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Relationship between Waist Circumference, Waist-Height Ratio, Body Fat Percentage, Visceral Fat and Bone Mineral Density in Middle-Aged and Elderly Zhuang of China

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Abstract

Objective: To understand the correlation between different degrees of obesity and bone mineral density (BMD). Methods: 772 cases (300 men and 472 females) of Zhuang over 40 years old were randomly selected. The BMD and T score were calculated by measuring the right heel bone using a quantitative-ultrasound densitometer. Body composition index of body weight, waist circumference (WC), waist height ratio (WtHR), body fat percentage (BFP) and visceral fat (VF) were measured using a bioelectrical impedance method. **Results:** The BMI, WC, and WtHR of the male osteoporosis group were lower than those of the normal bone mass (NBM) group ($P < 0.05$). BMI, BFP, and WC in the female osteoporosis group were lower than those in the NBM group ($P < 0.05$); The BMI and WC in the osteoporosis group were lower than those of the NBM group ($P < 0.05$). After adjusting for factors such as age, weight, height, etc., the binary multivariate conditional logistic regression analysis showed that BMI was a protective factor for bone mass loss in men and women ($P < 0.01$). While the level of visceral fat was a risk factor for reduced bone mass ($P < 0.05$). **Conclusion:** BMI is positively correlated with BMD in Zhuang. BFP has a greater correlation with female BMD, and a small reduction in BFP can result in a significant decrease in BMD. BMD of male was positively correlated with abdominal obesity indicators (WC, WtHR, VF).

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However, abdominal obesity has no obvious effect on the promotion of BMD in women, and increased WtHR can lead to a decrease in BMD. Zhuang can appropriately increase the amount of fat within the normal weight range. At the same time, reasonable exercise and balanced nutrition to avoid excessive obesity or low body weight can reduce the incidence of osteoporosis and osteoporosis fractures.

Keywords

Middle-Aged and Old People, Bone Mineral Density, Obesity, Correlation

1. Introduction

Obesity and osteoporosis have become common diseases in middle-aged and elderly people. Osteoporosis (OP) is a systemic bone disease characterized by decreased bone mass, destruction of bone microstructure, increased bone fragility, and is prone to fracture [1]. The complication of brittle fracture can seriously affect the quality of life of middle-aged and elderly people. Previous studies have suggested that body weight is a protective factor for OP, but some studies have found that obesity is associated with OP [2] [3]. One study showed that obesity was associated with a lower risk of hip (men and postmenopausal women) and wrist (postmenopausal women) fractures, but a higher risk of ankle fractures (postmenopausal women) [4]. And Anja found that BMI over 25 was associated with an increased risk of ankle fracture [5]. In addition, there was an inverted U-shaped association between BMI and lumbar BMD in obese middle-aged adults [6]. Therefore, understanding the effects of different obesity on bone mineral density (BMD) is necessary to prevent OP associated with obesity.

Characteristics and prevalence of OP are different due to differences in geographical environment, economic development, customs, and diet structure of various ethnic groups and regions in China. Currently, there are few studies on the effect of obesity on BMD in the Zhuang population. Zhuang is the most populous minority in China, distributed mainly in southwest China, with a total of 16.92 million. This study determined the BMD and obesity index including BMI, body fat percentage (BFP), waist circumference (WC), waist-to-height ratio (WtHR), visceral fat (VF), analyzed the correlation between BMD and different levels of obesity among middle-aged and elderly people in Zhuang, and provided scientific evidence for prevention of OP and treatment of its complications.

2. Research Objects and Methods

2.1. Research Object

From July 2016 to November 2016, in the case of informed consent, a random cluster sampling method was used to extract middle-aged and old people from Debao, Tiandeng, Daxin, Wuming County, and Yizhou City of southwest China in the Guangxi Zhuang Autonomous Region. A total of 837 people were selected, excluded according to the exclusion criteria, eventually 772 people including 300 males and 472 females.

Inclusion criteria: The study subjects selected people 40 to 90 years of age who were Zhuang and had no blood relationship with the three generations of grandparents in Guangxi province, China.

Exclusion criteria: Patients with chronic heart disease, liver and lung disease, patients with endocrine diseases, and those who have used drugs that affect bone metabolism within one year.

Since the age of 40, 10 years is an age group, 70 years and older are classified into the same age group, and men and women are divided into 4 age groups, a total of 8 groups.

2.2. Research Methods

The Medical Ethics Committee of Youjiang Medical University for Nationalities approved this study (2015030101). All procedures are carried out with the full understanding and written consent of all participants.

2.2.1. Height Measurement

The person in the test stands naturally and the height is measured by the height measurement to the nearest 0.1 cm.

2.2.2. Measurement of Body Composition

In this study, body composition was measured using a Bioelectrical Impedance Analyzer (Japan TANITA, MC-180). Before the test, relevant data are input, such as name, height, age, sex, etc. The subject removes all metal objects that come into contact with the body. In a quiet state, the subject bare feet step on the left and right foot electrodes.

Holding the hand electrodes with both hands, the thumb, palm and the other 4 fingers are respectively in contact with the corresponding electrode points, the body is relaxed, the upper limbs naturally sag, after about 30 s The subject's weight, WC, WtHR, BFP, VFG and other index values were obtained.

2.2.3. Measurement of Bone Mineral Density

Using an Ultrasound Bone Densitometer OSTEOSPACE (MEDILINK, France) to measure the site of the right heel of the inside and outside of the heel (95% of the heel is metabolically active sponge-like bone, sensitive to bone changes, the calcaneus is nearly parallel to both sides, and the test compliance is good, which can reduce the measurement error). Measurement method; the subject's skin surface is coated with a uniform amount of standard ultrasonic gel, the right foot is placed in the foot groove, the foot plate, and the heel is fully contacted, and the probe is fully coupled with the inner and outer sides of the heel by the gel to obtain a wide band ultrasound attenuation (BUA, db/MHz) of the calcaneus. The BUA can reflect the change in BMD, and thus the BMD value is expressed and the corresponding T score is calculated. Standard calibration is performed before each measurement, and the operation is performed by a fixed professional.

2.3. Diagnostic Criteria and Grouping Basis

For OP, the diagnostic criteria established by the World Health Organization are used and the T score (T score is the value obtained by dividing the difference between the BMD of the measured person and the maximum bone mass of the healthy young person by the standard deviation) is judged. T > −1 SD is normal bone mass, −2.5 SD ≤ T < −1 SD for bone loss, and T < −2.5 SD for OP. Body mass index (BMI) = body weight (kg)/height (m^2), diagnostic criteria: BMI < 18.5 for underweight, 18.5 ≤ BMI < 24 for normal weight, 24 BMI < 28 for overweight, BMI 28 is obesity. Grouping of BFP: male BFP < 12%, female body fat rate < 22%, low BFP group; male BFP 12% to 18%, female BFP 22% to 30%, standard BFP group; male BFP > 18%, female BFP > 30%, high BFP group.

2.4. Statistical Processing

The measured data was exported by body composition analysis software by Health Fitness Central Station Management System V9 (ACMEWAY Health Technology Co., Ltd., Beijing, CHINA). The data was analyzed using IBM SPSS Statistics version 18 (IBM SPSS Inc., Chicago, USA) software. Statistical methods such as the chi-square test, single-factor analysis, analysis of variance, and Pearson's correlation analysis were used. $P < 0.05$ was considered significant. Classification variables were analyzed using logistic regression analysis for possible influencing factors. The difference was highly significant at $P < 0.01$.

3. Results

3.1. Comparison of Baseline Data between Male and Female of Zhuang Nationality in Southwest China

WC, WtHR, and VFG in the male OP group were lower than in the normal bone mass group ($P < 0.05$), while the difference in BMI was statistically significant ($P < 0.01$). The BMI, WC and BFP of the female OP group were lower than those in the normal bone group ($P < 0.05$), but there was no significant difference in WtHR and VFG ($P > 0.05$) (**Table 1**).

The detection rates of OP in men and women were 29.3% and 64.2%, respectively, the detection rates of bone loss were 27.7% and 14.4%. The female OP detection rate is 2.19 times that of males, and bone loss reduction and OP are combined into the abnormal bone mass group. The abnormal bone mass rate for female bone mass is 78.6% higher than that of male 57%.

3.2. Correlation Analysis between Bone Mineral Density, Body Fat Percentage, Visceral Fat Grade, Waist Circumference, and Waist-to-Height Ratio

Male BMD was positively correlated with BMI, WC, WtHR and VFG ($P < 0.05$), and negatively correlated with age ($P < 0.05$) (**Table 2**). Female BMD was positively correlated with BMI and BFP ($P < 0.01$), negatively correlated with age ($P < 0.01$) and did not have a significant correlation with WtHR and VFG ($P > 0.05$).

Table 1. Baseline data of different levels of obesity in normal, bone mass and osteoporotic levels groups in middle-aged and elderly people of Zhuang nationality in southwest China.

Project	Male			total	Female			Total
	Normal bone mass	Low bone mass	Osteoporosis		Normal bone mass	Low bone mass	Osteoporosis	
N (%)	129 (43%)	88 (29.3%)	83 (27.7%)	300	101 (21.4%)	68 (14.4%)	303 (64.2%)	472
Age (year)	58.22 ± 12.28	60 ± 10.72	60.96 ± 9.71	59.5 ± 11.19	48.42 ± 7.58	53.82 ± 8.82**	59.08 ± 11.03**	56.04 ± 10.97
BMD (db/MHz)	67.31 ± 4.60	57.87 ± 1.82**	48.08 ± 4.82**	59.22 ± 8.92	66.97 ± 4.09	58.26 ± 1.50**	49.87 ± 4.61**	54.74 ± 8.16
BMI (kg/m^2)	23.49 ± 3.06	22.64 ± 3.37	21.79 ± 2.92**	22.78 ± 3.18	24.19 ± 2.81	23.69 ± 3.05	22.46 ± 3.16**	22.99 ± 3.16
Body fat percentage	17.32 ± 5.97	16.37 ± 6.32	15.83 ± 7.27	16.63 ± 6.46	29.79 ± 6.03	29.55 ± 6.76	27.49 ± 7.25**	28.28 ± 7.00
Waist circumference (cm)	85.44 ± 9.12	83.77 ± 8.89	82.58 ± 8.73*	84.16 ± 9.00	82.34 ± 20.62	83.6 ± 11.67	78.81 ± 13.58*	80.26 ± 15.23
Waist-to-height ratio, WtHR	0.53 ± 0.05	0.52 ± 0.05	0.52 ± 0.05*	0.53 ± 0.05	0.55 ± 0.13	0.56 ± 0.05	0.57 ± 0.08	0.56 ± 0.09
Visceral fat grade	11.14 ± 3.31	10.55 ± 3.27	10.08 ± 2.89*	10.67 ± 3.2	5.34 ± 2.19	5.81 ± 2.71	5.37 ± 2.56	5.42 ± 2.51

Note: Compared to the normal group ** $P < 0.01$ * $P < 0.05$.

Table 2. Correlation analysis of bone mineral density with BMI, body fat percentage, visceral fat grade, waist circumference, waist-to-height ratio.

		Age	BMI	Waist circumference	Waist-to-height ratio	Body fat percentage	Visceral fat grade
Male	*r*	−0.135*	0.218**	0.165**	0.144*	0.092	0.116*
(*n* = 300)	*P*	0.019	0.000	0.004	0.013	0.111	0.044
Female	*r*	−0.490**	0.240**	0.015	−0.087	0.135**	−0.023
(*n* = 472)	*P*	0.000	0.000	0.749	0.060	0.003	0.611

Note: ** $P < 0.01$ * $P < 0.05$.

3.3. Bone Mineral Density and Osteoporosis Detection Rate between Different Groups of Body Fat Percentage

The difference in bone mineral density and OP rate between the high body fat group and the low body fat group was statistically significant only in women ($P < 0.05$) (Table 3).

3.4. Analysis of Risk Factors for the Reduction of Calcaneal Bone Mass in the Zhuang Population

T value ($T \geq -1$ is normal bone mass. $T < -1$ is bone mass loss) as a dependent variable. Age, height, weight, waist circumference, waist-to-height ratio, body fat percentage, visceral fat grade, visceral fat grade group, waist-to-hip ratio grouping, and body fat percentage grouping were used as covariates, and forward step (condition) of logistic regression was used for the analysis.

Regardless of whether male and female, BMI was a protective factor for bone mass reduction in model a ($P < 0.01$). In model b, BMI was still a protective factor for bone mass reduction ($P < 0.001$), while visceral fat grade was a risk factor for reduced bone mass ($P < 0.05$) (Table 4).

3.5. Influence of BMI on Bone Mineral Density of Different Ethnic Groups

In the same BMI group, the BMD of males in Zhuang was lower than that of the Jing nationality. There was significant statistical significance between the normal BMI group and the obesity group ($P < 0.01$). The difference between the other two groups was not statistically significant ($P < 0.01$); the same BMI group of Zhuang female and Jing female had statistical significance ($P < 0.01$), and the bone density of each group of Zhuang female was lower than that of Jing (Table 5) and (Figure 1).

Table 3. Results of bone mineral density and osteoporosis in different body fat percentages of middle-aged and elderly people in Zhuang.

	Male				Female			
Group of body fat percentage	*n*	BMD (db/MHz)	Number of OPs (% in group)	OP of total males (%)	*n*	BMD (db/MHz)	Number of OPs (% in group)	OP of total females (%)
Low	85	57.47 ± 9.31	32 (37.60)	10.67	94	52.52 ± 7.45**	73 (77.70)	15.47
Normal	178	59.74 ± 8.65	43 (24.20)	14.33	322	55.06 ± 8.29	200 (62.10)	42.37
High	37	60.75 ± 8.95	8 (21.60)	2.7	56	56.61 ± 7.91**	30 (53.60)	3.36
		F = 2.496 $P = 0.084$		$\chi^2 = 7.410$ $P = 0.116$		F = 5.291, $P = 0.005$		$\chi^2 = 10.857$ $P = 0.028$

Compared with female body fat rate standard group** $P < 0.01$.

Table 4. Multivariate the forward stepping-conditional Logistic regression analysis of risk factors for bone mass loss in male and female.

	Variables	B	Error	Wald	*P*	*OR*	95%CI	
							Lower limit	Upper limit
Model 1[a]	Body mass index	−0.231	0.063	13.610	0.000	0.794	0.702	0.898
	Visceral fat grade	0.591	0.276	4.600	0.032	1.807	1.052	3.102
	constant	4.506	1.109	16.518	0.000	90.545		
Model 2[b]	Body mass index	−0.243	0.048	25.709	0.000	0.784	0.714	0.861
	Visceral fat grade	2.014	0.624	10.430	0.001	7.496	2.208	25.455
	constant	4.947	1.036	22.786	0.000	140.719		

a. Variables entered in Model 1: Body mass index. Visceral fat grade (male); b. Variables entered in Model 2: Body mass index Visceral fat grade (female).

Table 5. Comparison of bone mineral density among middle-aged and elderly People of Zhuang and Jing nationality in southwest China.

Group of BMI	Male						Female					
	Zhuang people		Jing people				Zhuang people		Jing people			
	n	BMD (db/MHz)	*n*	BMD (db/MHz)	*t*	*P*	*n*	BMD (db/MHz)	*n*	BMD (db /MHz)	*t*	*P*
Underweight	23	55.54 ± 8.54*	22	58.55 ± 5.59**	1.404	0.170	39	48.78 ± 5.20**	19	56.28 ± 4.23**	5.269	0.000
Normal weight	187	58.71 ± 8.81	116	64.29 ± 5.93	6.584	0.000	267	53.92 ± 7.90	122	59.91 ± 6.32	7.608	0.000
Overweight	68	61.24 ± 7.52*	41	63.50 ± 5.65	1.780	0.078	129	56.83 ± 8.17**	49	63.15 ± 6.45**	5.47	0.000
Obesity	22	62.08 ± 7.87	53	67.55 ± 4.63**	3.048	0.005	37	56.87 ± 7.39**	38	61.93 ± 7.02	2.638	0.010
		F = 3.501		-				F = 10.403		-		
		P = 0.016		-				*P* < 0.001		-		

Compared with normal same BMI group * $P < 0.05$ ** $P < 0.01$.

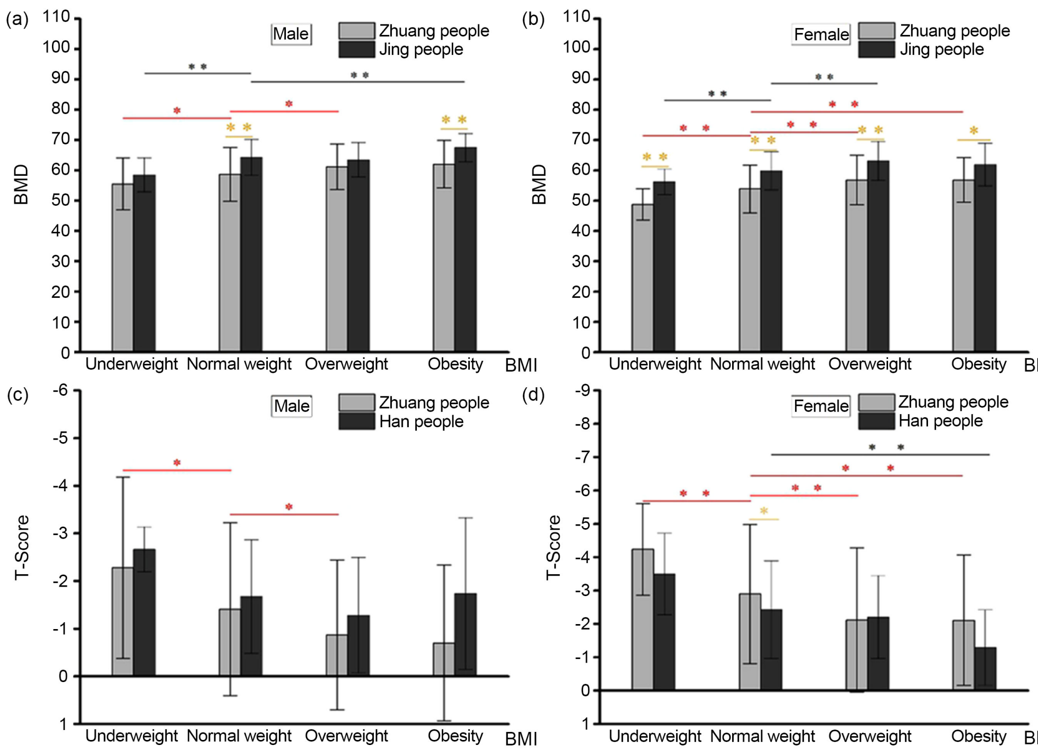

Figure 1. Comparison of bone mineral density or T score among male/female of Zhuang and Jing/Han [5]. Compared with normal same BMI group * $P < 0.05$ ** $P < 0.01$.

4. Discussion

4.1. The Effect of BMI on Bone Mineral Density of Zhuang and Comparison with Other Ethnic Groups

With the increasing incidence of osteoporosis and obesity, OP common complications, cardiovascular diseases and other chronic diseases caused by obesity seriously affect the health and quality of life of middle-aged and elderly people [7].

However, the effect of obesity on bone density remains controversial [3] [8]. Body weight, as a reflection of the body's nutritional status, has been shown to be a protective factor for bone density, including fat free mass (FFM) and fat mass (FM), which is composed of muscle mass and bone mass. The amount of fat includes the amount of VFG and the amount of subcutaneous fat [9]. BMI can indirectly reflect the degree of fatness and thinness. In this study, the above indicators were used to evaluate the effect of obesity on BMD. Previous studies have suggested that the amount of fat has a protective effect on BMD [10] [11]. This study also showed that the BMD of the middle-aged and elderly people in Zhuang is positively correlated with BMI.

The BMI in the normal bone mass group is higher than that in the osteoporosis group, which is consistent with previous studies [12]. Multivariate conditional regression analysis showed that BMI was a protective factor for normal bone mass [13]. Small and middle-aged people are more likely to suffer from osteoporotic fractures than those with high height and high body weight [12]. However, studies found that obese people are more stressed on the vertebral body, and spinal fractures are more likely to occur when the bone density decreases [13]. This was also found in our research (data not show).

Comparing the research data of Zhuang and Jing and Han, high BMI also has a protective effect on BMD of Jing and Han people, which is consistent with the above conclusions. Under the same BMI group, BMD of male and female groups in Zhuang was lower than that of Jing and Han nationalities (**Figure 1**). The BMD of female in Zhuang was significantly different from that of Jing female. Because Zhuang and Jing belong to the same branch genetically, the possible reasons are presumed: Zhuang people live in hilly areas. Rice, corn and vegetables are their mainly food, while Jing people live on the coast for a long time with seafood such as fish and shrimp. This seafood is rich in protein and calcium ions, which are beneficial to increase the bone density of the Jing people and slow down their bone loss.

4.2. Effect of Abdominal Obesity on Bone Mineral Density of Middle-Aged and Elderly People in Zhuang

Recently, it has been found that obesity also has an adverse effect on bone. The bone density changes with the effects of fat on sugar, fat metabolism and endocrine in different parts [14]. When the local fat is excessively accumulated and the bone metabolism is increased, the bone loss of the relative parts is increased [15]. As the age increases, fat can be redistributed, the accumulation of visceral and abdominal fat increases, and abdominal obesity occurs [16].

This study found that the effect of abdominal obesity on BMD in Zhuang female is not obvious, and the increase in female WtHR may lead to a decrease in bone density. The WC, WtHR and VFG of the Zhuang male normal bone group were higher than those of the osteoporosis group. The BMD was positively correlated with abdominal obesity index (WC, WtHR, VFG). However, after adjusting the age, body mass, height and other factors, using multivariate conditional logistic regression analysis showed that visceral fat grade was significantly associated with calcaneal bone mass loss and independent of bone mass loss of traditional risk factors. In the male population, the risk of bone mass loss was significantly higher in individual with visceral fat grade (over high), which was 9.286 times that of Visceral fat grade (normal). Visceral fat grade increases per unit in the female population, the individual's risk of osteopenia increased by 38%.

Although fat has a certain protective effect on BMD, VFG over high is associated with bone mass loss, hyperglycemia, hyperlipemia, hypertension and coronary heart disease. Therefore, reducing VFG accumulation, proper physical exercise, and avoiding abnormal abdominal obesity can effectively delay bone mass loss and other chronic diseases [17].

4.3. Effect of Body Fat Percentage on Bone Mineral Density in Zhuang Population

The effect of body fat percentage on the BMD of Zhuang female is larger than that of male. The small decrease of BFP can decrease the bone density, which may be related to the load of fat and bone tissue and the promotion of estrogen production [18]. The muscle mass ratio is consistent with the BFP. The higher the BFP, the higher the muscle mass, and the lower the incidence of osteoporosis, which is consistent with the study [19] [20]. Within a certain range, the greater the mechanical stimulation produced by exercise, the stronger the effect on bone promotion [21] [22], which is related to the effect of osteoblasts and bone marrow stem cells on motor stimuli response and muscle strength [23] [24]. Therefore, high body fat ratio can cause many chronic diseases, so proper diet and proper physical activity are the main factors to maintain normal BFP and bone health [25] [26] [27].

5. Conclusions

The BMD of middle-aged and elderly people in Zhuang decreased with age, and increased with the increase of BMI and body fat percentage. Among them, body fat percentage has a greater effect on female BMD than males, and proper abdominal obesity can increase male BMD. Therefore, it is recommended that male Zhuang people in southwest China can increase the amount of fat in the normal weight range, but to avoid excessive visceral fat, and women should maintain normal body fat rate. Both men and women should strengthen physical exercise and the reasonable diet to prevent or slow bone loss.

In the past, although many studies have studied the relationship between obesity and BMD by using BMI, but at the same time, it was rare to study the relationship between several obesity evaluation indicators and BMD. This study clarifies the correlation between different obesity evaluation indexes and BMD, to provide a certain degree of innovation in assessing the relationship between fat content, fat distribution and bone density. However, this study only studied the Zhuang population, and this conclusion may not apply to Han or other people.

6. Limitations

This cross-sectional study found an association between waist circumference, waist height ratio, body fat percentage, visceral fat, and bone mineral density in middle-aged and elderly people, although its causal relationship remains unknown. Furthermore, the subjects of this study are township residents with average living standards, and the research results cannot represent the situation of urban residents with better living standards.

Compliance with Ethical Standards

Ethical Approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments and/or comparable ethical standards.

Informed Consent

Additional informed consent was obtained from all individual participants for whom identifying information is included in this article.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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