Lipids in Health and Disease

Association between life's simple 7 (LS7) and arthritis: the mediating role of body fat percentage (BFP)

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Abstract

Background Life's Simple 7 (LS7), developed by the American Heart Association, addresses seven key health behaviors and relationship factors. Although LS7 has been studied in relation to various chronic diseases, its association with arthritis remains unclear. This study seeks to investigate the association between LS7 and arthritis, with particular emphasis on the mediating role of body fat percentage (BFP).

Methods Data from the 2011–2018 National Health and Nutrition Examination Survey (NHANES), including 16,332 adult participants, were analyzed. The connection between LS7 and arthritis was evaluated using multivariable logistic regression, smooth curve □tting, and subgroup analysis. Mediation analysis assessed the role of BFP in this relationship. Additionally, ROC curve analysis was used to assess the predictive performance of the model, and the Boruta algorithm identi□ed the in□uential factors associated with arthritis.

Results After adjusting for relevant covariables, each standard deviation increase in LS7 was linked to a 13% lower likelihood of arthritis [OR = 0.87, 95% CI: 0.84, 0.89]. Participants in the highest LS7 tertile (T3) exhibited a 50% reduced likelihood of developing arthritis compared to those in the lowest tertile (T1) [OR = 0.50, 95% CI: 0.43, 0.60]. Mediation analysis con□rmed that BFP signi□cantly mediated the LS7-arthritis relationship. Furthermore, the Boruta algorithm identi□ed LS7 and BFP as key variables associated with arthritis.

Conclusion Elevated LS7 scores were associated with a lower likelihood of arthritis, with BFP serving as a mediating factor. Improving LS7 scores and managing body fat may help prevent arthritis. Due to the study's cross-sectional design, causality cannot be con□rmed. Future research should use longitudinal studies to verify these □ndings and target high-risk groups.

Keywords Life's simple 7, Arthritis, Body fat percentage, Mediation analysis, NHANES

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Introduction

Arthritis, a chronic in ammatory disorder, a ects millions globally, particularly the elderly, causing considerable disability and severely impairing daily life quality [1–3]. e increasing prevalence of arthritis, driven by an aging population, poses substantial challenges for public health systems [4]. Approximately 3% of the global population is a ected by in ammatory arthritis, with rheumatoid arthritis impacting 460 out of every 100,000 individuals worldwide [5, 6]. 2017, osteoarthritis accounted for 118.8 disability-adjusted life years per 100,000, adjusted for age, re ecting a 9.6% increase since 1990 [7]. Patients commonly experience joint pain, sti - ness, and swelling, which worsen over time and a ect mobility. Furthermore, arthritis frequently coexists with other chronic conditions like cardiovascular disease and diabetes, amplifying the health and economic burdens on both individuals and healthcare systems [8, 9]. Despite a range of treatments—including medications, physical therapy, and surgery—e ectively managing and preventing arthritis remains a challenge, highlighting the need for preventive strategies focused on lifestyle changes.

Life's Simple 7 (LS7), developed by the American Heart Association, is a comprehensive tool for assessing cardiovascular health by evaluating seven key factors: smoking, Body Mass Index (BMI, is an indicator that assesses weight in relation to height (kg/m²) and is utilized to categorize weight status among adults), physical activity, diet, blood pressure, blood glucose, and cholesterol levels [10]. While primarily designed for cardiovascular assessment, recent research has connected LS7 to various chronic conditions, including diabetes and obesity [11, 12]. However, the link between LS7 and arthritis has not been extensively studied. is study seeks to investigate the link between LS7 and arthritis, particularly through the mediating e ect of Body Fat Percentage (BFP).

BFP serves as a vital indicator of body fat content and is a well-established marker of obesity [13]. Research indicates that obesity is a signi cant contributor to the development of arthritis, particularly knee osteoarthritis, due to the increased mechanical stress it places on the joints [14]. Moreover, obesity is associated with chronic in ammation, a key mechanism in arthritis progression [15]. Although BMI is frequently utilized as an indicator of obesity; however, its e ectiveness in accurately depicting obesity is still a subject of discussion [37, 38]. On the other hand, body fat percentage (BFP), which was de ned as the proportion of body fat relative to total body weight, is viewed as a more accurate measure of body fat composition and provides a more accurate assessment of obesity [17, 18]. erefore, BFP may play a mediating role between LS7 and arthritis, a ecting the condition through its in uence on body fat levels. Understanding BFP's role could help shed light on the mechanisms underlying arthritis and know potential pathways for lifestyle interventions.

is research utilizes data from the National Health and Nutrition Examination Survey (NHANES) to perform a cross-sectional analysis of the link between LS7 and arthritis, and investigated the mediating role of BFP. We hypothesize that higher LS7 scores are associated with a reduced likelihood of arthritis, with BFP serving as a partial mediator in this relationship. is research's novelty lies in identifying BFP as a mediating factor in arthritis development, o ering valuable theoretical insights and recommendations for personalized preventive strategies.

Methods

Study population

is study made use of data from the National Health and Nutrition Examination Survey (NHANES), o ering a representative cross-sectional snapshot of the health and nutritional conditions of the U.S. population. Information was gathered through interviews and physical exams at mobile centers. We analyzed NHANES data from 2011 to 2018, encompassing four survey cycles (n=39,156). Participants were excluded if they did not have arthritis diagnosis data (n=16,590), were missing key variable values (total n=6,205, including PIR (n=2,367), TC (n=1,842), alcohol consumption (n=1,836), and BFP (n=160)), or were classi ed as outliers (n=39). is led to a nal pool of 16,322 adults (Fig. 1). Informed consent was obtained from all participants, and the de-identi ed data is available to the public.

Construction and utilization of tertiles for LS7 and BFP

Tertiles for LS7 and BFP were constructed based on the 33rd and 66th percentiles, calculated using survey-weighted quantiles from the NHANES design. is approach facilitated precise classi cation within the intricate sampling framework, segmenting participants into three categories (T1, T2, T3) for each variable. Subsequently, these tertiles were utilized as categorical independent variables in multivariable survey-weighted logistic regression models to examine their relationships with arthritis.

Description of life's simple 7 (LS7) and body fat percentage (BFP)

e primary exposure variable was the LS7 score, established by the American Heart Association to evaluate cardiovascular health using seven criteria: physical activity, tobacco use, BMI, nutritional habits, blood glucose levels, blood pressure, and total cholesterol. Each component receives a score from 0 (indicating poor health) to 2 (indicating ideal health), resulting in a total possible score

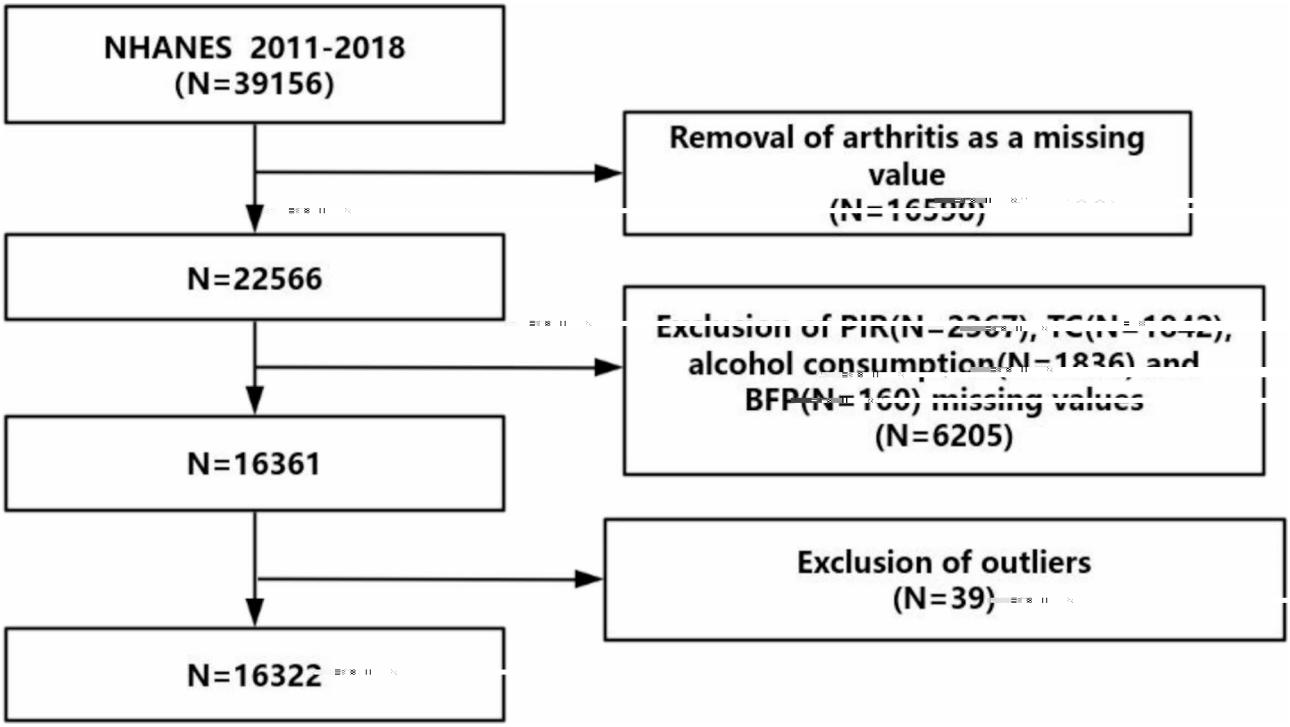

Fig. 1 A □ow diagram of eligible participant selection in the National Health and Nutrition Examination Survey. Abbreviation: PIR, Ratio of family income to poverty; TC, Total cholesterol; BFP, body.fat.percentage

that ranges from 0 to 14. Increased scores indicate better health outcomes [16] (see Supplementary Table S1).

BFP was determined by applying the formula:

$BF\%=-44.988+(0.503\times age)+(10.689\times sex)+(3.172\times BMI)-(0.026\times BMI^2)+(0.181\times BMI\times sex)-(0.02\times BMI\times age)-(0.005\times BMI^2\times sex)+(0.00021\times BMI^2\times age)$.

where age is expressed in years and sex is represented as men = 0 and women = 1 [34].

De□nition of arthritis

Arthritis was diagnosed based on self-reported answers to the NHANES inquiry: "Have you ever been told by a doctor or other healthcare provider that you have arthritis?" is self-reported approach is widely accepted in the NHANES study [19, 20].

Covariables

We controlled for several covariables to address potential confounding variables: age, gender, ethnicity, educational attainment, marital status, poverty income ratio (PIR), smoking status, alcohol consumption, diabetes, hypertension, and total cholesterol (see Supplementary Table S2). ese covariables were selected based on existing literature that associates these factors with arthritis [21, 26].

Statistical analysis

All analyses were conducted with R software (version 4.3.2). e assessment of normality for continuous variables was conducted through the use of Q-Q plots and histograms (see the Supplementary Material Figure S1) [36]. Variables that exhibit a normal distribution are expressed as mean ± standard deviation (SD), those that do not follow a normal distribution are represented by median and interquartile range (IQR), whereas categorical variables are shown as frequencies and percentages. Given NHANES's complex multistage probability sampling design representing the U.S. civilian non-institutionalized population, we incorporated sampling weights, clusters, and strata into all analyses. Continuous variables that followed a normal distribution were evaluated using weighted t-tests, whereas those that were not normally distributed were analyzed through the weighted Wilcoxon rank-sum test. For categorical variables, di erences among LS7, BFP, and arthritis were examined using weighted chi-square tests.

To assess the relationship between LS7, BFP, and arthritis, we employed multivariable logistic regression models. ree models were constructed: (1) unadjusted, (2) controlled for age, gender, education, marital status, PIR, and race, and (3) additionally accounted for smoking, alcohol use, hypertension, and diabetes. Smooth curve tting was applied to investigate possible non-linear relationships involving LS7 and arthritis. Speci cally, for the

Restricted Cubic Splines (RCS) used to examine non-linear associations, we employed the lrm function from the rms package to t a logistic regression model with RCS terms. We selected 3 knots based on model t criteria to allow exibility in capturing non-linear relationships. Subgroup analyses examined associations within di erent population strata. To con rm the robustness of our ndings, machine learning techniques, including ROC curve analysis, were used to evaluate model performance. e area beneath the curve (AUC) indicated the models' ability to predict outcomes, with greater AUC values re ecting superior performance.

Furthermore, we implemented the Boruta algorithm, a machine learning-based feature selection method, to identify the signi cant factors of arthritis. e Boruta algorithm, built on the random forest framework, enhances model interpretation by comparing the importance of original variables to randomly shu ed variables, referred to as "shadow features." Variables with importance scores signi cantly higher than those of shadow features are considered meaningful and retained in the model, while those with lesser importance are excluded. is ensures that only factor with true signi cance for arthritis are included. Provide valuable insights for targeted interventions and prevention strategies.

To investigate BFP's intermediary role in the association between LS7 and arthritis, we utilized the "mediation" package. e analysis involved two stages: Modeling the relationship between LS7 and BFP: A linear regression model was tted to assess the association between LS7 scores and body fat percentage, adjusting for covariables. Modeling the relationship between BFP, LS7, and arthritis: A probit regression model was used to examine the e ect of body fat percentage and LS7 scores on arthritis, while adjusting for the same covariables. We estimated indirect, direct, and total e ects using the bootstrap resampling method (1,000 iterations) and calculated mediation proportions to assess BFP's contribution to the relationship. e mediation proportion was computed as:

$$\text{mediationproportion} = \left(\frac{\text{indirect effect}}{\text{indirect effect} + \text{direct effect}}\right) \times 100\%$$

Given the reliance of speci c components in the BFP formula on BMI, we conducted a deeper examination of the association between BMI and BFP through Pearson association analysis and linear regression analysis.

Results

Baseline characteristics

is study analyzed data from 16,332 participants, representing approximately 185 million adults in the U.S. Among these, 4,467 were diagnosed with arthritis, while 11,685 did not have the condition. e mean LS7 score was recorded at 8.29 (SD 2.43), and the average body fat percentage (BFP) was 35% (SD 10). Initial ndings indicated that individuals with arthritis were generally older, exhibited higher total cholesterol levels, had lower LS7 scores, and presented with higher BFP compared to their non-arthritis counterparts. Furthermore, the prevalence of arthritis was notably greater among women, Non-Hispanic Whites, individuals with higher education, smokers, drinkers, and those su ering from hypertension. Detailed participant traits are presented in Table 1.

Association between LS7 and arthritis

Table 2 illustrates the ndings from three models assessing the link between LS7 and arthritis. In Model 3, following the adjustment for all covariables, every one standard deviation increase in LS7 was associated with a 13% reduction in the likelihood of arthritis [OR=0.87 (95% CI: 0.84, 0.89)]. Moreover, participants in the top tertile of LS7 (T3) demonstrated a 50% lower likelihood of developing arthritis when compared to individuals in the bottom tertile (T1) [OR=0.50 (95% CI: 0.43, 0.60)]. As LS7 scores increased from T1 to T3, the odds ratios (OR) correspondingly decreased, with a statistically signi cant trend ($p<0.001$). e restricted cubic spline (RCS) analysis (Fig. 2) further demonstrated a non-linear negative relationship between LS7 and arthritis (nonlinearity $p=0.0043$).

Relationship between LS7 and BFP

Linear regression analysis indicated a signi cant relationship between LS7 and BFP (β = -0.11, 95% CI: -0.12, -0.11, $p<0.001$) (refer to Supplementary Table S3).

Subgroup analysis of LS7 and arthritis

Figure 3 presents the results of the subgroup analysis, examining the relationship between LS7 and arthritis across several covariables, including age, sex, education level, marital status, poverty income ratio (PIR), race, smoking habits, alcohol intake, hypertension, diabetes, and total cholesterol. Results consistently showed a negative association between LS7 and arthritis across subgroups, with signi cant interactions noted for age, gender, smoking, drinking, HP, and DM ($p<0.05$), indicating that the protective e ect of LS7 might be stronger in certain populations. Furthermore, the consistently low p-values (<0.001) observed in most subgroups suggest that the relationship between LS7 and arthritis is robust and stable across di erent demographic and clinical variables.

Relationship between BFP and arthritis

Table 2 also outlines the association between BFP and arthritis. In Model 3, after controlling for all covariables,

Table 1 Baseline characteristics of all participants were strati□ed by arthritis

Characteristic	N[1]	Overall N = 185,247,649[2]	Non-arthritis N = 135,818,816[2]	Arthritis N = 49,428,833[2]	p-value[3]
Age	16,332	48 (33, 61)	42 (30, 55)	61 (52, 70)	< 0.001
Gender	16,332				< 0.001
male		8081 (49%)	6273 (52%)	1808 (40%)	
female		8251 (51%)	5592 (48%)	2659 (60%)	
Race	16,332				< 0.001
Mexican American		2163 (8.1%)	1731 (9.6%)	432 (4.2%)	
Non-Hispanic White		6593 (68%)	4351 (65%)	2242 (77%)	
Non-Hispanic Black		3527 (10%)	2526 (11%)	1001 (9.3%)	
Other Hispanic		4049 (14%)	3257 (15%)	792 (9.8%)	
Education level	16,332				0.01
Below high school		6959 (35%)	4870 (35%)	2089 (38%)	
High School or above		9373 (65%)	6995 (65%)	2378 (62%)	
Married/live with partner	16,332				0.7
Yes		9617 (63%)	7147 (63%)	2470 (63%)	
No		6715 (37%)	4718 (37%)	1997 (37%)	
PIR	16,332	2.99 (1.48, 5.00)	3.00 (1.49, 5.00)	2.96 (1.46, 5.00)	0.6
TC	16,332	192± (42)	191± (41)	194± (44)	0.003
Smoking	16,332				< 0.001
Yes		7240 (45%)	4817 (41%)	2423 (54%)	
No		9092 (55%)	7048 (59%)	2044 (46%)	
Drinking	16,332				< 0.001
Yes		10,939 (73%)	8153 (74%)	2786 (69%)	
No		5393 (27%)	3712 (26%)	1681 (31%)	
DM	16,332				< 0.001
Yes		3096 (14%)	1730 (11%)	1366 (24%)	
No		13,236 (86%)	10,135 (89%)	3101 (76%)	
HP	16,332				< 0.001
Yes		7587 (42%)	4474 (33%)	3113 (64%)	
No		8745 (58%)	7391 (67%)	1354 (36%)	
LS7	16,332	8.29± (2.43)	8.72± (2.36)	7.13± (2.24)	< 0.001
LS7	16,332				< 0.001
T1		6870 (37%)	4077 (30%)	2793 (56%)	
T2		4752 (30%)	3612 (30%)	1140 (29%)	
T3		4710 (33%)	4176 (40%)	534 (15%)	
BFP	16,332	35± (10)	34± (10)	40± (9)	< 0.001
T1		5399 (33%)	4628 (39%)	771 (18%)	
T2		5127 (33%)	3789 (34%)	1338 (31%)	
T3		5806 (34%)	3448 (28%)	2358 (51%)	

1 N not Missing (unweighted)

2 n (unweighted) (%); Mean± (SD); Median (p25, p75)

3 Pearson's X^2: Rao & Scott adjustment; Design-based KruskalWallis test

Continuous variables that followed a normal distribution were evaluated using weighted t-tests, whereas those that were not normally distributed were analyzed through the weighted Wilcoxon rank-sum test

Percentages (weighted N, %) for categorical variables: the *P* value was calculated by the weighted chi-square test

Abbreviation: PIR, Ratio of family income to poverty; TC, Total cholesterol; DM, Diabetes; HP, hypertension; LS7, Life's Simple 7; BFP, Body Fat Percentage

each standard deviation increase in BFP was linked with a 5% increase in the likelihood of developing arthritis [OR=1.05, 95% CI: 1.05, 1.06]. Further analysis revealed that participants in the highest BFP tertile (T3) faced a 1.47-fold increased likelihood of arthritis when contrasted with individuals in the lowest tertile (T1) [OR=2.47, 95% CI: 2.04, 3.00]. As BFP rose from T1 to T3, the OR values progressively increased, with a statistically signi cant trend ($p<0.001$), underscoring a positive relationship between BFP and arthritis.

Mediation analysis

e mediation analysis indicated an indirect impact of -0.019 (95% CI: -0.0214 to -0.02, $p<2e-16$), re ected

Table 2 Association between LS7, BFP, and arthritis

Characteristics	Model 1 [OR (95% CI)]	*p*-value	Model 2 [OR (95% CI)]	*p*-value	Model 3 [OR (95% CI)]	*p*-value
LS7 - Arthritis						
Continuous	0.75(0.74,0.77)	< 0.001	0.84(0.82,0.86)	< 0.001	0.87(0.84,0.89)	< 0.001
Tertile						
T1	1 (ref.)		1 (ref.)		1 (ref.)	
T2	0.50(0.45,0.56)	< 0.001	0.67(0.59,0.76)	< 0.001	0.77(0.67,0.88)	< 0.001
T3	0.20(0.17,0.23)	< 0.001	0.39(0.33,0.46)	< 0.001	0.50(0.43,0.60)	< 0.001
P for trend	< 2e-16		4.70e-16		1.68e-10	
BFP - Arthritis						
Continuous	1.07(1.06,1.07)	< 0.001	1.06(1.05,1.07)	< 0.001	1.05(1.05,1.06)	< 0.001
Tertile						
T1	1 (ref.)		1 (ref.)		1 (ref.)	
T2	2.05(1.76,2.39)	< 0.001	1.46(1.24,1.73)	< 0.001	1.37(1.14,1.63)	< 0.001
T3	4.08(3.57,4.67)	< 0.001	2.86(2.41,3.40)	< 0.001	2.47(2.04,3.00)	< 0.001
P for trend	< 2e-16		< 2e-16		1.45e-12	

Model 1: no covariables were adjusted

Model 2: age, gender, education level, marital, PIR, and race were adjusted

Model 3: age, gender, education level, marital, PIR, race, smoking, drinking, hypertension, diabetes, and total cholesterol were adjusted

Abbreviation: LS7, Life's Simple 7; BFP, Body Fat Percentage

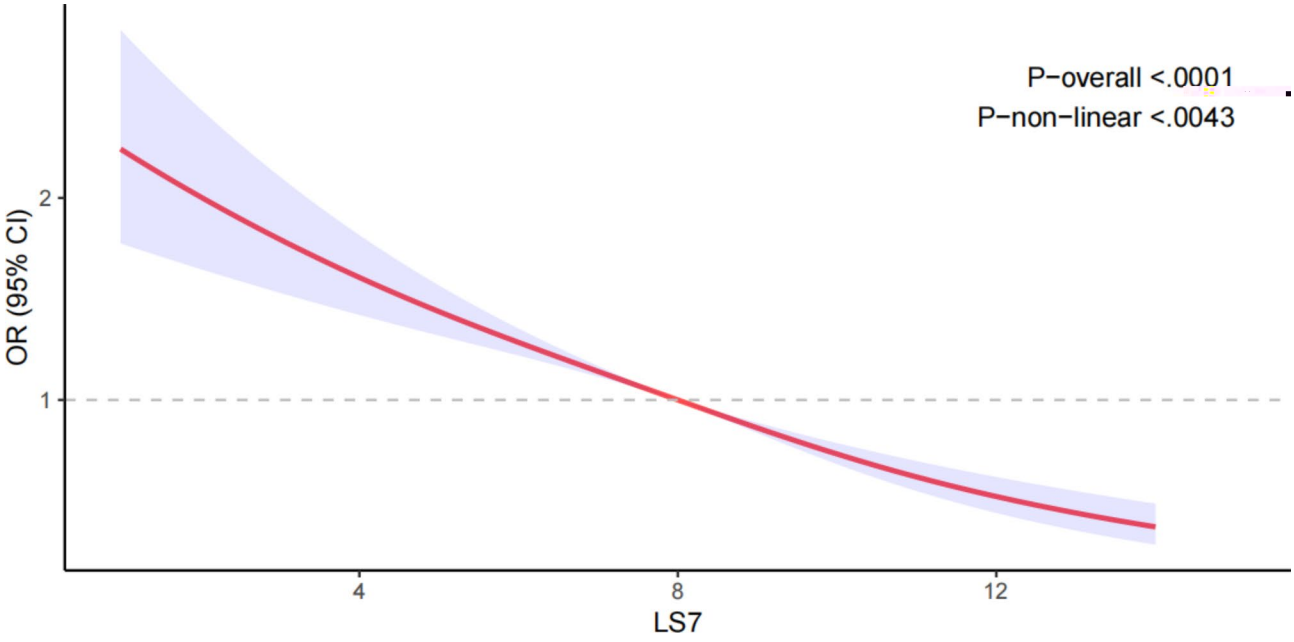

Fig. 2 Dose-response relationships between LS7 and arthritis. OR (solid lines) and 95% con□dence levels (shaded areas) were adjusted for age, gender, education level, marital, PIR, race, smoking, drinking, hypertension, diabetes, and total cholesterol

indirect e ect of the mediator on the relationship between LS7 and arthritis. e direct e ect was measured at -0.009 (p=0.02), suggesting a remaining portion of the direct e ect. e total e ect was calculated as -0.027 (p<2e-16), with approximately 68% of the e ect being mediated by the mediator variable. erefore, BFP is identi ed as a mediator in the association between LS7 and the occurrence of arthritis. e mediation pathways (Path A, Path B, and Path C) and their e ects are illustrated in Fig. 4.

Comparison of ROC curves across □ve models

Figure 5 compares the ROC curves of ve models used to classify arthritis versus non-arthritis cases. Model D demonstrated the best performance, achieving an AUC (area under the curve) of 0.789, signifying excellent classi cation capability. With a sensitivity of 0.664, the speci city was 0.779, indicating strong generalizability for Model D in this study. Model A presented an AUC of 0.692, slightly lower than Model D but still showing

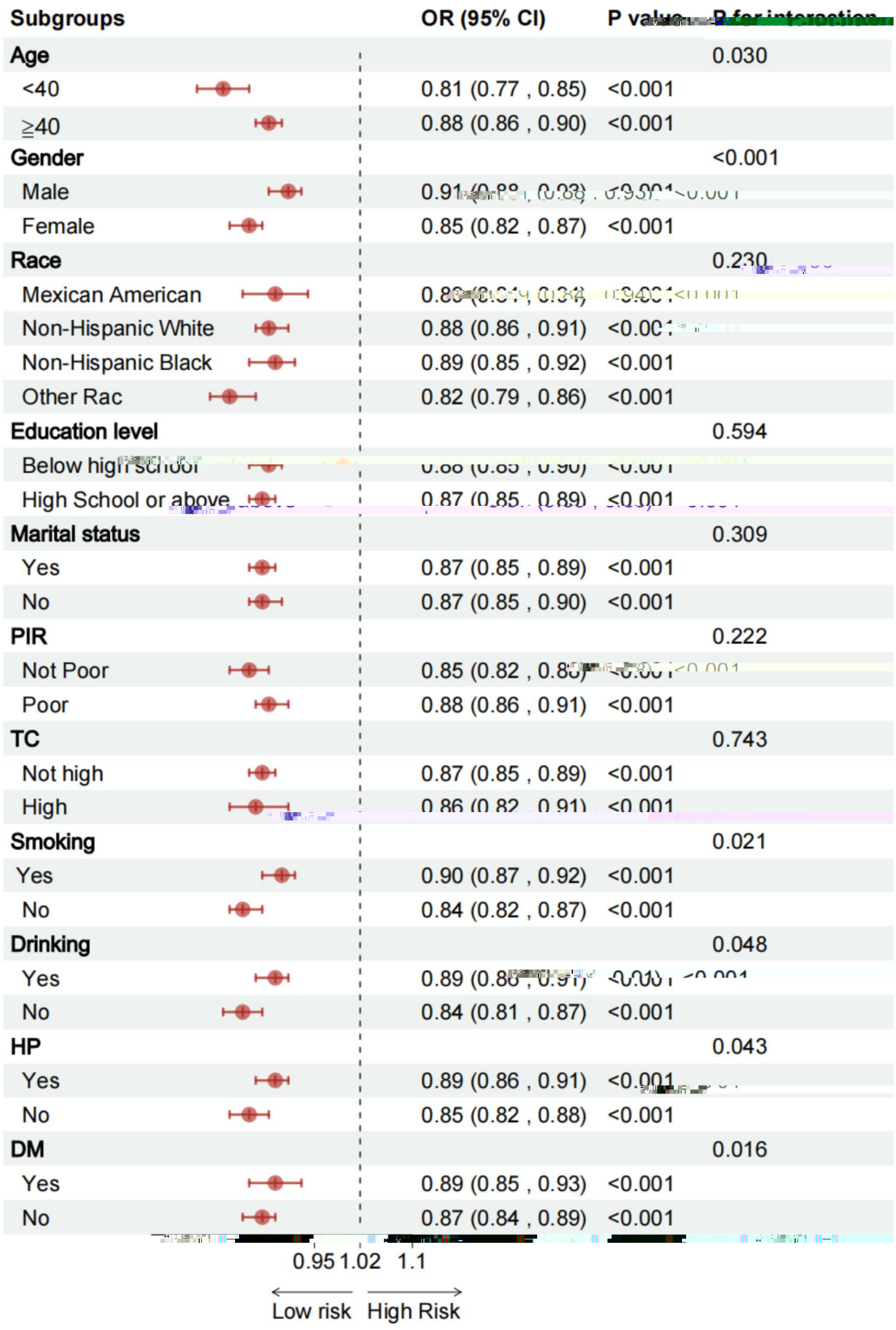

Fig. 3 Subgroup analysis between LS7 and arthritis. Abbreviation: PIR, Ratio of family income to poverty; TC, Total cholesterol; DM, Diabetes; HP, hypertension; LS7, Life's Simple 7; BFP, Body Fat Percentage

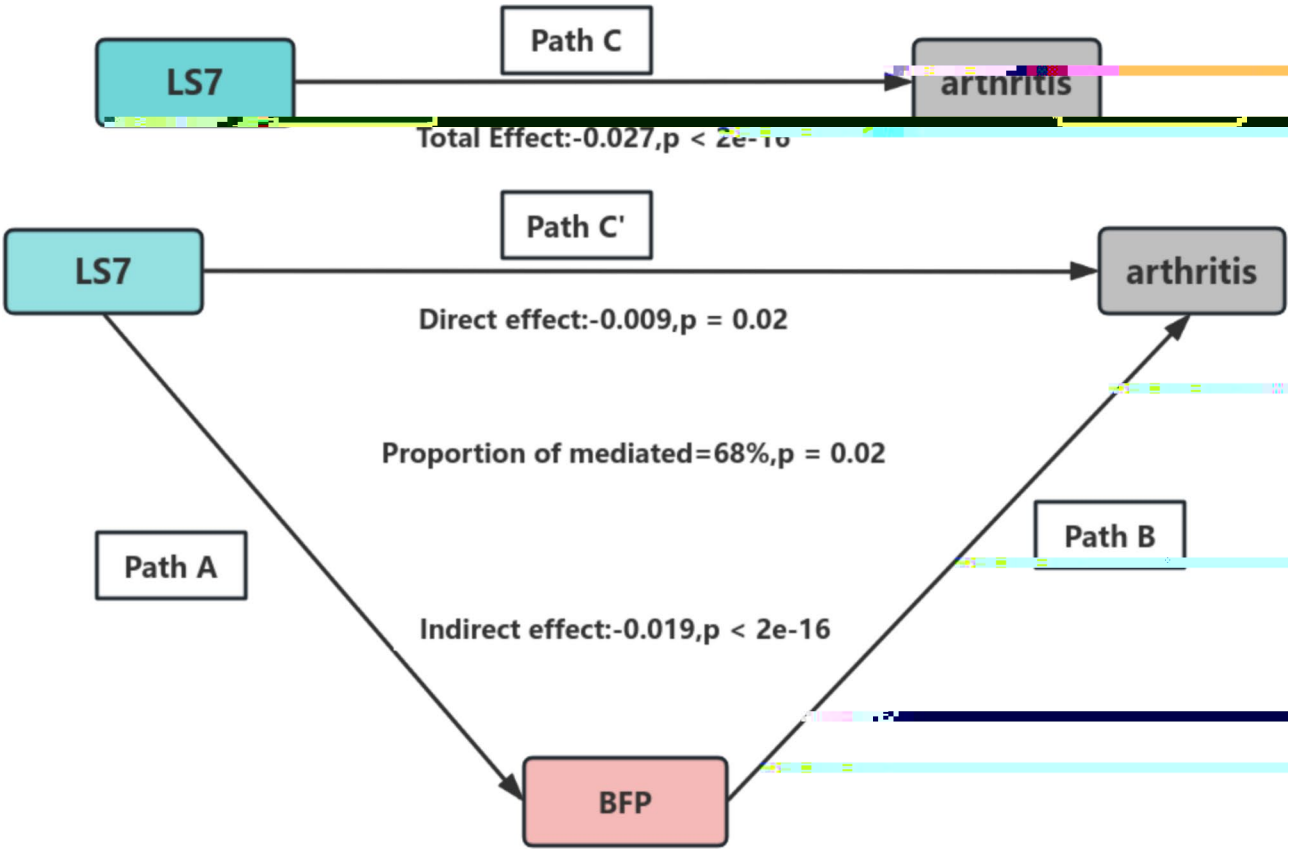

Fig. 4 Schematic diagram of the mediation e□ect analysis. Path C (Total E□ect): This represents the overall relationship between LS7 and arthritis, combining both direct and indirect e□ects. Path C′ (Direct E□ect): This refers to the e□ect of LS7 on arthritis that is not mediated by BFP, represent the independent in□uence of LS7. Path A : This pathway shows the e□ect of LS7 on the BFP. Path B : This pathway shows the e□ect of BFP on the arthritis. The indirect e□ect is estimated as the multiplication of paths A and B (path A*B). The mediated proportion is calculated as indirect e□ect/ (indirect e□ect + direct e□ect) × 100%. Abbreviation: LS7, Life's Simple 7; BFP, Body Fat Percentage

commendable classi cation performance, especially with a sensitivity of 0.656 and speci city of 0.625.

Boruta algorithm for feature selection in arthritis

Figure 6 illustrates the outcomes of the Boruta algorithm, which identi ed critical features related to arthritis. Variables highlighted in the green box were con rmed as signi cant feature. BFP and LS7 ranked second and third in importance, emphasizing their vital roles in arthritis assessment. Additional key variables included drinking, education, marital status, PIR, total cholesterol, race, smoking, diabetes, gender, hypertension, and age. e Boruta algorithm e ectively identi ed these factors as signi cant contributors to arthritis.

Relationship between BMI and BFP

e analysis using Pearson relationship indicates a robust positive association (Pearson r=0.86) between BFP and BMI, suggesting that as BMI rises, BFP also experiences a signi cant increase (Refer to Supplementary Figure S2). Furthermore, the linear regression analysis reinforces this connection, exhibiting a slope of 1.586. is indicates that for every unit increase in BMI, BFP tends to rise by approximately 1.586 units on average. e goodness-of- t of the model (R^2 = 0.740) implies that roughly 74% of the variability observed in BFP can be accounted for by BMI. Nonetheless, the residuals from the regression model exhibit some uctuations, ranging from a minimum of -76.39 to a maximum of 18.80, which suggests that the relationship between BFP and BMI is not entirely linear. erefore, while there is a strong relationship between BMI and BFP, they are not perfectly equivalent.

Discussion

is study used NHANES data to explore the association between LS7 scores and arthritis, while also investigating the mediating role of BFP. e ndings indicate a signi cant negative association between higher LS7 scores and arthritis, with BFP acting as an important mediator in this relationship. ese enhance the understanding of the mechanisms involved in the onset of arthritis and suggest potential preventive measures, especially in terms of lifestyle choices and metabolic health.

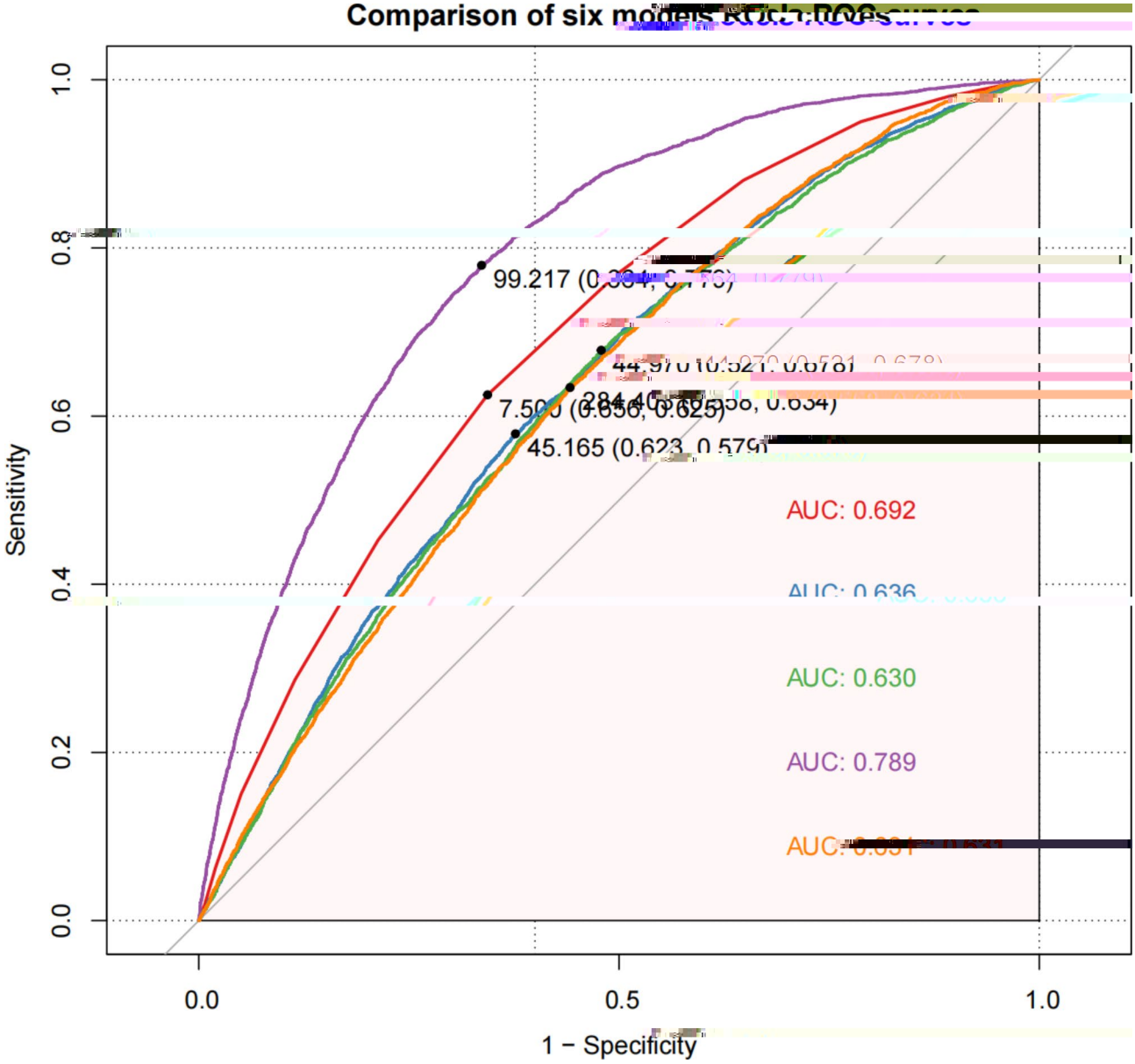

Fig. 5 Evaluating Predictive Power of Variables Using ROC Curves. Each of the ve models is added in order LS7, BFP, PIR, AGE and TC. (A: AUC: LS7;B: AUC: LS7 + BFP; C:AUC: LS7 + BFP + PIR; D:AUC: LS7 + BFP + PIR + AGE; E:AUC: LS7 + BFP + PIR + AGE + TC)

Our results reveal a meaningful negative relationship between LS7 scores and arthritis. After controlling for all covariables, each standard deviation increase in LS7 was linked to a 13% decrease in the likelihood of arthritis. Additionally, individuals in the highest LS7 tertile (T3) exhibited a 50% reduced likelihood of developing arthritis when contrasted with those in the lowest tertile (T1). ese ndings suggest that improving the LS7 scores may reduce the likelihood of arthritis.

e LS7 score, which includes tobacco use, body mass index (BMI), physical activity, dietary habits, blood sugar levels, blood pressure, and cholesterol, re ects key lifestyle factors in uencing arthritis. Smoking increases pro-in ammatory cytokines like TNF-α and interleukin-1β, exacerbating joint damage and arthritis progression [28]. us, reducing tobacco use may help prevent arthritis by lowering in ammation. Obesity, indicated may by a high BMI, contributes to arthritis, particularly osteoarthritis, by adding mechanical stress to joints and promoting the release of pro-in ammatory adipokines like interleukin-6 and TNF-α, which degrade cartilage [23, 24, 27]. Maintaining a healthy BMI can reduce both mechanical and in ammatory stress on joints. Physical activity strengthens muscles and joints, reducing degeneration, and has anti-in ammatory e ects, lowering pro-in ammatory cytokines and improving

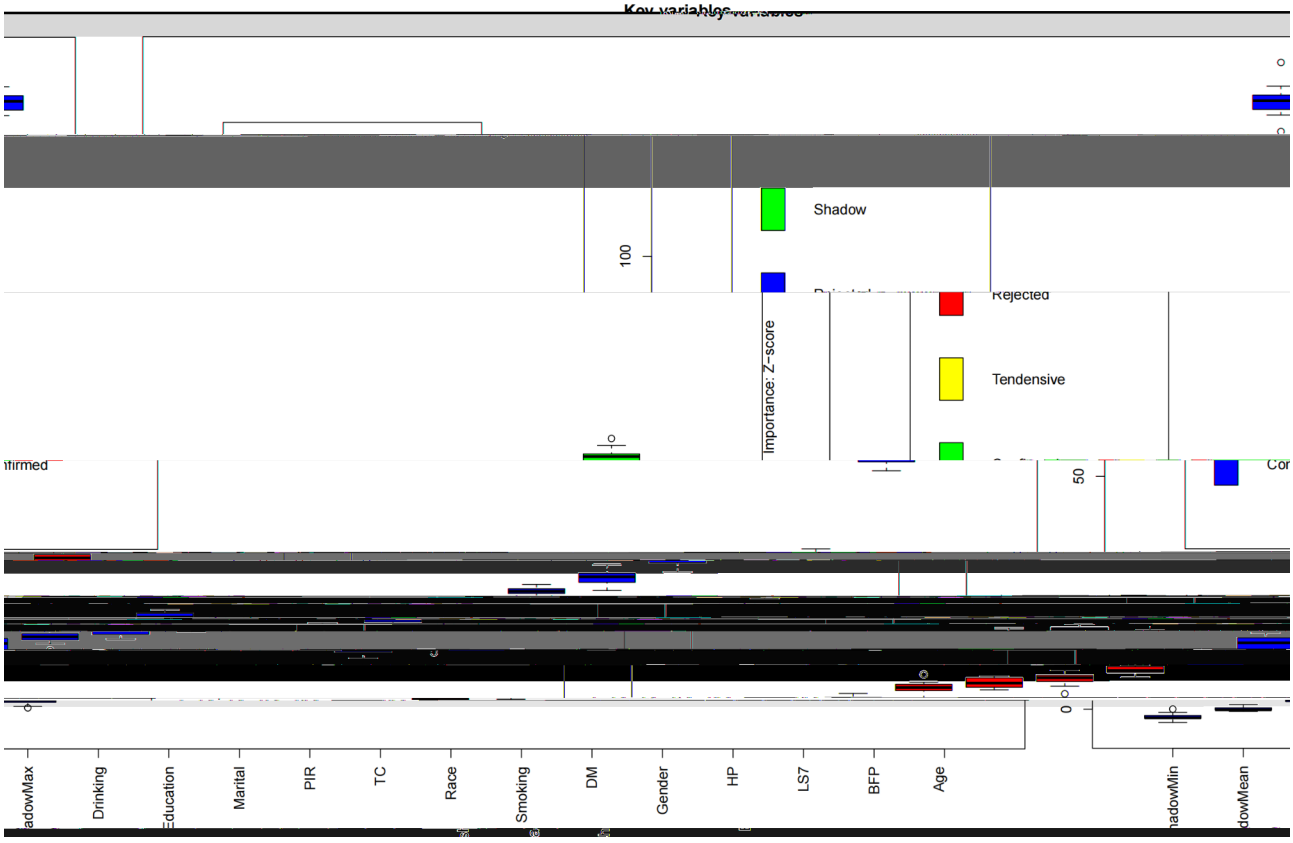

Fig. 6 Important characteristic variables identi□ed as associated with arthritis by the Boruta algorithm. Abbreviation: PIR, Ratio of family income to poverty; TC, Total cholesterol; DM, Diabetes; HP, hypertension; LS7, Life's Simple 7; BFP, Body Fat Percentage

metabolism [31, 32]. Diets rich in fruits, vegetables, and healthy fats, such as the Mediterranean diet, help reduce in ammation and support joint health by modulating oxidative stress and lipid metabolism [33]. Elevated blood sugar and insulin resistance, common in metabolic syndrome, exacerbate joint in ammation and promote arthritis [29]. Managing blood glucose through diet and exercise may alleviate these e ects. Hypertension also increases systemic in ammation, raising pro-in ammatory cytokines that damage joints [30]. Managing blood pressure through lifestyle changes may protect joint health. High cholesterol, like LDL, triggers in ammatory pathways that damage joint tissues and contribute to arthritis [39]. Maintaining healthy cholesterol levels can help modulate these pathways. In conclusion, optimizing LS7 scores by improving lifestyle factors—reducing tobacco use, maintaining a healthy BMI, staying active, eating a balanced diet, and managing blood sugar, blood pressure, and cholesterol—may help reduce arthritis development and progression through e ects on in ammation and joint health.

e mediation analysis we conducted reveals that BFP plays a signi cant role in mediating the association between LS7 and arthritis. Serving as an indicator of obesity, BFP represents an individual's fat content. Obesity not only imposes mechanical stress on joints but also fosters chronic in ammation. Adipocytes release a variety of cytokines, including interleukin-6, resistin, and tumor necrosis factor-alpha, all of which can intensify joint in ammation [22–25]. Furthermore, studies show that children who are obese have an increased likelihood of developing arthritis, with this risk escalating as they age and being more common among females [35]. Our ndings suggest that improving LS7 scores to reduce BFP levels may help lowering the likelihood of arthritis. is re ects the mediating role of BFP in the LS7-arthritis relationship and may provide strategies for the prevention of arthritis in the future.

e ROC analysis o ers further con rmation of the ndings from the study. rough the comparison of predictive models, it was shown that integrating LS7, BFP, and additional covariables (such as PIR, age, and TC) improved the classi cation ability between arthritis and non-arthritis cases, with Model D attaining the peak AUC of 0.789. is underscores the importance of incorporating BFP along with LS7 and other factors, reinforcing its signi cance in detecting individuals with arthritis.

In our subgroup analysis, the inverse association between LS7 and arthritis exhibited signi cant interactions in speci c groups, particularly concerning age,

gender, smoking habits, alcohol consumption, HP and DM. e results indicated that older adults, females, smokers, and individuals with hypertension or diabetes may experience greater bene ts from higher LS7 scores, suggesting that the impact of healthy lifestyles may vary across di erent populations. Moreover, the consistently low p-values (<0.001) across most subgroups underscore the robustness and stability of the association between LS7 and arthritis, lending greater credibility to these ndings. erefore, personalized lifestyle interventions should be designed to address the speci c characteristics and needs of the target populations to achieve optimal prevention outcomes.

e relationship between BMI and BFP shows a strong positive relationship, But not exactly the same. While BMI serves as a straightforward and practical indicator, BFP o ers a more thorough measurement that includes additional elements like age, sex, and their interplay with BMI. Consequently, BMI may be more suited for regular preliminary screening, BFP can deliver a more detailed, accurate, and holistic evaluation of body fat.

While this study highlights important relationships between LS7, BFP, and arthritis, several limitations should be noted. First, the cross-sectional design of this study prevents the establishment of causality. Although the mediating role of BFP provides insights into the potential pathways linking LS7 to arthritis, further research, such as prospective cohort studies, randomized controlled trials, or experimental studies, is required to con rm these mechanisms and establish causative relationships. Second, the reliance on self-reported arthritis diagnoses in NHANES data may introduce information bias. Participants may underreport or misclassify their condition due to recall inaccuracies or lack of medical con rmation, potentially a ecting the reliability of the results. Using physician-con rmed diagnoses or integrating biomarkers in future studies could improve diagnostic accuracy. ird, although we adjusted for a broad range of covariables to enhance the robustness of our ndings, the inherent limitations of the NHANES dataset mean that residual confounding cannot be fully excluded. Unmeasured factors, such as genetic predispositions or environmental in uences, may still in uence the observed associations. Finally, the ndings are based on data from the NHANES population, which, while representative of the U.S., may not fully generalize to other populations with di ering demographic, lifestyle, or health pro les. Given these limitations, the results of this study should be interpreted cautiously and objectively. Further research, particularly longitudinal and experimental studies, is essential to validate these ndings and explore the underlying mechanisms in greater depth.

Conclusion

In summary, this study identi ed an association between higher LS7 scores and a lower likelihood of arthritis, with BFP acting as a mediating factor in this relationship. e ndings suggest that lifestyle factors and body fat levels may play a role in arthritis. While these results highlight the potential importance of promoting healthy lifestyle behaviors and managing body fat, the study's cross-sectional design limits causal interpretation. Future research should employ longitudinal studies to further explore these associations and to develop tailored strategies for high-risk populations to better address the burden of arthritis.

Abbreviations

BFP	Body Fat Percentage
LS7	Life's Simple 7
BMI	Body Mass Index
NCHS	National Center for Health Statistics
NHANES	National Health and Nutrition Examination Survey
OR	Odds Ratio
CI	Con□dence Interval
PIR	Ratio of family income to poverty
TC	Total cholesterol
DM	Diabetes
HP	Hypertension

Supplementary Information

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Supplementary Material 1

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Author contributions

Huan Chen conceptualized and drafted the manuscript. Chan Kang provided the study design and critical feedback, while other contributors o□ered supervision and additional guidance.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

Approval for utilizing human participant data was granted by the National Center for Health Statistics (NCHS) Research Ethics Review Board. This study adhered to institutional guidelines and relevant local regulations. Written informed consent was obtained from all participants before their inclusion in the study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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