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Combining OSTA and BMR to predict osteoporosis in Chinese population

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Abstract

Introduction Osteoporosis is a debilitating bone disease that significantly contributes to disability and a loss of autonomy among older adults. This study aimed to characterize osteoporosis and explore the feasibility of combining OSTA and BMR for osteoporosis prediction.

Methods A cross-sectional study involving 1435 participants (1300 women and 135 men) was conducted. Spearman's correlation, simple linear regression analyses, and multiple linear regression models were utilized to investigate the association between OSTA, BMR, and bone mineral density (BMD). Furthermore, the efficacy of integrating OSTA with BMR for osteoporosis screening and prediction was assessed through receiver operating characteristic (ROC) curves.

Results In the total population, the sensitivity of combination variable W was 58.63%, and the specificity was 70.90%. When OSTA and BMR were employed separately to diagnose osteoporosis, the sensitivity was 47.70% and 55.34%, respectively, while the specificity was 63.80% and 69.80%, respectively.

Conclusions The combined utilization of OSTA and BMR formula represents an effective screening method for osteoporosis.

Keywords Osteoporosis, OSTA, BMR, China

Introduction

Osteoporosis, a prevalent bone disease [1], poses a significant threat to the health and independence of older adults [2], particularly postmenopausal women [3]. Osteoporosis is characterized by reduced bone mineral density (BMD) and compromised bone strength, leading to an increased risk of fractures. The prevalence of osteoporosis escalates with age, and its associated medical and economic burdens are projected to rise steeply in the coming years [4]. It is anticipated that by 2025, there will be over 3 million fracture cases attributed to osteoporosis, with an estimated cost of $25.3 billion, representing an increase of over 48% compared to previous years [5]. This trend underscores the urgency of implementing effective prevention and management strategies to mitigate the impact of osteoporosis on public health.

Bone mineral density (BMD) is a pivotal metric for assessing bone mass and structural integrity [6]. It is typically evaluated using T-scores and Z-scores [7]. Notably, the World Health Organization (WHO) defines a T-score threshold of less than −2.5 as indicative of osteoporosis [8]. Despite BMD being the gold standard for diagnosing osteoporosis, its measurement requires a specialized healthcare facility. Consequently, researchers have sought relevant and reliable screening tool for osteoporosis.

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Multiple serological markers [9], including protein levels [10, 11], blood calcium [12], and vitamin D concentrations [13, 14], have been identified as potential indirect predictors of BMD [15]. Additionally, research has shown a positive correlation between hand grip strength and maximum peak expiratory flow with BMD among adolescent students of both sexes [16]. Correlations between BMD and factors such as muscle strength, lung capacity, and height [17] have also been reported.

The Osteoporosis Self-Assessment Tool for Asians (OSTA), proposed by Koh et al. in 2001, serves as an indicator for screening osteoporosis. It is calculated using the formula: OSTA score = [body weight - age] × 0.2 [18, 19]. The basal metabolic rate (BMR) is a metric that reflects the overall body metabolism [20], albeit with some individual variability. Notably, it may also serve as an indicator of bone metabolism, suggesting its potential as a modifiable factor in reducing the incidence of osteoporosis [20].

To explore the potential of combining OSTA and BMR as a predictive tool for osteoporosis, in the population of northwestern China, a cross-sectional study was conducted involving 1435 subjects. Ultrasound BMD measurements were employed to determine these metrics. The study delved into the impact of OSTA, and BMR on BMD and fracture risk in this specific population. Furthermore, an innovative approach was taken by combining OSTA and BMR into a single, novel variable. The objective of this integration was to ascertain whether the combined variable could offer a more comprehensive perspective on BMD and potentially enhance its prediction. The analysis focused on assessing the feasibility of using this new variable as a predictive tool for BMD.

Methods

Ethical approval

The Second Affiliated Hospital of Xi'an Jiaotong University has approved the trial (No.2023264) and written informed consent was obtained from each participant.

Study design and population

This is a cross-sectional study. A total of 1300 female and 135 male participants aged 30 years or older were randomly recruited from Chinese square dance groups in Xi'an, Shaanxi province of China between July 2022 and August 2022. Each participant should undergo anthropometric and wrist BMD measurements.

Data collection

A general anthropometric measurement was performed on all participants. Weight and height were measured by wearing thin clothes and removing shoes. BMI was calculated as weight (kg) divided by height squared (m^2). OSTA score = [body weight - age] × 0.2. The Mifflin-St Jeor formula is widely used for estimating basal metabolic rate (BMR) [21], the minimum number of calories required for the body to function at rest. The formula is as follows:

For males: BMR (Kcal/day) = Weight (kg) × 10 + Height (cm) × 6.25 - Age (years) × 5 + 5.

For females: BMR (Kcal/day) = Weight (kg) × 10 + Height (cm) × 6.25 - Age (years) × 5–161.

To assess bone health, we utilized a quantitative ultrasound bone mineral density (BMD) instrument to measure the bone mineral density (BMD) of the right wrist in our subjects, adhering to methodologies previously established in the literature. This approach ensures the accuracy and reliability of our findings, contributing to the ongoing research on bone health and its associated factors [22].

The Fracture Risk Assessment Tool (FRAX) was first employed in 2008 to assess a patient's risk of developing an osteoporotic fracture [23], utilizing risk factors such as body measurement parameters [24]. The FRAX score was used to ascertain the participants' 10-year risk of major osteoporotic fracture and hip fracture.

Definition

A diagnosis of osteoporosis is made based on the WHO definition [25]. According to the WHO, T-score represents the number of standard deviation (SD) below or above the average BMD. Participants were classified as normal (T-score > -1.0), osteopenia (-2.5 < T-score < -1.0), and osteoporosis (T-score < -2.5). Based on the OSTA value it can be classified as, low risk (OSTA > -1), intermediate risk (-1 < OSTA < -4), and high risk (OSTA < -4).

Statistical analysis

Statistical analyses were performed using the Statistical Package for the Social Sciences version 26 (SPSS Inc., Chicago, IL, USA). Continuous variables are expressed as mean±SD and categorical data are presented as percentages. Student's t-tests, unpaired and paired, were used to compare linear variables, while dichotomous variables were assessed using a chi-squared test. Spearman regression analyses, as well as univariate and multiple linear regression analyses, were conducted to examine the correlations between the T-score and various variables, including OSTA score, BMR, and gender. Furthermore, univariate and multiple linear regression analyses were utilized to assess the relationships between the FRAX score and the variables above OSTA, BMR, and gender. These comprehensive statistical approaches allowed for a rigorous evaluation of the potential associations between bone health indices and various demographic and physiological factors. A P-value < 0.05 is considered statistically significant.

Table 1 The baseline specificity of the study population

Clinical variables	Overall	Female	Male
Numbers	1435	1300	135
Height (cm)	160.36 ± 6.14	159.46 ± 5.23	169.06 ± 6.54
Weight (kg)	60.22 ± 8.65	59.30 ± 7.87	69.10 ± 10.67
BMI (kg/m^2)	24.37 ± 2.62	24.29 ± 2.68	25.10 ± 2.93
Age (years)	62.95 ± 7.21	62.82 ± 6.92	64.21 ± 9.52
SOS(m/s)	3927.45 ± 391.27	3927.60 ± 392.11	3927.54 ± 392.02
BMD, n (%)			
Normal	366 (25.54)	307 (23.63)	60 (44.44)
Osteopenia	461 (32.12)	414 (31.81)	47 (34.81)
Osteoporosis	608 (42.34)	579 (44.56)	28 (20.74)
T-score	-2.19 ± 1.91	-2.19 ± 1.91	-2.19 ± 1.91
Z-score	-0.25 ± 4.47	-0.24 ± 4.48	-0.25 ± 4.48
OSTA, n (%)			
Low	781(54.42)	683(52.51)	98(72.39)
Moderate	586(40.84)	553(42.55)	34(25.54)
High	68(4.74)	64(4.94)	5(3.73)
BMR(kcal/d)	1144.25 ± 145.98	1114.52 ± 108.86	1431.59 ± 147.31

BMI, body mass index; BMD, bone mineral density; OSTA, Osteoporosis Self-Assessment Tool for Asians; BMR, Basal Metabolic Rate

Table 2 Spearman regression analysis of bone mineral density T-values

Variable	Overall		Female		Male	
	Coefficient	*P*	Coefficient	*P*	Coefficient	*P*
Gender	-0.165	< 0.001	-	-	-	-
BMR	0.267	< 0.001	0.219	< 0.001	0.198	0.022
OSTA	0.104	< 0.001	0.277	< 0.001	0.347	< 0.001

Results

The baseline specificity of the study population

The baseline characteristics of the overall population are presented in Table 1. A total of 1435 participants (1300 women and 135 men) were included in this cross-sectional study. According to Table 1, there is no significant difference in the mean BMI between the sexes. The prevalence of osteoporosis among all participants was 42.34%, with a higher prevalence in the female population (44.56%) than in the male population (20.74%).

The mean ultrasonic velocity (UV) was 3927.45 ± 391.27 m/s in the total population, 3927.60 ± 392.11 m/s in the female population, and 3927.54 ± 392.02 m/s in the male population. The average BMR among the entire population was 1144.25 ± 145.98 kcal/d. Specifically, within the female subpopulation, the mean BMR was 1114.52 ± 108.86 kcal/d. Conversely, among the male subpopulation, the mean BMR was 1431.59 ± 147.31 kcal/d.

Spearman regression analysis between BMR, OSTA, and BMD

Table 2 illustrates a correlation between gender, OSTA, and BMD T-values ($P < 0.05$). Spearman's correlation analysis shows a positive correlation between BMR and T score and between OSTA and T score. This indicates that an elevated BMR and OSTA are associated with elevated T-score levels.

Our detailed investigation into gender-specific subgroups revealed some fascinating insights. Among the female group, we observed a significant correlation between BMR and OSTA scores with T-score ($P < 0.05$), indicating that these two factors play a crucial role in predicting T-scores in females. In contrast, for the male group, we found a similar significant correlation between BMR and OSTA scores with T-score. These findings suggest that both these variables have an important impact on T-scores, albeit in a gender-specific manner.

Regression analysis between BMR, OSTA, and BMD

The results of the statistical analysis, as demonstrated in Table 3, indicate that gender, BMR, and OSTA are all associated with the T-score in the overall study population($P < 0.001$). Moreover, the multivariate linear regression analysis showed that BMR and OSTA remained significant predictors of the T-score, even after controlling for the effects of the other variables.

Additionally, separate univariate and multivariate linear regression analyses on the female study population were conducted, as presented in Table 3. The finding of OSTA was further supported by the multiple linear regression analysis, which showed that BMR was negatively

Table 3 Linear regression analysis for T-score

Population	Variable	Univariate linear regression		Multivariate linear regression	
		β (95% CI)	*P*	β (95% CI)	*P*
Overall	Gender	-1.027(-1.359, -0.695)	< 0.001	0.006(0.414, -0.427)	0.977
	BMR	0.003(0.003, 0.004)	< 0.001	0.005(0.004, 0.007)	< 0.001
	OSTA	0.089(0.047, 0.131)	< 0.001	-0.128(-0.186, -0.069)	< 0.001
Female	BMR	0.004(0.003, 0.005)	< 0.001	-0.015(-0.019, -0.011)	< 0.001
	OSTA	0.239(0.193, 0.284)	< 0.001	0.793(0.635, 0.950)	< 0.001
Male	BMR	0.002(0.000, 0.004)	0.046	-0.008(-0.012, -0.003)	0.001
	OSTA	0.171(0.078, 0.264)	< 0.001	0.515(0.288, 0.742)	< 0.001

Table 4 Multivariate linear regression analysis for fracture risks

Population	Variable	major osteoporotic fracture		hip fracture	
		β (95% CI)	*P*	β (95% CI)	*P*
Overall	Gender	-0.120(-0.336, 0.096)	0.276	-0.900(-1.049, -0.750)	< 0.001
	T-score	-0.112(-0.139, -0.086)	< 0.001	-0.060 (-0.079, -0.042)	< 0.001
	BMR	-0.005(-0.006, -0.005)	< 0.001	-0.004(-0.004, -0.003)	< 0.001
	OSTA	0.052(0.022, 0.081)	< 0.001	-0.010(-0.030, 0.011)	0.357
Female	T-score	-0.022(-0.034, -0.009)	0.001	0.004(-0.007, 0.015)	0.464
	BMR	0.013(0.013, 0.014)	< 0.001	0.008(0.007, 0.008)	< 0.001
	OSTA	-1.051(-1.079, -1.023)	< 0.001	-0.657 (-0.682, -0.633)	< 0.001

MO, 10-year risk of major osteoporotic fracture; HP, 10-year risk of hip fracture

correlated with the T-score ($P<0.001$) and OSTA was positively correlated with the T-score ($P<0.001$).

Association between gender, BMR, OSTA, BMD, and fracture risks

To address the association between BMR, OSTA, and the 10-year risk of major osteoporotic fracture (MO) and hip fracture (HP), we carried out multiple linear regression analyses. The results demonstrated that T-score, BMR, and OSTA were significantly correlated with MO in the total population. In particular, OSTA was positively correlated with MO, while T-score and BMR were negatively correlated with MO (Table 4). Furthermore, our analysis revealed that gender, T-score, and BMR were significantly associated with HP in the total population. In particular, gender, T-score, and BMR were negatively correlated with HP (Table 4).

After we analyzed the total population, we then carried out the subgroup analyses for females. According to Table 4, in the female population, T-score, BMR, and OSTA were significantly associated with both MO. Moreover, BMR and OSTA were significantly related to both HP. In particular, BMR was positively correlated with MO and HP. Specifically, T-score and OSTA were negatively correlated with both MO. Finally, OSTA was negatively correlated with HP.

Representation of W, OSTA, and BMR in the prediction of osteoporosis

In this study, we combined OSTA and BMR to create a new variable, W, specifically tailored for assessing osteoporosis risk. For the entire study population, we calculated W using a formula that also considered weight ($W = -7.128 - 0.02\times OSTA + 0.008\times BMR - 0.07\times weight$). To enhance accuracy, we further customized the formula for men and women separately ($W = 9.757 + 0.75\times OSTA - 0.0035\times BMR - 0.225\times BMI$ for males and $W = -0.911 + 0.321\times OSTA + 0.004\times BMR - 0.094\times weight$ for females). (Fig. 1; Table 5)

Analyzing the overall results, we found that the predictive power of W, as measured by the area under the curve (AUC), was 0.688, outperforming both OSTA and BMR individually. Specifically, OSTA's AUC was 0.568, while BMR's was 0.655.

When focusing on women alone, W's AUC increased slightly to 0.706, demonstrating even better predictive accuracy compared to OSTA (0.681) and BMR (0.634). Similarly, in men, W's AUC was 0.710, again exceeding both OSTA (0.685) and BMR (0.631) in terms of predictive performance.

In summary, our novel variable W, derived from a combination of OSTA, BMR, and weight (or BMI for men), provides a more accurate assessment of osteoporosis risk compared to using these factors individually, especially when tailored for specific genders.

Discussion

This study aimed to investigate the characteristics and screening methods for osteoporosis in Northwest China by assessing the prevalence of osteoporosis in the region using ultrasound bone mineral density in combination with body measure parameters, OSTA, and BMR to

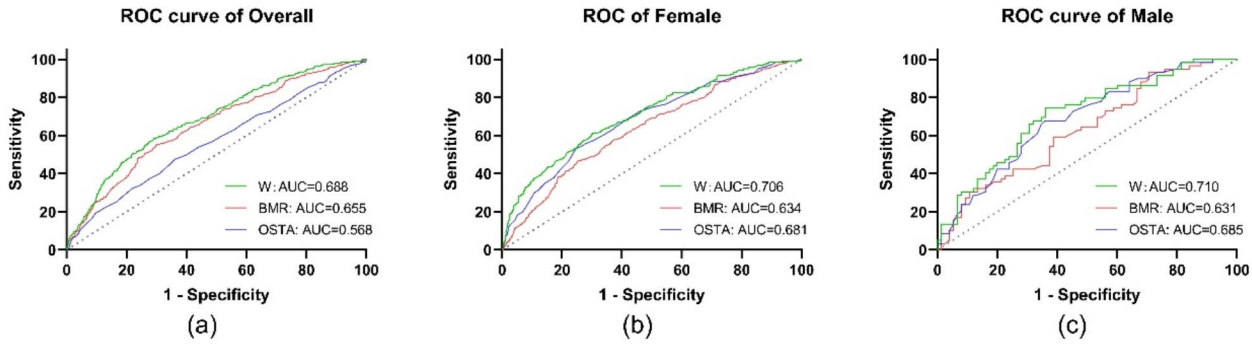

Fig. 1 Representation of W, OSTA, and BMR in the prediction of osteoporosis. (**a**) The receiver operating characteristic (ROC) curve illustrates the performance of W, OSTA, and BMR across the entire population. (**b**) The receiver operating characteristic (ROC) curve illustrates the performance of W, OSTA, and BMR across the female population (**c**) The receiver operating characteristic (ROC) curve illustrates the performance of W, OSTA, and BMR across the female population

Table 5 Performance of W, OSTA, and BMR in the prediction of osteoporosis in different populations

Variable	Population	Sensitivity(%)	Specificity(%)	Area under the curve	95% CI	*P* value
W	Male	69.50	61.30	0.710	0.622–0.797	< 0.001
	Female	61.11	69.90	0.706	0.672–0.740	< 0.001
	Overall	58.63	70.90	0.688	0.657–0.719	< 0.001
OSTA	Male	67.80	64.00	0.685	0.596–0.775	< 0.001
	Female	52.90	75.50	0.681	0.646–0.715	< 0.001
	Overall	47.70	63.80	0.568	0.533–0.602	< 0.001
BMR	Male	93.20	29.30	0.631	0.537–0.725	0.006
	Female	46.73	74.60	0.634	0.599-0.700	< 0.001
	Overall	55.34	69.80	0.655	0.622–0.687	< 0.001

assess their fracture risk. Spearman's correlation analysis revealed a positive correlation between BMR and T score, as well as a positive correlation between OSTA and T score. This indicates that an elevated BMR and OSTA are associated with elevated T-score levels. In addition, this study assesses W, OSTA, and BMR's performance in predicting osteoporosis using ROC curves, the ROC curve revealed a clear hierarchy: W was the most effective, followed by BMR, and then OSTA. Among females, W remained the top predictor, resulting in an order of W > OSTA > BMR. Similarly, in the male population, W retained its leading position, maintaining the same sequence of W > OSTA > BMR.

The pervasiveness of osteoporosis and its attendant risk of fractures pose a formidable challenge to public health. In addition to pharmacological treatment of osteoporosis [26–28], there is a need to identify more reliable screening methods. Prior to this investigation, the combined efficacy of OSTA and BMD measurements in preventing osteoporosis had not been explored. Fan et al.'s cross-sectional study, encompassing 2055 postmenopausal women aged 45 and above residing in the community, underscores the potential of OSTA and FRAX as reliable instruments for identifying postmenopausal individuals at risk of fractures, independent of BMD assessments [29]. Furthermore, Subramaniam et al.'s study on 786 Malaysian subjects demonstrated that fine-tuning the OSTA threshold value markedly enhanced its sensitivity, thereby elevating its clinical value in osteoporosis screening [30]. Huang et al.'s findings in Chengdu, China, also attest to OSTA's utility as a screening tool for middle-aged and elderly women [31]. In a validation study conducted by Park et al. among 1,101 postmenopausal women from a South Korean clinic, femoral neck BMD measurements via dual-energy X-ray absorptiometry (DXA) revealed OSTA's high sensitivity (87%) and good specificity (67%) in detecting osteoporosis [32]. Collectively, these studies underscore OSTA's sensitivity as a predictor of osteoporosis across diverse populations, with a particular emphasis on women.

The present study incontrovertibly establishes a positive correlation between BMR and BMD, a finding buttressed by robust statistical analyses including Spearman's correlation coefficient and simple linear regression. The application of multiple linear regression analysis further consolidates this relationship, yielding statistically significant results ($P<0.05$), underscoring the veracity of the observed association. Echoing this, Kirilov et al.'s

cross-sectional study of 313 women aged 20–90 years, utilizing multispectral radiofrequency ultrasound for osteoporosis screening, revealed a pronounced positive correlation between BMR and BMD (R=0.765, 95% CI: 0.715, 0.807) [33]. Our investigation concurs, demonstrating a positive correlation between BMR and BMD (R=0.267). Complementing these findings, Xu et al.'s cross-sectional analysis of 289 women aged 40–80 years highlights the significance of BMR in older women, with elevated BMR, BMI, and body fat observed in individuals over 50 years compared to those with osteoporosis. Notably, the study underscores BMR's strong association with BMD in the elderly, proposing it as a potential novel strategy for intervening against age-related BMD declines [34]. Expanding on these insights, Choi et al.'s extensive examination of the intricate relationships among BMI, BMD, TBF, fat distribution, BMR, and site-specific BMD (lumbar and proximal femoral) in a cohort of 345 postmenopausal women and 224 older men, underscores the more robust correlation of lumbar BMD with BMR (R=0.51, P<0.01) than with lean body mass (R=0.39, P<0.01) or waist-to-hip ratio (R=-0.28, P<0.01) in postmenopausal women. This underscores the intricate interplay between metabolic factors and bone health, particularly in the context of aging and gender-specific considerations. Additionally, among elderly individuals, our findings revealed a notably stronger correlation between BMR and BMD compared to total body fat (TBF), BMI, or lean body mass [35]. Consequently, BMR emerges as a potential biomarker, intimately tied to osteoporosis risk, that could be harnessed as a predictive factor in clinical settings.

In this comprehensive investigation, we undertook an exhaustive assessment of the synergetic potential of OSTA and BMR for the identification of osteoporosis. Our results underscore a marked enhancement in screening accuracy when these two indices are employed in tandem, as evidenced by the ROC curve area exceeding the critical threshold of 0.5, not only in the general population but also within sex-specific subgroups. This statistically significant improvement in diagnostic efficacy (P<0.05) underscores the merit of the combined approach in facilitating the screening and diagnosis of osteoporosis.

In this study, we conducted a comprehensive comparison of W, OSTA, and BMR in predicting osteoporosis. Previous studies have demonstrated that OSTA has been used more frequently for osteoporosis screening [29, 36–39], whereas BMR has not been used for osteoporosis prediction. Several studies provide insight into the potential role of BMR in osteoporosis, even in males. Choi measured the physical characteristics of 569 participants, including 345 postmenopausal women and 224 elderly men. The study found that 9.5% of elderly men with a BMR below 1390 kcal had osteoporosis in the proximal femur, which is significantly higher than the 2.2% observed in those with a BMR of 1390 kcal or above (P<0.01) [35]. In another study, Bilge Yilmaz and colleagues examined 30 males with chronic spinal cord injury and found a significant correlation between BMR and BMD in the total femur, femoral neck, trochanter, and shaft [40]. Our results firstly demonstrate that when both metrics are used together, the accuracy of screening is significantly improved, as evidenced by the ROC curve area exceeding the critical value of 0.5, not only in the general population but also in gender-specific subgroups. A statistically significant improvement in diagnostic performance was observed (P<0.05), which highlights the advantages of the combined approach in facilitating the screening and diagnosis of osteoporosis. When examining BMR in isolation, we found it to be suboptimal for osteoporosis prediction, with specificity in males at 29.30% and sensitivity in females at 46.73%. Conversely, the application of W yielded substantial gains, boosting specificity to 61.30% in males and sensitivity to 61.11% in females. Furthermore, when OSTA was employed as a stand-alone method, it demonstrated a sensitivity of 47.70% and a specificity of 63.80% across the entire study population. Notably, predictor W surpassed OSTA, exhibiting a remarkable enhancement in diagnostic accuracy, with sensitivity climbing to 58.63% and specificity soaring to 70.90% in the total population. This suggests that the application of W may offer enhanced diagnostic accuracy compared to OSTA and BMR when used individually for osteoporosis prediction.

Nonetheless, several limitations must be acknowledged. Notably, our findings are predicated solely on a study conducted within the confines of Northwest China, necessitating further validation across a broader spectrum of geographical regions within the country to ensure their generalizability. Additionally, given the multifaceted influence of various factors on basal metabolic rate, our study did not account for potential confounding variables, which may have inadvertently impacted our results. Hence, future endeavors should address these limitations to refine the understanding of the combined OSTA-BMR approach in osteoporosis detection.

Conclusions

The combined utilization of OSTA and the BMR can serve as an effective screening method for osteoporosis, particularly in areas where advanced BMD measurement instruments are not readily available. This combined approach not only enhances the accessibility of osteoporosis screening but also facilitates its promotion in underserved communities.

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Author contributions
Jiaxin Zhao was responsible for drafting the abstract, introduction, discussion, and results sections, as well as for collating the data. Yulin Wang and Shuo Wang collected the data, performed the statistical analysis, and wrote the results section. Qin Guo and Wei Wang undertook a review of the study and implemented the requisite corrections. The study was designed by Jidong Song, who is also the corresponding author. All authors reviewed the manuscript.

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Data availability
The data packages used and analyzed in this article are kept by specific researchers and are obtainable through the corresponding author upon application to a legitimate extent.

Declarations

Ethics approval and consent to participate
The study protocol was approved by the Ethics Committee of The Second Affiliated Hospital of Xi'an Jiaotong University (No.2023264) and written informed consent was obtained from each participant.

Consent for publication
All authors consented to the publication of this study. The hospital committee of ethics approved the study, and informed consent was obtained from the patients/participants included in this study. Following the guidelines, the patient's permission to publish is indicated as "Not Applicable" in this section.

Figures authenticity
All figures submitted have been created by the authors who confirm that the images are original with no duplication and have not been previously published in whole or in part.

Competing interests
The authors declare no competing interests.

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