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Association between body roundness index and non-alcoholic fatty liver disease detected by Fibroscan in America

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Abstract

Background: The prevalence of non-alcoholic fatty liver disease (NAFLD) and obesity is worldwide on the rise. Body roundness index (BRI), as a newly developed anthropometric indicator, has been recently reported to identify obesity. However, it is still unclear whether BRI is associated with the prevalence of NAFLD.

Methods: Data were from the National Health and Nutrition Examination Survey (NHANES) 2017–2018. NAFLD was diagnosed based on hepatic steatosis defined by CAP values ≥274 dB/m. Multivariable logistic regression analysis was performed to detect the association between BRI and the odds of NAFLD. Subgroup analysis stratified by age, gender, BMI, and race was further conducted. To explore the potential ability of BRI in predicting NAFLD, the area under the curve (AUC) of BRI was calculated by receiver operating characteristic (ROC) analysis.

Results: Among the 4467 study participants, 1718 (38.5%) were diagnosed with NAFLD. Compared to the non-NAFLD group, participants with NAFLD had a higher level of BRI. The positive associations between BRI and NAFLD were detected in all three models (mode 1: OR = 1.71, 95% CI: 1.65–1.78, $p < 0.0001$; mode 2: OR = 1.78, 95% CI: 1.71–1.86, $p < 0.0001$; mode3: OR = 1.23, 95% CI: 1.11–1.35, $p < 0.0001$). The positive association steadily existed in different subgroups after stratified by age, gender, and BMI. Moreover, the non-linear association between BRI and NAFLD was detected, presenting inverted U-shaped curves. Furthermore, BRI had a high predictive value (AUC = 0.807) in identifying NAFLD.

Conclusions: BRI was positively associated with the prevalence of NAFLD among individuals in America, regardless of age, gender, and BMI. Besides, BRI presented a high ability for identifying NAFLD.

Ningning Jiang and Shengguo Zhang contributed equally.

KEYWORDS
body roundness index, cross-sectional, NAFLD, NHANES

1 | INTRODUCTION

With changes in diet pattern and lack of physical exercise, non-alcoholic fatty liver disease (NAFLD) has been recently an emerging health problem.[1–3] As reported, the global prevalence of NAFLD was 25% in 2016 and increased to >30% in 2019.[4] Over the last decade, the clinical burden of NAFLD is not only confined to liver-related morbidity and mortality, but also associated with extra-hepatic adverse outcomes, such as cardiovascular diseases (CVDs) and non-hepatic cancers.[5] How to identify out high-risk individuals for NAFLD as exactly for further targeted management is of one of the overriding important work in the area of research. Since no effective medical treatment, identifying potential modifiable factors to diagnose or even prevent NAFLD is urgently necessary.

The increasing prevalence of NAFLD has been in parallel with obesity and type 2 diabetes mellitus (T2DM).[4] It was reported that obesity was present in half of (NAFLD) patients and 82% of non-alcoholic steatohepatitis (NASH) patients.[6] NAFLD patients in clinical practice are always obese, with insulin resistance (IR), T2DM, dyslipidemia, hypertension, hypertriglyceridemia, and CVDs.[7] The body roundness index (BRI), a new obesity indices, has been explored to identify obesity, T2DM, IR, CVDs, and metabolic syndrome (MetS).[8–10] Besides, BRI has also been verified to be related to metabolic dysregulation.[11–14] In terms of the close association between obesity and NAFLD, BRI was also introduced to predict the presence of NAFLD in recent years; however, the study design and outcomes remain inconsistent.[9,15–18] Therefore, a well-designed study with a large-scale sample focused on the association between BRI and the prevalence of NAFLD is still vacant, especially in American nationally representative population.

This current study aimed to detect the potential link between BRI and NAFLD and to explore the possibility of BRI as a predictor for NAFLD in a representative sample of American people using data from National Health and Nutritional Examination Survey (NHANES) database. It may be beneficial for primary healthcare practitioners, clinicians, and researchers to recognize the population with high risk of NAFLD.

2 | METHODS

2.1 | Data sources and study population

The data were obtained from NHANES 2017–2018, which is a large cross-sectional survey designed by National Center for Health Statistics (NCHS) to provide comprehensive data on nutrition and health.[19] Among the total 9254 participants, we excluded 550 participants with missing MEC examination, 162 participants with missing WC or height data, 258 participants with transient elastography ineligible, 2459 participants with missing transient elastography, and 493 with partial examination. Furthermore, 27 participants with hepatitis B, 86 participants with hepatitis C, and 752 participants who over-drank were excluded. Eventually, 4467 participants were adopted to analyze the relationship between BRI and NAFLD.

2.2 | Covariates

BRI was the independent variable in our analysis, and NAFLD was the dependent variable in our analysis. Controlled attenuation parameter (CAP) and liver stiffness measurement (LSM) were determined by measuring transient elastography with M or XL probe.[20] NAFLD status was defined according to the criteria as follows: CAP values ≥274 dB/m without hepatitis B or C virus infection and significant alcohol intake.[21] There were also many confounding variables, including continuous and categorical variables, that might affect the relationship between the independent variable BRI and the dependent variable NAFLD status. Continuous variables included age, BMI, height, WC, total cholesterol, HDL-cholesterol, glycohemoglobin, aspartate aminotransferase (AST), alanine aminotransferase (ALT), gamma-glutamyl transpeptidase (GGT), serum albumin, platelet count, serum creatinine, and uric acid. BMI was calculated by dividing kilograms by weight in meters squared. Categorical variables included gender, race/ethnicity, education attainment, diabetes, smoking status, alcohol use, etc. T2DM was diagnosed when any of the following conditions were met: (1) self-reported diabetes; (2) using antidiabetic medicines; (3) fasting plasma glucose ≥126 mg/dL (7 mmol/L); (4) random plasma glucose ≥200 mg/dL (11.1 mmol/L); and (5) glycohemoglobin ≥6.5% (48 mmol/mol).[8] Smoke status was divided into three types: never smokers were those who responded "NO" to the question: "Smoked at least 100 cigarettes in life (%)"; current smokers were those who responded "YES" to the above question and the question: "SMQ040 - Do you now smoke cigarettes?"; ever smokers were those who responded "YES" to the question "Smoked at least 100 cigarettes in life (%)" and but "NO" to the question "SMQ040 - Do you now smoke cigarettes?" The amount of daily alcohol consumption was also collected in two 24-h recalls. If an individual completed both 24-h recalls, we used the average alcohol intake from the two 24-h recalls. Otherwise, we used the data from the first 24-h recall.[22] Significant alcohol consumption is confirmed as >2 drinks per day for women and >3 drinks per day for men in the last 12 months.[23] Educational attainments, including less than high school graduate, high school graduate or GED, some college, or college graduate or above, were extracted from the self-reported questionnaire data.

TABLE 1 Weight characteristics of study participants based on the presence of NAFLD.

	Total ($n=4467$)	Non-NAFLD ($n=2749$)	NAFLD ($n=1718$)	p-value
Age (years)	44.8 ± 21.5	40.5 ± 22.0	51.7 ± 18.8	<0.001
Gender (%)				
Male	2182 (48.9%)	1254 (45.6%)	928 (54.0%)	<0.001
Female	2285 (51.1%)	1495 (54.4%)	790 (46.0%)	
Race/Ethnicity (%)				
Mexican	595 (13.3%)	311 (11.3%)	284 (16.5%)	<0.001
Hispanic	389 (8.7%)	242 (8.8%)	147 (8. 6%)	
White	1482 (33.2%)	896 (32.6%)	586 (34.1%)	
Black	1054 (23.6%)	715 (26.0%)	339 (19.7%)	
Asian	685 (15.3%)	417 (15.2%)	268 (15.6%)	
Other race	262 (5.9%)	168 (6.1%)	94 (5.5%)	
Diabetes (%)	968 (21.7%)	424 (15.4%)	544 (31.7%)	<0.001
BMI (kg/m^2)				
Normal weight	1544 (34.6%)	1380 (50.2%)	164 (9.6%)	<0.001
Overweight	1356 (30.4%)	829 (30.2%)	527 (30.7%)	
Obese	1567 (35.1%)	540 (19.6%)	1027 (59.8%)	
Smoking status				
Never	3154 (70.6%)	2037 (74.1%)	1117 (65.0%)	<0.001
Ever	822 (18.40%)	403 (14.66%)	419 (24.4%)	
Current	491 (11.0%)	309 (11.3%)	182 (10.6%)	
Alcohol use				
Never	2251 (50.4%)	1477 (53.7%)	774 (45.0%)	<0.001
1 drink	1093 (24.5%)	615 (22.4%)	478 (27.8%)	
2 drinks	890 (19.9%)	527 (19.2%)	363 (21.1%)	
3 drinks	233 (5.2%)	130 (4.7%)	103 (6.0%)	
Education attainment				
Lower than high school	1080 (24.2%)	806 (29.3%)	274 (16.0%)	<0.001
High school	1303 (29.2%)	760 (27.7%)	543 (31.6%)	
College or above	2076 (46.5%)	1181 (43.0%)	895 (52.1%)	
Not available	8 (0.2%)	2 (0.1%)	6 (0.4%)	
BMI (kg/m^2)	28.4 ± 7.0	25.7 ± 5.8	32.6 ± 6.8	<0.001
Height (m)	1.7 ± 0.1	1.7 ± 0.1	1.7 ± 0.1	<0.001
WC (m)	1.0 ± 0.2	0.9 ± 0.2	1.1 ± 0.2	<0.001
Total Cholesterol (mg/dL)	182.6 ± 39.7	178.9 ± 38.7	188.5 ± 40.6	<0.001
HDL-cholesterol (mg/dL)	53.1 ± 14.4	56.1 ± 14.2	48.43 ± 13.4	<0.001
Glycohemoglobin (%)	5.8 ± 1.0	5.6 ± 0.8	6.1 ± 1.2	<0.001
AST (IU/L)	21.1 ± 10.8	20.3 ± 9.4	22.6 ± 12.5	<0.001
ALT (IU/L)	20.9 ± 15.2	17.9 ± 13.0	25.6 ± 17.1	<0.001
GGT (IU/L)	27.3 ± 33.4	22.3 ± 23.8	35.3 ± 43.5	<0.001
Serum albumin (g/L)	41.1 ± 3.2	41.3 ± 3.1	40.6 ± 3.2	<0.001
Platelet count ($10^9/L$)	246.0 ± 61.8	245.5 ± 60.9	246.8 ± 63.4	0.529
Serum Creatinine (mmol/L)	76.8 ± 37.5	74.9 ± 30.3	79.8 ± 46.6	<0.001
Uric acid (μmol/L)	319.3 ± 84.0	303.3 ± 78.7	344.8 ± 86.0	<0.001
BRI	5.2 ± 2.4	4.3 ± 2.0	6.7 ± 2.3	<0.001

Note: Mean ± SD was for continuous variables. p-value was calculated by weight linear regression model. % was for categorical variables. p-value was calculated by weighted chi-square test.

Abbreviations: ALT, alanine aminotransferase; AST, aspartate aminotransferase; BMI, body mass index; BRI, body roundness index; GGT, gamma-glutamyl transpeptidase; HDL, high density lipoprotein; LSM, liver stiffness measurement.

TABLE 2 The association between BRI and the prevalence of NAFLD.

Model	Model 1: OR (95% CI) *p*-value	Model 2: OR (95% CI) *p*-value	Model 3: OR (95% CI) *p*-value
BRI	1.71 (1.65, 1.78) <0.0001	1.78 (1.71, 1.86) <0.0001	1.23 (1.11, 1.35) <0.0001
BRI (Quartile)			
Q1 (1.04–3.45)	Reference	Reference	Reference
Q2 (3.46–4.91)	6.27 (4.68, 8.40) <0.0001	5.39 (3.98, 7.28) <0.0001	2.85 (2.06, 3.95) <0.0001
Q3 (4.91–6.59)	19.10 (14.35, 25.40) <0.0001	17.79 (13.18, 24.01) <0.0001	5.98 (4.16, 8.60) <0.0001
Q4 (6.59–19.10)	41.48 (31.04, 55.43) <0.0001	48.61 (35.55, 66.48) <0.0001	7.05 (4.42, 11.23) <0.0001
p for trend	<0.001	<0.001	<0.001

Note: Model 1: No covariates were adjusted. Model 2: Gender, age, and race were adjusted. Model 3: Gender, age, race, BMI, diabetes status, smoking status, alcohol use, education attainment, uric acid, and glycohemoglobin were adjusted.

TABLE 3 The correlation between BRI and the prevalence of NAFLD stratified by age, gender, BMI, or race.

Model	Model 1: OR (95% CI) *p*-value	Model 2: OR (95% CI) *p*-value	Model 3: OR (95% CI) *p*-value
Subgroup analysis stratified by age (years)			
Age <20	2.06 (1.84, 2.31) <0.0001	2.17 (1.92, 2.45) <0.0001	1.39 (1.06, 1.84) 0.0192
Age ≥20, <40	1.61 (1.49, 1.73) <0.0001	1.79 (1.64, 1.96) <0.0001	1.31 (1.06, 1.61) 0.0132
Age ≥40, <60	1.65 (1.53, 1.78) <0.0001	1.78 (1.64, 1.94) <0.0001	1.38 (1.15, 1.67) 0.0007
Age ≥60	1.54 (1.45, 1.65) <0.0001	1.64 (1.53, 1.75) <0.0001	1.17 (1.00, 1.36) 0.0483
Subgroup analysis stratified by gender			
Male	2.10 (1.96, 2.25) <0.0001	2.11 (1.96, 2.27) <0.0001	1.38 (1.17, 1.64) 0.0002
Female	1.62 (1.55, 1.70) <0.0001	1.61 (1.53, 1.70) <0.0001	1.15 (1.02, 1.29) 0.0212
Subgroup analysis stratified by race			
Mexican American	1.97 (1.74, 2.22) <0.0001	2.07 (1.80, 2.38) <0.0001	1.56 (1.15, 2.12) 0.0040
Other Hispanic	1.86 (1.61, 2.15) <0.0001	1.83 (1.56, 2.14) <0.0001	1.71 (1.22, 2.39) 0.0019
Non-Hispanic White	1.80 (1.68, 1.92) <0.0001	1.84 (1.71, 1.97) <0.0001	1.08 (0.92, 1.28) 0.3346
Non-Hispanic Black	1.56 (1.46, 1.66) <0.0001	1.59 (1.48, 1.71) <0.0001	1.14 (0.96, 1.37) 0.1429
Non-Hispanic Asian	2.03 (1.77, 2.32) <0.0001	1.99 (1.72, 2.29) <0.0001	1.21 (0.90, 1.63) 0.1997
Other race	1.80 (1.54, 2.11) <0.0001	1.77 (1.50, 2.10) <0.0001	1.50 (0.95, 2.36) 0.0804
Subgroup analysis stratified by BMI			
Normal weight	2.47 (2.08, 2.94) <0.0001	1.87 (1.49, 2.35) <0.0001	1.77 (1.39, 2.24) <0.0001
Overweight	1.68 (1.50, 1.89) <0.0001	1.69 (1.46, 1.95) <0.0001	1.69 (1.45, 1.96) <0.0001
Obese	1.28 (1.20, 1.36) <0.0001	1.35 (1.26, 1.45) <0.0001	1.29 (1.21, 1.38) <0.0001

Note: Model 1: No covariates were adjusted. Model 2: Gender, age, and race were adjusted. Model 3: Adjust for: gender, age, race, BMI, diabetes status, smoking status, alcohol use, education attainment, uric acid, and glycohemoglobin were adjusted. In the analysis stratified by age, gender, BMI, and race, the model is not adjusted for age, gender, BMI, and race, respectively.

2.3 | Statistical analysis

All analyses were conducted using *EmpowerStats* software based on R version 3.4.3, with *p*-value <0.05 was considered as statistically significant. Weighted multivariable logistic regression models were used to evaluate the relationship between BRI and NAFLD. Model 1 was a crude model in which no covariates were adjusted. In model 2, gender, age, and race were adjusted. In model 3, gender, age, race, BMI, diabetes status, smoking status, alcohol use, education attainment, uric acid, and glycohemoglobin were adjusted. Smooth curving fittings and generalized additive models were performed to study the potential non-linear relationships. To access the ability of BRI in identifying NAFLD, the area under the curve (AUC) of predictable indices was calculated by receiver operating characteristic (ROC) analysis, in which NAFLD was considered as a reference variable and BRI as a classification variable.

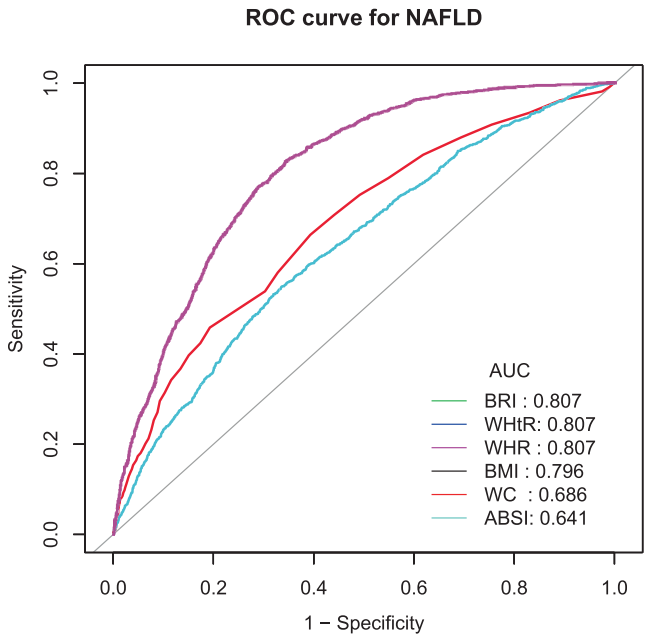

FIGURE 1 ROC curve analysis of obesity-related parameters for diagnosis of NAFLD. ABSI: a body shape index; AUC: area under receiver operating characteristic (ROC) curve; BMI: body mass index; BRI: body roundness index; NAFLD: non-alcoholic fatty liver disease; WC: waist circumference; WHR: waist-to-hip ratio; WHtR: waist-to-height ratio.

3 | RESULTS

3.1 | Baseline characteristics

The weighted characteristics were presented in Table 1. Of all the 4467 participants, 1718 (38.5%) were diagnosed with NAFLD and the others were included into non-NAFLD group. Compared to the non-NAFLD group, participants with NAFLD were older, had lower levels of education, higher BMI, prevalence of diabetes and higher total cholesterol, glycohemoglobin, AST, ALT, GGT, serum albumin, serum creatinine, uric acid, HDL-cholesterol, and BRI. Especially, participants with NAFLD had a higher level of BRI when compared with those in the non-NAFLD group. There was no statistical difference in platelet count between the two groups ($p=0.529$).

3.2 | Association between BRI and the prevalence of NAFLD

As shown in Table 2, the positive associations between BRI and the prevalence of NAFLD were found in all three models (mode1: OR=1.71, 95% CI: 1.65–1.78, $p<0.0001$; mode 2: OR=1.78, 95% CI: 1.71–1.86, $p<0.0001$; mode3: OR=1.23, 95% CI: 1.11–1.35, $p<0.0001$). Each unit increase in BRI was associated with 1.23-fold higher odds of NAFLD after fully adjustment for confounding factors. After a quarter classification of BRI, higher BRI levels in Q2–Q4 were associated with higher prevalence of NAFLD after fully adjusted potential confounding factors (p for trend <0.001) compared with the lowest level of BRI in Q1.

Subgroups analysis on the relationship between BRI and NAFLD stratified by age, gender, race and BMI were further performed as shown in Table 3. In subgroup analysis stratified by age, the associations remained positive in <20 years group (OR=1.39, 95% CI: 1.06–1.84, $p=0.0192$), 20–40 years group (OR=1.31, 95% CI: 1.06–1.61, $p=0.0132$), 40–60 years group (OR=1.38, 95% CI: 1.15–1.67, $p=0.0007$), and ≥60 years group (OR=1.17, 95% CI: 1.00–1.36, $p=0.0483$) in model 3 after fully adjustment for confounding factors. After subgroup analysis stratified by gender, the association remained positive both in men (OR=1.38, 95% CI: 1.17–1.64, $p=0.0002$) and women (OR=1.15, 95% CI: 1.02–1.29, $p=0.0212$) in model 3 after fully adjustment for confounding factors. After subgroup analysis stratified by race, the association was positive in Mexican American (OR=1.56, 95% CI: 1.15–2.12, $p=0.004$), other Hispanic (OR=1.71, 95% CI: 1.22–2.39, $p=0.0019$), but not in non-Hispanic White (OR=1.08, 95% CI: 0.92–1.28, $p=0.3346$), non-Hispanic Black (OR=1.14, 95% CI: 0.96–1.37, $p=0.1429$), non-Hispanic Asian (OR=1.21, 95% CI: 0.90–1.63, $p=0.1997$), and other race (OR=1.50, 95% CI: 0.95–2.36, $p=0.0804$) in model 3 after fully adjustment for confounding factors. After subgroup analysis stratified by BMI, the positive associations steadily existed in normal weight group (OR=1.77, 95% CI: 1.39–2.24, $p<0.0001$), overweight group (OR=1.69, 95% CI: 1.45–1.96, $p<0.0001$), and obese group (OR=1.29, 95% CI: 1.21–1.38, $p<0.0001$) after fully adjustment for confounding factors.

As shown in Figure 1, we analyzed and compared the diagnostic value of BRI and obesity-related parameters (including BMI, WC, WHtR, WHR, and ABSI) for NAFLD by ROC in our current study. We discovered that BRI has a better predictive potential (AUC=0.807) for NAFLD than other common anthropometric obesity-related indices, including BMI (AUC=0.796), WC (AUC=0.686), and ABSI (AUC=0.641).

Furthermore, we revealed an inverted U-shaped relationship between BRI and the prevalence of NAFLD using the smooth curve fitting method as shown in Figure 2. We subsequently confirmed that the inflection point was 5.85 using the two-piecewise linear regression model as seen in Table 4. After subgroup analysis stratified by age, gender, race, and BMI, we found that inverted U-shaped curves steadily existed as shown in Figure 3. An inflection point at 5.82 among men and at 5.85 among women was found.

4 | DISCUSSION

The present study elicited four main findings. Firstly, BRI was positively associated with NAFLD in the American general population, even after removing the effects of other potential mediators such as gender, age, race, BMI, diabetes, smoking, alcohol use, education attainment, uric acid, and glycohemoglobin. Secondly, the positive association between BRI and NAFLD steadily existed, regardless of age, gender, and BMI. Moreover, the risk of NAFLD increased

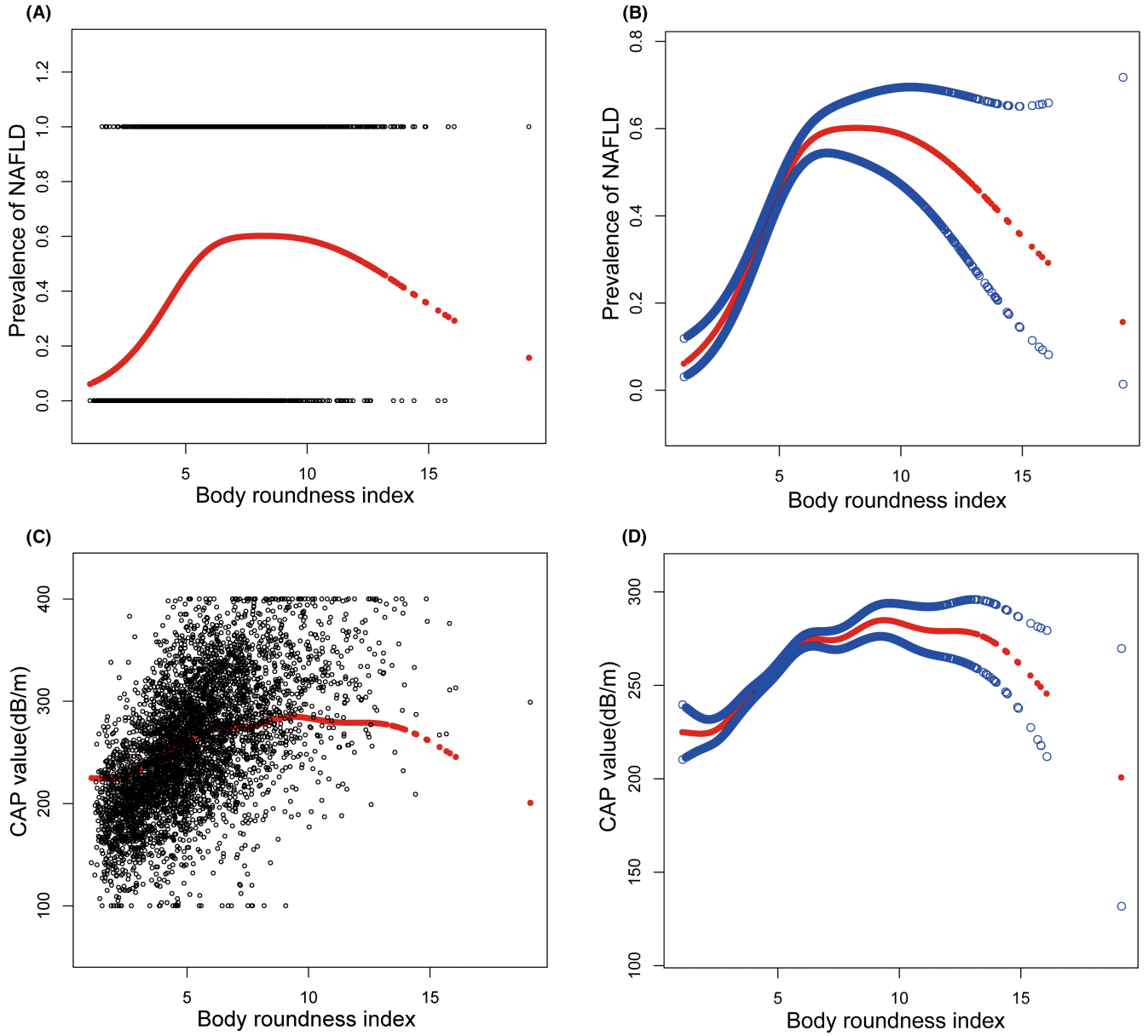

FIGURE 2 The association of BRI with the prevalence of NAFLD and CAP values. (A) and (C): Each black point represents a sample. Solid red line represents the smooth curve fit between variables. (B) and (D): Solid red line represents the smooth curve fit between variables. Blue bands represent the 95% of confidence interval from the fit. Adjust for: gender, age, race, BMI, diabetes status, smoking status, alcohol use, education attainment, uric acid, and glycohemoglobin were adjusted.

more progressively in the higher quartile groups of BRI when compared to the lowest quartile group. Thirdly, the non-linear association between BRI and NAFLD was detected, presenting an inverted U-shaped curve with an inflection point at 5.85. Finally, BRI had a higher predictive ability in identifying NAFLD, compared with other obesity indices including BMI, WC, and ABSI. Our results also revealed an equal discriminatory ability of BRI with WHtR and WHR in the diagnosis of NAFLD.

Several previous studies involving the association between BRI and the prevalence of NAFLD have reported in the past years, but the study designs and outcomes remain rather inconsistent. In a cross-sectional, large community-based study of 4872 participants aged 18–74 years in northern Iran, the authors discovered that BRI has a strong association (OR = 5.484 for men and OR = 3.482 for women) with NAFLD defined by ultrasonography after logistic regression analysis.[9] They also revealed that BRI has a high discriminatory ability in the diagnosis of NAFLD, with the AUC for men was 0.8457 (95% CI = 0.8320–0.8593) and the AUC for women was 0.8566 (95% CI = 0.8419–0.8714). Moreover, BRI and WHtR had equally high discriminatory abilities in the diagnosis of NAFLD than ABSI and WHR. Both the above study and ours clarified that BRI had a strong association with NAFLD, presenting a high ability in predicting NAFLD. Although their analysis was based on Iran's population and ours was relied on polyethnic American population, NAFLD

TABLE 4 Threshold effect analysis between BRI and NAFLD using the two-piecewise linear regression model.

Incidence rate of NAFLD	Adjusted OR (95% CI), *p*-value
All participants	
Fitting by the standard linear model	1.23 (1.11, 1.35) <0.0001
Fitting by the two-piecewise linear model	
Inflection point	5.85
BRI <5.85	1.90 (1.67, 2.16) <0.0001
BRI >5.85	0.97 (0.87, 1.07) 0.4979
Log likelihood ratio	<0.001
Male	
Fitting by the standard linear model	1.38 (1.17, 1.64) 0.0002
Fitting by the two-piecewise linear model	
Inflection point	5.82
BRI <5.82	1.94 (1.58, 2.38) <0.0001
BRI >5.82	0.97 (0.80, 1.18) 0.7444
Log likelihood ratio	<0.001
Female	
Fitting by the standard linear model	1.15 (1.02, 1.29) 0.0212
Fitting by the two-piecewise linear model	
Inflection point	5.85
BRI <5.85	1.76 (1.47, 2.10) <0.0001
BRI >5.85	0.97 (0.86, 1.10) 0.6845
Log likelihood ratio	<0.001

Note: Adjust for: gender, age, race, BMI, diabetes status, smoking status, alcohol use, education attainment, uric acid, and glycohemoglobin were adjusted. In the analysis stratified by age, gender, BMI, and race, the model is not adjusted for age, gender, BMI, and race, respectively.

was diagnosed by liver ultrasonography in their study and Fibroscan in ours. The adjusted confounding factors in their study included age, triglyceride levels, HDL, HOMA, and mean arterial pressure, which were different with that in ours. Those slight discrepancies might contribute to the higher OR values in their study than that in ours (OR = 1.23, 95% CI: 1.11–1.35). While their participants were enrolled from a large community in northern Iran, our results were drawn based on the data of nationally representative American general population, strengthening the reliability of the above findings. Moreover, it was also reported that BRI positively associated with the severity or progression of NAFLD in a study from Taiwan.[15] Procino et al. found AVI showed a better performance than BRI in the two-step method evaluating percentage reduction of the number of liver ultrasonography, percentage of false negative, and percentage of NAFLD identified.[16] Sheng et al. found TyG index-related parameters showed a better predictive potential for NAFLD diagnosed by abdominal ultrasound than BRI.[17] In contradiction with the above conclusion, a cross-sectional study comprehensively evaluated the predictive performance of anthropometric and metabolic indices to identify NAFLD in Chinese adults, but found BRI had the best diagnostic ability than other obesity-related indices.[18] These inconsistent findings among the studies can be partly attributed to the difference in anthropometric characteristics among various ethnic and racial groups, different study designs, the method to diagnose NAFLD, and the study sample size.

In the current study, we discovered that BRI has the best predictive potential for NAFLD after compared with other common anthropometric obesity-related indices, showing a bright potential to predict the incidence of NAFLD. Besides, we revealed that the positive relationship between BRI and the prevalence of NAFLD was detected by Fibroscan in a large database with polyethnic American general population. For the first time, we revealed that the positive relationships between BRI and the prevalence of NAFLD, regardless of age, sex, and BMI. Therefore, the positive results were not caused by some special population. We also considered the prevalence of NAFLD was increased with higher BRI when BRI was <5.85, but decreased with higher BRI when BRI was >5.85. Therefore, there was a saturation effect between BRI and the prevalence of NAFLD.

As we know, this study is the largest sample-sized study about the topic of the association between BRI and the prevalence of NAFLD. The sample size and nationally representative of participants is the biggest advantage of our current study; therefore, the conclusion is relatively reliable. Meanwhile, there are several limitations to this study. First, economic status, sleep disorders, and physical activity were not adjusted in our analysis, which may affect the development of NAFLD. Second, the casual relationships between BRI and the prevalence of NAFLD cannot be defined due to the cross-sectional design of this study. Third, all of the participants from America, thus our results may not be applied to other national

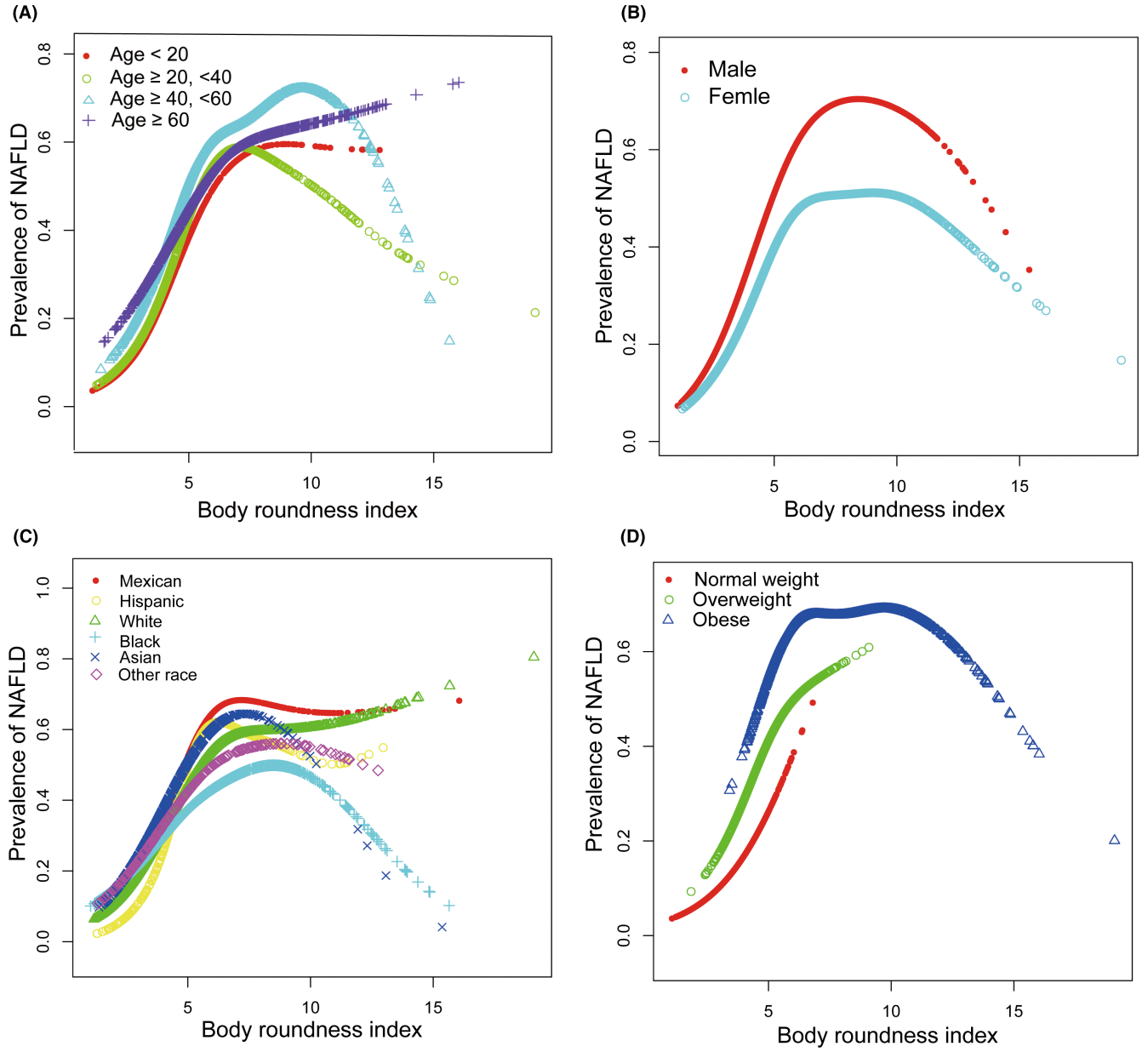

FIGURE 3 The association between BRI and the prevalence of NAFLD with stratification. (A) These lines represent the smooth curve fit between the two variables stratified by age. (B) These lines represent the smooth curve fit between the two variables stratified by gender. (C) These lines represent the smooth curve fit between the two variables stratified by race. (D) These lines represent the smooth curve fit between the two variables stratified by BMI. Adjust for: gender, age, race, BMI, diabetes status, smoking status, alcohol use, education attainment, uric acid, and glycohemoglobin were adjusted. In the analysis stratified by age, gender, BMI, and race, the model is not adjusted for age, gender, BMI, and race, respectively.

populations. In addition, usage of Fibroscan to identify NAFLD instead of liver biopsy seems to be insufficient, while liver biopsy is the golden standard for the diagnosis of NAFLD.

5 | CONCLUSION

Our study reported a positive association between BRI and the prevalence of NAFLD among participants in America. BRI might be a simple and convenient predictor of NAFLD, and its specific role in the non-invasive risk assessment of NAFLD should be evaluated in further research.

AUTHOR CONTRIBUTIONS

Mingqin Lu and Naibin Yang made a contribution to the conception. Shengguo Zhang and Jinguo Chu were in charge of execution, acquisition of data, analysis, and interpretation. Ningning Jiang took charge in drafting, revising, and critically reviewing the article. Naibin Yang was in charge of the study design. All authors gave final approval of the version to be published and agreed to be accountable for all aspects of the work.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data are publicly available on the Internet and researchers throughout the world http://www.cdc.gov/nchs/nhanes/.

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