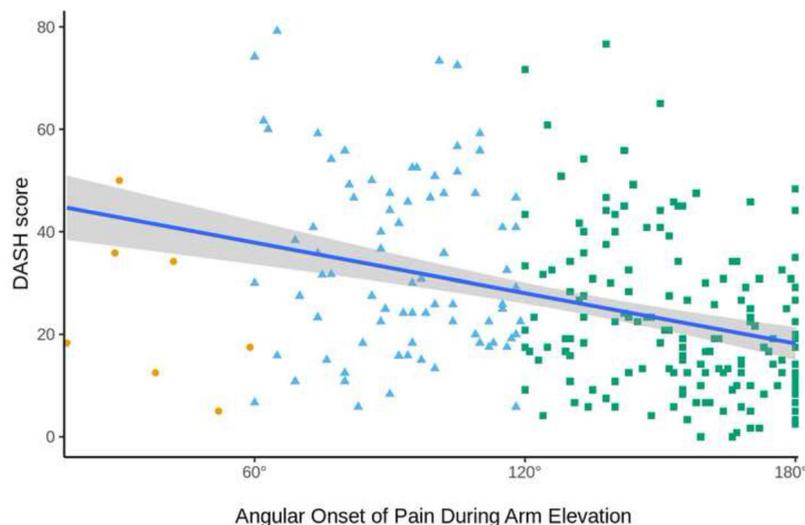


Fig. 1 Distribution of the participants according to the Disabilities of arm, shoulder and hand (DASH) score and angular onset of pain during arm elevation. Orange circles: <60°; Blue triangles: 60° - 120°; Green squares: >120°. The bold blue line indicates the regression line estimated for the data. The gray area represents the standard error of the regression line.

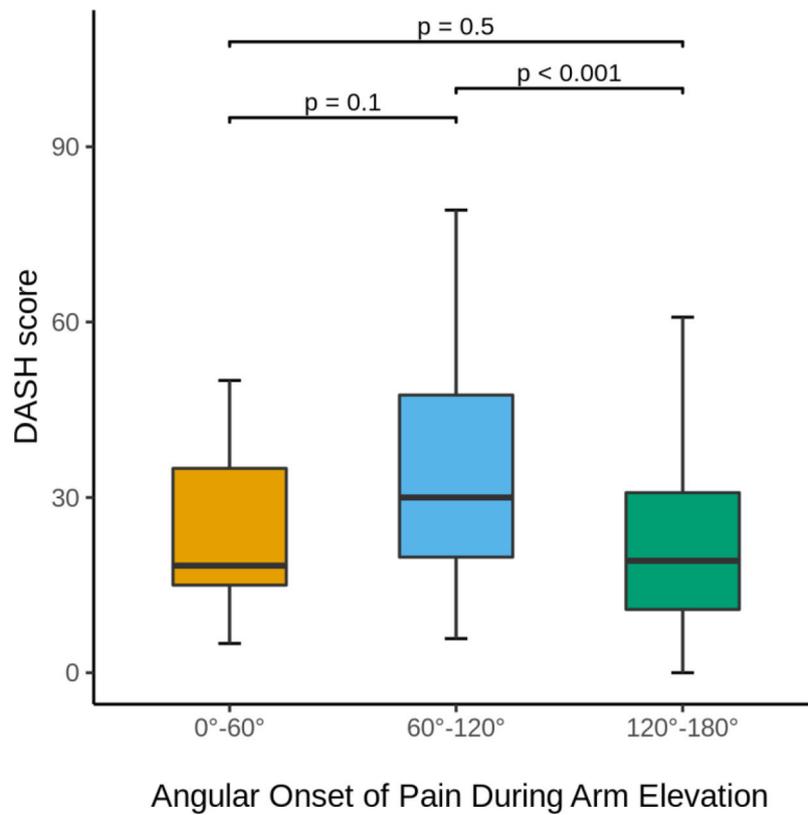


Fig. 2 Boxplots from Disabilities of arm, shoulder and hand (DASH) score and the angular onset of pain during arm elevation in individuals with rotator cuff related shoulder pain.

Age (young age - better functioning) and duration of symptoms (longer duration - better functioning) provided less important contributions to the DASH variance. This might be explained by the inclusion of mostly young adults, and of individuals with chronic symptoms (equal or greater than 6 months). Individuals experiencing persistent shoulder pain seem to have no signs of shoulder pain related to bio-mechanical impairments,³⁰ and may have developed a compensatory strategy to cope with their own condition, which may justify the better use of the upper limb in daily activities. Further studies should consider a wider range of age and inclusion of individuals in the acute stage of the condition (less than 6 months) and also of other variables such as psychosocial factors like kinesiophobia and fear avoidance, for example.

The choice of the DASH questionnaire to assess functioning of the upper extremities in these individuals may have influenced the results of this investigation. Further studies should

assess the influence of the angular onset of pain during arm elevation on functioning by using questionnaires more specific to the shoulder, such as the Shoulder Pain and Disability Index (SPADI) and the Western Ontario Rotator Cuff (WORC) Index. Future research should also include more individuals with the angular onset of pain below 60° to further clarify their functional abilities and limitations. Furthermore, adding variables related to psychological components (kinesiophobia, fear-avoidance, and pain catastrophizing) and other clinical measures (muscle strength, for example) commonly used to assess patients with RCRSP to the model may lead to a better explanation of the DASH variance and should be included in future studies. Our findings should not be generalized to all planes of arm elevation. Although the “painful arc” was originally described in the frontal plane, elevation of the arm is also commonly assessed in the scapular and sagittal planes in clinical practice as most of our activities are performed between these planes. Finally, clinicians should consider exercises

Table 2 Results for the stepwise multivariable linear regression model.

Dependent variable	R ²	Adjusted R ²	p-value
DASH score	0.31	0.30	<0.001
Independent variables	Unstandardized β Coefficient	Standard error	95% Confidence Interval
Male sex	-9.51	1.80	-13.03, -5.96
Age, years	0.26	0.07	0.13, 0.39
Non-dominant side affected	-6.15	1.85	-9.79, -2.51
Duration of symptoms, months	-0.07	0.02	-0.11, -0.03
Angular onset of pain, degrees	-0.15	0.02	-0.20, -0.11

addressing functional limitations of daily living activities because these are most compromised in patients with RCRSP and angular onset of pain between 60° and 120°.

Conclusions

The angular onset of pain during arm elevation in the sagittal plane is associated to self-reported functioning of the upper limbs in individuals with RCRSP. Individuals with RCRSP and angular onset of pain above 120° of arm elevation present better functioning than individuals with onset of pain between 60° and 120°, and similar functioning as those with onset of pain below 60°. Male sex, lower age, non-dominant side being affected, and longer duration of symptoms are also associated to better functioning as assessed by the DASH questionnaire. Most of the individuals with RCRSP presented the angular onset of pain above 120° of arm elevation, suggesting internal impingement.

Conflicts of interest

The authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest, or non-financial interest in the subject matter or materials discussed in this manuscript.

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