

Association Between Forward Head Posture, Pectoralis Minor Tightness and Shoulder Pain in Competitive Swimmers

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ABSTRACT

Problem statement: Freestyle swimming places high, repetitive loads on the shoulder girdle while the lower limbs experience relatively low impact. Tightness of the pectoralis minor (PM) and forward head posture (FHP) have each been linked to swimmer's shoulder, but their relationship in symptomatic competitive swimmers is not well quantified.

Approach: In this analytical cross-sectional study, 100 competitive freestyle swimmers from clubs in Gujarat, India, were screened; 60 swimmers aged 15–18 years who met inclusion criteria and reported shoulder pain >4/10 on the Penn Shoulder Pain subscale were enrolled. Craniovertebral angle (CVA) was measured by photogrammetry to index FHP, and bilateral PM tightness was assessed in supine via acromion–table distance. Pearson correlations examined associations between right, left and mean PM tightness and CVA. Univariate and multivariable linear regression models were fitted with CVA as the dependent variable, adjusting for age.

Results: Participants were predominantly male (70%), with a mean age of 16.37 ± 1.53 years and mean CVA of $52.02 \pm 2.66^\circ$. Mean right and left PM tightness were 9.74 ± 1.97 cm and 9.66 ± 1.73 cm, respectively; mean bilateral PM tightness was 9.70 ± 1.81 cm. Small-to-moderate positive correlations were observed between PM tightness and CVA ($r = 0.25\text{--}0.30$). In univariate regression, each 1-cm increase in mean PM tightness was associated with a 0.42° higher CVA (95% CI 0.05–0.79, $p = 0.03$; adjusted $R^2 = 0.06$). In the final multivariable model including age and mean PM tightness, mean PM tightness remained an independent predictor of CVA ($\beta = 0.42^\circ$, 95% CI 0.00–0.84, $p = 0.05$), whereas age was not associated with CVA ($\beta = -0.00^\circ$, 95% CI $-0.50\text{--}0.49$, $p = 0.98$; adjusted $R^2 = 0.05$).

Conclusions and recommendations: In competitive freestyle swimmers with shoulder pain, greater PM tightness is modestly but independently associated with increased forward head posture, while age is not. Screening protocols for swimmer's shoulder should consider both CVA and PM length, and intervention programmes may need to address PM tightness and cervicothoracic posture alongside other training and technique factors.

Keywords: Pectoralis Minor; Forward Head Posture; Craniovertebral Angle; Swimmers; Shoulder Pain; Photogrammetry; Posture)

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INTRODUCTION

Swimming is a whole-body, cyclic sport that develops strength and endurance while placing relatively low impact on the lower limbs. In contrast, the shoulder girdle is exposed to high repetitive loads, because propulsion in freestyle depends predominantly on upper-extremity pull rather than the kick.¹⁻⁴ Competitive swimmers often train 6000–10 000 m per day at high intensities, and shoulder pain is reported in 40–91% of this population, making the glenohumeral joint the most frequent site of musculoskeletal complaints.^{5,6}

The freestyle stroke requires large ranges of humeral elevation, internal and external rotation, and coordinated scapular protraction and retraction.⁴ Complex and highly coordinated musculoskeletal sequences in a swim cycle exert significant multidirectional stresses and forces on the shoulder region.⁷ When this choreography works well, the scapula rotates and tilts to maintain a centred humeral head and adequate subacromial space. When it is disturbed—through fatigue, muscle imbalance or poor technique—scapular dyskinesia may develop, predisposing swimmers to impingement, rotator-cuff pathology and glenohumeral instability.⁸⁻¹⁰ A key contributor to such dyskinesia is a shortened pectoralis minor muscle, the only muscle linking the scapula directly to the anterior thoracic cage.¹¹ Tightness of the pectoralis minor increases scapular anterior tilt and internal rotation, narrows the subacromial space and is frequently implicated in “swimmer’s shoulder”.¹⁰⁻¹²

Breathing patterns in freestyle can further influence cervico-thoracic alignment. Repeated unilateral breathing and excessive neck rotation can create asymmetrical trunk roll, cervical muscle imbalance and, over time, a forward-head posture (FHP).^{2,13,14} FHP is characterised by lower cervical flexion with upper cervical extension and shortening of the posterior cervical and scapular elevator musculature.^{9,16,17} Several studies have linked FHP and pectoralis minor tightness independently with shoulder pain in overhead athletes and swimmers,^{9,14} suggesting that combined alterations in head–neck posture and scapular position may be clinically important.

However, despite these biomechanical links, there is limited evidence quantifying how pectoralis

minor tightness and FHP relate to each other in symptomatic competitive swimmers. In particular, the association between clinically measured pectoralis minor length and craniovertebral angle—a widely used photogrammetric index of FHP—has not been clearly described in this group. Understanding this relationship could refine screening protocols and guide targeted interventions aimed at modifiable postural and muscular factors in swimmer’s shoulder.

Therefore, the primary aim of this cross-sectional study was to examine the association between pectoralis minor tightness and forward-head posture, expressed as craniovertebral angle, in competitive freestyle swimmers with shoulder pain. Specifically, we sought ¹ to describe the distribution of craniovertebral angle and bilateral pectoralis minor tightness in this cohort, and ² to evaluate the correlations between right, left and mean pectoralis minor tightness and craniovertebral angle, and to determine whether mean pectoralis minor tightness independently predicts craniovertebral angle after adjusting for age using linear regression. This focused objective aligns with current recommendations that the Introduction clearly state the purpose and significance of the work without an exhaustive literature review.

METHODS

Study design and Setting

This analytical cross-sectional study was conducted among competitive freestyle swimmers recruited from clubs in Gujarat, India, with data collection coordinated through Srinivas College of Physiotherapy and Research Centre, Mangalore. Ethical approval was obtained from the Institutional Ethics Committee of Srinivas College of Physiotherapy and Research Centre under Rajiv Gandhi University of Health Sciences, Bengaluru, and all procedures adhered to the Declaration of Helsinki. Swimmers and, when applicable, parents or guardians received information about the study and provided written informed consent before participation.

A total of 100 competitive freestyle swimmers were approached at their usual training venues and assessed for eligibility. Swimmers were eligible if they were 15–35 years old; specialised in freestyle; trained at least five times per week, for 1–2 hours per session over a 16-week training phase; typically

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covered 6–8 miles per practice; and reported shoulder pain greater than 4/10 on the strenuous-activity item of the Penn Shoulder Pain subscale, which has demonstrated good reliability and validity for assessing shoulder pain.^{11,12,18} Swimmers were excluded if they had a history of upper-extremity injury or surgery in the previous 12 months; a history of spinal surgery or vertebral fracture in the previous 12 months; any current musculoskeletal pain other than shoulder pain (such as neck, back, or knee pain); or had been unable to participate in regular swimming practice for the preceding 3 days because of shoulder pain.^{9,14} Of the 100 swimmers screened, 40 did not meet the inclusion criteria and were excluded; the final sample therefore consisted of 60 competitive freestyle swimmers who fulfilled all criteria and completed the full assessment battery.

After consent, participants completed a brief demographic form capturing age, sex and training characteristics, followed by the Penn Shoulder Pain subscale to confirm clinically meaningful shoulder symptoms. On the same visit, postural and muscle length assessments were performed using a standardised sequence and a fixed set of instruments: a Sony Alpha A68M digital camera mounted on a tripod, a plumb line and mirror for photogrammetry, an inch tape for anthropometric measurements, and skin-safe body markers for anatomical landmarks. Forward-head posture was quantified by the craniovertebral angle (CVA) obtained through photogrammetry. Markers were placed over the tragus of the ear and the spinous process of the seventh cervical vertebra (C7). Participants stood barefoot in their habitual posture with arms relaxed by the sides; they wore tight shorts, and female swimmers additionally wore sleeveless tops and tied their hair back to fully expose the neck region. A plumb line suspended from the ceiling acted as the vertical reference. The camera was positioned 1.5 m lateral to the participant at shoulder height, and a right-lateral photograph was taken once the swimmer had assumed a relaxed stance. Using image-analysis software, the CVA was measured as the angle between a horizontal line through C7 and the line connecting C7 to the tragus; smaller angles reflected a more pronounced forward-head posture.^{17,18}

Pectoralis minor tightness was assessed with the swimmer lying supine on a firm plinth. Participants were positioned with knees comfortably flexed,

arms resting by the sides, shoulders in slight lateral rotation, forearms supinated (palms up), and the lumbar spine gently flattened against the plinth. They were instructed to relax the shoulder girdle completely. The examiner palpated the most posterolateral aspect of the acromion process on each side and used an inch tape held perpendicular to the table to measure the vertical distance from the acromion to the plinth. This acromion–table distance was recorded in centimetres for the right and left sides, with larger distances interpreted as greater pectoralis minor tightness; mean pectoralis minor tightness was calculated as the average of the two measurements.^{19,20} All assessments were carried out by a physiotherapist trained in the protocol, and no therapeutic intervention was provided as part of the study.

All 60 swimmers with complete data were included in the analysis (complete-case analysis). Continuous variables, including age, CVA, and right, left and mean pectoralis minor tightness, were summarised as mean \pm standard deviation, and sex as frequency and percentage. Assumptions of normality and linearity were examined visually using histograms, Q–Q plots and residual plots and were judged acceptable, so parametric methods were applied. Pearson correlation coefficients were calculated between CVA and each pectoralis minor measure and displayed in a correlation heatmap. To examine associations adjusted for age, linear regression models were fitted with CVA (degrees) as the dependent variable. Univariate models were first run for age and for each pectoralis minor variable; variables with $P < 0.15$ in univariate analysis, together with the clinically important covariate age, were then considered for multivariable modelling. Because of collinearity among right, left and mean pectoralis minor tightness, only age and mean pectoralis minor tightness were retained in the final model. Regression results are presented as unstandardised β coefficients with 95% confidence intervals, P -values and adjusted R^2 . All analyses were performed using IBM SPSS Statistics version 29.0, with two-sided tests and statistical significance set at $P < 0.05$.

Statistical methods

All 60 eligible swimmers with complete data were included (complete-case analysis). Continuous variables (age, CVA, right/left and mean PM tightness) were summarised as mean \pm SD; sex as n (%). Assumptions of normality and linearity were

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checked visually (histograms, Q–Q plots, residual plots) and were acceptable, so parametric tests were used.

Pearson correlation coefficients were calculated between CVA and right, left, and mean PM tightness and illustrated in a correlation heatmap (Figure 3). To examine associations adjusted for age, linear regression models were fitted with CVA ($^{\circ}$) as the dependent variable. Univariate models were first run for age and each PM variable. Variables with $P < 0.15$ (right, left, mean PM) plus the clinically important covariate age were candidates for multivariable modelling; due to collinearity, only age and mean PM tightness were retained in the final model. Results are presented as β coefficients with 95% CIs, P-values, and adjusted R^2 (Table 2). All analyses were performed using IBM SPSS Statistics, version 29.0, with two-sided tests and significance set at $P < 0.05$.

Results

Participant flow and characteristics

Sixty competitive freestyle swimmers from clubs in Gujarat were screened, met the eligibility criteria, provided written informed consent, and completed all assessments; thus, all 60 were included in the analysis (Figure 2). The sample had a mean age of 16.37 ± 1.53 years, and the majority were male (42/60, 70.0%). The mean CVA was $52.02 \pm 2.66^{\circ}$, indicating a mild forward-head posture in this cohort. Mean right and left PM tightness were 9.74 ± 1.97 cm and 9.66 ± 1.73 cm, respectively, with an overall mean PM tightness of 9.70 ± 1.81 cm (Table 1).

Correlation between pectoralis minor tightness and craniocervical angle

Pearson correlation analysis demonstrated small-to-moderate positive relationships between PM tightness and CVA. Correlation coefficients ranged from $r = 0.25$ to $r = 0.30$ for the associations of right, left, and mean PM tightness with CVA (Figure 3). These findings indicate that swimmers with greater pectoralis minor tightness tended to present with larger CVA values (i.e. greater forward-head posture), although the strength of these relationships was modest.

Regression analyses

Univariate linear regression models are summarised in Table 2. Age was not significantly associated with CVA ($\beta = 0.21^{\circ}$, 95% CI -0.24 to 0.67 , $P = 0.35$). In contrast, all three PM measures showed positive associations with CVA. Each 1-cm increase in right PM tightness was associated with

an estimated 0.40° increase in CVA (95% CI 0.06 to 0.74 , $P = 0.02$). Left PM tightness showed a similar but borderline-significant association ($\beta = 0.39^{\circ}$, 95% CI -0.00 to 0.78 , $P = 0.05$). Mean PM tightness demonstrated a significant association with CVA ($\beta = 0.42^{\circ}$, 95% CI 0.05 to 0.79 , $P = 0.03$). The explanatory power of the univariate mean-PM model was modest (adjusted $R^2 = 0.06$), indicating that PM tightness alone accounted for approximately 6% of the variance in CVA.

In the final multivariable model including age and mean PM tightness, only mean PM tightness remained an important predictor of CVA. Each 1-cm increase in mean PM tightness was associated with a 0.42° higher CVA (95% CI 0.00 to 0.84 , $P = 0.05$), whereas age showed no independent association ($\beta = -0.00^{\circ}$, 95% CI -0.50 to 0.49 , $P = 0.98$). The adjusted R^2 for this model was 0.05 , suggesting that, although statistically significant, the combined effect of age and mean PM tightness explains only a small proportion of the variability in forward-head posture among these swimmers (Table 2).

Taken together, these results indicate that greater pectoralis minor tightness—particularly when expressed as mean bilateral tightness—is modestly but independently associated with increased forward-head posture in competitive freestyle swimmers, while age does not appear to confound this relationship.

DISCUSSION

This analytical cross-sectional study examined whether pectoralis minor (PM) tightness is associated with forward head posture—quantified by craniocervical angle (CVA)—in competitive freestyle swimmers with shoulder pain. In this relatively homogeneous sample of adolescent swimmers, we found small-to-moderate positive correlations between right, left and mean PM tightness and CVA ($r \approx 0.25$ – 0.30), and in regression models each 1-cm increase in mean PM tightness was associated with an approximately 0.4° increase in CVA. Age was not independently related to CVA, and the final model explained about 5% of the variance in head–neck posture.

These findings are consistent with current biomechanical concepts of swimmer's shoulder. Freestyle training exposes the shoulder girdle to high, repetitive loads and large ranges of elevation and rotation, predisposing swimmers to scapular dyskinesia and subacromial impingement.^{1–5,8,10,15,21,23,26,31} A shortened PM, the only muscle

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linking the scapula to the anterior thoracic cage, promotes anterior tilt and internal rotation of the scapula and reduces subacromial space, thereby contributing to pain and dysfunction in overhead athletes.^{11,12,19,20,25,26} Our data extend this literature by showing that, even in young competitive swimmers, greater PM tightness is measurably associated with a more forward head posture, a pattern that has been linked to shoulder pain, rounded shoulders and scapular dyskinesia in swimmers and other overhead populations.^{9,14,17,18,24,29,30} The modest effect size and low adjusted R², however, indicate that PM tightness is likely one of several contributory factors, alongside thoracic kyphosis, cervical muscle endurance, breathing pattern and training load, which were not formally modelled here.^{2,9,13,14,16,22,27,28,30}

From a clinical standpoint, the direction of association supports including both CVA and PM length in screening protocols for swimmers with shoulder symptoms. Identifying athletes with pronounced PM tightness and forward head posture may help clinicians target modifiable impairments through tailored interventions such as PM stretching, thoracic mobility work, scapular stabilisation and exercise programmes shown to improve upper-quarter posture in swimmers and individuals with upper crossed patterns.^{9,11,12,19,20,22,25,27,29} At the same time, the cross-sectional design, purposive sampling from a single region and narrow age range limit generalisability and preclude causal inference. Potential confounders such as breathing side dominance, training age, weekly yardage, scapular muscle strength and spinal alignment were not included in the final model and may partly explain the unexplained variance. Future longitudinal and interventional studies should evaluate whether baseline PM tightness and forward head posture predict incident shoulder pain or performance limitation, and whether correcting these impairments changes clinical trajectories in competitive swimmers.

DECLARATIONS

Consent to participate

Informed consent was obtained from all individual participants included in the study.

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Conflict of interest

The authors declare that they have no conflicts of interest related to this study.

Ethics approval

Ethical approval was obtained from the xxxxxx and reference number xxxxxx.

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Consent for publication

Author's contributions

Ulka Mori (UM) was the primary investigator; she contributed to the study concept, coordinated participant recruitment and data collection, and drafted the first version of the manuscript. Akshay Bagul (AB), Deepak Kumar Padhan (DKP), R. Kamala Kannan (RKK), and Algappan Thiyagarajan (AT) assisted in refining the study protocol, collecting data, checking data quality, and providing critical revisions to the manuscript; these authors contributed equally to these tasks. Vijayakumar Palaniswamy (VP) served as the corresponding and senior author; he led the overall study design and methodological planning, supervised the statistical analysis and interpretation, guided the structuring and rewriting of all manuscript sections, and approved the final version for submission. All authors read and approved the final manuscript and agree to be accountable for all aspects of the work.

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Figure 1. (A) Photogrammetric method used to assess forward head posture, with reflective markers placed over the tragus and C7 spinous process for craniocervical angle (CVA) measurement. (B) Pectoralis minor muscle length testing in supine, showing measurement of the vertical distance from the acromion process to the treatment table using an inch tape.

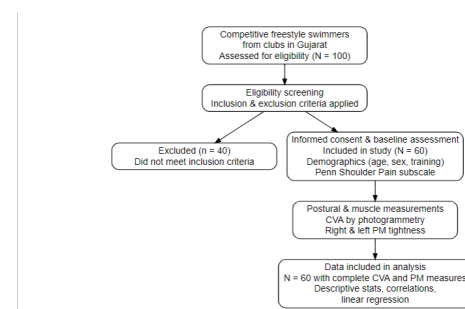


Figure 2. Flow of participants and assessment procedures. Competitive freestyle swimmers from clubs in Gujarat (N = 100) were assessed for eligibility; 40 were excluded for not meeting the inclusion criteria. The remaining 60 swimmers provided informed consent, completed baseline demographics and Penn Shoulder Pain subscale, underwent craniocervical angle (CVA) measurement by photogrammetry and bilateral pectoralis minor tightness assessment, and were all included in the final statistical analyses.

Table 1. Demographic and Clinical Characteristics of the participants (N = 60)

Variable	Mean ± SD or n (%)
Age (years)	16.37 ± 1.53
Gender (Male/Female)	42 (70.0%) / 18 (30.0%)
Craniocervical angle (°)	52.02 ± 2.66
Right PM tightness (cm)	9.74 ± 1.97
Left PM tightness (cm)	9.66 ± 1.73
Mean PM tightness (cm)	9.70 ± 1.81

Baseline characteristics of the swimmer cohort, including age, gender, pectoralis minor muscle

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tightness, and postural alignment via craniovertebral angle.

associations. Moderate positive correlations were observed between PM tightness measures and CVA ($r = 0.25-0.30$).

Table 2. Univariate and multivariate linear regression analyses examining age and pectoralis minor tightness associated with craniovertebral angle (CVA) (N = 60).

Variables	CVA, β (95% CI) P	CVA, β (95% CI) P
Age (years)	0.21 (-0.24, 0.67) 0.35	-0.00 (-0.50, 0.49) 0.98
Pectoralis minor tightness measures		
Right PM Tightness (cm)	0.40 (0.06, 0.74) 0.02	
Left PM Tightness (cm)	0.39 (-0.00, 0.78) 0.05	
Mean PM Tightness (cm)	0.42 (0.05, 0.79) 0.03	0.42 (0.00, 0.84) 0.05
Adjusted R ²	0.06	0.05

β = unstandardised regression coefficients; statistically significant $P < 0.05$. CI, confidence interval; CVA, craniovertebral angle; PM, pectoralis minor.

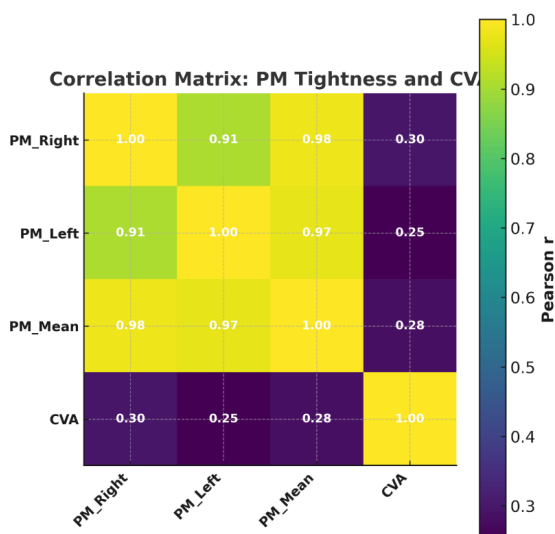


Figure 3. Heatmap of Pearson correlation coefficients between pectoralis minor tightness (right, left, and mean values) and craniovertebral angle (CVA) in competitive swimmers (N = 60). Warmer colors indicate stronger positive