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Association of body roundness index with uterine fibroids in women of childbearing age: a cross-sectional analysis of NHANES 1999–2006

Feng Zhang[1], Min Liu[2*], Shanshan Hu[2*], Ningying Zhou[1], Danni Wu[1], Yuqing Zan[1] and Fei Sun[3]

Abstract

Background and aim Previous studies have shown an association between obesity and uterine fibroids (UF). Body roundness index (BRI) is an anthropometric measure associated with obesity. However, the association with UF has not been thoroughly elucidated, and further investigation is required to explore the possible link. Our study investigated the possible link between BRI and UF in women aged 20 to 44 years, with a view to providing effective scientific evidence for health management and disease prevention in this population.

Methods This cross-sectional study analysis included data from 4043 women of childbearing age from the National Health and Nutrition Examination Survey (NHANES) database 1999–2006.We applied multiple regression analysis to study the association between BRI and UF, subgroup analysis was used to ensure broad applicability and representativeness of conclusions, and finally linear correlation between BRI and UF was explored by smooth curve fitting.

Results This study involved 4,043 female participants aged 20–44 years, of whom 331 (8.19%) had fibroids. After controlling for all potential confounders, each additional unit of BRI increased the prevalence of UF by 7% (OR = 1.07,95% CI: 1.01,1.12), Sensitivity analysis by dividing BRI into four groups found a 54% increase in the prevalence of UF within the fourth quartile (Q4) of BRI compared with the first quartile (Q1) of BRI (OR = 1.54, 95% CI: 1.08, 2.20).The link between BRI and UF maintained in subgroup analyses. Furthermore, the study showed a linear positive correlation between BRI and the probability of UF prevalence.

Conclusions Higher levels of BRI may be linked to a higher prevalence of UF, according to studies conducted on American women of childbearing age. The study's conclusions highlight how important BRI is for managing and preventing UF.

Keywords Body roundness index, Leiomyoma, Obesity, NHANES, Women's health, Cross-sectional studies

*Correspondence:
Min Liu
liumin_76@163.com
Shanshan Hu
hss0632@163.com

[1]Wuxi Medical College of Jiangnan University, Wuxi 214122, China
[2]Department of Nursing, Wuxi Maternity and Child Health Care Hospital, Wuxi 214002, China
[3]Department of Obstetrics, Hangzhou First People's Hospital, Affiliated to Westlake University School of Medicine, Hangzhou 310006, China

Introduction

Uterine fibroids (UF) are among the commonly occurring benign tumors in gynecology, especially prevalent in women of reproductive age [1, 2]. Research indicates that the prevalence of UF among women of reproductive age is estimated to be between 5.4% and 77% [1], and studies have reported an increasing trend in recent decades in several countries [3]. Although UF are benign tumors and usually asymptomatic, symptomatic women usually exhibit infertility, pelvic masses, pelvic discomfort, irregular bleeding, or miscarriage [4], and about one-third of women will require medication or surgery due to the development of severe symptoms [5]. For women of reproductive age, UF pose a serious public health risk, impacting personal well-being and resulting in major financial hardships [6]. In the United States alone, the annual cost of treating UF ranges from $5.9 billion to $34.4 billion [7], in addition to decreasing weman's quality of life [8]. Therefore, understanding the easily modifiable risk factors for UF is essential for prevention and management of UF.

Obesity arises from the intricate interaction of multiple factors, including genetics, metabolism, behavior, and environment. These factors mutually influence one another and collectively dictate an individual's weight and obesity risk, thereby constituting a significant global public health challenge [9]. To date, obesity has been identified as the fifth leading cause of death worldwide [10]. According to a population-based obesity prediction study, it's predicted that more than 85% of adults in the United States will fall into the overweight or obese categories by 2030 [11]. Research indicates that obesity is associated with a variety of health issues, including diabetes, hypertension, cardiovascular diseases, breast cancer, and infertility [12, 13]. Furthermore, prior studies have also highlighted obesity as a significant risk factor for UF [14]. As reported by the WHO, obesity refers to abnormal or excessive accumulation of adipose tissue [15], and BMI is a common index used to assess obesity [16], However, there are limitations of BMI, such as the inability to distinguish between individuals with different body fat distributions or body fat and lean body mass [w16, 17]. The body roundness index (BRI) is a new obesity assessment metric proposed by Thomas et al. [18], defined as $364.2–365.5 \times (1-[WC(m)/2\pi]^2 / [0.5 \times height(m)]^2)^{1/2}$. It integrates height and waist circumference (WC) data to reflect body roundness. Compared with traditional indicators like BMI, BRI can more accurately estimate the content of visceral fat in the body. Previous investigations have found that BRI is strongly associated with diverse health problems, such as cardiovascular disease, diabetes, and depression [19–21]. However, to date, it's unclear how BRI relates to the prevalence of UF.

To explore the connection between BRI and UF in greater depth and understand the underlying mechanisms, we examined large data from the 1999–2006 National Health and Nutrition Examination Survey (NHANES). We aimed that this cross-sectional study would not only shed light on the relationship between BRI and UF, but also provide important scientific evidence for improving prevention and treatment strategies for UF, thereby significantly improving patients' quality of life.

Materials and methods

Study population

In our study, we analyzed NHANES participants with complete data on BRI and UF over four survey cycles between 1999 and 2006. Initially, the study enrolled 40,525 participants. Male participants ($n = 20,264$), those younger than 20 years ($n = 10,509$), those older than 44 years ($n = 5,731$), those who did not respond to the uterine fibroids question ($n = 782$), those with missing BRI($n = 82$), and those with missing age at menarche ($n = 63$) were excluded. Missing covariate values are indicated by others. In the final analysis, 4,043 eligible participants were included in the study (Fig. 1).

Definition of UF as an outcome indicator

The diagnosis of UF was identified by the Reproductive Health Questionnaire:"Has a doctor or other health professional ever told you that you have fibroids?"Participants who answered "yes" to this question were recorded as having fibroids.

Exposure factor: BRI

In this study, BRI was considered an exposure variable. A sample of BRI from NHANES participants was obtained in the examination data, The formula for BRI is $364.2–365.5 \times (1-[WC(m)/2\pi] / [0.5 \times height(m)]^2)^{1/2}$ [18].

Selection of covariates

We collected demographic information about participants, including age, race, marital status, education level, poverty to income ratio, and pregnancy status. We also obtained detailed data on smoking status, alcohol consumption, age of first menstruation, number of pregnancies, and whether participants had ever taken contraceptives through the NHANES reproductive health questionnaire.

Statistical analysis

For the final assessment, the overall population was divided into two groups: UF patients and non-UF patients. The data description and statistical analysis applied complex weighting methods in the context of descriptive analysis. Continuous variables were

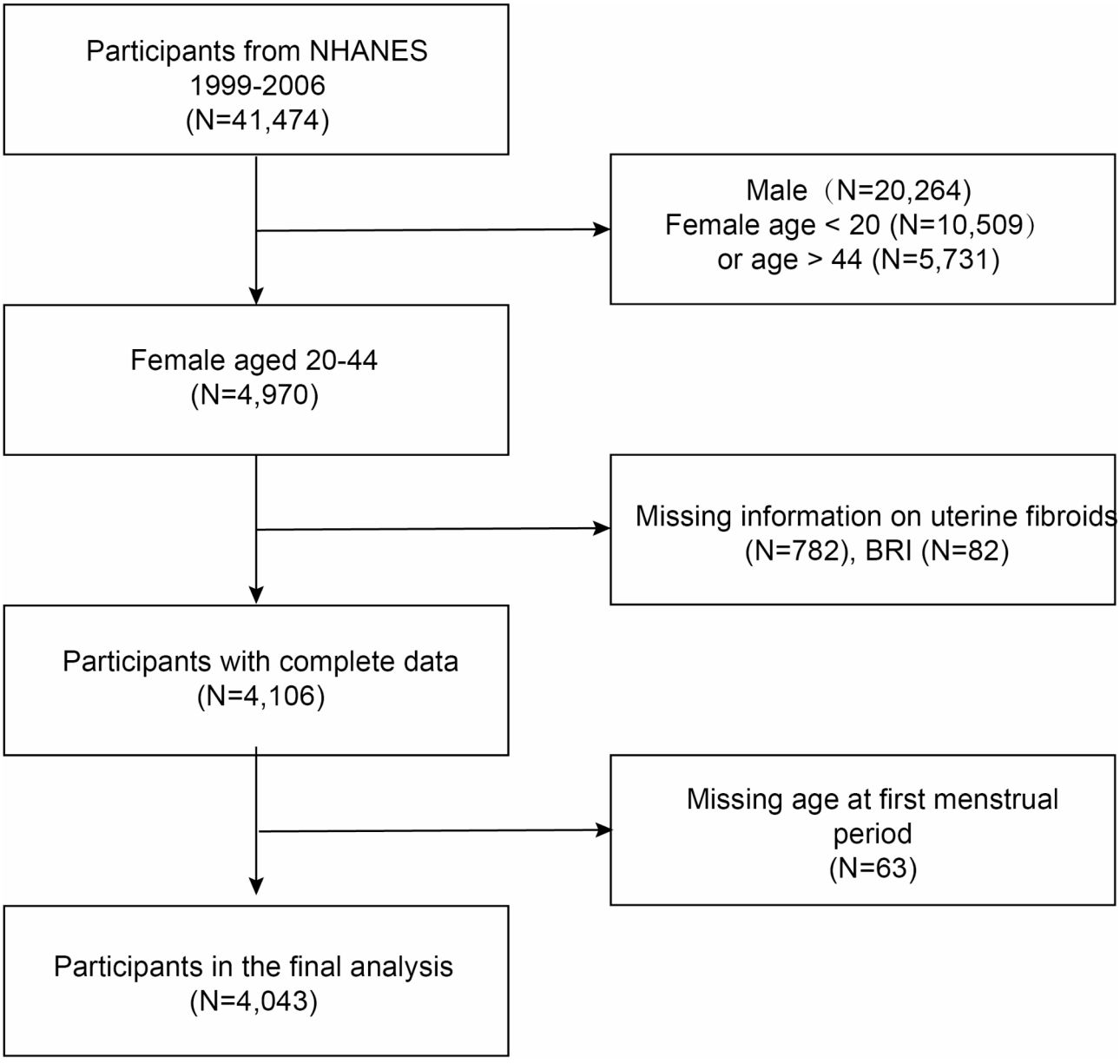

Fig. 1 NHANES Study Population Inclusion Flowchart, 1999–2006

summarized as mean ± standard deviation, while categorical variables were reported as proportions. To assess the link between BRI and UF, a multivariate logistic regression model was used in this study. In Model 1, we did not adjust for any confounding variables. In Model 2, age and race were taken into account and adjusted accordingly, and age, race, education level, marital status, household income, pregnancy status, smoking, alcohol consumption, age of first menstrual occurrence, number of pregnancies, and ever having taken the pill were adjusted for in Model 3. In sensitivity analyses, subgroup analyses were performed using stratified multivariate logistic regression models in which age, race, education level, marital status, and household income were divided. Smoothed curve fitting was used in this research to see if the correlation between BRI and UF was linear. Missing values in categorical variables for available data are indicated by other. All analyses were conducted using EmpowerStats (version 2.0) and R software (version 3.4.3).

Results

Baseline characteristics of participants

In the final analysis, 4,043 women of childbearing age were included in our study, of whom 331 had UF, accounting for 8.19% of the participants. Table 1 details

Table 1 Characteristics of the NHANES study population by fibroid status

Variable	Total (*N* = 4043)	Non-uterine fibroid (*N* = 3712)	Uterine fibroid (*N* = 331)	*P*-value
Age y,%				< 0.001
20–30	1999 (49.44%)	1958 (52.75%)	41 (12.39%)	
31–44	2044 (50.56%)	1754 (47.25%)	290 (87.61%)	
Race,%				< 0.001
Mexican American	1024 (25.33%)	974 (26.24%)	50 (15.11%)	
Other Hispanic	208 (5.14%)	198 (5.33%)	10 (3.02%)	
Non-Hispanic White	1817 (44.94%)	1688 (45.47%)	129 (38.97%)	
Non-Hispanic Black	802 (19.84%)	674 (18.16%)	128 (38.67%)	
Other Race	192 (4.75%)	178 (4.80%)	14 (4.23%)	
Family income, %				< 0.001
< 1	862 (21.32%)	818 (22.04%)	44 (13.29%)	
≥ 1	2946 (72.87%)	2673 (72.01%)	273 (82.48%)	
Other	235 (5.81%)	221 (5.95%)	14 (4.23%)	
Education level, %				0.006
Less than 9th grade	313 (7.74%)	300 (8.08%)	13 (3.93%)	
9-11th grade	642 (15.88%)	600 (16.16%)	42 (12.69%)	
High school graduate/GED or equivalent	893 (22.09%)	809 (21.79%)	84 (25.38%)	
Some college or AA degree	1291 (31.93%)	1165 (31.38%)	126 (38.07%)	
College graduate or above	901 (22.29%)	835 (22.49%)	66 (19.94%)	
Other	3 (0.07%)	3 (0.08%)	0 (0.00%)	
Marital Status, %				< 0.001
Married	2130 (52.68%)	1925 (51.86%)	205 (61.93%)	
Widowed	19 (0.47%)	15 (0.40%)	4 (1.21%)	
Divorced	247 (6.11%)	205 (5.52%)	42 (12.69%)	
Separated	165 (4.08%)	149 (4.01%)	16 (4.83%)	
Never married	971 (24.02%)	932 (25.11%)	39 (11.78%)	
Living with partner	406 (10.04%)	388 (10.45%)	18 (5.44%)	
Other	105 (2.60%)	98 (2.64%)	7 (2.11%)	
Alcohol use, %				0.054
Yes	799 (19.76%)	724 (19.50%)	75 (22.66%)	
No	762 (18.85%)	715 (19.26%)	47 (14.20%)	
Other	2482 (61.39%)	2273 (61.23%)	209 (63.14%)	
Ever taken birth control pills				< 0.001
Yes	3018 (74.65%)	2733 (73.63%)	285 (86.10%)	
No	1023 (25.30%)	977 (26.32%)	46 (13.90%)	
Other	2 (0.05%)	2 (0.05%)	0 (0.00%)	
Smoking status, %				0.013
Yes	1442 (35.67%)	1310 (35.29%)	132 (39.88%)	
No	2600 (64.31%)	2402 (64.71%)	198 (59.82%)	
Other	1 (0.02%)	0 (0.00%)	1 (0.30%)	
Pregnancy status, %				< 0.001
Yes	973 (24.07%)	939 (25.30%)	34 (10.27%)	
No	2982 (73.76%)	2695 (72.60%)	287 (86.71%)	
Other	88 (2.18%)	78 (2.10%)	10 (3.02%)	
Number of pregnancies, %				< 0.001
1	656 (16.23%)	627 (16.89%)	29 (8.76%)	
> 1	2671 (66.06%)	2398 (64.60%)	273 (82.48%)	
Other	716 (17.71%)	687 (18.51%)	29 (8.76%)	
Age when first menstrual period occurred, years	12.57 ± 1.67	12.59 ± 1.66	12.31 ± 1.76	0.010
BRI	5.13 ± 2.33	5.09 ± 2.31	5.52 ± 2.45	0.001

the demographic and clinical characteristics of study participants, categorized by UF status. Participants with UF differed significantly from those without in terms of age, race, educational background, marital status, household income, and pregnancy status. Participants with UF had higher rates of having ever taken birth control pills, and more importantly, women with UF exhibited higher BRI.

Association between BRI and UF

The association between BRI and UF is presented in Table 2.

Table 2 highlights the connection between BRI and UF. Logistic regression analysis maintained the significance of the link between BRI and UF after considering all confounders. With each unit rise in BRI, there was a corresponding 7% increase in the prevalence of UF. This correlation remained statistically significant when BRI was categorized into quartiles (OR = 1.11,95% CI: 1.04–1.19; $P = 0.0030$).

Upon full adjustment for potential confounders, elevated BRI levels in the fourth quartile were related to a higher incidence of UF compared to the lowest BRI levels in the first quartile (p for trend = 0.003). We also performed subgroup analysis (Table 3). Subgroup analyses categorized by a age, race, education level, marital status, and household income showed that none of the above stratification affected the positive connection between BRI and UF. Furthermore, we performed a smoothed curve fit analysis. It showed a linear association between BRI and UF (Fig. 2).

Discussion

This study's main goal was to look at the relationship between UF and BRI in American women who are of reproductive age. In this study of 4,043 participants, we found that individuals with a higher BRI had an increased likelihood of developing UF. There was a linear positive association between BRI and UF, and this relationship persisted even after adjusting for various confounding factors, including age, ethnicity, educational background, marital status, household income, pregnancy status, smoking habits, alcohol use, age at menarche, number of pregnancies, and history of contraceptive use. Subgroup studies revealed that the connection between BRI and UF was consistent across demographic circumstances, and the positive association remained when BRI was used as the quartile. These findings suggest that the incidence of UF may be attenuated by lowering the BRI.

As far as we know, this is the pioneering study assessing the link between BRI and UF. In earlier studies,

an expanding body of research shows that obesity is instrumental in the pathogenesis of UF. For instance, Templeman et al. [22] conducted a prospective cohort study that revealed higher BMI was related to a higher risk of UF relative to women of normal body size, and that women who gained 20 kg or more had a markedly increased risk compared to those with less than 10 kg weight gain. A Japanese case-control study [23] reported that women with BMI less than 24.0, body fat percentage greater than or equal to 30% or upper body fat distribution, i.e. waist-to-hip ratio greater than 0.80, had a substantially elevated risk of UF. Additionally, studies have explored a possible connection between UF and central obesity. For instance, research from China implied that the chance of UF might be closely tied to an individual's overweight status and central adiposity [24]. BRI is a recently introduced obesity indicator that assesses abdominal obesity more accurately than traditional anthropometric indices by height and WC [25]. BRI is effective in predicting fat distribution in terms of percentage of body fat. Similar to the results of earlier studies, we found in this study that individuals with high levels of BRI may be more likely to develop UF.

To date, the association between BRI and various diseases has received extensive academic attention [26–28]. For example, Wang et al. reported a marked positive link between BRI and the incidence of infertility in American women [29]. In addition, Wei et al. observed that BRI

Table 2 Association between BRI and UF

Variable	Model 1		Model 2		Model 3	
	OR (95% CI)	*P*-value	OR (95% CI)	*P*-value	OR (95% CI)	*P*-value
BRI	1.08 (1.03, 1.12)	0.0014	1.06 (1.01, 1.11)	0.0251	1.07 (1.01, 1.12)	0.0141
Quartiles of BRI						
Q1	1.0 (Reference)		1.0 (Reference)		1.0 (Reference)	
Q2	1.00 (0.71, 1.41)	0.9951	0.90 (0.63, 1.29)	0.5702	0.88 (0.61, 1.26)	0.4846
Q3	1.11 (0.79, 1.55)	0.5514	0.98 (0.69, 1.40)	0.9248	1.00 (0.69, 1.44)	0.9947
Q4	1.63 (1.20, 2.23)	0.0020	1.50 (1.07, 2.08)	0.0171	1.54 (1.08, 2.20)	0.0172
P for trend	1.11 (1.05, 1.18)	0.0005	1.10 (1.03, 1.17)	0.0039	1.11 (1.04, 1.19)	0.0030

Insensitivity analysis to convert BRI from continuous to categorical variable (quartiles)

Model 1: unadjusted for covariates

Model 2: adjusted for age and race

Model 3: age, race, education level, marital status, household income, pregnancy status, smoking, alcohol use, age of first menstrual period onset, number of pregnancies, and ever having taken birth control pills

Table 3 Subgroup analysis of the effect of BRI on uterine fibroids

	OR 95% CI	*P*-value	*P* for interaction
Stratified by age			0.5333
20–30	1.11 (0.97, 1.26)	0.1191	
31–44	1.06 (1.00, 1.12)	0.0398	
Stratified by race			0.0974
Mexican American	1.01 (0.87, 1.16)	0.9173	
Other Hispanic	1.07 (0.60, 1.90)	0.8151	
Non-Hispanic White	1.05 (0.96, 1.15)	0.2708	
Non-Hispanic Black	1.11 (1.03, 1.20)	0.0099	
Other Race	0.49 (0.23, 1.04)	0.0634	
Stratified by PIR			0.0882
< 1	0.96 (0.84, 1.09)	0.5407	
≥ 1	1.10 (1.04, 1.16)	0.0019	
Other	1.30 (0.94, 1.79)	0.1120	
Stratified by Education level			0.9096
Less than 9th grade	1.11 (0.82, 1.50)	0.5117	
9-11th grade	1.06 (0.93, 1.21)	0.3544	
High school graduate/GED or equivalent	1.08 (0.97, 1.19)	0.1656	
Some college or AA degree	1.05 (0.96, 1.14)	0.2652	
College graduate or above	1.14 (0.99, 1.31)	0.0700	
Other	0.00 (0.00, Inf)	0.9985	
Stratified by Marital Status			0.6204
Married	1.10 (1.02, 1.18)	0.0109	
Widowed	0.11 (0.00, Inf)	0.9991	
Divorced	0.97 (0.82, 1.15)	0.7279	
Separated	1.35 (0.95, 1.91)	0.0895	
Never married	1.09 (0.97, 1.24)	0.1484	
Living with partner	0.95 (0.73, 1.24)	0.7143	
Other	1.04 (0.56, 1.93)	0.8908	

"Inf" is used to represent infinity in floating-point format, arising from division operations where the divisor is zero

had a positive correlation with an increased likelihood of gallstones in the American adult population and showed better discriminatory ability in predicting the risk of gallstones compared with BMI [30]. Studies in Chinese populations further support the disease predictive value of BRI: Cai et al. found that elevated BRI was associated with the risk of new-onset hyperuricemia [31], while a longitudinal cohort study by Zhan et al. confirmed a positive association between BRI and hypertension [32]. Previous studies have indicated that BRI, as an indicator reflecting body fat and visceral fat levels, has significant possibility of functioning as a new instrument for health evaluation and disease risk forecasting [25].

UF are a common problem. The underlying mechanisms linking obesity and UF have not been fully understood. The following are some of the theoretical pathways that may exist between them that have been reported to date.

One pathway suggests that, as an endocrine organ, adipose tissue plays a key role in converting circulating androgens to estrone in peripheral tissues. Whereas UF is an estrogen- and progesterone-dependent tumor defined by the excessive growth of smooth muscle cells, increased body fat may therefore lead to an excess of estrogen that stimulates UF cell proliferation [33, 34]. Another mechanism suggests that central obesity may trigger insulin resistance and hyperinsulinemia, which may influence fibroid development in two ways: directly by promoting proliferation of myometrial smooth muscle cells and indirectly by increasing circulating levels of ovarian hormones [35, 36].

After accounting for all confounders, the study found that each one-unit increase in BRI corresponded to a 7% increase in the risk of developing UF. This discovery enhances our understanding of how BRI relates to the risk of developing UF. Since BRI is a readily quantifiable and significant marker of obesity, it is recommended that women in their childbearing years have routine BRI measurements. Effective measures to address obesity, especially by managing abdominal fat in individuals with higher BRI, may positively contribute to the prevention of UF.

Strengths and limitations

This study found a significant link between BRI and the occurrence of UF in women of childbearing age,

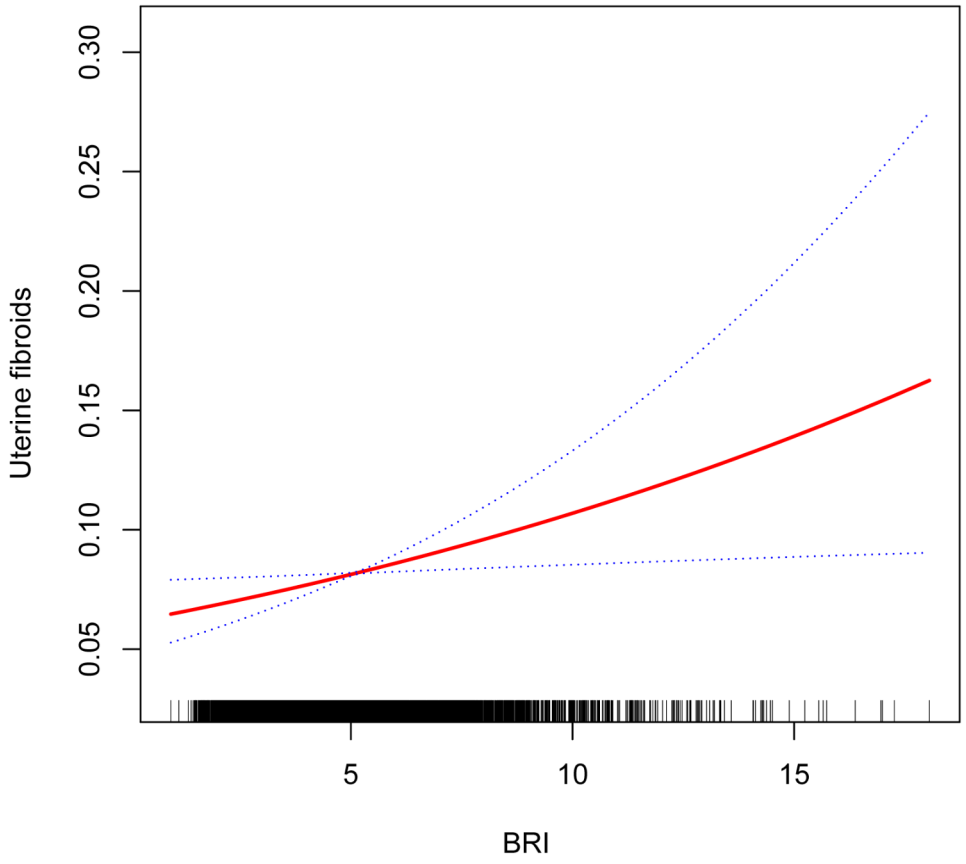

Fig. 2 Association between BRI and UF

deepening our insight into the intricate link between obesity and UF. This study has several advantages: First, it is a large nationally representative cross-sectional survey of US women of childbearing age, which makes our findings more reliable. Second, in our analytical approach, we used multivariate logistic regression models to adjust for a range of relevant confounders in order to examine the effect of BRI on UF. Third, it innovatively examines the association between BRI and UF in a population of U.S. women of childbearing age to gain greater insight into the complex relationship between obesity and UF by utilizing a new body measure.

Nonetheless, some limitations exist within our study. First, owing to the cross-sectional nature of the research, it was not feasible to ascertain a causal connection between BRI and UF in this demographic. Second, although we adjusted for some known confounding factors, other unknown or unmeasured confounding variables may still have an impact, so the results should be viewed with caution. Third, the classification of the presence or absence of UF depends on self-reporting without adequate clinical examination. Future investigations should aim to be more in-depth and meticulous to further confirm this relationship and use more precise techniques for follow-up assessments. Fourth, our study lacks detailed data on the number and size of fibroids. Future studies should employ more objective measurement methods to address these limitations and achieve accurate and precise results. Finally, our survey data focuses on the American population, and further validation of the generalizability of our main findings to a broader population is needed due to differences in lifestyle and dietary habits.

Conclusion

In summary, our analysis of NHANES data revealed a correlation between BRI and UF among women of reproductive age, indicating that higher BRI levels could potentially increase UF risk. However, additional research is needed to substantiate these findings.

Abbreviations

UF	Uterine fibroids
NHANES	National health and nutrition examination survey
BRI	Body roundness index
BMI	Body mass index
WC	Waist circumference
OR	Odds ratio
CI	Confidence interval
Family income	The ratio of family income to poverty
PIR	Poverty income ratio

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Author contributions
FZ: Conceptualization, data wrangling, writing - first draft of the original manuscript. ML: Access to funding, data analysis and oversight of research. SH: Data analysis and surveillance studies. NZ, DW, YZ and FS: Data Wrangling and Analysis.

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Data availability
Detailed data for the study are publicly available at https://www.cdc.gov/nchs/nhanes.

Declarations

Ethics approval and consent to participate
Participants in this study have provided written consent for the NHANES study, and ethical clearance has been secured for the project.

Competing interests
The authors declare no competing interests.

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