

Trends in osteoarthritis burden and the role of body mass index among older U.S. adults, 1999–2023: a NHANES and GBD analysis

Rongxiang SUN¹, Zhifeng MO¹, Maolin LIU¹, Qinglong JIAN^{1,*}

¹Department of Emergency and Disaster Medicine Center, The Seventh Affiliated Hospital, Sun Yat-sen University, Shenzhen 518107, China

*Corresponding author, jianqinglong@sysush.com

Abstract

Objective: To examine the association between body mass index (BMI) and osteoarthritis (OA) among U.S. adults aged ≥ 55 years and to characterize national temporal trends, geographic patterns, and future burden projections. **Methods:** This multi-source study integrated NHANES (1999–2023) and GBD data. Multivariable logistic regression assessed BMI–OA associations with sex-stratified, subgroup, and interaction analyses. NHANES survey-weighted temporal trends in obesity and OA prevalence were examined across cycles. GBD estimates were used to evaluate OA incidence, prevalence, disability-adjusted life years, age-standardized rates, geographic variation, decomposition analyses, and projections through 2040. **Results:** Among 7,857 participants, 1,054 had OA. Each 1 kg/m² increase in BMI was independently associated with 5% higher odds of OA after full adjustment, with a dose–response gradient; associations were stronger among women, older adults, and lower-income participants. NHANES temporal trends showed that obesity prevalence rose from 29.3% to a peak of 41.8% between 2011 and 2020 while OA prevalence remained stable (27.8–32.3%), consistent with GBD findings. Incident OA cases increased substantially from 1999 to 2023, driven by population growth and ageing; age-standardized rates changed modestly. Projections indicate persistently high burden through 2040. **Conclusion:** Higher BMI was independently associated with increased odds of OA, with a clear dose–response gradient. NHANES and GBD data consistently showed that population growth and ageing, rather than rising age-specific risk, have driven the increase in OA burden, while rising obesity may portend additional future burden. Targeted weight management and risk-stratified prevention are warranted for ageing populations.

Keywords Osteoarthritis; Body mass index; NHANES; Global Burden of Disease; Public health

1 Introduction

Osteoarthritis (OA) is one of the most common chronic musculoskeletal disorders and a leading contributor to pain, disability, and impaired quality of life among middle-aged and older adults^[1,2]. With population ageing and increasing life expectancy, the number of individuals living with OA has continued to rise worldwide^[3]. Recent Global Burden of Disease (GBD) analyses have shown that OA imposes a substantial

and growing burden across countries and regions, with older adults and women carrying a disproportionate share of this burden^[4,5]. In the United States, the progressive ageing of the population is expected to further increase the demand for OA-related diagnosis, pain management, rehabilitation, and long-term care^[6,7].

Excess body weight is a major modifiable factor linked to OA. Obesity increases mechanical stress on weight-bearing joints and may also reflect broader metabolic dysfunction that contributes to joint vulnerability^[8,9]. Previous systematic reviews and dose-response analyses have reported positive associations between body mass index (BMI) and OA risk, particularly knee OA^[10,11]. More recent GBD-based studies further indicate that high BMI contributes substantially to the global and regional burden of OA and knee OA^[12–14]. These findings support weight management as a key target for OA prevention, especially in older adults.

Despite this evidence, several important gaps remain. First, many studies have examined either individual-level risk factors or population-level disease burden, but fewer have integrated these perspectives within a unified analytical framework^[15,16]. Second, although BMI is routinely used in clinical and epidemiological research, its role in OA requires further clarification because excess body weight may influence OA through mechanical overload of weight-bearing joints^[17–18]. Understanding BMI-related OA risk is therefore important for linking individual susceptibility with population-level burden. Third, the association between BMI and OA may differ across demographic and clinical subgroups, including sex, age, socioeconomic status, and comorbidity profiles^[19]. Identifying vulnerable subgroups is essential for translating epidemiological evidence into targeted prevention strategies.

In addition to individual-level risk, understanding the population-level burden of OA is essential for healthcare planning and public health decision-making^[20]. Recent studies using GBD data have examined high BMI-attributable OA burden, temporal trends, health inequalities, and future projections^[21,22]. However, evidence focusing specifically on U.S. adults aged 55 years or older remains limited, particularly with respect to the integrated interpretation of BMI–OA associations, geographic variation, decomposition of disease burden, and future projections. Such evidence is needed to inform risk stratification, prevention priorities, and resource allocation in an ageing population.

Therefore, this study integrated the National Health and Nutrition Examination Survey (NHANES) 1999–2023 data with GBD estimates to systematically evaluate the association between BMI and OA among U.S. adults aged 55 years or older and to characterize the changing burden of OA in the United States. First, we examined the association between BMI and OA using multivariable regression models, sex-stratified analyses, subgroup analyses, and interaction testing. We then assessed national and state-level OA burden, temporal trends, decomposition of burden changes, and projected burden through 2040. By combining individual-level risk factor analysis with population-level burden assessment, this study aims to provide evidence to support targeted weight management, risk-stratified OA prevention, and resource planning for older adults.

2 Materials and Methods

2.1 Study Design and Data Sources

This study was conducted as a multi-source epidemiological analysis integrating individual-level data from the NHANES and population-level disease burden estimates from the GBD. First, a cross-sectional analysis based on NHANES data from 1999 to 2023 was performed to investigate the association between BMI and OA among adults aged 55 years or older in the United States. Second, GBD 2023 data were used to characterize the temporal trends, geographic distribution, sex- and age-specific patterns, decomposition of temporal changes, and future projections of OA burden in the United States.

NHANES is a nationally representative survey conducted by the National Center for Health Statistics (NCHS) of the Centers for Disease Control and Prevention (CDC), using a complex, multistage proba-

bility sampling design to collect health-related data from the noninstitutionalized U.S. civilian population. We included all available NHANES cycles from 1999 to 2023 and applied sampling weights, strata, and primary sampling units according to NCHS analytic guidelines when combining cycles to account for the survey design and generate nationally representative estimates. All protocols were approved by the NCHS Research Ethics Review Board, and written informed consent was obtained from all participants. As only publicly available, de-identified data were analyzed, no additional ethical approval was required.

As shown in Fig. 1, a total of 119,555 participants were initially identified from NHANES between 1999 and 2023. Participants were excluded if they were younger than 55 years ($n=80,137$), had missing covariate information ($n=10,899$), or had missing OA-related information ($n=20,662$). Finally, 7,857 eligible participants were included in the NHANES-based analysis.

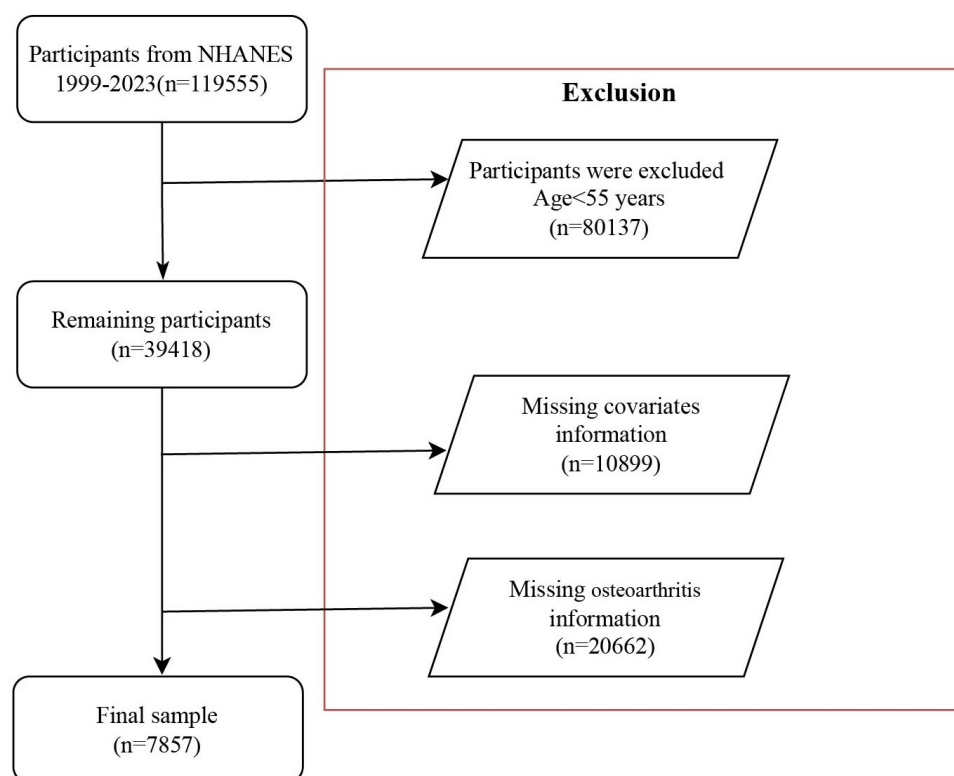


Figure 1: NHANES database workflow.

GBD data were obtained from the publicly available Global Burden of Disease Study 2023 Results Tool maintained by the Institute for Health Metrics and Evaluation (IHME) (<https://vizhub.healthdata.org/gbd-results/>)^[24]. The GBD analysis focused on OA burden among adults aged 55 years or older in the United States from 1999 to 2023.

2.2 Study Population

Eligible participants in the NHANES analysis were adults aged ≥ 55 years with complete data on BMI and osteoarthritis status. Participants with rheumatoid arthritis or rheumatic arthritis, as well as those with missing key variables, were excluded. For the GBD-based region-specific assessment, the United States was divided into 51 geographic units, comprising all 50 states, including Alaska and Hawaii, and the District of Columbia.

2.3 Exposure and Outcome Assessment

2.3.1 Assessment of BMI

BMI was calculated as weight in kilograms divided by height in meters squared (kg/m^2), based on height and weight measured by trained examiners using standardized protocols during the NHANES physical examination. BMI was analyzed both as a continuous variable (per $1 \text{ kg}/\text{m}^2$ increment) and as a categorical variable according to the World Health Organization (WHO) classification: underweight ($<18.5 \text{ kg}/\text{m}^2$), normal weight ($18.5\text{--}24.9 \text{ kg}/\text{m}^2$), overweight ($25.0\text{--}29.9 \text{ kg}/\text{m}^2$), and obesity ($\geq 30.0 \text{ kg}/\text{m}^2$)^[23].

2.3.2 Assessment of OA

OA status was assessed using the NHANES Medical Conditions Questionnaire. Participants were first asked whether a doctor or other health professional had ever told them that they had arthritis. Participants who answered “yes” were further asked to report the type of arthritis. Participants reporting osteoarthritis were classified as having OA and were included as OA cases in the primary analysis. Participants without OA were classified as the non-OA group according to available questionnaire responses. Responses of “refused,” “don’t know,” or missing responses to the OA-related questions were treated as missing and excluded from the corresponding analyses.

2.4 Covariate Collection

Demographic characteristics, including sex, age, and race/ethnicity; socioeconomic factors, including marital status, education level, and income; lifestyle factors, including smoking, alcohol consumption, sleep status, physical activity, and daily energy intake; medical history, including diabetes, hypertension, cardiovascular disease, chronic kidney disease, osteoporosis, and cancer; anthropometric measures, including height, weight, waist circumference, and BMI; and laboratory parameters, including serum albumin (ALB), alanine aminotransferase (ALT), aspartate aminotransferase (AST), high-density lipoprotein cholesterol (HDL), triglycerides (TG), total cholesterol (TC), estimated glomerular filtration rate (eGFR), and C-reactive protein (CRP), were collected.

2.5 Statistical Analysis

NHANES sampling weights, strata, and clusters were incorporated to account for the complex survey design and to ensure nationally representative estimates for the U.S. OA population. The normality of continuous variables was assessed using histograms, Q-Q plots (Supplementary Fig. S1–S2 and Supplementary Table S4), and the Kolmogorov–Smirnov test. As all continuous variables showed non-normal distributions, they were summarized as medians with interquartile ranges and compared between participants with and without OA using the Kruskal–Wallis test. Categorical variables were presented as counts with weighted percentages and compared using the χ^2 test.

Multivariable logistic regression was used to examine the association between BMI and OA. Three sequential models were fitted: Model 1 was unadjusted; Model 2 was adjusted for demographic factors, including sex, age, and race/ethnicity; and Model 3 was further adjusted for socioeconomic factors, lifestyle factors, and comorbidities, including PIR, education, marital status, smoking status, alcohol consumption, physical activity, sleep disorder, hypertension, diabetes, osteoporosis, and cancer. Analyses were performed in the overall population and further stratified by sex. With BMI $<18.5 \text{ kg}/\text{m}^2$ as the reference category, odds ratios (ORs) and 95% confidence intervals (CIs) were estimated for each BMI category across the three models, with P values for trend calculated to assess dose–response associations. Receiver operating characteristic (ROC) curves were constructed, and the area under the curve (AUC) was used to evaluate model performance.

Stratified analyses were conducted across prespecified subgroups, including sex, age, race/ethnicity, PIR, education level, marital status, smoking status, alcohol consumption, physical activity, sleep disorder, hypertension, diabetes, osteoporosis, and cancer. Interaction effects were tested to assess potential effect

modification. Subgroup results were presented using forest plots.

Temporal trends in the survey-weighted prevalence of BMI categories and self-reported OA were examined across five NHANES cycles (2011–2023), the period during which OA-specific data were available. Linear trends were assessed using the χ^2 test for trend. NHANES-derived temporal patterns of obesity and OA prevalence were compared with GBD-derived OA incidence trends to evaluate consistency between individual-level survey estimates and population-level burden estimates.

GBD estimates were used to characterize the burden of OA among U.S. adults aged ≥ 55 years from 1999 to 2023. Outcomes included incident cases, prevalent cases, disability-adjusted life years (DALYs), age-standardized incidence rates (ASIRs), age-standardized prevalence rates (ASPRs), and age-standardized DALY rates, all reported with 95% uncertainty intervals (UIs). National temporal trends in age-standardized rates were assessed using Joinpoint regression, and annual percentage changes (APCs) with 95% CIs were estimated to identify significant increasing or decreasing trends.

Geographic variation in OA burden was evaluated across 51 U.S. geographic units, comprising the 50 states and the District of Columbia. Choropleth maps were used to visualize the spatial distribution of ASIR and ASPR in 2023. Sex- and age-specific analyses were conducted to describe differences in OA incidence and prevalence, with case numbers and rates summarized separately by sex and age group. Decomposition analysis was further performed to quantify the contributions of population growth, population ageing, and epidemiological change to changes in OA incidence, prevalence, and DALYs between 1999 and 2023.

The future burden of OA from 2024 to 2040, including incidence, prevalence, and DALYs, was projected using the Autoregressive integrated moving average (ARIMA) model. Historical GBD estimates from 2004 to 2023 were used to fit the model and generate projections for adults aged 55 years or older in the United States. All projected estimates were presented with corresponding CIs.

All analyses were performed using R software, version 4.5.2. Statistical tests were two-sided, with significance set at $P < 0.05$. Missing data were addressed using multiple imputation.

3 Results

3.1 Baseline Characteristics of the Study Population

As shown in Table 1, a total of 7,857 participants were included in our study, of whom 1,054 (16.5%) had OA. Participants with OA were older than those without OA [62–74 vs. 60–73 years; $P < 0.001$], with the largest proportion of OA cases observed in the 65–69-year age group [$n = 231$, 23.4%]. Compared with the non-OA group, participants with OA were more likely to be female (67.2% vs. 53.9%), non-Hispanic White (84.0% vs. 77.5%), have a college-level or equivalent education (34.3% vs. 26.5%), report current alcohol consumption (69.2% vs. 59.3%), sleep-related anxiety (39.9% vs. 20.6%), and physical activity (55.8% vs. 35.4%). They also had higher proportions of osteoporosis (15.9% vs. 9.9%), cardiovascular disease (19.2% vs. 15.1%), cancer (29.3% vs. 20.3%), and BMI ≥ 30 kg/m² (43.4% vs. 33.8%) than those without OA; all differences were statistically significant (all $P < 0.001$). No significant differences were observed between the two groups in marital status, PIR, smoking status, hypertension, diabetes, or chronic kidney disease (all $P > 0.05$). Notably, BMI was higher in the OA group than in the non-OA group [25.5–33.5 vs. 24.3–31.6 kg/m²; $P < 0.001$], supporting further investigation of the association between BMI and OA.

Table 1: Demographic characteristics from NHANES, 1999–2023

Characteristic	Total participants (<i>n</i> = 7,857)	Osteoarthritis		
		No (<i>N</i> = 6,803; 83.5%)	Yes (<i>N</i> = 1,054; 16.5%)	<i>P</i>
Age (years), <i>n</i> (%)	66(60–73)	66(60–73)	67(62–74)	<0.001
55–59	1,236 (23.1%)	1,099 (24.1%)	137 (17.6%)	
60–64	1,764 (21.6%)	1,563 (22.1%)	201 (19.2%)	
65–69	1,438 (19.0%)	1,207 (18.1%)	231 (23.4%)	
70–74	1,278 (14.3%)	1,093 (14.0%)	185 (15.8%)	
75–79	861 (9.9%)	739 (9.8%)	122 (10.5%)	
≥80	1,280 (12.1%)	1102 (11.8%)	178 (13.6%)	
Gender, <i>n</i> (%)				<0.001
Male	3,671 (43.9%)	3,330 (46.1%)	341 (32.8%)	
Female	4,186 (56.1%)	3,473 (53.9%)	713 (67.2%)	
Race/Ethnicity, <i>n</i> (%)				<0.001
Hispanic	1,489 (7.7%)	1,367 (8.2%)	122 (5.2%)	
Non-Hispanic white	4,536 (78.6%)	3,807 (77.5%)	729 (84.0%)	
Non-Hispanic black	1,208 (7.5%)	1,096 (8.0%)	112 (5.0%)	
Other races	624 (6.2%)	533 (6.3%)	91 (5.8%)	
Education status, <i>n</i> (%)				<0.001
Less than high school	3,909 (43.3%)	3,561 (45.5%)	348 (31.9%)	
College or equivalent	2,042 (27.8%)	1,671 (26.5%)	371 (34.3%)	
College graduate or above	1,895 (28.8%)	1,560 (27.9%)	335 (33.8%)	
Not recorded	11 (0.1%)	11 (0.1%)	0 (0.0%)	
Marital status, <i>n</i> (%)				0.056
Married/Living with partner	4,827 (65.8%)	4,187 (66.0%)	640 (64.6%)	
Widowed/Divorced/Separated	2,554 (29.2%)	2,192 (28.7%)	362 (32.0%)	
Never married	403 (4.2%)	352 (4.4%)	51 (3.3%)	
Not recorded	73 (0.8%)	72 (1.0%)	1 (0.1%)	
PIR (%)				0.068
<1.3	1,660 (13.8%)	1,481 (14.3%)	179 (11.3%)	
1.3–3.5	2,882 (34.7%)	2,505 (35.1%)	377 (32.5%)	
>3.5	2,475 (41.7%)	2,087 (40.7%)	388 (46.8%)	
Not recorded	840 (9.8%)	730 (9.8%)	110 (9.5%)	
Alcohol status, <i>n</i> (%)				<0.001
Never	1,098 (12.0%)	989 (12.6%)	109 (8.8%)	
Ever	2,011 (22.9%)	1,787 (24.0%)	224 (17.5%)	
Now	4,368 (60.9%)	3,702 (59.3%)	666 (69.2%)	
Not recorded	380 (4.2%)	325 (4.1%)	55 (4.5%)	
Smoking, <i>n</i> (%)				0.432
Never	3,919 (49.7%)	3,364 (49.4%)	555 (51.1%)	
Ever	2,958 (38.4%)	2,570 (38.3%)	388 (38.9%)	
Now	972 (11.9%)	862 (12.3%)	110 (9.9%)	
Not recorded	8 (0.0%)	7 (0.1%)	1 (0.0%)	
Sleep disorder, <i>n</i> (%)				<0.001
No	2,936 (41.4%)	2,548 (41.3%)	388 (42.1%)	
Yes	1,473 (23.8%)	1,147 (20.6%)	326 (39.9%)	
Not recorded	3,448 (34.8%)	3,108 (38.2%)	340 (17.9%)	
Physical activity, <i>n</i> (%)				<0.001
Inactive	1,439 (17.3%)	1,151 (15.5%)	288 (26.3%)	
Less active or Active	2,267 (38.8%)	1,841 (35.4%)	426 (55.8%)	
Not recorded	4,151 (43.9%)	3,811 (49.0%)	340 (17.9%)	
History of diabetes, <i>n</i> (%)				0.416
No	6,026 (80.0%)	5,249 (80.3%)	777 (78.7%)	
Yes	1,831 (20.0%)	1,554 (19.7%)	277 (21.3%)	
History of hypertension, <i>n</i> (%)				0.541
No	2,905 (41.0%)	2,517 (41.4%)	388 (39.1%)	
Yes	4,952 (58.9%)	4,286 (58.6%)	666 (60.9%)	
History of osteoporosis, <i>n</i> (%)				<0.001
No	5,165 (66.2%)	4,818 (70.9%)	347 (42.3%)	
Yes	787 (10.9%)	630 (9.9%)	157 (15.9%)	
Not recorded	1,905 (22.9%)	1,355 (19.2%)	550 (41.7%)	

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Table 1: Demographic characteristics from NHANES, 1999–2023 (Continued)

Characteristic	Total participants (<i>n</i> = 7,857)	Osteoarthritis		
		No (<i>N</i> = 6,803; 83.5%)	Yes (<i>N</i> = 1,054; 16.5%)	<i>P</i>
CVD, <i>n</i> (%)				0.019
No	6,454 (83.6%)	5,626 (84.2%)	828 (80.5%)	
Yes	1,334 (15.8%)	1,116 (15.1%)	218 (19.2%)	
Not recorded	69 (0.6%)	61 (0.7%)	8 (0.4%)	
CKD, <i>n</i> (%)				0.622
No	5,429 (73.5%)	4,690 (73.4%)	739 (73.9%)	
Yes	2,419 (26.4%)	2,104 (26.5%)	315 (26.1%)	
Not recorded	9 (0.1%)	9 (0.1%)	0 (0.0%)	
Cancer				<0.001
No	6,254 (78.2%)	5,500 (79.7%)	754 (70.7%)	
Yes	1,598 (21.8%)	1,299 (20.3%)	299 (29.3%)	
Not recorded	5 (0.0%)	4 (0.0%)	1 (0.0%)	
Weight (kg)	78.1 (66.5 – 91.2)	77.7 (66.2 – 90.6)	80.5 (67.8 – 93.9)	0.01
Standing height (cm)	165.9 (159.2 – 173.9)	166.4 (159.4 – 174.4)	163.3 (157.9 – 171.8)	<0.001
Waist circumference (cm)	100.2 (91.0 – 110.3)	99.8 (90.5 – 109.8)	102.6 (93.6 – 113.4)	<0.001
BMI group (kg/m²), <i>n</i> (%)				<0.001
Underweight (<18.5)	85 (1.0%)	79 (1.2%)	6 (0.3%)	
Normal weight (18.5–24.9)	2,142 (27.5%)	1,929 (28.8%)	213 (21.3%)	
Overweight (25–29.9)	2,863 (36.1%)	2,504 (36.3%)	359 (35.1%)	
Obese (≥30)	2,767 (35.4%)	2,291 (33.8%)	476 (43.4%)	
Daily energy (kcal)	1,796.5 (1,333.0 – 2,351.0)	1,786.0 (1,334.0 – 2,342.0)	1,821.0 (1,330.0 – 2,364.0)	0.29
eGFR (mL/min/1.73 m ²)	79.0 (65.3 – 91.2)	79.0 (65.3 – 91.5)	79.8 (64.5 – 89.7)	0.683
ALB (g/L)	42.0 (40.0 – 44.0)	42.0 (40.0 – 44.0)	41.0 (39.0 – 43.0)	<0.001
ALT (U/L)	20.0 (16.0 – 25.0)	20.0 (16.0 – 26.0)	18.0 (15.0 – 25.0)	0.001
AST (U/L)	22.0 (19.0 – 27.0)	23.0 (19.0 – 27.0)	21.0 (18.0 – 26.0)	<0.001
Glycohemoglobin (%)				0.006
Fasting glucose (mg/dL)	104.0 (96.0 – 115.0)	104.0 (96.0 – 115.0)	106.0 (98.0 – 117.0)	0.005
HDL (mg/dL)	54.0 (44.0 – 67.0)	54.0 (44.0 – 66.0)	57.0 (46.0 – 70.0)	0.003
TC (mmol/L)	5.1 (4.3 – 5.8)	5.1 (4.4 – 5.8)	4.9 (4.2 – 5.6)	<0.001
TG (mmol/L)	1.3 (0.9 – 1.8)	1.3 (0.9 – 1.8)	1.2 (0.8 – 1.7)	0.005
CRP (mg/L)	0.3 (0.1 – 0.5)	0.3 (0.1 – 0.5)	0.3 (0.2 – 0.5)	0.283

Note: M, mean; SD, standard deviation; PIR, poverty income ratio; CVD, cardiovascular disease; CKD, chronic kidney disease; BMI, body mass index; ALB, serum albumin level; ALT, alanine aminotransferase; AST, aspartate aminotransferase; HDL, high-density lipoprotein; TG, triglycerides; TC, total cholesterol; eGFR, estimated glomerular filtration rate; CRP, C-reactive protein.

3.2 Relationship between BMI and Osteoarthritis

As shown in Table 2, in the overall study population, each one-unit increase in BMI was associated with 4% higher odds of OA in the unadjusted model (Model 1: OR = 1.04, 95% CI: 1.02–1.06). This association remained essentially unchanged after adjustment for demographic characteristics (Model 2: OR = 1.04, 95% CI: 1.03–1.06). After further adjustment for socioeconomic status, lifestyle factors, and comorbidities, the association between BMI and OA remained statistically significant (Model 3: OR = 1.05, 95% CI: 1.03–1.07). In the categorical analysis, compared with participants in the lowest BMI category (<18.5 kg/m²), those in the highest BMI category (≥30 kg/m²) had markedly higher odds of OA (OR = 7.26, 95% CI: 2.42–21.80). A significant dose–response relationship was observed across BMI categories (*P* for trend < 0.001).

Sex-stratified analyses further showed that the trend across BMI categories was not statistically significant among men (*P* for trend > 0.05). In contrast, among women, each one-unit increase in BMI was associated with 3% higher odds of OA in the unadjusted model (Model 1: OR = 1.03, 95% CI: 1.02–1.05). This association persisted after adjustment for demographic characteristics (Model 2: OR = 1.04, 95% CI: 1.02–1.06), and became stronger after additional adjustment for socioeconomic status, lifestyle factors, and comorbidities (Model 3: OR = 1.06, 95% CI: 1.03–1.08). Compared with women with BMI <18.5 kg/m², those with BMI ≥30 kg/m² had substantially higher odds of OA (OR = 9.78, 95% CI: 3.25–29.45), with a

more pronounced dose–response pattern than that observed in the overall population (P for trend < 0.001).

Table 2: Association of BMI with osteoarthritis

BMI (kg/m ²)	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)
Total			
Continuous	1.04(1.02,1.06)	1.04(1.03,1.06)	1.05(1.03,1.07)
<i>Categories</i>			
<18.5	Reference	Reference	Reference
18.5–24.9	2.82(0.90,8.91)	3.04(0.96,9.61)	3.38(1.13,10.14)
25–29.9	3.70(1.19,11.52)	4.26(1.36,13.35)	5.18(1.70,15.82)
≥30	4.91(1.59,15.22)	5.70(1.83,17.72)	7.26(2.42,21.80)
P for trend	0.006	0.003	<0.001
Male			
Continuous	1.05(1.02,1.08)	1.05(1.02,1.08)	1.05(1.02,1.08)
<i>Categories</i>			
<18.5	Reference	Reference	Reference
18.5–24.9	2.01(0.41,9.81)	1.92(0.39,9.46)	1.46(0.27,7.83)
25–29.9	2.36(0.51,10.97)	2.23(0.47,10.45)	1.83(0.35,9.55)
≥30	3.70(0.80,17.21)	3.55(0.75,16.74)	2.86(0.55,14.84)
P for trend	0.095	0.109	0.208
Female			
Continuous	1.03(1.02,1.05)	1.04(1.02,1.06)	1.06(1.03,1.08)
<i>Categories</i>			
<18.5	Reference	Reference	Reference
18.5–24.9	3.41(1.10,10.54)	3.42(1.11,10.50)	4.22(1.45,12.26)
25–29.9	5.21(1.62,16.77)	5.33(1.67,17.07)	7.37(2.35,23.12)
≥30	5.81(1.86,18.17)	6.43(2.06,20.06)	9.78(3.25,29.45)
P for trend	0.003	0.002	<0.001

Note: Model 1, unadjusted; Model 2, adjusted for gender, age, and race; Model 3, adjusted for gender, age, race, PIR, education, marital status, smoking status, alcohol consumption, physical activity, sleep disorders, hypertension, diabetes, osteoporosis, and cancer. PIR, poverty income ratio; BMI, body mass index; OR, odds ratio; CI, confidence interval.

Taken together, these findings suggest that higher BMI is independently associated with increased odds of OA, particularly among women. As shown in Figure 2, receiver operating characteristic curve analyses were further conducted for the overall population (Fig. 2A), men (Fig. 2B), and women (Fig. 2C). The areas under the curve for the unadjusted model and the model adjusted for demographic characteristics were all greater than 0.5. Notably, after further adjustment for socioeconomic status, lifestyle factors, and comorbidities, the AUC values of Model 3 exceeded 0.8 in all groups, indicating good discriminatory performance of the fully adjusted model.

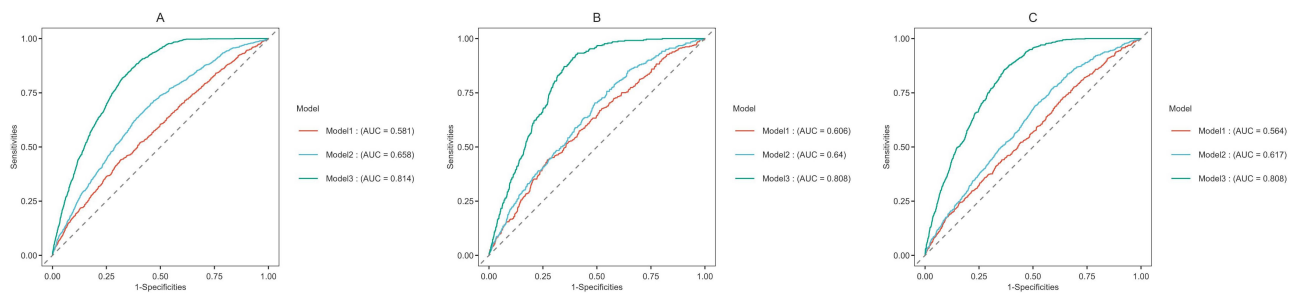


Figure 2: Receiver operating characteristic (ROC) curves comparing the discriminative performance of three predictive models for osteoarthritis in the overall population (A), men (B), and women (C). AUC, area under the curve; ROC, receiver operating characteristic.

From 2011–2012 to 2021–2023, obesity prevalence (BMI ≥ 30 kg/m²) among U.S. adults aged ≥ 55 years increased from 29.3% to 37.6%, peaking at 41.8% in 2017–2020 (P for trend <0.001). Normal weight prevalence (BMI 18.5–24.9 kg/m²) declined from 34.8% to 25.8%, while overweight prevalence (BMI 25.0–29.9 kg/m²) remained stable (35.1–37.1%). In contrast, OA prevalence showed no significant temporal trend, ranging from 27.8% to 32.3% across the same period (Figure 3).

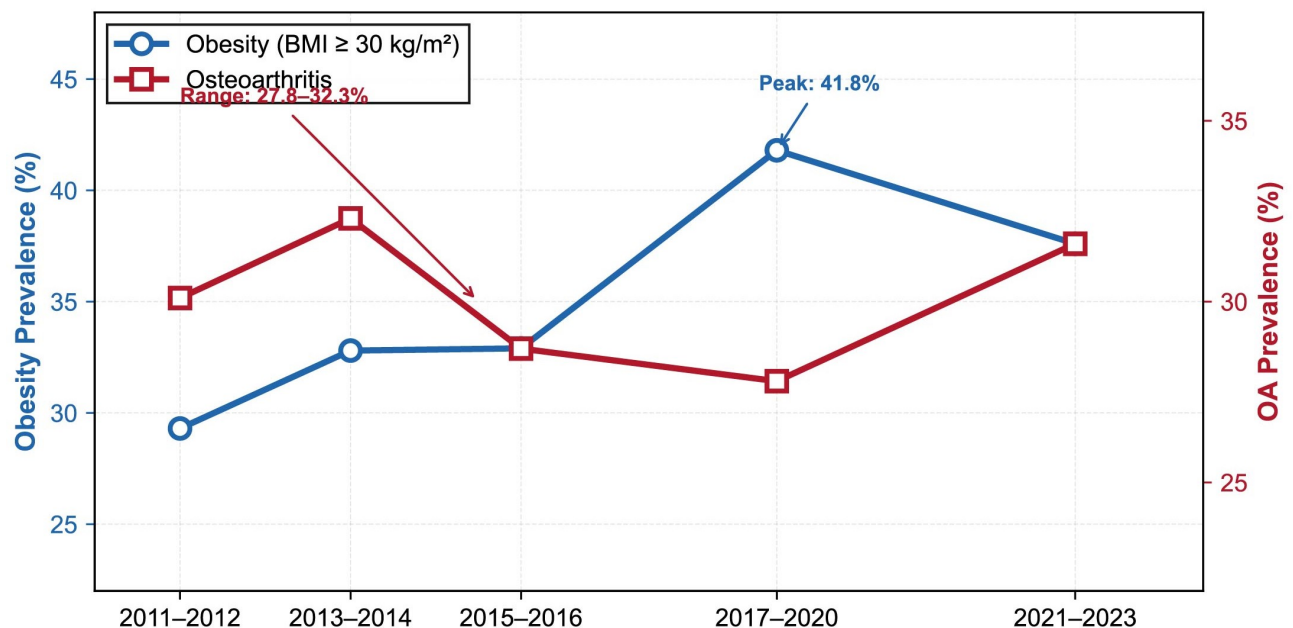


Figure 3: Temporal trends in obesity prevalence (BMI ≥ 30 kg/m²) and osteoarthritis (OA) prevalence among U.S. adults aged ≥ 55 years: NHANES 2011–2023. Obesity prevalence (blue line, circles; left y-axis) and OA prevalence (red line, squares; right y-axis) are shown across five survey cycles. BMI, body mass index; NHANES, National Health and Nutrition Examination Survey; OA, osteoarthritis.

3.3 Stratified Analysis Results

Figure 4 presents the subgroup analyses evaluating heterogeneity in the association between BMI and OA. Significant interactions were identified for age (P for interaction = 0.044), income level (P for interaction = 0.010), marital status (P for interaction <0.001), diabetes status (P for interaction = 0.030), and cancer status (P for interaction <0.001). The association between BMI and OA was more pronounced among participants with low income (OR = 1.07, 95% CI: 1.04–1.09), those who were widowed, divorced, or separated (OR = 1.05, 95% CI: 1.03–1.07), participants with diabetes (OR = 1.06, 95% CI: 1.04–1.09), and those with cancer (OR = 1.05, 95% CI: 1.02–1.08). In the age-stratified analysis, the strongest association

was observed among participants aged ≥ 80 years (OR = 1.08, 95% CI: 1.04–1.13), indicating that the BMI–OA association may be amplified in advanced age.

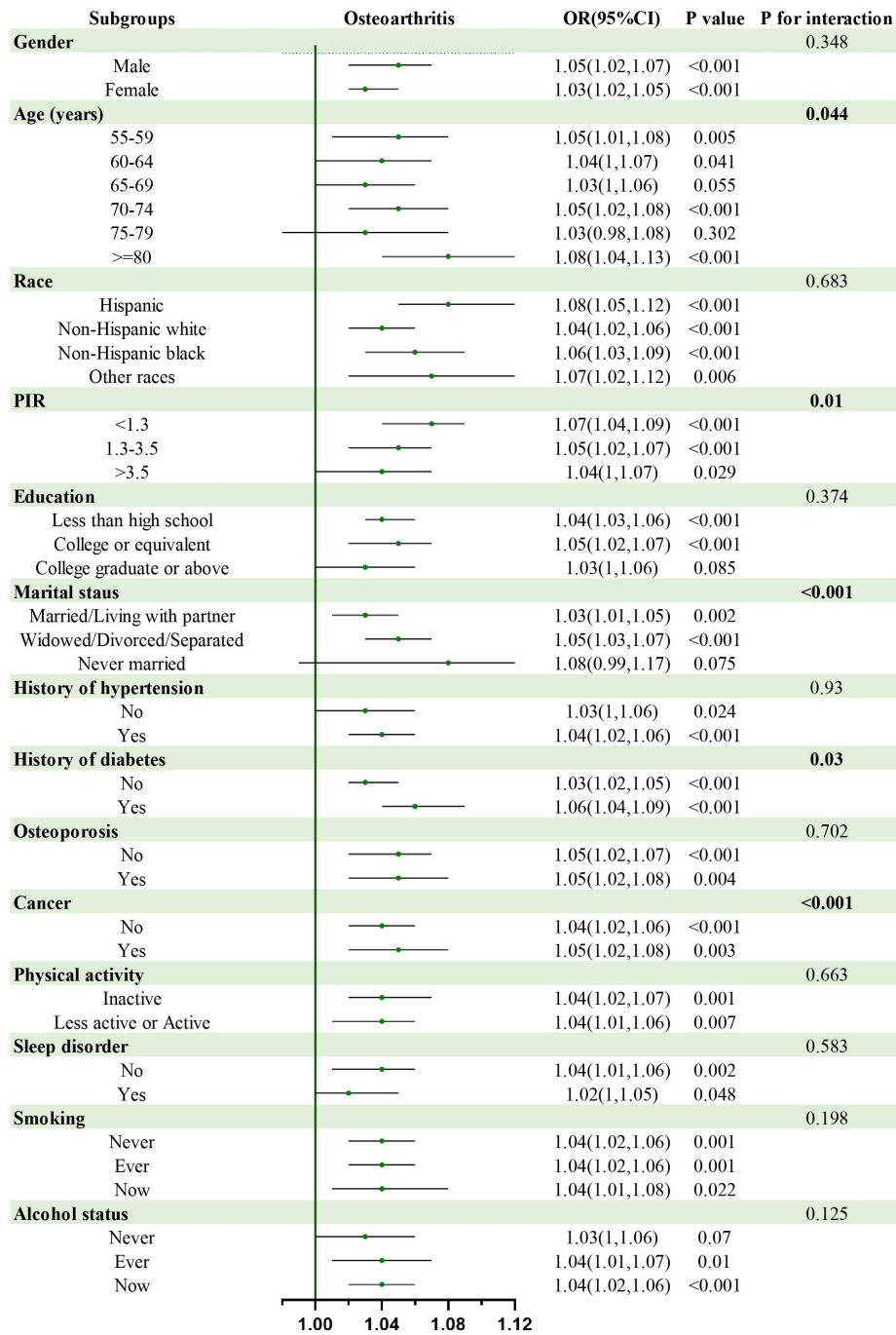


Figure 4: Subgroup analyses of heterogeneity in the association between BMI and osteoarthritis. Participants were compared by gender, age, race, poverty income ratio, education, marital status, hypertension, diabetes, osteoporosis, cancer, physical activity, sleep disorder, smoking, and alcohol status. $P < 0.05$ was considered statistically significant.

3.4 Trends in the Burden of OA in the United States

Table 3 and Figure 5 summarize temporal and geographic patterns in the burden of osteoarthritis (OA) across the United States. Nationally, incident OA cases increased from 1,089,903 in 1999 (95% UI: 948,147–1,231,461) to 1,941,687 in 2023 (95% UI: 1,687,815–2,226,438), corresponding to an increase of approximately 78.2%. By contrast, the ASIR remained relatively stable, changing from 1,983.19 per

100,000 population in 1999 (95% UI: 1,562.39–2,457.59) to 1,966.22 per 100,000 population in 2023 (95% UI: 1,532.30–2,478.34). The annual percentage change in the age-standardized rate was modest but statistically significant (APC = 0.21, 95% CI: 0.06–0.35; $P = 0.007$).

Table 3: Incidence, age-standardized rates, and annual percentage changes in osteoarthritis among the U.S. population aged 55 years and older, 1999–2023

Location	1999		2023		APC of ASR (95% CI)	<i>P</i> value
	Incident cases (95% UI)	ASIR per 100,000 (95% UI)	Incident cases (95% UI)	ASIR per 100,000 (95% UI)		
USA	1089903 (948147, 1231461)	1983.19 (1562.39, 2457.59)	1941687 (1687815, 2226438)	1966.22 (1532.3, 2478.34)	0.21 (0.06, 0.35)	0.007
Alabama	18768 (16319, 21374)	2007.28 (1578.8, 2500.73)	30674 (26515, 35653)	1982.59 (1517.32, 2521.66)	0.14 (−0.12, 0.40)	0.286
Alaska	1545 (1334, 1805)	1934.89 (1512.13, 2454.9)	3662 (3132, 4226)	1906.55 (1486.72, 2415.83)	0.21 (0.02, 0.40)	0.034
Arizona	19955 (17351, 22632)	1964.35 (1536.68, 2427.86)	42683 (37385, 49108)	1966.65 (1513.49, 2501.11)	0.24 (0.09, 0.39)	0.004
Arkansas	11065 (9570, 12604)	1879.54 (1469.21, 2340.51)	16770 (14335, 19351)	1877.91 (1452.38, 2399.45)	0.20 (−0.06, 0.47)	0.13
California	106543 (94326, 121059)	1824.76 (1431.69, 2245.84)	200259 (171610, 231522)	1833.31 (1411.58, 2308.61)	0.28 (0.14, 0.44)	0.001
Colorado	14266 (12464, 16277)	2012.56 (1580.16, 2514.53)	32487 (28332, 37471)	2011.57 (1566.24, 2556.18)	0.29 (0.12, 0.47)	0.002
Connecticut	14144 (12385, 16179)	1984.73 (1556.57, 2489.67)	23231 (20136, 27011)	1985.53 (1535.55, 2515.62)	0.29 (0.14, 0.44)	0.001
Delaware	3487 (3026, 4006)	2166.32 (1696.22, 2740.19)	7222 (6233, 8332)	2107.63 (1620.45, 2687.62)	0.14 (0.00, 0.27)	0.044
District of Columbia	2178 (1892, 2514)	1894.29 (1476.36, 2381.55)	2748 (2359, 3191)	1839.66 (1441.9, 2318.57)	0.09 (−0.07, 0.25)	0.246
Florida	77762 (68047, 88463)	1978.41 (1557.55, 2455.7)	145062 (126440, 166993)	1956.64 (1518.81, 2477.41)	0.19 (0.06, 0.33)	0.007
Georgia	27399 (23836, 31353)	1989.78 (1564.09, 2495.79)	58894 (50398, 68106)	1955.69 (1511.23, 2465.15)	0.12 (−0.06, 0.30)	0.185
Hawaii	4575 (3957, 5213)	1844.61 (1439.22, 2324.28)	8162 (7078, 9403)	1812.45 (1398.31, 2291.69)	0.16 (−0.08, 0.40)	0.181
Idaho	4474 (3922, 5086)	1919.03 (1491.99, 2395.27)	10328 (8910, 11877)	1901.89 (1480.64, 2381.49)	0.24 (0.09, 0.38)	0.003
Illinois	45877 (39830, 51795)	1956.62 (1534.77, 2425.78)	73101 (63098, 84068)	1944.22 (1498.92, 2444.24)	0.23 (0.10, 0.36)	0.001
Indiana	23906 (20866, 27012)	2017.2 (1579.93, 2508.97)	40143 (34710, 46624)	2020.39 (1555.15, 2571.52)	0.22 (0.03, 0.41)	0.025
Iowa	11893 (10390, 13482)	1902.38 (1496.04, 2407.99)	17974 (15581, 20653)	1873.41 (1445.71, 2370.95)	0.15 (−0.05, 0.35)	0.134
Kansas	10005 (8743, 11398)	1914.54 (1505.97, 2411.72)	15828 (13611, 18229)	1886.31 (1460.84, 2386.1)	0.17 (0.00, 0.35)	0.045
Kentucky	16924 (14616, 19254)	2051.95 (1602.49, 2565.69)	27774 (23718, 32227)	2038.48 (1578.88, 2590.05)	0.19 (−0.00, 0.38)	0.05
Louisiana	17186 (14928, 19563)	2032.81 (1596.27, 2566.47)	27014 (23351, 31211)	1998.48 (1541.39, 2534.46)	0.20 (0.04, 0.36)	0.019
Maine	5468 (4718, 6224)	1939.94 (1524.45, 2429.64)	9690 (8481, 11217)	1927.7 (1495.39, 2463.54)	0.21 (0.08, 0.34)	0.002
Maryland	20963 (18304, 23877)	2067.18 (1629.67, 2583.05)	38223 (32628, 44043)	2041.6 (1589.16, 2593.84)	0.18 (0.04, 0.33)	0.016
Massachusetts	25290 (22134, 28704)	1980.31 (1570.01, 2450.49)	43182 (37345, 49769)	1946.73 (1512.19, 2485.86)	0.13 (0.02, 0.24)	0.02
Michigan	42207 (36358, 48458)	2192.93 (1733.6, 2736.13)	67335 (58037, 77857)	2114.02 (1621.02, 2686.65)	0.05 (−0.10, 0.20)	0.519
Minnesota	16951 (14788, 19106)	1865.67 (1469.36, 2320.18)	31910 (27670, 36997)	1848.8 (1435.87, 2321.51)	0.19 (0.07, 0.32)	0.004
Mississippi	10344 (8984, 11723)	1867.21 (1461.96, 2313.98)	16035 (13874, 18449)	1857.38 (1432.78, 2369.93)	0.15 (−0.04, 0.34)	0.112

Continued on next page

Table 3: Incidence, age-standardized rates, and annual percentage changes in osteoarthritis among the U.S. population aged 55 years and older, 1999–2023 (Continued)

Location	1999		2023		APC of ASR (95% CI)	<i>P</i> value
	Incident cases (95% UI)	ASIR per 100,000 (95% UI)	Incident cases (95% UI)	ASIR per 100,000 (95% UI)		
Missouri	23361 (20710, 26418)	2011.22 (1581.76, 2500.26)	37160 (32162, 42513)	1988.54 (1527.88, 2507.56)	0.17 (0.01, 0.32)	0.034
Montana	3669 (3198, 4225)	1914.55 (1502.93, 2398.98)	6739 (5811, 7750)	1892.34 (1467.1, 2393.84)	0.20 (0.08, 0.33)	0.002
Nebraska	6745 (5879, 7673)	1992.01 (1573.46, 2476.36)	10901 (9398, 12631)	1956.29 (1505.02, 2479.01)	0.13 (−0.01, 0.28)	0.075
Nevada	7606 (6628, 8748)	1943.82 (1516.21, 2434.09)	18081 (15590, 21095)	1937.87 (1518.8, 2467.28)	0.23 (0.02, 0.45)	0.036
New Hampshire	4804 (4174, 5456)	2020.13 (1586.93, 2533.58)	9877 (8480, 11465)	2016.3 (1560.58, 2564.02)	0.27 (0.12, 0.42)	0.001
New Jersey	34153 (29629, 38821)	1970.78 (1557.24, 2471.28)	57609 (50205, 66708)	1996.62 (1538.56, 2540.52)	0.36 (0.19, 0.53)	<0.001
New Mexico	6862 (5955, 7804)	1976.61 (1540.97, 2486.1)	12495 (10702, 14417)	1949.96 (1506.04, 2484.34)	0.21 (0.04, 0.39)	0.019
New York	78181 (68006, 87848)	2025.08 (1601.27, 2518.45)	125833 (110126, 145658)	2041.26 (1575.93, 2591.14)	0.34 (0.17, 0.51)	<0.001
North Carolina	29293 (25486, 33028)	1833.04 (1433.61, 2291.31)	58909 (50503, 68018)	1846.22 (1415.39, 2337.19)	0.27 (0.12, 0.42)	0.001
North Dakota	2549 (2231, 2912)	1930.69 (1512.08, 2407.39)	4025 (3439, 4687)	1896.91 (1460.24, 2399.66)	0.16 (−0.01, 0.33)	0.07
Ohio	49295 (43035, 55911)	2122.37 (1668.29, 2636.66)	77260 (66696, 89171)	2124.39 (1636.12, 2707.18)	0.26 (0.11, 0.40)	0.002
Oklahoma	14587 (12687, 16598)	2026.05 (1590.69, 2537.71)	22286 (19358, 25910)	2017.45 (1563.37, 2569.75)	0.22 (0.04, 0.41)	0.019
Oregon	12890 (11327, 14544)	1898.94 (1497.61, 2358.59)	24887 (21620, 28400)	1905.55 (1480.07, 2380.1)	0.28 (0.13, 0.43)	0.001
Pennsylvania	60990 (53077, 70053)	2218.43 (1735.23, 2759.58)	89665 (76760, 102865)	2142.36 (1660.91, 2727.47)	0.02 (−0.12, 0.17)	0.737
Rhode Island	4302 (3776, 4878)	1981.99 (1555.7, 2500.36)	6937 (6029, 7976)	1947.45 (1517.44, 2452.43)	0.22 (0.05, 0.39)	0.012
South Carolina	15711 (13624, 17815)	1944.14 (1524.04, 2428.26)	32231 (27897, 37117)	1942.96 (1510.38, 2490.88)	0.25 (0.08, 0.42)	0.006
South Dakota	2890 (2537, 3299)	1887.01 (1477.13, 2362.46)	5016 (4369, 5782)	1851.86 (1438.13, 2361.16)	0.16 (−0.01, 0.32)	0.061
Tennessee	23841 (20793, 27085)	2055.38 (1614.47, 2596.17)	42594 (37121, 49329)	2039.94 (1580.04, 2615.55)	0.22 (−0.05, 0.49)	0.103
Texas	66848 (58134, 76229)	1932.08 (1520.16, 2427.64)	143829 (123946, 168088)	1946.99 (1498.14, 2458.88)	0.30 (0.17, 0.44)	<0.001
Utah	6300 (5478, 7227)	2038.91 (1587.03, 2564.26)	14447 (12417, 16819)	2005.15 (1548.78, 2539.58)	0.20 (−0.00, 0.39)	0.051
Vermont	2367 (2058, 2711)	1919.09 (1508.97, 2412.46)	4293 (3729, 4966)	1895.22 (1477.84, 2388.26)	0.21 (0.04, 0.39)	0.019
Virginia	26961 (23235, 30774)	1996.15 (1562.8, 2500.2)	50633 (43606, 58865)	1980.32 (1524.65, 2532.09)	0.17 (0.03, 0.32)	0.024
Washington	42 (35 to 49)	1.11 (0.93 to 1.32)	57 (46 to 68)	1.38 (1.1 to 1.71)	−0.15 (−0.55, 0.26)	0.461
West Virginia	8 (7 to 9)	0.73 (0.62 to 0.87)	11 (9 to 13)	1.21 (0.98 to 1.49)	1.95 (1.72, 2.18)	<0.001
Wisconsin	25 (21 to 30)	0.78 (0.65 to 0.94)	29 (24 to 35)	1.01 (0.81 to 1.25)	0.93 (0.73, 1.14)	<0.001
Wyoming	3 (2 to 3)	0.83 (0.69 to 0.99)	3 (3 to 4)	1.14 (0.91 to 1.41)	1.38 (1.16, 1.61)	<0.001

Note: USA, United States of America; ASIR, age-standardized incidence rate; ASR, age-standardized rate; APC, annual percentage change; CI, confidence interval; UI, uncertainty interval.

Marked geographic heterogeneity was observed across states. In 2023, the largest numbers of incident cases were reported in California, Florida, Texas, New York, and Pennsylvania, largely reflecting population size. In contrast, the distribution of age-standardized burden showed a different spatial pattern. As illustrated in Figure 5, the states with the highest ASIR and ASPR, highlighted in red, were Pennsylvania,

Ohio, Michigan, Delaware, and West Virginia. These findings indicate that, although the national age-standardized incidence of OA remained broadly stable over time, the absolute number of incident cases increased substantially, and the age-standardized burden varied considerably across states.

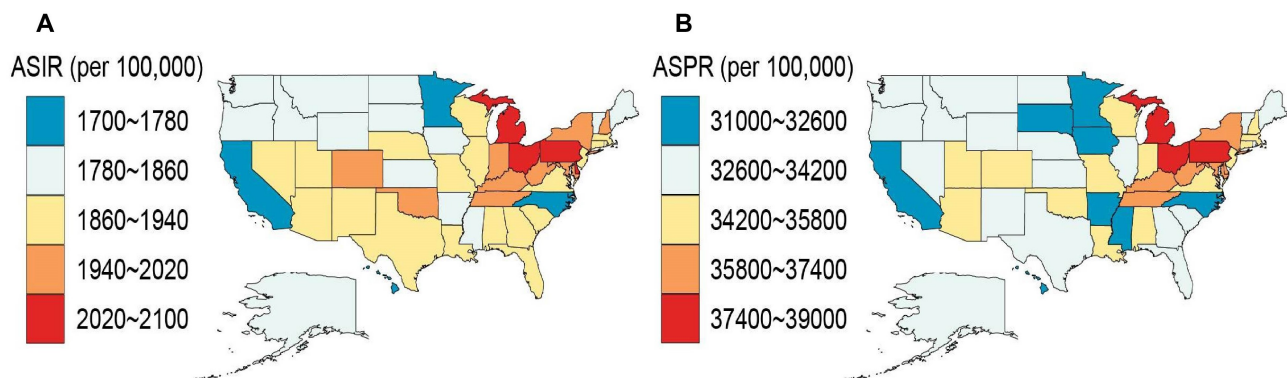


Figure 5: Geographic distribution of osteoarthritis among adults aged 55 years and older in the United States in 2023. ASIR, age-standardized incidence rate; ASPR, age-standardized prevalence rate.

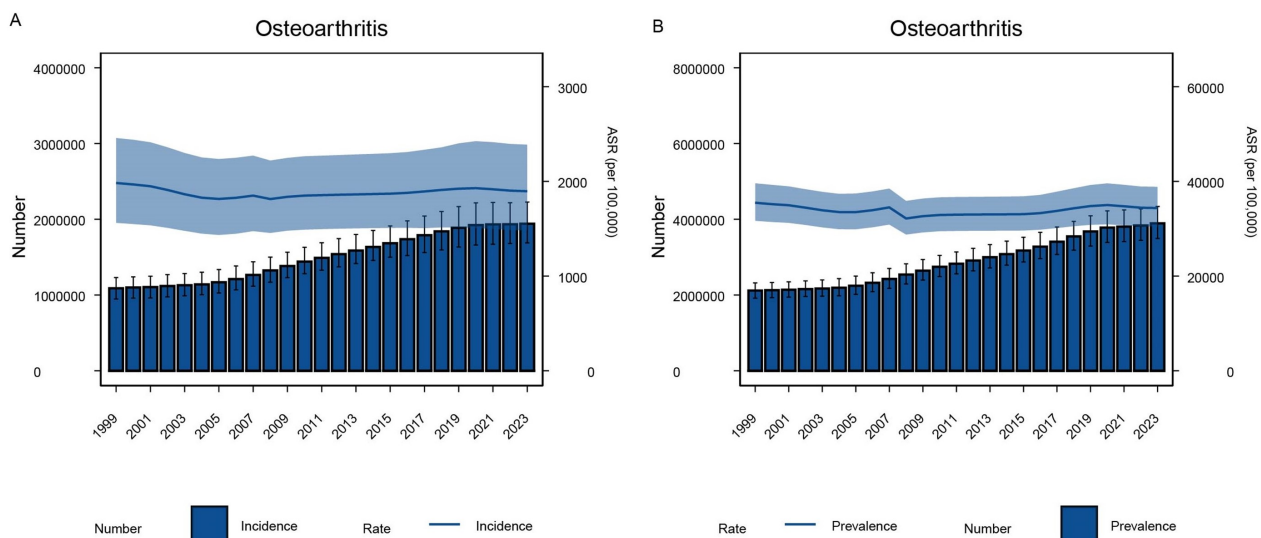


Figure 6: Temporal trends in osteoarthritis burden among adults aged 55 years and older in the United States.

3.5 Gender- and Age-Specific Patterns of OA Burden and Decomposition of Temporal Changes

From 1999 to 2023, the absolute burden of osteoarthritis among adults aged ≥ 55 years in the United States increased in both sexes, with women consistently showing higher numbers and rates of incidence and prevalence than men (Fig. 7). Age-stratified analyses further showed that incident cases were concentrated in the younger older-age groups and then declined with advancing age. In 2023, the number of incident cases peaked at 287,121.48 in women aged 55–59 years and 210,324.63 in men aged 55–59 years, while incidence rates decreased progressively across age groups. In contrast, prevalent cases peaked in the 65–69-year age group in both women and men, reaching 4,478,429.90 and 3,202,790.27 cases, respectively, before declining in older age groups (Fig. 7; Supplementary Table S1-2). However, prevalence rates increased with age and remained high after 80 years, with rates of 51,657.73 per 100,000 in women and 42,141.91 per 100,000 in men aged 80–84 years. Decomposition analysis indicated that population growth and population ageing were the principal contributors to the increase in osteoarthritis-related incidence, prevalence, and DALYs, whereas epidemiological change made a comparatively smaller contribution (Fig. 8).

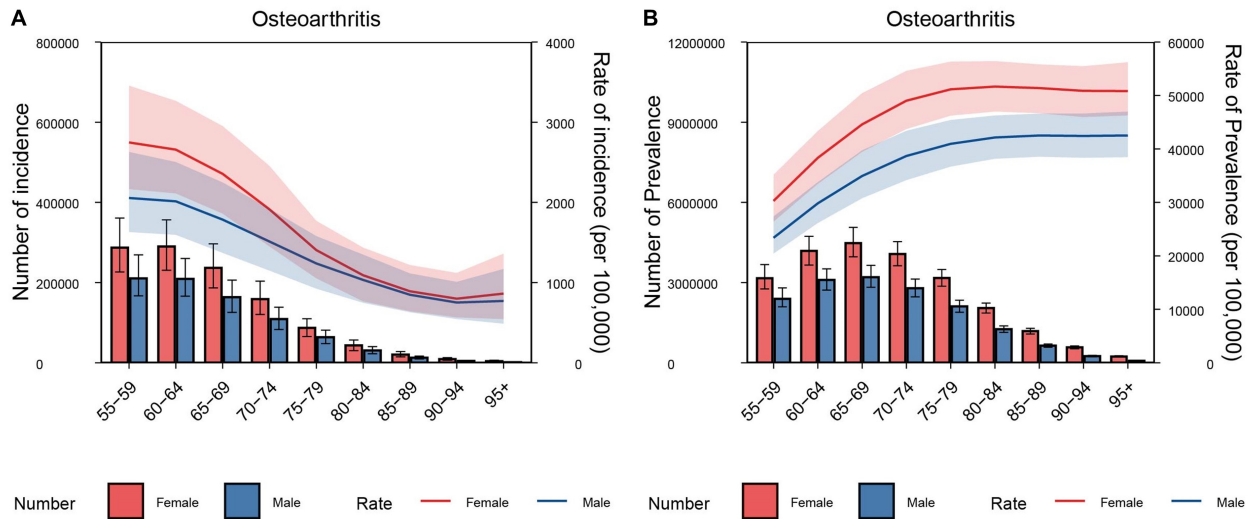


Figure 7: Sex- and age-stratified distribution of osteoarthritis among adults aged 55 years and older in the United States.

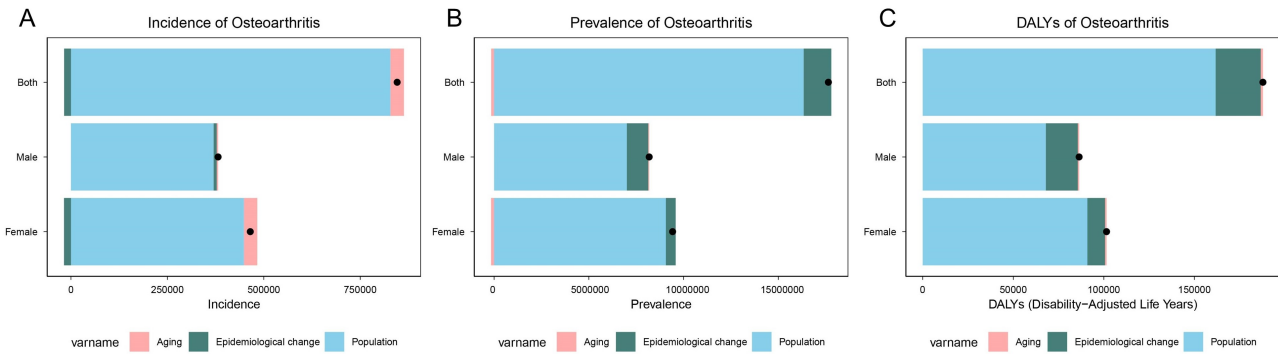


Figure 8: Decomposition analysis of changes in osteoarthritis burden in the United States.

3.6 Future Projections of OA Incidence, Prevalence, and DALYs

From 2024 to 2040, the projected burden of osteoarthritis among adults aged ≥ 55 years in the United States showed a modest upward trend across all three indicators (Fig. 9; Supplementary Table S3). The incidence rate was projected to increase from 1967.68 per 100,000 in 2024 to 2018.32 per 100,000 in 2040. Similarly, the prevalence rate increased from 37,544.29 to 38,878.45 per 100,000, while the DALYs rate rose from 382.04 to 422.99 per 100,000 over the same period. The uncertainty intervals widened progressively over the projection period, particularly for prevalence and DALYs. Overall, these findings indicate that osteoarthritis is expected to remain a persistent and gradually increasing public health burden among older adults in the United States through 2040.

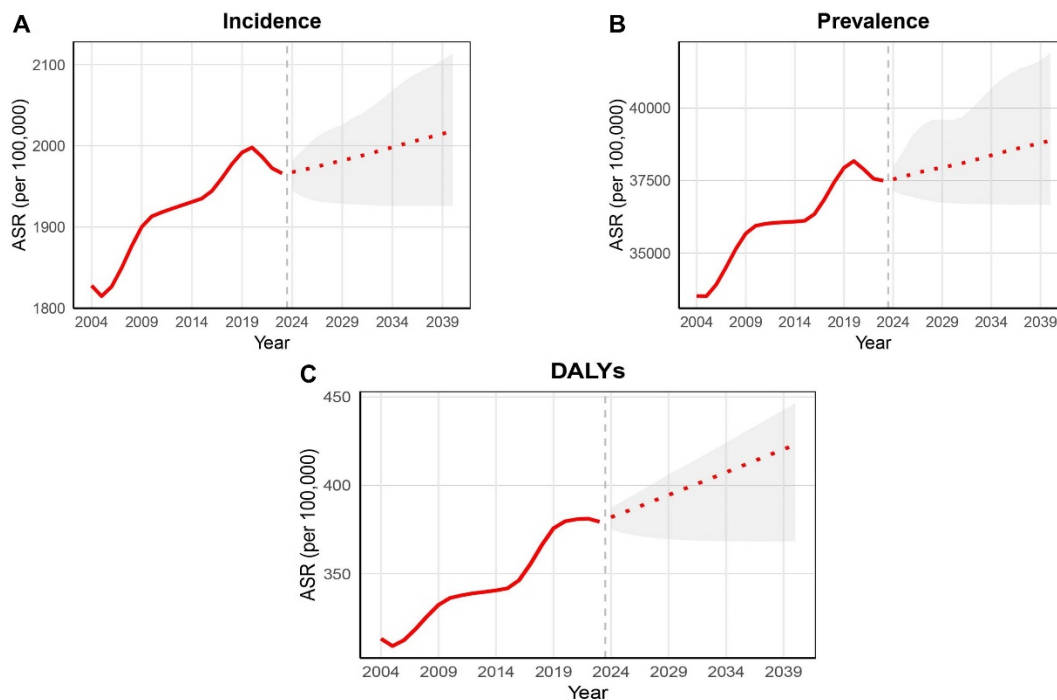


Figure 9: Projected incidence, prevalence, and disability-adjusted life years (DALYs) of osteoarthritis, 2024–2040.

4 Discussion

In this multi-source analysis integrating NHANES 1999–2023 data with GBD 2023 estimates, higher BMI was significantly associated with increased odds of OA among U.S. adults aged 55 years or older. This association remained robust after adjustment for demographic, socioeconomic, lifestyle, and comorbidity-related factors, with a clear dose–response pattern observed across BMI categories. The association appeared more pronounced among women, older adults, lower-income individuals, and participants with selected chronic conditions, suggesting potential heterogeneity in BMI-related OA susceptibility. At the population level, the absolute burden of OA increased substantially in the United States from 1999 to 2023, largely driven by population growth and ageing, whereas future projections indicate that OA will remain a persistent public health challenge through 2040 in the ageing U.S. population.

Our findings are consistent with high-quality epidemiological evidence indicating that excess body weight is an important contributor to OA risk and burden^[25,26]. Previous systematic reviews and population-based analyses have identified obesity as a major modifiable risk factor for OA^[27], while recent GBD studies have further shown that high BMI contributes substantially to OA-related disability at the population level^[28–29]. In line with these findings, our analysis demonstrated a graded increase in the odds of OA across BMI categories. The persistence of this association in the fully adjusted model suggests that BMI is independently associated with OA among older adults, beyond the influence of age, sex, socioeconomic status, lifestyle factors, and major comorbidities. The stronger BMI–OA association observed among women is also consistent with evidence showing a higher OA burden in women, particularly among postmenopausal women^[30,31]. In our study, women accounted for a larger proportion of OA cases, and the association between BMI and OA was more evident in female participants. Although our analysis was not designed to investigate sex-specific biological mechanisms, this finding suggests that older women with elevated BMI may represent a priority population for OA prevention. Weight management, early functional assessment, and timely intervention may therefore be particularly important in this subgroup.

The NHANES temporal trend analysis further corroborated the GBD findings. Obesity prevalence—a principal modifiable risk factor for OA—rose substantially from 2011 to 2023, yet OA prevalence among

older adults remained broadly stable across the same period. This divergence is consistent with the GBD decomposition analysis, which identified population growth and ageing, rather than rising age-specific risk, as the primary drivers of the increase in absolute OA cases. The parallel between stable OA prevalence in NHANES and stable age-standardized incidence rates in GBD supports the interpretation that demographic forces have thus far dominated OA burden trends. Nevertheless, the sustained rise in obesity prevalence warrants continued surveillance, as the full population-level impact of excess body weight on OA may manifest over longer time horizons than captured in the present analysis.

The mechanisms linking BMI to OA are likely multifactorial. The most direct explanation is mechanical loading: higher BMI reflects greater body weight, which may increase stress on weight-bearing joints and contribute to OA development or progression^[32,33]. Earlier evidence linking body fat distribution with OA, together with recent NHANES-based studies evaluating abdominal obesity and obesity-related anthropometric indices^[34,35]. Therefore, our findings support BMI as a practical and widely applicable population-level indicator, while also highlighting the need for future studies to incorporate body fat distribution and central adiposity measures for more refined risk assessment. Metabolic status may also partly explain why the BMI–OA association appeared stronger among participants with selected chronic conditions. Recent NHANES-based studies have linked visceral fat metabolic score, insulin resistance-related indices, and broader metabolic status with OA or OA-related outcomes^[36,37]. In our subgroup analyses, stronger associations were observed among participants with diabetes or cancer.

The subgroup findings further suggest that the relationship between BMI and OA is shaped by demographic and social contexts. The stronger association among older adults may reflect the cumulative effect of excess body weight on joint health over time. Similarly, the stronger association among lower-income participants may be related to differences in access to preventive care, weight management resources, early diagnosis, and rehabilitation services. These findings indicate that BMI-related OA risk is not solely a biological issue, but also a matter of prevention, healthcare access, and social vulnerability, particularly among older adults with clinical or socioeconomic disadvantages^[38,39].

The GBD component of this study provides a broader public health context for interpreting these individual-level findings. Although age-standardized OA rates changed only modestly, the absolute number of OA cases increased markedly in the United States from 1999 to 2023. This pattern suggests that demographic changes, rather than a large increase in age-specific risk alone, have been central to the growing OA burden. High-impact GBD analyses have similarly identified OA as a major contributor to chronic pain and disability and have emphasized the continuing roles of high BMI and population ageing in shaping future OA burden^[40–42]. Consistent with this evidence, our decomposition analysis further indicated that population growth and ageing were major contributors to the increase in OA burden over time.

Our study found substantial geographic variation in OA burden across U.S. states. California, Florida, Texas, New York, and Pennsylvania had the largest numbers of incident OA cases, largely reflecting population size, whereas Pennsylvania, Ohio, Michigan, Delaware, and West Virginia had the highest age-standardized incidence and prevalence rates. These findings suggest that absolute burden and age-standardized risk provide complementary information for healthcare planning. States with large case numbers may require greater capacity for diagnosis, pain management, rehabilitation, and long-term care, while states with higher standardized rates may need targeted prevention strategies. Integrating BMI control into OA prevention programs and applying risk stratification by BMI, sex, age, income, and comorbidity status may help prioritize older adults most likely to benefit from early lifestyle intervention, functional preservation, and rehabilitation services.

This study has several strengths. (1) By integrating nationally representative NHANES data with GBD 2023 estimates, this study linked individual-level BMI–OA associations with population-level OA burden, enhancing the applicability of the findings to older U.S. adults. (2) The study focused on adults aged 55

years or older, a population at high risk for OA and highly relevant to prevention strategies. (3) Multivariable regression, sex-stratified analyses, subgroup analyses, and interaction testing enabled the identification of high-risk populations in whom the BMI–OA association was more pronounced. (4) State-level GBD estimates allowed us to characterize geographic variation in OA burden across the United States. (5) Joint-point regression, decomposition analysis, and ARIMA projection provided a comprehensive evaluation of past trends, driving factors, and future OA burden.

Several limitations should be noted. (1) The NHANES analysis was cross-sectional, so causality cannot be established. (2) OA status was based on questionnaire data and may be subject to recall bias or misclassification. (3) BMI cannot distinguish fat mass from lean mass or capture body fat distribution. (4) Residual confounding from unmeasured factors, such as occupational joint loading, previous joint injury, medication use, and healthcare access, cannot be excluded. (5) GBD estimates and future projections are model-based and depend on the quality of underlying data and assumptions about future changes in obesity patterns, prevention strategies, clinical practice, and population structure.

Future research should address several key questions. (1) Longitudinal studies are needed to clarify the temporal relationship between BMI change and OA onset or progression. (2) Studies incorporating joint-specific OA phenotypes, imaging data, physical function measures, body composition, and central adiposity indicators may provide more precise risk assessment than BMI alone. (3) Intervention studies are needed to determine whether weight reduction or weight maintenance can reduce OA risk or delay functional decline in high-risk older adults. (4) Future burden projections should incorporate changes in obesity prevalence, population ageing, healthcare access, and prevention policies to improve long-term OA burden estimates.

5 Conclusion

This multi-source study demonstrated that higher BMI was independently associated with increased odds of osteoarthritis among U.S. adults aged ≥ 55 years, with a clear dose–response gradient. NHANES temporal trends further showed that obesity prevalence rose substantially from 2011 to 2023, whereas OA prevalence remained stable—a pattern consistent with GBD evidence that population growth and ageing, rather than rising age-specific risk, have driven the increase in absolute OA burden. Future projections indicate that OA incidence, prevalence, and DALYs will persist and modestly increase through 2040. The sustained rise in obesity, a major modifiable risk factor, may portend additional future burden beyond current projections. These findings underscore the importance of targeted weight management and risk-stratified prevention for ageing populations.

Data Availability Statement

The datasets presented in this study can be found in the following publicly accessible online repositories. The individual-level data were obtained from the National Health and Nutrition Examination Survey (NHANES), available at <https://www.cdc.gov/nchs/nhanes/>. The population-level disease burden estimates were derived from the Global Burden of Disease (GBD) 2023 Results Tool, accessible at <https://vizhub.healthdata.org/gbd-results/>.

Ethics Statement

Not applicable. Only publicly available summary statistics were used.

Author Contributions

Rongxiang Sun: conceptualization, methodology, writing – original draft, Funding acquisition. Zhifeng Mo: Writing –review editing, Investigation, Formal Analysis. Maolin Liu: writing – original draft, Supervision, Validation. Qinglong Jian: Writing –review editing, Data curation, project administration, Funding acquisition.

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Conflict of Interest

The authors declare that they have no competing interests.

Generative AI Statement

The authors declared that Generative AI was not used in the creation of this manuscript.

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