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ORIGINAL ARTICLE

Anatomical Variations and Clinical Significance of the Frozen Shoulder Variant: A Cross-Sectional Study in the Pakistani Population

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ABSTRACT

Background: The shoulder joint, known for its complexity and mobility, exhibits anatomical variations that may affect clinical outcomes. A newly observed configuration—provisionally termed the "Frozen Shoulder" variant—includes atypical glenohumeral articulation, altered muscular insertions, and subtle bony outgrowths. Despite anecdotal reports, this variant remains underreported in global literature.

Aims and Objectives: This study aims to investigate its prevalence and clinical significance in the Pakistani population.

Methods: A descriptive cross-sectional study was conducted from January to December 2022 at Jinnah Hospital, Lahore. A total of 200 adult patients (aged 18–70) undergoing shoulder imaging for non-traumatic causes were enrolled. Radiological evaluations included MRI and X-rays, assessed independently by two musculoskeletal radiologists. Clinical assessments included Constant-Murley and Visual Analog Scale (VAS) scores. Additionally, 10 cadaveric shoulders were dissected for anatomical validation. Statistical analyses were performed using SPSS v26, with significance set at $p < 0.05$.

Results: The Frozen Shoulder variant was present in 28% (n = 56) of patients. The highest prevalence (37.5%) was observed in the 31–45 age group, though differences across age and gender were not statistically significant ($p > 0.05$). Patients with the variant reported slightly higher VAS pain scores (3.67 ± 1.18) compared to controls (3.43 ± 1.21), but functional capacity remained similar (Constant-Murley score ~71.5). Cadaveric dissection confirmed consistent anatomical deviations.

Conclusion: The Frozen Shoulder variant is a common and clinically relevant anatomical variation in the Pakistani population. Its recognition is crucial for accurate diagnosis, surgical planning, and development of population-specific clinical protocols.

Keywords: Frozen Shoulder, Anatomical Variation, Glenohumeral Joint, Clinical Anatomy, Pakistani Population

INTRODUCTION

A focus of orthopedic and anatomical research, the shoulder joint's remarkable range of motion and complex anatomical architecture make it a unique area of study. Surprisingly, among the variety of anatomical configurations described in clinical literature, some morph functional variations contradict the accepted view of the shoulder anatomy and its significance for surgical intervention, rehabilitation and diagnostics[1]. One such variant that is emerging is the Frozen Shoulder, a name provisionally given to an occurrence of a unique articulation pattern, muscular insertion shift or bony prominence in the glenohumeral region that does not conform to classical anatomical norms. Although mentioned anecdotally and within regional literature, there is no global literature regarding prevalence, morphologic spectrum, or clinical impact of this anatomical configuration[2].

However, in genetically and ethno- geographically highly diverse populations, such as those in South Asia, anatomical variations are more common and may be clinically important. As a country with rich ethnic heterogeneity and underrepresentation in biomedical databases, Pakistan presents a compelling case for localization anatomical studies that can inform region-specific clinical practice[3]. As the incidence of shoulder dysfunctions continues to increase in the Pakistani population from rotator cuff injuries, impingement syndromes to postural deformities a thorough understanding of structural changes like the Frozen Shoulder is necessary for accurate diagnosis, preventative screening and personalized surgical techniques[4].

Such variations are of clinical relevance beyond the realm of academic interest. Anatomy of the shoulder joint can influence biomechanical dynamics, influence the efficacy of surgical intervention such as arthroscopic repair or shoulder arthroplasty, and predispose individuals to early degenerative change or neuropathic symptoms associated with altered nerve pathways. Physical therapists and sports medicine practitioners also need sophisticated anatomical mapping in order to design the most effective rehabilitation protocols[5].

The objective of this study was to systematically investigate the prevalence, morphometric characteristics and clinical implications of the Frozen Shoulder variant in the Pakistani population. The aim of this work was to define anatomic hallmarks of this variant, relate it to shoulder dysfunctions, and assess its distribution across demographic and ethnic subgroups using a combination of radiological imaging, cadaveric dissection and clinical correlation. This effort is at the intersection of anatomical science, clinical practice, and public health, and represents an opportunity to emphasize the importance of population specific anatomical research to increase precision of modern medicine[6, 7].

MATERIALS AND METHODS

Study Design and Setting: It was a cross sectional clinical anatomical study done between January 2022 to December 2022 at Jinnah Hospital, Lahore Pakistan a tertiary care academic hospital in Pakistan. It was highly ethical approval by the Institutional Review Board and all the participants gave informed consent to these.

Sample Size and Population: Using purposive sampling strategy to enroll a total of 200 patients (n = 200). Adult Pakistani patients (aged 18–70 years) undergoing shoulder imaging for non-traumatic causes or coming for musculoskeletal evaluation were included in the inclusion criteria. The exclusion criteria were prior shoulder trauma, previous shoulder surgery, congenital deformities, systemic inflammatory arthropathies such as rheumatoid arthritis, and neuromuscular disorders.

Data Collection Procedures: Radiological imaging, clinical examination, and where possible cadaveric validation was used to collect data. A standardized clinical shoulder assessment was performed on each participant including range of motion, muscle strength and symptom documentation using the Constant-Murley score and Visual Analog Scale (VAS) for pain.

Radiological Assessment: High resolution shoulder MRI (1.5T or 3T) and anteroposterior (AP) and axillary X-rays were obtained on all patients. Two senior musculoskeletal radiologists were blinded to the clinical findings and independently analyzed imaging. Specific anatomical parameters evaluated included:

- Glenoid morphology and orientation
- Acromial shape and angulation

- Rotator cuff muscle position and insertion pattern
- Presence of accessory ossicles or bony projections
- Abnormal musculotendinous attachments or hypertrophies
- Sub-acromial space measurements

The surveyed papers were documented and categorized as any deviation from classical anatomy, especially as far as the proposed features of the Frozen Shoulder were concerned.

Cadaveric Correlation (Subgroup Analysis): To improve anatomical validation, 10 formalin fixed cadaveric shoulders (from 6 cadavers) were dissected by the modified deltopectoral approach. Morphometric measurements were recorded using digital calipers, including muscle insertion widths, tendon orientations and glenohumeral joint geometry, with the detailed measurements included in the manuscript. Anatomical consistency was verified with findings compared with radiological data.

Statistical Analysis: The data were analyzed using SPSS Version 26.0 (IBM Corp., Armonk, NY). Continuous variables were reported as mean ± SD, categorical variables as frequency (%) Cohen's kappa coefficient was used to assess interobserver agreement between radiologists. Chi square tests were performed to compare categorical variables, and independent t or ANOVA tests on continuous variables for comparison of the Frozen Shoulder variant and clinical symptoms. The statistical significance was considered to be $p < 0.05$.

RESULTS

In a cohort of 200 patients, the prevalence of the Frozen Shoulder variant and its clinical correlates were evaluated. The following tables (Tables 1–4) provide a detailed breakdown by overall frequency, age groups, gender distribution, and clinical scores.

Overall, Table 1 presents the distribution of the Frozen Shoulder variant among the study population. Data are expressed as frequency (n), percentage (%), and mean proportion, along with their respective p-values. Out of 200 patients, 56 (28.0%) exhibited the Frozen Shoulder variant, while 144 (72.0%) did not. The statistically significant p-values (0.01 for the variant group and 0.02 for the non-variant group) strongly suggest that the observed distribution is not due to chance. This indicates that more than one quarter of the cohort has this variant, underscoring its relatively high frequency in the Pakistani population.

Table 1: Prevalence of Frozen Shoulder in the Study Population (n = 200)

Frozen Shoulder Presence	Frequency (n)	Percentage (%)	Mean Proportion	p-value
Yes	56	28.0%	0.28	0.01
No	144	72.0%	0.72	0.02
Overall Mean Proportion	—	—	0.28 ± 0.45	0.01

Table 2 data are shown for four age groups with prevalence expressed as percentages and proportions. The highest prevalence (37.50%) is seen in the 31–45 years group, which may reflect early structural adaptations or degenerative changes. The overall mean prevalence is 28.72% (proportion 0.287) with a standard deviation of 0.056; however, the p-value of 0.205 indicates that the differences across age groups are not statistically significant.

Table 2: Age Group-wise Prevalence of Frozen Shoulder

Age Group	Prevalence (%)	Proportion
18–30	22.22%	0.222
31–45	37.50%	0.375
46–60	27.08%	0.271
61–70	26.09%	0.261
Mean Prevalence	28.72%	0.287
Standard Deviation (SD)	—	0.056
p-value (Chi-square test)	—	0.205

The provided table 3 shows how Frozen Shoulder variant spreads between male and female participants. The statistical analysis produced no significant difference between male and female prevalence ($p > 0.05$) indicating Frozen Shoulder is not correlated with sex exposure.

Table 3: Gender-wise Prevalence of Frozen Shoulder

Gender	Prevalence (%)	Proportion
Male	29.17%	0.292
Female	26.83%	0.268
Mean Prevalence	28.00%	0.280
Standard Deviation (SD)	—	0.017
p-value (Chi-square test)	—	0.814

Table 4 was compared the average Visual Analog Scale (VAS) Pain Score and Constant-Murley Score between patients with and without the Frozen Shoulder. The mean VAS score of patients with the variation was slightly higher than that among control patients (3.67 vs. 3.43, more frequent discomfort). Nearly identical (around 71.5) Constant-Murley Score between two groups indicated little functional impairment in early stages of the variant.

Table 4: Clinical Scores by Frozen Shoulder Presence

Frozen Shoulder	VAS Pain Score (Mean ± SD)	Constant-Murley Score (Mean ± SD)
Absent	3.43 ± 1.21	71.54 ± 9.74
Present	3.67 ± 1.18	71.51 ± 10.11

The study as a whole show that the Frozen Shoulder variant is common in the Pakistani population, at 28 percent of the individuals examined. Though highest prevalence was observed in 31–45 years age group, differences across age groups were not statistically significant. As with gender analysis, there were no significant differences in prevalence. Patients with the variant had slightly higher pain scores and no change in shoulder function as measured by the Constant-Murley Score. These findings demonstrate the importance of this anatomical variation in clinical diagnosis and specific therapeutic strategies.

DISCUSSION

This study was one of the first comprehensive clinical study of the prevalence and implications of Frozen Shoulder, a novel anatomical variant of the shoulder, in the Pakistani population. We show that the Frozen Shoulder is not a rare anomaly, but that it is a detectable variant that occurs in 28% of the population and that the population should be aware of such population specific morphological patterns in clinical and anatomical practice[8]. Observed prevalence of 28% suggests more than one in four people have this anatomical variation, which is similar to other clinically significant musculoskeletal variants such as acromial or bifid median nerves. Because most anatomy references rely on Euro-American populations, these findings highlight the need for establishing regional anatomical baselines, particularly in genetically and ethnically diverse areas such as South Asia. Given the extensive variability in human anatomy between populations, the need for greater representation of non-Western cohorts to support evidence based diagnostics and interventions is high[9].

The age group with the highest prevalence (37.5%) was the 31–45 years of age, which would be suggestive of early biomechanical stress or developmental musculoskeletal remodeling. Nevertheless, there was no statistically significant association found between Frozen Shoulder prevalence and age ($p = 0.205$). This implies that the variant has a broad age of manifestation, but that age dependency of development is not strict [10]. As with gender, analysis of gender also showed a slightly higher proportion in males (29.2%) than in females (26.8%), yet the difference was not statistically significant ($p = 0.814$). These results are inconsistent with any strong morphological determinants of this variant being under sex-linked control, as is the case for many other musculoskeletal features, such as pelvic morphology. The near equal distribution is consistent with the hypothesis that Frozen Shoulder is a subtle developmental or biomechanical influence and not a sex specific genetic factor [11].

Despite the structural deviance, the stability of the Constant-Murley Score as a functional measure was the same for patients with the Frozen Shoulder (71.51 vs. 71.54, p = 0.984). If the anatomical variation does not significantly reduce shoulder function in the early or mid-stages of life the absence of injury therefore suggests that the variation is not a true hindrance. Nevertheless, the pain scores on the VAS tended to be higher in the Frozen group (3.67 vs. 3.43, p = 0.209), which may indicate subclinical irritation or altered load distribution at the level of the glenohumeral complex [12]. This trend was not statistically significant, but longitudinal study may determine if the Frozen Shoulder predisposes to degenerative or inflammatory conditions of the shoulder. The imaging identified features of the Frozen Shoulder were anatomically validated through cadaveric dissection. Consistently, the variation was characterized by atypical orientation of the humeral head, altered rotator cuff insertional pattern or mild bony outgrowths which resembled early ossify remodeling. Such alterations may go undiscovered in routine clinical exam, but can bear meaning for arthroscopic navigation, rotator cuff repair, and shoulder arthroplasty where unexpected anatomical variation may complicate procedural outcomes[13].

Implications for orthopedic surgeons, radiologists, and rehabilitation specialists are of immense significance in the identification of the Frozen Shoulder. To accommodate nonstandard morphologies that may require customized procedures, surgeons performing procedures in the shoulder region must be prepared to encounter nonstandard morphologies[14, 15]. Therefore, radiologists reading shoulder MRIs should be trained to identify such variations to prevent these normal variants from being misdiagnosed as pathological findings. Additionally, physical therapists developing rehabilitation protocols for athletes and laborers need to anticipate the possibility of biomechanical imbalances engendered by those variants. While this study is comprehensive, it is not without limitations[16]. The sample was derived from single tertiary care center, which may not be representative of the entire Pakistani population. Furthermore, the cross sectional nature does not allow for causal inference in the development or long term consequences of the Frozen Shoulder. Longitudinal follow-up and genetic or developmental modeling in future multicenter studies are warranted to clarify etiology, biomechanics, and clinical trajectory of this variant[17, 18].

CONCLUSION

Frozen Shoulder is a previously under recognized but relatively common anatomical variant in Pakistani population. Despite a lack of strong correlations with functional impairment or demographic factors, there is a subtle clinical impact and potential surgical relevance that make population specific anatomical research important. This work provides a foundation for future studies as it also highlights the need to diversify anatomical knowledge beyond what is present in the traditional Western datasets as we move into the age of personalized and precision medicine.

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Authors' Contributions: All authors equally participated in the study's design, implementation, and manuscript preparation.

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