OPEN ACCESS

Journal of Advances in Sports and Physical Education

Abbreviated Key Title: J Adv Sport Phys Edu
ISSN 2616-8642 (Print) | ISSN 2617-3905 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: https://saudijournals.com

Original Research Article

Association of Vitamin D Deficiency with Frozen Shoulder Syndrome and Repetitive Strain Injury on Spine

Prof Maj Dr S Bakhtiar Choudary (Retd), DLit, MD, PhD[1*], Prof. Rajesh Kumar[2]

[1]Senior Consultant in Sports Medicine and Occupational Health, Director, Hyderabad Spine Clinics, 36-134, defence colony, Sainikpuri post, Hyderabad, Telangana, India
[2]I/c Director of Physical Education and Head, Department of Physical Education, Osmania University, Hyderabad

DOI: https://doi.org/10.36348/jaspe.2025.v08i08.002 | **Received:** 11.07.2025 | **Accepted:** 04.09.2025 | **Published:** 10.09.2025

***Corresponding author:** Prof Maj Dr S Bakhtiar Choudary (Retd), DLit, MD, PhD
Senior Consultant in Sports Medicine and Occupational Health, Director, Hyderabad Spine Clinics, 36-134, defence colony, Sainikpuri post, Hyderabad, Telangana, India

Abstract

Background: The global incidence of partial restriction or completely frozen shoulder joints is on the rise. This study explored the Frozen Shoulder Syndrome (FSS), its relationship with Vitamin D Deficiency and insufficiency (VDD), and its impact on the spine owing to Repetitive Strain Injury (RSI), across a diverse Indian population. ***Methods:*** FSS was assessed using Shoulder Active Abduction Range (SAAR) through a standard Goniometer. Vitamin D levels were measured using the CLIA technology. The Windows version 26.0 of IBM SPSS was used to compute means, standard deviations, multivariate regression analysis utilised to adjust confounders, Chi-square tests, ANOVA, and post hoc testing were done through the Least Significant Difference (LSD) method. Risk estimates and odds ratios (95% CI) were calculated. The significance level was set at 0.05. This study retrospectively analysed 5265 approved patient records across various occupations and ages (4 to 90 years), over two decades. The gender distribution among individuals seeking treatment for back and neck pain was 2696 males and 2569 females. ***Results:*** Both left and right SAAR values were significantly lower and VDD was associated with both SAAR values. Upper back (UB) pain indicated a stronger correlation with the SAAR left than with the SAAR right. Lower back (LB) pain was moderately associated with the SAAR left and significantly with the SAAR right. A significant relationship between VDD and UB and LB pain was observed. Risk estimates were calculated and analyzed. ***Conclusion:*** This study proved the prevalence of repeated RSI on the spine owing to FSS and its relation to VDD. A simple non-invasive test like SAAR is highly beneficial for both clinician and health experts. There is an urgent need to identify FSS and VDD at an early age and across different ethnic groups and population.

Keywords: vitamin D; disc disease; back pain; neck pain; repetitive strain injury, frozen shoulder syndrome etc.

INTRODUCTION

This retrospective exploratory study aims to address the connections between Frozen Shoulder Syndrome (FSS), Vitamin D Deficiency (VDD), and spine-related pain. The objectives of this study are to investigate the underlying causes of FSS, the prevalence of VDD in diverse age groups, and examined the relationship between VDD and FSS. This research also studies the impact of FSS on spine-related painful conditions owing to repetitive strain injury (RSI).

FSS is classified as primary or secondary to other underlying conditions. While similar "frozen" syndromes can affect various joints, FSS is the most prevalent among them [1]. Defining, diagnosing and treating FSS effectively is challenging, thereby, emphasizing the need to research on its causes. Risk factors, including diabetes, hypothyroidism, Dupuytren's syndrome, cancer [2], and Complex regional pain syndrome (CRPS) [3] are associated with the development of FSS. Comorbidities affect 85% of the patients, sometimes with one to three conditions. FSS is disabling and can persist for more than three years if left untreated4 [4] and is often associated with diminished external rotation and poor functioning of deltoid muscles.

Vitamin D Deficiency is a global health concern impacting diverse populations. The active form, 1,25-dihydroxy Vitamin D3, plays a vital role in calcium homeostasis, bone metabolism, muscle function, and immune system regulation. About 40% of the general

population is affected by this deficiency [5]. The causes behind VDD include limited sun exposure, cultural practices like clothing, a diet lacking in Vitamin D-rich foods, malabsorption disorders, and sedentary lifestyles. Pregnant women, children, and the elderly, are affected by this deficiency [6-10]. Vitamin D receptor (VDR) sites are found in the intestine, bone, kidney, parathyroid gland, pancreas, skin, immune cells, and reproductive organs where vitamin D binds to a specific receptor protein, it activates, a series of biochemical pathways that regulate a wide range of cellular functions and gene expression [11]. Some studies have suggested that exposure to environmental toxins or other factors during childhood or adolescence may affect VDR function [12].

The limited availability of studies that explore the relationship between VDD and FSS, emphasize the need of comprehensive research in this area. Some systematic reviews and meta-analyses suggest a potential role of vitamin D in the development of FSS. Cross-sectional studies and other systematic reviews have investigated the correlation between vitamin D levels and adhesive capsulitis; explained the potential association between vitamin D and FSS; and focused on the role of vitamin D deficiency as a potential risk factor for FSS [13,14].

The lifetime prevalence of LBP in India was higher, especially among women, rural inhabitants, and elementary workers than global and ethnic populations [15]. Research suggests a higher incidence among women, peaking in the 35-49 age groups. The incidence of neck pain is higher in urban than in rural areas [16]. About 57.7% of individuals from Northern India with LBP had evidence of disc degeneration on MRI scans with higher incidence among women [17]. Disc degeneration was common in individuals with a history of smoking [18]. One study projected an estimated 300,000 to 350,000 spinal surgeries performed annually in urban India, at specialized spine centers [19].

The evolution of primates and their adaptations to different environments has led to the vertical orientation of the spine which allowed greater mobility in upper limbs [20]. In response to different lifestyles, the vertebral column developed significant curvatures, functional versatility, and also exposed vulnerable areas prone to injury [21]. Thereby, the risk of developing musculoskeletal disorders (MSDs) elevated. Some injuries may be acute, while others could occur owing to performing repetitive activities as part of their occupations [22]. These are broadly termed Repetitive Strain Injuries (RSI). The individuals with RSI owing to repetitive work had a higher prevalence of cervical degenerative disc disease compared with individuals without RSI [23]. People with FSS are likely to have significant difficulty in abducting their upper limbs while performing occupational and domestic activities. Forcible abduction may result in RSI on the cervical and lumbosacral spine resulting in undue strain on discs and compression on spinal nerve roots resulting in LB and UB pain.

METHODS

The research objectives involved three aspects – [1] to examine the prevalence of FSS within different age groups and occupational categories; [2] to assess the levels of vitamin D deficiency among the subjects; [3] to establish potential associations between FSS and vitamin D deficiency, in patients with both UB and LB pain.

This retrospective study analyzed 5265 subjects' data from 9000 patient case studies. The diverse sample included various occupations (students. sports, police, defence, IT industry, housewives, agriculture, retired, other sedentary jobs) aged from 4 to 90 years, and included 2696 males and 2569 females. Data sampling of over two decades were collected from three outpatient clinics (including Hyderabad Spine Clinic) that treat musculoskeletal problems. Exclusions included individuals with congenital anomalies, recent shoulder injuries, surgeries on the neck, back, and upper limb, super morbid obesity (BMI and percent body fat $\geq$ 50), residual neurological disorder disabilities, chronic immunosuppressant use, pregnant mothers, and bedridden patients. Mild to severe instances of mechanical LBP, sciatica, multilevel disc disease, disc degeneration, disc prolapse, and radiculopathy-related pains were categorized as LB pain. Mechanical neck pain, shoulder pain, and non-ENT related vertigo with neck pain were categorized as UB pain. Over 80% opted for non-surgical approaches to manage spinal problems, with a notable proportion of young individuals with recurrent musculoskeletal pains.

The active and passive range of motion in various shoulder movements were assessed using a standard goniometer (The measurement Goniometer was purchased from Chitra Scientific Company 27, 1st Main Road, V.S Nagar, Valasaravakkam, Chennai, Tamil Nadu, 600087, India). The abduction was measured by positioning the subject upright with arms at their sides as the goniometer was placed over the shoulder joint with one arm parallel to the torso. The angle of outward-raised arm was recorded with the trapezius held intact. Measurements for both shoulders at varying degrees of abduction at the SAAR were recorded. External rotation and manual muscle testing of the deltoid muscle were measured using established techniques [24]. Vitamin D levels (vitamin D3 25-OH) were evaluated using the chemiluminescent immunoassay (CLIA) technology by standard laboratories[25].

2.1 STATISTICAL ANALYSIS

Quantitative variables were summarized using mean and standard deviation, while qualitative variables were presented as frequencies and percentages. The Chi-square test investigated relationships between SAAR measurements, Vitamin D levels, demographic factors, and occupational categories. ANOVA test examined the

impact of independent variables on SAAR angles, Vitamin D levels, and occurrences of LB and UB pain. Post hoc testing (Least Significant Difference - LSD) identified specific mean differences. Associations between variables were assessed using odds ratios (with 95% confidence intervals). The multivariate logistic regression identified predictors and the stepwise logistic regression included or excluded variables based on their significance. An IBM SPSS Windows version 26.0 software was used for analysis with a significance level set at 0.05.

CALCULATION

Based on data and observations made over two decades, the author notes the ease in treating and preventing surgeries for patients reporting LB and UB pain-related problems. The key lies in modifying activities which could potentially prevent FSS which develops owing to activities of daily living (ADL) and other occupational demands. This proactive approach could help FSS patients in managing and recovering from their conditions. The identification of VDD and supplementation, coupled with improvements in other lifestyle factors, could potentially reduce the need for unnecessary surgical interventions.

RESULTS

Frozen Shoulder Syndrome was assessed using SAAR measurements on both sides categorized into SAAR on the left (Pearson Chi-Square - 45.879, df - 8, *P* 0.000) and SAAR on the right (Pearson Chi-Square – 62.491, df - 8, *P* 0.000). There was a marked restriction in active shoulder abduction on the left side (SAAR Left) associated with different age groups, which is significantly improving with increasing age. Housewives and students exhibited significant FSS (Pearson Chi-Square - 66.3, *P* 0.000) on the left side, while retired persons indicated better results. SAAR on the right side indicated similar associations with different age groups, with housewives and students exhibiting moderately significant FSS (Pearson Chi-Square - 27.3, *P* 0.005). Severe VDD was observed in all age groups (Table 1), and significant VDD was observed among various occupations (Table 2).

Table 1: Vitamin D levels in different age groups (%)

Vitamin D Deficiency	**Age groups (years)**					**Total**
ng/mL	04-19 n=670 (12.7%)	20-35 n=1576 (29.9%)	36-50 n=1938 (36.8%)	51-65 n=920 (17.5%)	66-90 n=165 (3.1%)	4-90 n=5265
= <10	271 (40.4%)	649 (41.2%)	778 (40.1%)	318 (34.6%)	53 (32.1%)	2069 (39.3%)
11-20	335 (50.0%)	762 (48.4%)	931 (48.0%)	483 (52.5%)	86 (52.1%)	2597 (49.3)
21-30	51 (7.6%)	127 (8.1%)	177 (9.1%)	93 (10.1%)	14 (8.5%)	462 (8.8%)
=>30	13 (1.9%)	38 (2.4%)	52 (2.7%)	26 (2.8%)	12 (7.3%)	141 (2.07%)
Pearson Chi-Square – 31.566, df - 12, *P* 0.002						100%

Table 2: Vitamin D levels (ng/mL) in different occupations (%)

Occupations	**n**=5265	**<10**	**11-20**	**21-30**	**=>31**
Housewives	1602 (30.4%)	43.2	45.1	8.5	3.2
Students	725 (13.8%)	42.9	49.1	6.8	1.2
Agriculture and related jobs	91 (1.7%)	39.6	45.1	9.9	5.5
IT jobs and sitting jobs	1969 (37.4%)	38.0	51.2	8.1	2.7
Retired	179 (3.4%)	24.2	59.5	11.8	4.5
Business persons	530 (10.1%	35.8	50.9	11.3	1.9
Active jobs: sports, military, police	172 (3.3%)	27.3	54.1	15.7	2.9
Pearson Chi-Square – 73.3, df - 7, *P* 0.000					

Results indicated a significant association between low Vitamin D levels and restricted shoulder abduction. There was improvement with increase in Vitamin D levels. UB pain had a strong association with FSS on the left side, while LB pain indicated a significant association on both sides (Table 3). A significant relationship is observed between low Vitamin D levels and UB and LB pain (Table 4). The study estimated the risk of developing FSS, UB pain, and LB pain based on age, occupation, and Vitamin D levels. The risk of FSS development with SAAR on the left $\leq 30°$ is higher in the age group of 4-19 years, particularly in females. Low Vitamin D values increased the risk of FSS development on both sides, with a higher risk associated with VDD (Table 5).

Table 3: Association of Vitamin D levels with FSS (SAAR on both sides)

Vitamin D ng/mL	n	Distribution (%) of SAAR Left *		
		=<30°	31-45°	46-60°
=<10	2069	47.4	48.5	4.1
11 – 20	2593	12.2	77.8	10.0.
21 – 30	462	6.9	63.6	29.5
=>30	141	4.3	43.3	52.5
Distribution (%) of SAAR Right**				
=<10	2069	16.6	61.2	22.2
11 – 20	2593	2.0	53.6	44.4
21 – 30	462	2.2	19.7	78.1
=>30	141	2.1	16.3	81.6
*Chi-Square 1300, *P* 0.000, ** Chi-Square 90.92, *P* 0.000				

Table 4: Association of LB and UB pain with Vitamin D deficient levels

Vitamin D ng/mL				
Problem	=<10	11-20	21-30	=>31
UB pain*	n-1339 (40.5%)	1601 (48.4%)	295 (8.9%)	73 (2.2%)
LB Pain**	n-1210 (38.4%)	1548 (49.2%)	297 (9.4%)	93(3.0%)
**Pearson Chi-Square 22.286 df 5 P 0.001* ***Pearson Chi-Square 20.451 df 4 P 0.005*				

Table 5: Association of FSS, SAAR with LB and UB Pain

The degree of SAAR on the Left side				
	=<30°	31-45°	45-60°	n=5265
LB Pain*	768 (24.4%)	2019 (64.1%)	361 (11.5%)	3148
UB Pain**	856 (25.9%)	2082 (62.9%)	370 (11.2%)	3308
*Pearson Chi-Square 6.9, df 2, *P* 0.032, ** Pearson Chi-Square 18.32, *P* 0.001				
The degree of SAAR on the right side				
	<=30°	31-45°	45-60°	n=5265
LB Pain *	237 (7.5%)	1528 (48.5%)	1383 (43,9%)	3148
UB Pain **	267 (8.1%)	1721 (52.0%)	1320 (39.9%)	3308
*Pearson Chi-Square 60.635, df 2, *P* 0.000, ** Pearson Chi-Square 1.7, df 2, *P* 0.041				

DISCUSSION

This study revealed that FSS can occur as early as age 4, leading to muscle and joint discomfort in infants. The biomechanics of shoulder joints, specially the supraspinatus, deltoid, and supporting muscles play a crucial role. The deltoid muscle is responsible for lifting the arm away from the body (0-180 degrees) during various stages of shoulder abduction. Trapezius, serratus anterior, teres minor, and infraspinatus help stabilize during complete abduction [26]. MRI scans indicated injured supraspinatus tendons and weakened deltoid muscles in FSS patients. Pathological processes involve fibroblast activation, collagen synthesis deregulation, chronic immune cells, and inflammatory mediators [27]. Cadaveric evaluations revealed characteristic manifestations like synovial hyperplasia and thickening of ligaments. Advanced stages of FSS result in severe movement restrictions [28].

Abduction is more restricted than flexion and extension owing to evolutionary transition to bipedalism, where the shoulder girdle became more mobile. In early quadrupedal hominids, locomotion relied on flexion and extension owing to the scapulae's lateral position. This limitation in the shoulder joint abduction, observed in many quadrupeds such as dogs [29], persists even after the loss of more than 80 percent [30].

Vitamin D deficiency and insufficiency affects approximately 1 billion people globally, with D2 from yeast and sun-exposed mushrooms and D3 synthesized in human skin. Ingested Vitamin D becomes 25(OH)D, undergoing hydroxylation in the liver and kidneys, to form biologically active 1,25(OH)2D [31]. The widespread occurrence of VDD is observed across age groups in India. Low VDD levels are associated with impaired rotator cuff healing, attributed to elevated matrix metalloproteinase-9 influenced by VDD. Conversely, Vitamin D exhibits anti-inflammatory properties, downregulating the effects of tumor necrosis factor-alpha [32].

The current study demonstrates that shoulder abduction angles are correlated with Vitamin D levels and pain. A significant association is found between SAAR $\leq 30°$ on the left and upper back (UB) pain and SAAR $\leq 30°$ on the right side with lower back (LB) pain (Table 5). Enhanced coordination in the right shoulder's

abduction may shift the center of gravity, contributing to lower back issues. Left-sided abduction exhibits stiffness, impacting the neck and upper back. Non-dominant shoulders, especially the left, indicate a higher incidence rate of 53.4% in FSS [33], suggesting a potential link to an asymmetrical brain control mechanism [34].

This study establishes a significant correlation between FSS and VDD across age groups. The Shoulder Abduction Angle Range (SAAR) test indicates an inverse relationship between VDD and abduction ability, particularly on the left side for right-dominant individuals. Individuals with FSS have reported significant instances of both LB and UB pain, indicating poor Vitamin D levels. This study also highlights the potential consequences of repetitive strain injury (RSI) on the spine during upper limb movement and abduction, causing Neuropraxias and recurrent radiating pain. Lifestyle factors contributing to VDD and their potential role in FSS development and RSI on the spine require further evaluation.

Primary and secondary spinal curvatures develop during early childhood. However, FSS-induced RSI could exert pressure on vulnerable spinal areas, contributing to the loss of cervical and lumbosacral spine curvatures. Weight-bearing activities and incorrect postures may potentially injure the cervical and lumbosacral spine, this might lead to herniated discs, especially in people pertaining to certain occupations. Evidence suggests an association between spinal disc disease and FSS, possibly owing to anatomical proximity. Recent studies have thrown light in the association between VDD and the vitamin D receptor (VDR) in progression of Intervertebral Disc Disease[35]. Patients with rotator cuff tendinopathy often exhibit cervical spine dysfunction, reduced range of motion, weakened muscles, and impaired joint position sense.

LIMITATIONS

The study is based on meticulous analysis of recorded data and methodologies. Left-handed subjects were excluded owing to insufficient data. Other movements of shoulder joints were not considered. Data from other biochemical tests like PTH, calcium, thyroid, and blood sugar were excluded. Seasonal effects on Vitamin D and its prevalence were not recorded in the analysis.

CONCLUSION

Our study has noted the wide occurrence of Frozen Shoulder Syndrome across diverse age groups. There is a difference in shoulder active abduction on the left and right side. The presence of low Vitamin D levels is noticed among a wide range of age groups, particularly in housewives, students, and other younger populations. FSS occurrence is significantly related to low Vitamin D levels across all age groups and occupations. FSS with reduced abduction of upper limbs has a repetitive strain on the spine causing a disturbance in its dynamics, thus leading to conditions such as LB and UB pain. This finding underlines the potential role of Vitamin D on joint function and its impact on musculoskeletal health. There is an urgent need for FSS and VDD assessment in children of both genders, to develop effective management strategies.

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