Obesity is Associated with an Increased Prevalence of Glenohumeral Osteoarthritis and Arthroplasty: A Cohort Study

Kevin C. Wall, MD, MPH[a,*], Cary S. Politzer, MD[b], Jorge Chahla, MD, PhD[c], Grant E. Garrigues, MD[c]

KEYWORDS

• Arthritis • Shoulder • Obesity • Arthroplasty • Body mass index • Glenohumeral

KEY POINTS

- The relationship between obesity and glenohumeral osteoarthritis is relatively understudied and poorly understood.
- Individuals with a body mass index of greater than 25 are at significantly increased odds of developing glenohumeral osteoarthritis when compared with those with a normal body mass index.
- Individuals with a body mass index of less than 19 are significantly less likely to develop glenohumeral osteoarthritis than compared with individuals with a normal body mass index.
- A body mass index of greater than 30 confers an increased odds of undergoing arthroplasty among individuals with glenohumeral osteoarthritis.

INTRODUCTION

Osteoarthritis and obesity are widely recognized as 2 integrally associated pathologies, both with a rising incidence worldwide. The classic model of their relationship states that increasing body weight places a proportionally greater degree of mechanical stress on weight-bearing joints, leading to the development and progression of primary osteoarthritis.[1] An increased prevalence of osteoarthritis of the hip and knee in obese individuals is consistent with this theory,[2–5] and additional research has shown that, although the prevalence of osteoarthritis among all normal or underweight Americans is 16%, this number increases to 23% among overweight adults and to 31% for obese individuals.[6] Globally, obesity has become an epidemic not only among high-income countries, but also in third-world countries. Between 1975 and 2016, the number of obese individuals tripled, such that now 1.9 billion adults are overweight and 650 million are obese.[7]

Economically, osteoarthritis is the leading cause of disability among American adults,[8] and annually results in $80.8 billion in direct medical costs and $47 billion in indirect costs, such as lost productivity.[9] Similarly, obesity's annual cost is $147 billion in medical spending alone, amounting to 42% more per capita medical spending than that which is spent on non-obese individuals.[10] Although these numbers are not as well-defined on global scale, it stands to reason that the medical and financial

[a] Department of Orthopaedic Surgery, University of Alabama at Birmingham, 1313 13th Street South, Birmingham, AL 35205, USA; [b] Department of Orthopaedic Surgery, University of California San Diego, 4150 Regents Park Row, La Jolla, CA 92037, USA; [c] Midwest Orthopaedics at Rush, Rush University Medical Center, 1611 West Harrison Street, Chicago, IL 60612, USA
* Corresponding author.
E-mail address: kcwall@uabmc.edu
Twitter: @grant_garrigues (G.E.G.)

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effect of the interplay between these diseases is profound and warrants further investigation.

Recent research into obesity has demonstrated that excess adipose tissue exerts an additional influence beyond the forces its mass applies to the body's susceptible joints. By a variety of mechanisms, obesity also induces a state of chronic, low-grade inflammation[11] with evidence of multiple systemic proinflammatory factors playing a role.[12] The adipokines (adipose tissue-secreted cytokines) are factors that have recently been reported to contribute to the pathophysiology of osteoarthritis affecting both cartilage loss in the knee[13–15] and pain.[16–18] In an attempt to further characterize the effect of obesity on the development of osteoarthritis, we analyzed a large joint classically described as non–weight-bearing, namely, the glenohumeral joint.

For these reasons, the purpose of this study was to determine the prevalence of glenohumeral osteoarthritis and arthroplasty when categorized by body mass index (BMI). Although the shoulder is a non–weight-bearing joint[19–22] and thus should not be as susceptible as the hip[2] and knee[4] to the increased mechanical forces secondary to obesity, we hypothesized that the obese state will still lead to an increased prevalence of shoulder osteoarthritis, and a greater number of shoulder arthroplasties when compared with nonobese individuals.

METHODS

Study Design

This retrospective review was conducted using the database of the United States private insurance payer, Humana, from 2007 to 2016 quarter 3 and was accessed with the PearlDiver Technologies user interface (Warsaw, IN). This database contains the entirety of the collected claims information from more than 25 million patients in the United States and is subjected to routine internal and external audits. Data available for analysis includes demographics, diagnoses, procedures performed, medications prescribed, and hospital admissions. This study was considered exempt from review by our institutional review board.

Database Query

The database was queried for BMI using *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9) diagnosis codes for a BMI of less than 19 kg/m^2 to a BMI of greater than 39 kg/m^2 in increments of 5 kg/m^2. The tenth edition (ICD-10) codes were also used for quarter 4 of 2015 to quarter 3 of 2016 (Table 1). Cases were grouped by BMI (<19, 20–24, 25–29, 30–34, 34–39, >39). To avoid any selection bias related to patients who are more likely to have a BMI diagnosis, all cohorts were matched by age and sex using PearlDiver command language. This resulted in 6 cohorts of 99,479 patients each, with identical age and sex makeup. Charlson Comorbidity Index (CCI), a measure of

Table 1
ICD codes

	Diagnosis vs Procedure	ICD-9 Code	ICD-10 Code
BMI <19	Diagnosis	V850	Z681
BMI 19–24	Diagnosis	V851	Z6820-Z6824
BMI 25–29	Diagnosis	V8521-V8525	Z6825-Z6829
BMI 30–34	Diagnosis	V8530-V8534	Z6830-Z6834
BMI 35–39	Diagnosis	V8535-V8539	Z6835-Z6839
BMI >39	Diagnosis	V8541-V8545	Z6841-Z6845
Shoulder osteoarthritis	Diagnosis	715.11	M19.011 (right), M19.012 (left), M19.019 (unspecified)
Total shoulder arthroplasty	Procedure	81.80	0RRJ07Z, 0RRJ0JZ, 0RRJ0KZ, 0RRK07Z, 0RRK0JZ, 0RRK0KZ
Reverse total shoulder arthroplasty	Procedure	81.81	0RRJ0J6, 0RRJ0J7, 0RRK0J6, 0RRK0J7
Hemiarthroplasty	Procedure	81.88	0RRJ0J6, 0RRJ0J7, 0RRK0J6, 0RRK0J7

10-year predicted mortality, was also calculated for each matched cohort.[23]

The prevalence of arthritis in each BMI cohort was attained using ICD-9 and ICD-10 diagnosis codes specifically for primary glenohumeral osteoarthritis. To determine how many patients with shoulder osteoarthritis underwent shoulder arthroplasty in each BMI cohort, ICD-9 and ICD-10 procedure codes for the various arthroplasty options were used (see Table 1). *Current Procedural Terminology* codes were not used because there is no code that identifies reverse total shoulder arthroplasty specifically, and we did want to systematically exclude these patients.

Statistical Analysis

When comparing BMI cohorts for osteoarthritis and arthroplasty incidence, odds ratios (ORs) and 95% confidence intervals (CIs) were calculated with an α of 0.05. Given that a BMI of 19 to 24 is considered normal, this cohort was used as the reference cohort to which all other cohorts were compared. CCI scores were grouped into values of 0, 1, 2 and at least 3 and Pearson's χ^2 was tested across all 6 BMI cohorts. Arthroplasty rates were calculated by dividing the number of shoulder arthroplasties performed in each BMI cohort by the number of patients in each respective cohort who have glenohumeral osteoarthritis, thus standardizing the rates across cohorts and minimizing any potential effect that changes in osteoarthritis rates may have on arthroplasty rates. Arthroplasty ORs were similarly calculated; only individuals who had glenohumeral osteoarthritis were included in the subanalysis sample so as to prevent any increased odds of osteoarthritis from also artificially increasing the odds of arthroplasty.

RESULTS

Demographics

Of the 2,748,702 patients with a BMI diagnosis code in the Humana database, 596,874 were able to be matched by age and sex into BMI cohorts so that each cohort had the same proportion of each age and sex group. Collectively, these age- and sex-matched BMI cohorts make up the primary cohort of this study. Of the primary cohort, 27,803 (4.66%) had a diagnosis of primary glenohumeral osteoarthritis. The BMI cohorts had statistically different CCI scores ($P<.001$), indicating each BMI cohort has a different average health status and 10-year estimated mortality (Table 2).

Primary Analysis

The underweight (BMI of <19) cohort and the cohorts above the normal range (25–29, 30–34, 35–39, and >39) were all compared with the normal BMI (19–24) cohort (see Table 2). Glenohumeral osteoarthritis was present in 3.76% of patients in the BMI 19 to 24 cohort versus 3.14% of patients in the BMI under-19 cohort (OR, 0.83; 95% CI, 0.79–0.87; $P<.001$), 4.4% of patients in the BMI 25 to 29 cohort (OR, 1.18;

Table 2
Glenohumeral osteoarthritis and arthroplasty prevalence and ORs by BMI cohort

	BMI (kg/m^2)					
	<19	**19–24**	**25–29**	**30–34**	**35–39**	**>39**
Cohort count (n)	99,479	99,479	99,479	99,479	99,479	99,479
Mean CCI (SD)	3.31 (3.58)	2.40 (2.98)	2.46 (2.93)	2.73 (3.02)	3.03 (3.09)	3.44 (3.24)
GH OA (%)	3119 (3.14)	3740 (3.76)	4380 (4.40)	5082 (5.11)	5648 (5.68)	5834 (5.86)
OR (95% CI)	0.83[a] (0.79–0.87)	REF REF	1.18[a] (1.13–1.23)	1.38[a] (1.32–1.44)	1.54[a] (1.48–1.61)	1.59[a] (1.53–1.66)
GH Arthro (st %)	219 (7.02)	256 (6.84)	329 (7.51)	418 (8.23)	590 (10.45)	600 (10.28)
OR (95%CI)	1.03 (0.85–1.24)	REF REF	1.11 (0.93–1.31)	1.22[a] (1.04–1.43)	1.59[a] (1.36–1.85)	1.56[a] (1.34–1.82)

Abbreviations: GH arthro, number of patients who underwent glenohumeral arthroplasty (st % = the standardized arthroplasty rate - the percentage of patients in the cohort who underwent arthroplasty divided by the total number of patients in the cohort with GH OA); GH OA, number of patients in cohort with glenohumeral osteoarthritis (% of cohort with GH OA); REF, referent cohort for OR calculations; SD, standard deviation.

[a] Indicates significance at $\alpha = 0.05$.

CI, 1.13–1.23; $P<.001$), 5.11% of patients in the BMI 30 to 34 cohort (OR, 1.38; CI, 1.32–1.44; $P<.001$), 5.68% of patients in the BMI 35 to 39 cohort (OR, 1.54; CI, 1.48–1.61; $P<.001$), and 5.86% of patients in the BMI over-39 cohort (OR, 1.59; CI, 1.53–1.66; $P<.001$).

Of patients with glenohumeral osteoarthritis, the odds of undergoing shoulder arthroplasty in the BMI under-19 cohort (OR, 1.03; CI, 0.85–1.24) was not significantly different from the BMI 19 to 24 cohort. Similarly, the BMI 25 to 29 cohort was not found to be at increased odds of undergoing arthroplasty when compared with the reference cohort (OR, 1.11; CI, 0.93–1.31). However, the cohorts with a greater BMI did have higher standardized rates of arthroplasty. The 30 to 34 BMI cohort had a prevalence of 8.23% of shoulder arthroplasty, significantly higher than 6.84% of patients who underwent arthroplasty in the BMI 19 to 24 cohort (OR, 1.22; CI, 1.04–1.43; $P = .016$). Additionally, the 10.45% standardized rate in the BMI 35 to 39 cohort demonstrated a statistically significant OR of 1.59 (CI, 1.36–1.85; $P<.001$) when compared with the reference cohort, as did the standardized rate of the BMI over-39 cohort, 10.28% (OR, 1.56; CI, 1.34–1.82; $P<.001$).

DISCUSSION

We hypothesized that the prevalence of glenohumeral osteoarthritis and rate of shoulder arthroplasty would increase as BMI increased. To test this hypothesis, we mined 9 years of data from a large insurance database for patients with a recorded BMI. Six BMI cohorts of these individuals were generated in an age- and sex-matched fashion, and then each cohort was filtered for a diagnosis of glenohumeral osteoarthritis and subsequent arthroplasty. The overall prevalence of glenohumeral osteoarthritis was 4.66%. As hypothesized, there was a small but significant and progressive increase in osteoarthritis prevalence with increased BMI, relative to the normal BMI cohort. As a corollary, lower BMI (<19) served as a protective factor against glenohumeral osteoarthritis with a statistically significant OR of 0.83.

The fact that there exists an association between obesity and osteoarthritis in what has customarily been described as a non–weight-bearing joint[19–22] requires perhaps reconsidering the role of mechanical forces experienced by the shoulder in the obese individual, as well further study of other mechanisms that may predispose an obese individual to osteoarthritis. One such plausible explanation is that glenohumeral osteoarthritis is also a result of the chronic, systemic inflammatory state of obesity. As adipokines increase with the accumulation of additional adipose tissue, leptin, which has been discovered in glenohumeral synovial fluid,[19,24] may be mediating increased cartilage destruction.[14,17,25,26]

Leptin has proven destructive effects on cartilage and local differences in leptin concentration suggest that all joints are not equally affected. Leptin simultaneously slows chondrocyte proliferation while stimulating the same cells to increase synthesis of the proinflammatory molecules IL-1β, matrix metalloproteinase-9 and matrix metalloproteinase-13.[25] Although increased leptin levels have been observed in the infrapatellar fat pad of obese individuals,[24,27,28] and thus posited as a mechanism for osteoarthritis development in the adjacent knee joint, there is only weak evidence to show that the adipose tissue surrounding the shoulder may behave similarly.[29] As our data show, however, even in the absence of the fat pad that theoretically affects the knee joint, the shoulder nonetheless suffers higher osteoarthritis rates in individuals with more overall adipose tissue.

In addition, we found that the standardized rates of shoulder arthroplasty among patients with glenohumeral osteoarthritis was greater in patients with higher BMI levels. All BMI cohorts of greater than 30 kg/m^2 demonstrated significantly greater odds of having this procedure than our referent, the BMI 19 to 24 cohort. To attempt to contextualize this finding, we note the reason why the decision to progress to operative management is often made: failure of conservative therapy, often manifesting as refractory or increased pain.[3]

One plausible explanation for why patients with a higher BMI may experience worsened pain is the theoretically increased forces exerted across this joint in this population that may promote currently unrecognized degeneration. This effect is relatively understudied in the literature and future biomechanical studies are necessary to demonstrate such an effect. Another way by which the effect found in this study may be explained is the concurrent upregulation of central NMDA receptors and enhanced excitation of the same pathway in the presence of leptin.[18] It is possible that, with increased plasma leptin levels, as seen in the obese patient,[14] the central nervous system of the patient with a higher BMI is modulated in such a fashion, thus predisposing the patient to the resultant sensitivity to neuropathic pain.

As highlighted by Gandhi and colleagues,[19] shoulder osteoarthritis pain may present as

constant, dull and aching pain or as what is presumed to be neuropathic pain, characterized as fleeting, but both physically and emotionally intense.[16] Gandhi and his colleagues additionally noted that synovial fluid leptin concentrations were predictive of scores on the short form of the McGill Pain Questionnaire (a patient-reported questionnaire for evaluating pain intensity, quality, and behavior), further reinforcing the leptin–pain hypothesis. Thus, the increased arthroplasty rates among the higher BMI cohorts may be a function of this modified pain pathway. This theory is supported by the numerous neuropathic pain medications already shown to be efficacious in osteoarthritis[30–38]; however, significantly more research is essential to establishing that this type of pain, and a possible, concurrent improved efficacy of medications that treat it, are present in the obese population.

This study was not without limitations. By accessing an existing database of insurance claims through PearlDiver, we were limited to only data based on ICD-9 and ICD-10 codes, hindering our ability to review charts for additional information or study any potentially confounding variables that were not collected for these claims. One such example of this limitation is the use of only postprocedure ICD codes to capture all arthroplasty events; indeed, some of these surgeries may have been performed but not captured by this specific coding for a myriad of reasons.

Similarly, it is possible that the indication for some of the reverse arthroplasties may have been rotator cuff disease concurrent with the requisite osteoarthritis. Issues such as these are theoretically mitigated by the auditing process that the PearlDiver database undergoes but it is difficult to fully assess the reliability of the data without access to the original medical records.

The difference in CCI scores across BMI cohorts also presents a source of potential confounding. However, the increase seen in these scores at the extremes of the BMI ranges is not entirely unexpected, because underweight and obese individuals generally tend to be more ill. Given that our cohorts were already matched for age and sex, we controlled for the main risk factors that predispose individuals to osteoarthritis, thus making it unlikely that any other comorbidity captured by the CCI scores would serve as a significant mediator of the BMI effect we found on osteoarthritis rates.

Despite these limitations, this study contributes to a better understanding of the influence that obesity has on the prevalence of glenohumeral osteoarthritis. Additionally, the previously unreported finding of an increased rate of glenohumeral arthroplasty performed on overweight and obese patients represents a novel source of a disproportionately high surgical burden among this segment of the population.

SUMMARY

Patients with a higher BMI are at increased odds of developing glenohumeral osteoarthritis, despite the conventional belief that such an association is limited to weight-bearing joints. There are also increased odds of undergoing arthroplasty in the higher BMI cohorts, disproportionate to the increase in osteoarthritis rates in these cohorts. These findings may prove to be useful in determining more targeted methods for treating osteoarthritis among the overweight and obese populations.

DISCLOSURE

The authors have nothing to disclose.

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