ISAKOS CONGRESS 2025 | MUNICH GERMANY June 8–11

3D Quantification of Subchondral Bone Mineralization Patterns of the Glenoid in Recreational Heavy Weightlifters

Luis A. Vargas MD PhD, Lizt Valladares BS, Jessica Leon BS, Nina Reddy BS, Chris Ciesla BS, Camila A. Torres-Caiaffa BA, Alexandra D. Moutafis BS, Matthias R. Schurhoff MD, Anshul Saxena BDS PhD, Jessica A. Bent BS, John E. Zvjiac MD, John W. Uribe MD

Baptist Health Orthopedic Institute

FIU Herbert Wertheim College of Medicine

United States of America

Faculty Disclosure Information

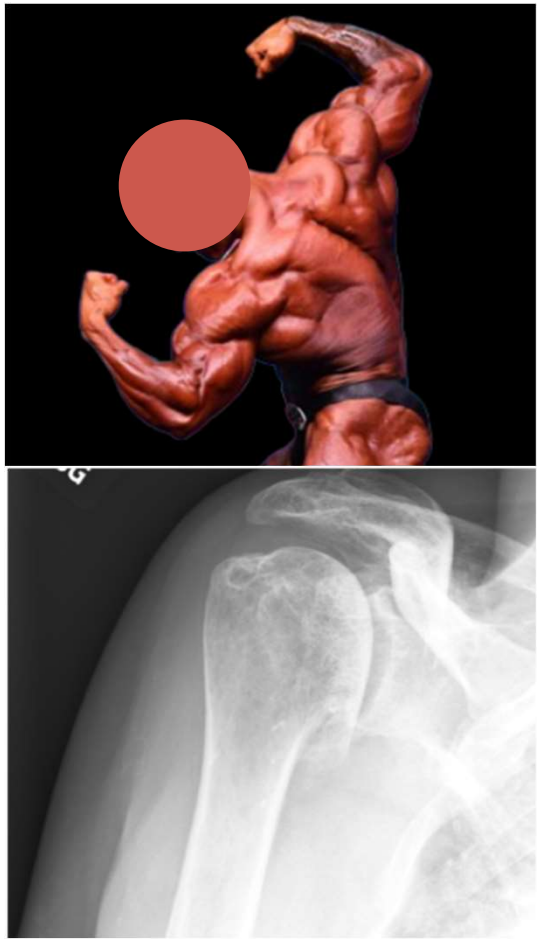
None of the authors have any financial conflicts to disclose in conjunction with the content of this study.

General financial disclosures for all authors are available on the American Academy of Orthopedic Surgeons

Introduction

- Repeated multidirectional mechanical loads at high forces may lead to mechanical strain adaptations in the glenohumeral joint, increasing subchondral bone mineralization[1]

- High risk population: Athletes subjecting their joints to extreme positions with significantly higher loads than the average active adult[2]



ISAKOS CONGRESS 2025 | MUNICH GERMANY June 8–11

Baptist Health Orthopedic Institute | FIU Herbert Wertheim College of Medicine

Quantifying Glenohumeral Stress Modifications

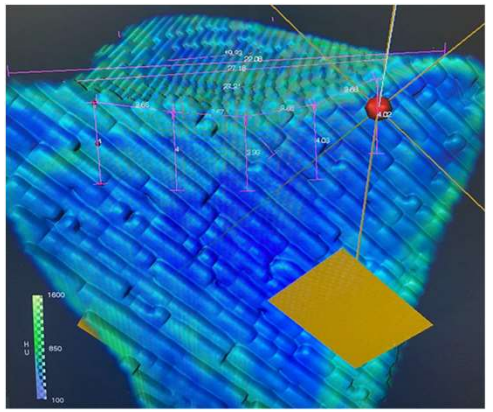
- Distribution of mineralization of the subchondral bone plate (DMSB) can measure stress modifications across the glenoid[3]

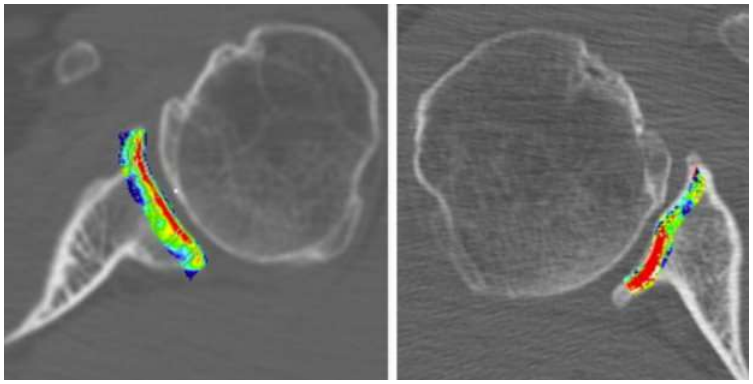
Purpose

- Measure bone mineralization at three levels of the subchondral bone
- Describe glenoid patterns in weightlifting athletes

Hypothesis

- Early DMSB changes can be detected and quantified in the weightlifting population





Representation of DMSB on axial slice[4]

ISAKOS CONGRESS 2025 | MUNICH GERMANY June 8–11

Baptist Health Orthopedic Institute | FIU Herbert Wertheim College of Medicine

Methods

Inclusion Criteria

- Asymptomatic athletes (18-50 years) with glenohumeral radiographs
- Minimum two years of bodybuilding, powerlifting, or heavy weightlifting

Exclusion Criteria

- History of shoulder surgery

Athlete Characteristics

- Powerlifting Total (Personal Best): Summation of an athlete's heaviest squat, bench press, and deadlift
- Wilks Classification: Strength relative to body weight

Baptist Health Orthopedic Institute

FIU Herbert Wertheim College of Medicine

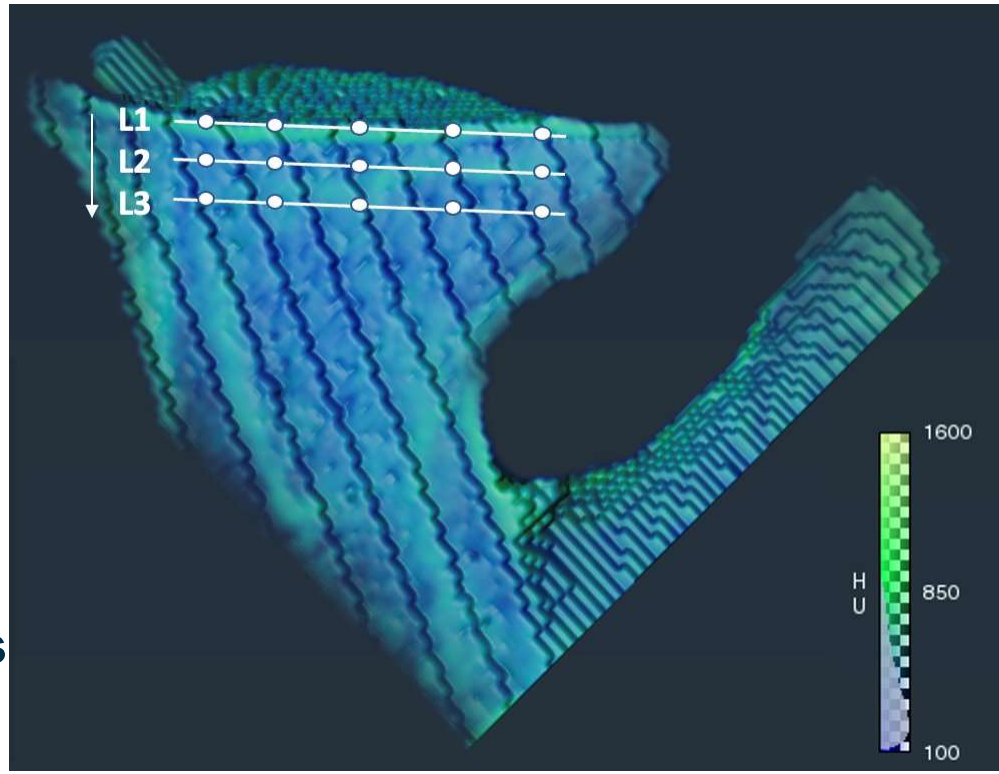
Methods Continued

Imaging

- Standardized Bilateral CT Imaging
- 3D reconstruction and glenoid segmentation (Amira, Thermofischer)
- DMSB quantification: Hounsfield units (HU) at three glenoid levels (L1, L2, L3) with 12 regions of interest (ROI)
  - L1: Subchondral bone plate
  - L2: Subchondral bone trabeculate
  - L3: Trabecular bone

Analysis

- Chi-squared and Kruskal-Wallis analyses
  - DMSB at each ROI
  - DMSB stratified by age group (<32, ≥32), retroversion, hand dominance, and Wilks classification

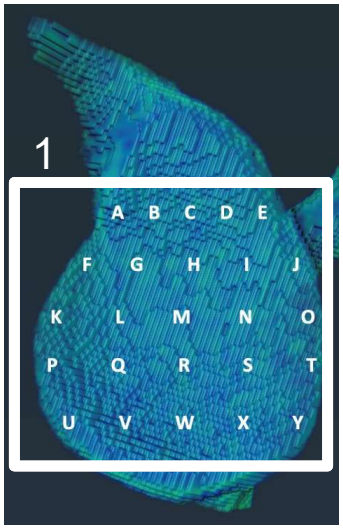


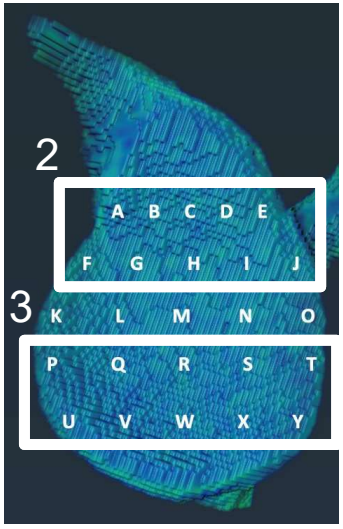
Baptist Health Orthopedic Institute

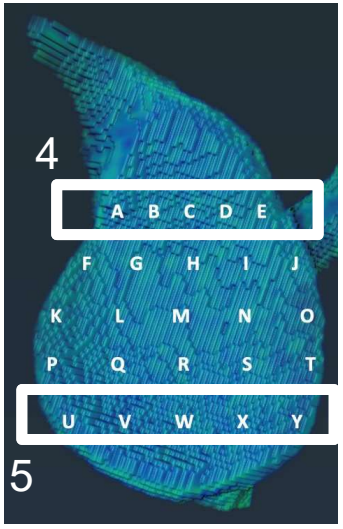
FIU Herbert Wertheim College of Medicine

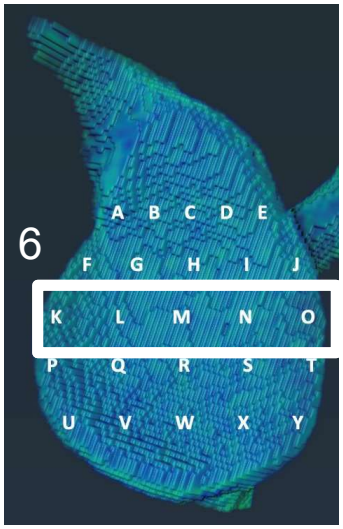
Methods - Regions of Interest

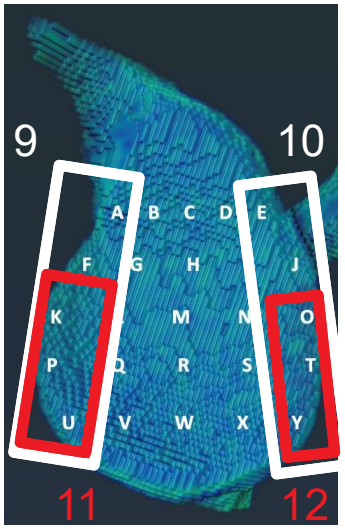
1. Full Glenoid
2. Superior
3. Inferior
4. Superior Rim
5. Inferior Rim
6. Central
7. Posterior
8. Anterior
9. Posterior Rim
10. Anterior Rim
11. Posteroinferior Rim
12. Anteroinferior Rim











Baptist Health Orthopedic Institute

FIU Herbert Wertheim College of Medicine

Study Population

Table 1. Athlete Characteristics

Count	14 athletes, 28 shoulders
Age	31.9 ± 5.6 years
Gender	10 Males, 4 Females
BMI	26.9 ± 2.0 kg/m^2
Hand Dominance	13 Right, 1 Left
Performance Type	8 Heavy Weightlifters, 4 Bodybuilders, 2 Powerlifters
Powerlifting Total (Personal Best)	990.8 ± 218.3 lbs
Wilks Classification	50% Advanced, 50% Intermediate
Weekly Training Sessions	6.1 (range 4-10)

Table 2. Radiographic Assessments

Walch Classification	19 A1, 8 B1, 1 B2
Samilson Prieto	100% Grade 0
Retroversion	6.9 ± 3.8 degrees

Results

- DMSB was significantly higher at L1 ($p < 0.001$) followed by L2 and L3
- Central, Superior, and Anterior ROI were higher than the average L1 HU

Table 3. Bone Mineralization at Glenoid Depths

Level	HU Median [IQR]
L1 subchondral bone plate	**473.6** [391.9, 558.3]
L2 subchondral bone trabeculate	261.8 [208.3, 325.0]
L3 trabecular bone	160.4 [122.6, 198.1]

Table 4A/B. Bone Mineralization at the Surface Level

A. Rim ROI	HU Median [IQR]
Superior	**483.7** [377.5, 538.9]
Anterior	**476.8** [396.9, 569.5]
Posterior	471.2 [378.9, 556.3]
Posteroinferior	469.2 [387.9, 552.5]
Anteroinferior	450.6 [388.3, 536.1]
Inferior	428.6 [363.3, 489.0]

B. ROI	HU Median [IQR]
Central	**490.3** [411.9, 597.4]
Superior	**485.5** [385.3, 573.2]
Anterior	**476.4** [403.8, 568.4]
Posterior	474.9 [379.4, 555.9]
Inferior	452.4 [378.5, 535.2]

ISAKOS CONGRESS 2025 | MUNICH GERMANY June 8–11

Baptist Health Orthopedic Institute | FIU Herbert Wertheim College of Medicine

Results – Subgroup Analyses

Baptist Health Orthopedic Institute | FIU Herbert Wertheim College of Medicine

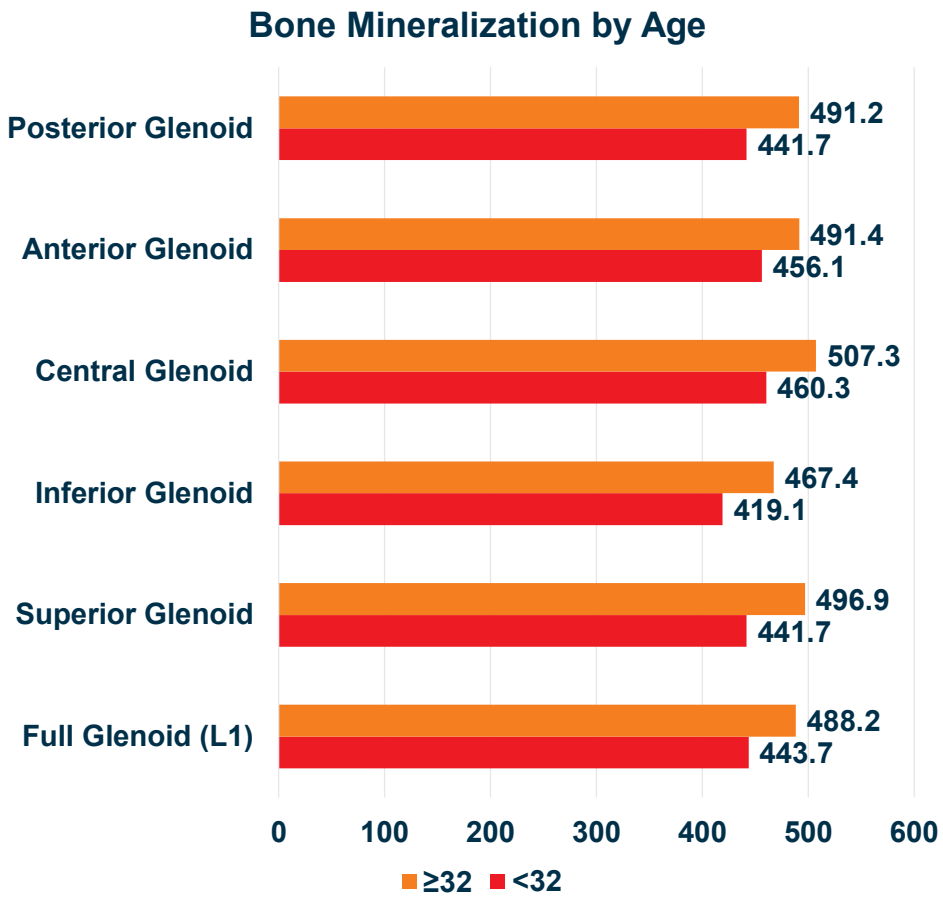
- DMSB was significantly higher at 7 ROI in athletes over 32 years old
- No significant differences in ROI between Advanced and Intermediate Wilks Classifications ($p > 0.05$)
- No significant differences in ROI based on retroversion ($p > 0.05$)
- Hand dominance had no significant effect in ROI ($p > 0.05$)

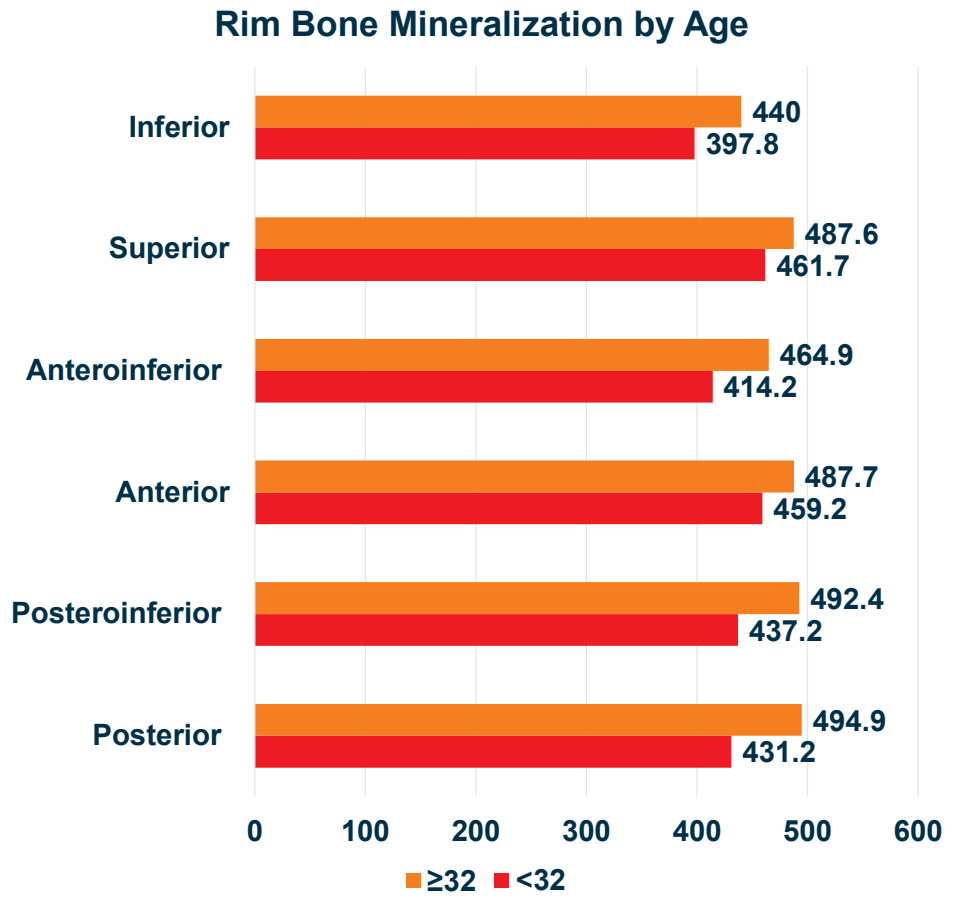
Table 5A/B Bone Mineralization at the Surface Level by Age Group

A. Rim ROI	Age Group
Superior	0.209
Anterior	0.099
Posterior	**0.002**
Posteroinferior	0.071
Anteroinferior	0.087
Inferior	0.127

B. ROI	Age Group
Full	**< 0.001**
Central	**0.022**
Superior	**0.007**
Anterior	**0.019**
Posterior	**0.001**
Inferior	**0.008**

Age Stratification





ISAKOS CONGRESS 2025 | MUNICH GERMANY June 8–11

Baptist Health Orthopedic Institute

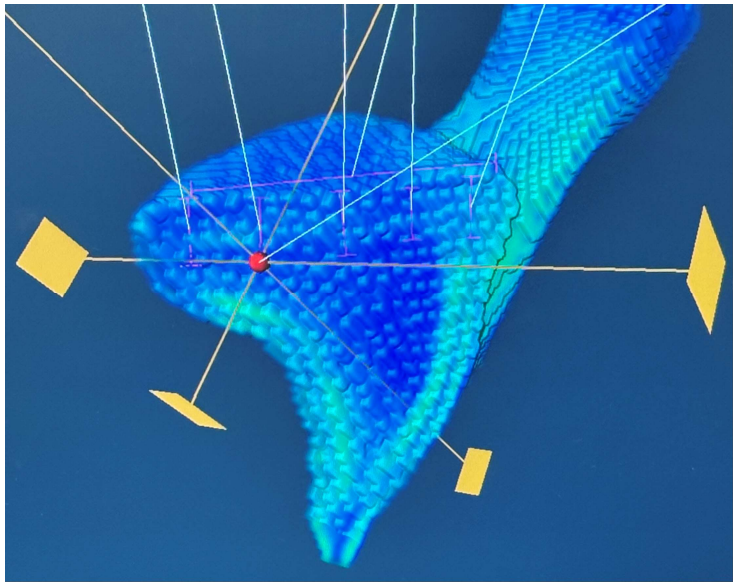
FIU Herbert Wertheim College of Medicine

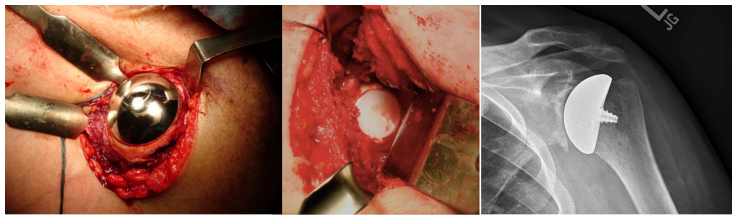
Conclusion

- Mineralization was highest at the subchondral bone layer
- Weightlifters showed high mineralization in the central, superior, and anterior glenoid
- Retroversion, hand dominance, and Wilks Classification did not impact DMSB

Future Directions

- Comparing glenoid bone remodeling in weightlifters to non-weightlifting controls
- Comparing glenoid bone remodeling in weightlifters to patients prior to total shoulder arthroplasty





ISAKOS CONGRESS 2025 | MUNICH GERMANY June 8–11

Baptist Health Orthopedic Institute | FIU Herbert Wertheim College of Medicine

References

1. Numaguchi K et al. Stress-Distrion Pattern Across the Glenohumeral Joint in Collegiate and Professional Baseball Players: A Computed Tomography Osteoabsorptiometry Study. Orthop J Sports Med 2021;9
2. Kawasaki T et al. Computed tomography osteoabsorptiometry for assessing the density distribution of subchondral bone as a measure of long-term mechanical stress in the "rugby shoulder". J Shoulder Elbow Surg 2013;22
3. Kraljevic M et al. A comparison of subchondral bone mineralization between the glenoid cavity and the humeral head on 57 cadaverous shoulder joints. Surg Radiol Anat 2013;35
4. Simon et al. Glenoid subchondral bone density distribution in male total shoulder arthroplasty subjects with eccentric and concentric wear. J Shoulder Elbow Surg 2015;24