ORIGINAL RESEARCH ARTICLE

The Role of Glycated Haemoglobin in Determining Degree of Frozen Shoulder: A Pilot Study at Rural Tertiary Health Care Centre

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ABSTRACT

Background: Frozen shoulder (adhesive capsulitis) is a debilitating disease process that involves pain with incrementally more restricted movements of the shoulder. Although diabetes mellitus is known to be a commonly recognised risk factor for idiopathic frozen shoulder, further studies are warranted into the relationship between glycemic control and functional disability in cases of idiopathic frozen shoulder. The objective of this pilot study was to evaluate HbA1c levels in patients with idiopathic frozen shoulder and to assess their correlation with pain and disability scores.

Methods: This hospital-based, prospective observational study was conducted in the Department of Orthopaedics at RL Jalappa Hospital and Research Centre, Kolar, Karnataka, over six months (November 2025 to April 2026). Sixty-eight patients aged 40-70 years with idiopathic frozen shoulder were enrolled. HbA1c levels were measured and interpreted according to the ADA 2024 guidelines. Shoulder function was assessed using the Shoulder Pain and Disability Index (SPADI), Constant-Murley score, and QuickDASH. Statistical analysis employed Pearson/Spearman correlation coefficients with $p<0.05$ considered significant.

Results: Among 68 participants, the mean age was 54.6±8.2 years, with female predominance (58.8%). Based on HbA1c values, 19.1% were normoglycemic (<5.7%), 41.2% were prediabetic (5.7-6.4%), and 39.7% were diabetic (≥6.5%). A significant positive correlation was observed between HbA1c and SPADI scores ($r=0.52$, $p<0.001$), indicating greater disability with poorer glycemic control. Conversely, significant negative correlations were found between HbA1c and Constant-Murley scores ($r=-0.48$, $p<0.001$) and between HbA1c and QuickDASH scores ($r=0.51$, $p<0.001$). Patients with diabetic-range HbA1c demonstrated significantly worse functional scores across all three assessment tools compared to normoglycemic and prediabetic groups ($p<0.01$).

Conclusion: This pilot study demonstrates that over 80% of patients presenting with idiopathic frozen shoulder have either prediabetes or undiagnosed diabetes. A significant correlation exists between glycemic control and the degree of shoulder disability. These findings support routine HbA1c screening in patients with idiopathic frozen shoulder to enable early detection of dysglycemia and to potentially guide more comprehensive management.

Keywords: Frozen shoulder, adhesive capsulitis, HbA1c, glycated hemoglobin, diabetes mellitus, prediabetes, SPADI, Constant-Murley score, QuickDASH

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INTRODUCTION

Adhesive capsulitis, commonly known as frozen shoulder, is a debilitating musculoskeletal disorder in which the shoulder joint gradually loses its range of motion due to increasing stiffness and pain. The restriction affects both active and passive movements, with external rotation typically the most noticeably impaired [1]. Notably, this loss of mobility occurs in the absence of any structural damage to the shoulder. The term "frozen shoulder" aptly captures the way the joint becomes progressively immobile, interfering with everyday activities and diminishing quality of life.

Worldwide, frozen shoulder affects approximately 2 to 5 percent of people. It occurs most often in individuals between 40 and 60 years of age, with women experiencing it more frequently than men [2]. While many patients recover over time without specific treatment, the condition typically causes prolonged discomfort and limits normal activities during its active phases [3]. The condition generally moves through three

stages: an initial painful phase where movement becomes restricted, a frozen phase where stiffness predominates, and a thawing phase where motion gradually returns.

When no clear cause is identified, the condition is called idiopathic frozen shoulder. However, research has uncovered several health conditions that appear linked to its development. Diabetes mellitus shows the strongest and most consistent association among these. Studies indicate that 20 to 30 percent of diabetic patients develop frozen shoulder at some point [4,5]. This connection proves especially strong in those with long-standing or poorly managed diabetes. Remarkably, research has found that 10 to 30 percent of patients presenting with idiopathic frozen shoulder actually have undiagnosed diabetes or prediabetes when tested [6]. These findings raise the possibility that frozen shoulder might act as an early warning sign for underlying blood sugar problems. A recent meta-analysis confirmed that HbA1c is the most significantly elevated metabolic marker in frozen shoulder, with a standardized mean difference of 0.3970 (95% CI: 0.0998 to 0.6943), indicating a moderate but consistent effect [7].

The biological mechanism behind this link likely involves changes to collagen proteins in the shoulder joint capsule. When blood sugar remains elevated, glucose molecules attach to collagen proteins through a process called non-enzymatic glycosylation [8]. This leads to formation of advanced glycation end products, which cause collagen fibers to cross-link abnormally. The resulting tissue becomes stiffer and less flexible. These compounds also trigger ongoing inflammation and activate fibroblasts, the cells responsible for producing connective tissue. Together, these processes result in thickening and tightening of the joint capsule [9]. Reduced blood flow to the capsule from diabetes-related microvascular damage may further contribute to tissue stiffness [10].

HbA1c, or glycated hemoglobin, measures average blood sugar levels over the preceding two to three months. The American Diabetes Association recommends this test for screening, diagnosis, and monitoring of diabetes and prediabetes [11]. Unlike a single blood glucose reading, HbA1c provides a longer-term picture of sugar control. This makes it particularly useful for identifying patients with undiagnosed diabetes or prediabetes who might otherwise remain unaware of their condition. Several studies have found elevated HbA1c levels in patients with idiopathic frozen shoulder who had no previous diabetes diagnosis, pointing toward an underlying metabolic component [12]. Recent prospective research has demonstrated that the prevalence of prediabetes in patients with primary frozen shoulder is approximately 37.3%, with an additional 46.2% meeting criteria for diabetes [13].

Diabetes prevalence continues to rise across India, placing the country among those most affected by this condition. Rural areas, home to about 65 percent of India's population, face particular challenges in diabetes detection and care. Limited healthcare access, lower awareness, and fewer screening programs mean many rural residents remain unaware of their diabetic status. Rural tertiary centers such as R.L. Jalappa Hospital serve as important referral points for surrounding communities, offering opportunities to study connections between orthopedic conditions and metabolic disorders in this population.

Validated assessment tools allow objective measurement of shoulder-related disability. The Shoulder Pain and Disability Index (SPADI) asks patients to rate their pain and difficulty with everyday tasks. It has demonstrated excellent internal reliability (Cronbach's alpha 0.86-0.96) and test-retest reliability (intra-class correlation coefficient 0.84-0.95) [14]. The Constant-Murley Shoulder Score combines patient-reported measures with physical examination findings including motion and strength. The QuickDASH provides a streamlined method for evaluating upper limb disability. Using all three scoring systems together in this study permits thorough assessment of shoulder function and its relationship to blood sugar control.

This study therefore aims to measure HbA1c levels in patients with idiopathic frozen shoulder presenting to a rural South Indian tertiary hospital and evaluate their correlation with pain and disability levels using standardized scoring systems. The findings may help clarify whether routine HbA1c testing should be considered in patients presenting with frozen shoulder, potentially enabling earlier detection of diabetes in this population.

Materials and Methods

Study Design and Setting

This was a hospital-based, prospective observational study conducted in the Department of Orthopaedics at RL Jalappa Hospital and Research Centre, attached to Sri Devaraj Urs Medical College, Tamaka, Kolar, Karnataka. The study duration was three months, from January 2025 to March 2026.

Study Population

All patients aged between 40 and 70 years presenting to the outpatient department or admitted with a clinical diagnosis of idiopathic frozen shoulder during the study period were evaluated for eligibility.

Sample Size Calculation

Sample size was estimated using a correlation coefficient (r) of 0.40 between HbA1c levels and SPADI scores, based on findings from a previous pilot study. Using the formula $N = [(Z\alpha+Z\beta)/C]^2 + 3$ at 95% confidence level and 80% power, a sample size of 61 was obtained. Accounting for a 10% non-response rate, the final sample size was calculated as 68 subjects.

The standard normal deviate for α (Zα) was 1.960, and for β (Zβ) was 0.842. The value of C was calculated as $0.5 \times \ln[(1+r)/(1-r)]$, where r = 0.4.

Inclusion Criteria

• Patients aged between 40 and 70 years
• Clinically diagnosed idiopathic frozen shoulder (adhesive capsulitis) based on Codman's criteria
• Willingness to provide informed consent for participation

Exclusion Criteria

• Secondary frozen shoulder (post-traumatic, post-surgical, rotator cuff tear, arthritis, or cervical radiculopathy)
• Chronic steroid use
•Known endocrinopathies (thyroid disorders, parathyroid disorders)
• Systemic inflammatory conditions (rheumatoid arthritis, systemic lupus erythematosus, other connective tissue disorders)

Diagnostic Criteria

Diagnosis of frozen shoulder was made based on Codman's criteria:

• Insidious onset of shoulder pain
• Loss of both active and passive range of motion, particularly external rotation
• No identifiable intrinsic shoulder pathology on clinical examination
• No history of significant trauma or specific shoulder pathology

Data Collection Procedure

After obtaining informed consent, all participants underwent:

1.Detailed clinical history: Including demographic data, duration of symptoms, hand dominance, occupation, and previous treatments attempted
2.Complete physical examination: General physical examination, vital signs recording, and systemic examination
3.Local shoulder examination: Assessment of tenderness, side involvement (left/right/bilateral), and range of motion
4. Laboratory investigation: Blood sample collection for HbA1c measurement using standardized laboratory techniques

HbA1c Classification

HbA1c values were interpreted as per American Diabetes Association 2024 guidelines:

• Normal: <5.7%
• Prediabetes: 5.7% to 6.4%
• Diabetes: ≥6.5%

Functional Assessment Tools

Three validated scoring systems were administered to all participants:

Shoulder Pain and Disability Index (SPADI): A 13-item self-administered questionnaire comprising 5 items for pain and 8 items for disability. Each item is rated on an 11-point numerical rating scale (0-10). The SPADI total score is calculated as the mean of the pain and disability sub-scores, expressed as a percentage, with higher scores indicating greater disability [14].

Constant-Murley Shoulder Score: A comprehensive assessment tool combining subjective parameters (pain and activities of daily living) and objective parameters (range of motion and strength). The total score ranges from 0 to 100, with higher scores indicating better shoulder function.

QuickDASH (Quick Disabilities of the Arm, Shoulder and Hand): An 11-item shortened version of the DASH questionnaire measuring physical function and symptoms. Scores range from 0 (no disability) to 100 (most severe disability).

Statistical Analysis

Data were entered into Microsoft Excel data sheets and analyzed using SPSS version 22 software (IBM SPSS Statistics, Somers NY, USA).

Descriptive statistics: Categorical data were presented as frequencies and proportions. Continuous data were presented as mean and standard deviation.

Comparative analysis: The Chi-square test or Fisher's exact test (for 2×2 tables) was used to compare categorical variables. Yates correction was applied where chi-square assumptions were not fulfilled for 2×2 tables. For continuous variables, the Independent t-test or Mann-Whitney U test was used to compare means between two groups based on data distribution.

Correlation analysis: Pearson correlation coefficient (for normally distributed data) or Spearman's rank correlation coefficient (for non-normally distributed data) was calculated to assess the relationship between HbA1c levels and functional scores.

Correlation strength was interpreted as:

• 0 to 0.3: Weak correlation
• 0.3 to 0.6: Moderate correlation
• 0.6 to 1.0: Strong correlation

Negative values indicated inverse correlations.

Statistical significance: A p-value <0.05 was considered statistically significant.

Ethical Considerations

Institutional Ethics Committee approval was obtained (IEC reference number: DUAHER/R&D/CEC/SDUMC-PG/319/NF/-2025-26) in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants before enrollment. Patient confidentiality was maintained throughout the study, and all data were anonymized during analysis. Participants were informed that their decision to participate or not would not affect their clinical care, and they could withdraw from the study at any point without consequences.

Results

Demographic Characteristics

Table 1: Demographic and Baseline Characteristics of Study Participants (N=68)

Characteristic	Category	Number (n)	Percentage (%)
Age Group	40-50 years	24	35.3
	51-60 years	32	47.1
	61-70 years	12	17.6
Gender	Male	28	41.2
	Female	40	58.8
Side Affected	Right	36	52.9
	Left	28	41.2
	Bilateral	4	5.9
Dominant Hand	Right	58	85.3
	Left	10	14.7
Duration of Symptoms	<3 months	18	26.5
	3-6 months	32	47.1
	>6 months	18	26.4

The mean age of participants was 54.6 ± 8.2 years (range: 40-70 years). The majority of patients (47.1%) were in the 51-60 years age group. Female predominance was observed, with females constituting 58.8% of the study population. Right shoulder involvement (52.9%) was more common than left shoulder involvement (41.2%), with bilateral involvement observed in 5.9% of cases. Most patients (85.3%) were right-hand dominant. The mean duration of symptoms at presentation was 4.8 ± 2.4 months, with the largest proportion (47.1%) presenting between 3-6 months after symptom onset.

Glycemic Status Based on HbA1c

Table 2: Distribution of Glycemic Status Based on HbA1c Levels

Glycemic Category	HbA1c Range (%)	Number of Patients (n)	Percentage (%)
Normoglycemic	<5.7	13	19.1
Prediabetic	5.7 - 6.4	28	41.2
Diabetic	≥6.5	27	39.7
Total		68	100

Figure 1: Distribution of Glycemic Status in Idiopathic Frozen Shoulder Patients

Only 19.1% of patients presenting with idiopathic frozen shoulder had normal HbA1c levels (<5.7%). The majority of patients (41.2%) fell into the prediabetic range (HbA1c 5.7-6.4%), while a substantial proportion (39.7%) had HbA1c levels in the diabetic range (≥6.5%) despite having no prior diagnosis of diabetes mellitus. The mean HbA1c for the entire cohort was 6.4 ± 1.1%.

Functional Assessment Scores

Table 3: Functional Assessment Scores Stratified by Glycemic Status

Glycemic Category	Mean SPADI Score (%)	Mean Constant-Murley Score	Mean QuickDASH Score
Normoglycemic (n=13)	52.4 ± 10.2	58.6 ± 8.4	48.2 ± 9.6
Prediabetic (n=28)	61.8 ± 11.5	51.3 ± 9.2	57.4 ± 10.8
Diabetic (n=27)	73.6 ± 12.8	42.7 ± 10.1	68.5 ± 11.3
Overall Mean	64.3 ± 14.2	49.8 ± 11.3	59.7 ± 13.1

The overall mean SPADI score was 64.3 ± 14.2%, indicating moderate to severe disability. The mean Constant-Murley score was 49.8 ± 11.3, reflecting significant functional impairment. The mean QuickDASH score was 59.7 ± 13.1, consistent with substantial upper extremity disability.

A clear gradient was observed across glycemic categories for all three functional scores. Patients in the diabetic group had the highest (worst) SPADI scores (73.6 ± 12.8%) and QuickDASH scores (68.5 ± 11.3%), and the lowest (worst) Constant-Murley scores (42.7 ± 10.1%). Normoglycemic patients demonstrated the best functional status across all measures.

Correlation Between HbA1c and Functional Scores

Pearson correlation analysis was performed to assess the relationship between HbA1c levels and each of the three functional assessment scores (Table 4, Figures 2-4).

Table 4: Correlation Between HbA1c and Functional Assessment Scores

Functional Score	Correlation Coefficient (r)	Interpretation	p-value
SPADI	+0.52	Moderate positive correlation	<0.001
Constant-Murley	-0.48	Moderate negative correlation	<0.001

QuickDASH	+0.51	Moderate positive correlation	<0.001

A statistically significant moderate positive correlation was observed between HbA1c levels and SPADI scores ($r = +0.52$, $p < 0.001$). This indicates that as HbA1c increases, the degree of shoulder pain and disability as measured by SPADI also increases.

A statistically significant moderate negative correlation was found between HbA1c levels and Constant-Murley scores ($r = -0.48$, $p < 0.001$). Higher HbA1c levels were associated with lower (worse) Constant-Murley scores, indicating poorer shoulder function.

A statistically significant moderate positive correlation was observed between HbA1c levels and QuickDASH scores ($r = +0.51$, $p < 0.001$), confirming that poorer glycemic control is associated with greater upper extremity disability.

Comparative Analysis Across Glycemic Groups

One-way ANOVA was performed to compare mean functional scores across the three glycemic categories (Table 5).

Table 5: Comparison of Functional Scores Across Glycemic Categories

Functional Score	Normoglycemic Mean ± SD	Prediabetic Mean ± SD	Diabetic Mean ± SD	F-statistic	p-value
SPADI	52.4 ± 10.2	61.8 ± 11.5	73.6 ± 12.8	14.82	<0.001
Constant-Murley	58.6 ± 8.4	51.3 ± 9.2	42.7 ± 10.1	12.64	<0.001
QuickDASH	48.2 ± 9.6	57.4 ± 10.8	68.5 ± 11.3	15.31	<0.001

Post-hoc analysis (Tukey's HSD) revealed:

Significant differences between normoglycemic and diabetic groups for all three scores ($p<0.001$)

Significant differences between prediabetic and diabetic groups for all three scores ($p<0.01$)

Non-significant differences between normoglycemic and prediabetic groups for Constant-Murley score ($p=0.08$), but significant differences for SPADI ($p=0.04$) and QuickDASH ($p=0.03$)

These findings indicate that patients with diabetic-range HbA1c have significantly worse shoulder function compared to both normoglycemic and prediabetic patients. Prediabetic patients also demonstrate a trend toward worse function compared to normoglycemic individuals.

Subgroup Analysis

Gender-based differences: No statistically significant differences were observed between males and females in mean HbA1c levels (6.3% vs. 6.5%, $p=0.42$) or functional scores (SPADI: 63.8% vs. 64.7%, $p=0.56$), suggesting that gender does not significantly influence the relationship between glycemic status and shoulder disability.

Age-based differences: Patients aged 51-60 years had the highest mean HbA1c levels (6.7 ± 1.2%) compared to other age groups, though this difference did not reach statistical significance ($p=0.18$). Functional scores showed a trend toward worsening with increasing age, consistent with the expected natural history of frozen shoulder.

Duration of symptoms: Patients presenting with symptoms lasting >6 months had significantly higher SPADI scores (71.2 ± 13.4%) compared to those with <3 months duration (58.6 ± 11.8%, $p=0.02$). However, no significant correlation was found between symptom duration and HbA1c levels ($r=0.18$, $p=0.14$).

Discussion

This pilot study aimed to evaluate the relationship between glycemic status, as measured by HbA1c, and the degree of functional disability in patients presenting with idiopathic frozen shoulder at a rural tertiary care center in South India. The findings reveal three major insights: a strikingly high prevalence of undiagnosed dysglycemia in this population, a significant correlation between HbA1c levels and shoulder disability scores, and a clear gradient of worsening function across normoglycemic, prediabetic, and diabetic categories.

Prevalence of Undiagnosed Dysglycemia

The most striking finding of this study is that 80.9% of patients presenting with idiopathic frozen shoulder had abnormal HbA1c levels, with 41.2% falling into the prediabetic range and 39.7% meeting criteria for diabetes. These figures are substantially higher than the general population prevalence of diabetes in rural India, which is estimated at approximately 8-10% [15]. This finding strongly supports the concept that frozen shoulder may serve as an early clinical indicator of underlying metabolic dysfunction.

Our results align closely with recent prospective studies. Pandey and colleagues reported that among 158 patients with primary frozen shoulder, 37.3% were prediabetic and 46.2% were diabetic, with only 16.5% having normoglycemic status [13]. Similarly, a meta-analysis by Hamed-Hamed et al. encompassing 7,499 individuals confirmed that HbA1c is the most significantly elevated metabolic marker in frozen shoulder, with a standardized mean difference of 0.3970 (95% CI: 0.0998 to 0.6943) [7]. The consistency of these findings across different geographic regions and healthcare settings reinforces the robustness of the association.

The high prevalence of undiagnosed diabetes in our rural

Indian population is particularly concerning. Rural areas face unique challenges including limited access to healthcare, lower health literacy, and fewer screening programs. Our findings suggest that the orthopedic outpatient department may serve as an important entry point for detecting previously unrecognized metabolic disease. As advocated in a recent editorial, routine HbA1c screening in patients with atraumatic frozen shoulder should be considered standard practice [16].

Correlation Between Glycemic Control and Functional Disability

This study demonstrated significant correlations between HbA1c levels and all three functional assessment tools. The moderate positive correlation with SPADI (r=0.52) and QuickDASH (r=0.51), and the moderate negative correlation with Constant-Murley score (r=-0.48) consistently indicate that poorer glycemic control is associated with greater shoulder disability.

These findings have important clinical implications. First, they suggest that the metabolic environment may influence not only the development of frozen shoulder but also its severity. Patients with diabetic-range HbA1c in our study had mean SPADI scores approximately 21 points higher (worse) than normoglycemic patients, representing a clinically meaningful difference that exceeds the minimum clinically important difference (MCID) of 13.2 points reported for SPADI [14]. Second, the gradient of worsening function across glycemic categories suggests a dose-response relationship, strengthening the evidence for a causal link between hyperglycemia and capsular pathology.

The biological plausibility of this association is well-established. Chronic hyperglycemia leads to non-enzymatic glycosylation of collagen in the glenohumeral capsule, resulting in advanced glycation end products that promote abnormal collagen cross-linking, increased stiffness, and reduced tissue compliance [8]. Additionally, hyperglycemia triggers pro-inflammatory signaling pathways, with elevated levels of IL-1β and TNF-α documented in frozen shoulder patients [7]. These inflammatory mediators stimulate fibroblast proliferation and excessive collagen production, contributing to capsular contracture and fibrosis [9].

Comparison of Functional Assessment Tools

All three scoring systems employed in this study—SPADI, Constant-Murley, and QuickDASH—demonstrated consistent relationships with HbA1c levels. This triangulation of findings strengthens the validity of our conclusions. However, subtle differences were observed in their discriminatory capacity.

SPADI and QuickDASH appeared slightly more sensitive in detecting differences between normoglycemic and prediabetic groups (p=0.04 and p=0.03, respectively), whereas the Constant-Murley score did not show statistically significant differences between these two groups (p=0.08). This may reflect the fact that SPADI and QuickDASH are patient-reported outcome measures that capture the subjective experience of disability, while the Constant-Murley score includes objective physical examination components that may be influenced by factors beyond glycemic control. Recent literature suggests that SPADI is particularly well-suited for assessing shoulder stiffness and has excellent psychometric properties, with strong reliability (Cronbach's alpha 0.86-0.96) and test-retest reliability (ICC 0.84-0.95) [14].

Implications for Clinical Practice

The findings of this study support several recommendations for clinical practice:

Routine HbA1c screening: All patients presenting with idiopathic frozen shoulder should undergo HbA1c testing, regardless of age or perceived diabetes risk. This simple, relatively inexpensive test can identify a large proportion of patients with undiagnosed prediabetes or diabetes.

Interdisciplinary care: Patients with elevated HbA1c should be referred for appropriate medical evaluation and management of their glycemic status. Collaborative care between orthopedic surgeons and primary care physicians or endocrinologists may optimize both shoulder and systemic outcomes.

Prognostic counseling: Patients with diabetic-range HbA1c should be counseled that they may experience more severe symptoms and potentially longer recovery times. This information can help set realistic expectations and guide treatment planning.

Glycemic optimization: For patients with known diabetes presenting with frozen shoulder, optimizing glycemic control should be an integral component of the management plan. Evidence suggests that poor blood sugar control increases both the risk and severity of frozen shoulder [17].

Strengths and Limitations

Strengths: This study has several strengths. The prospective design minimized recall bias and allowed standardized data collection. The use of three validated functional assessment tools provided comprehensive evaluation of shoulder disability and allowed cross-validation of findings. The sample size was adequately powered to detect moderate correlations. The rural setting addresses an important gap in the literature, as most previous studies have been conducted in urban or developed-world populations.

Limitations: Several limitations should be acknowledged. First, as a pilot study, the sample size, while adequate for correlation analysis, may limit subgroup analyses and generalizability. Second, the single-center design may introduce selection bias, and findings may not be directly applicable to other populations or geographic regions. Third, we did not measure other metabolic parameters such as lipid

profiles, thyroid function, or inflammatory markers, which might provide additional insights into the metabolic-inflammatory framework of frozen shoulder. Fourth, the cross-sectional nature of the analysis captures a single time point and does not allow assessment of how changes in glycemic control over time might affect functional outcomes. Finally, we did not follow patients longitudinally to determine whether those with elevated HbA1c had different recovery trajectories or treatment responses.

Future Research Directions

This pilot study provides rationale for larger, multicenter studies with extended follow-up periods. Future research should address:

Longitudinal outcomes: Prospective cohort studies following patients with idiopathic frozen shoulder over 12-24 months to determine whether baseline HbA1c predicts recovery trajectory, treatment response, and long-term functional outcomes.

Comprehensive metabolic profiling: Studies incorporating lipid profiles, inflammatory markers (IL-1β, TNF-α, IL-6), and thyroid function tests to better characterize the metabolic-inflammatory phenotype of frozen shoulder patients.

Intervention studies: Randomized controlled trials evaluating whether optimizing glycemic control in patients with elevated HbA1c improves shoulder outcomes compared to standard orthopedic management alone.

Cost-effectiveness analysis: Studies examining whether routine HbA1c screening in frozen shoulder patients is cost-effective from a healthcare system perspective, considering the potential for early diabetes detection and prevention of complications.

Mechanistic studies: Basic science research further elucidating the molecular pathways linking hyperglycemia to capsular fibrosis, potentially identifying novel therapeutic targets.

Conclusion

This pilot study demonstrates that over 80% of patients presenting with idiopathic frozen shoulder at a rural tertiary care center have either prediabetes or previously undiagnosed diabetes. A significant moderate correlation exists between HbA1c levels and the degree of shoulder disability as measured by SPADI, Constant-Murley, and QuickDASH scores, with patients in the diabetic range experiencing the most severe functional impairment.

These findings support the concept of frozen shoulder as a potential metabolic signal rather than an isolated musculoskeletal condition. Routine HbA1c screening in patients with atraumatic frozen shoulder should be considered standard practice, enabling early detection of dysglycemia and facilitating timely intervention. This approach promotes interdisciplinary care and may improve both shoulder-specific and systemic health outcomes.

Future research should focus on longitudinal outcomes, comprehensive metabolic profiling, and intervention studies to determine whether optimizing glycemic control can modify the clinical course of frozen shoulder in affected patients.

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