Association between a body shape index and abdominal aortic calcification in the general population: National Health and Nutrition Examination Survey 2013-2014

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Research Article

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Abstract

Background: The relationship between a body shape index (ABSI) and abdominal aortic calcification (AAC) is still unclear, so we tried to prove the relationship between ABSI and AAC in the general population free from cardiovascular disease.

Methods: The present study included 3140 participants aged 40-80 years from the 2013-2014 National Health and Nutrition Examination Survey. Logistic regression analysis and Receiver Operating Characteristic (ROC) curves were used to test the association between ABSI and AAC.

Results: Participants with higher ABSI showed significantly higher proportion of AAC. Participants with higher ABSI had an increased risk of developing AAC in the crude model (ABSI as a continuous variable: OR = 2.485, 95% CI: 2.099-2.942, $P < 0.001$; as a categorical variable: OR = 2.132, 95% CI: 1.826-2.489, $P < 0.001$), while higher ABSI remained to be an independent risk predictor of AAC with the increase of confounding factors (all adjusted $P < 0.05$). Further subgroup analyses showed that higher ABSI (regarding lower ABSI as reference) was consistently positively correlated with AAC in eleven subgroups, including sex, age, smoking history, hypertension, diabetes, sleep disorder, body mass index, systolic blood pressure, diastolic blood pressure, fasting plasma glucose and low-density lipoprotein cholesterol (P for interaction > 0.05). However, in the osteoporosis and hemoglobin A1c subgroups, the correlation was no longer synchronized (P for interaction < 0.05). The ROC curves analysis showed that the discriminant ability of ABSI was significantly higher than that of other models.

Conclusions: Independent of the related confounding factors, higher ABSI was significantly associated with higher prevalent AAC in the general population free from cardiovascular disease.

Background

Abdominal aortic calcification (AAC) refers to vascular calcification in the abdominal aorta, which has been proved by previous studies to be related to coronary artery calcification and the severity of cardiovascular disease (CVD)[1–3]. Calcium deposits may occur in all layers of blood vessels, including intima, media and adventitia[4, 5]. The mechanism of vascular calcification has not been fully elucidated. It has been reported that chronic inflammation, insulin resistance, oxidative stress, vascular smooth muscle cell transdifferentiation, mitochondrial dysfunction, apoptosis, autophagy and DNA damage are involved in the occurrence of vascular calcification[4, 6–8]. And in clinical practice, it has been reported that advanced age, smoking, obesity, diabetes, dyslipidemia and low relative lean mass may be the risk factors of AAC[4, 9–12]. However, there may be other risk factors for AAC, such as nutritional and metabolic disorders. Further elucidation of other risk factors of AAC and targeted intervention are beneficial to prevent the occurrence and development of AAC, thereby reducing the occurrence of cardiovascular events.

For decades, with the improvement of living conditions, obesity, especially central obesity, has become an increasingly serious global health problem[13]. In contrast to subcutaneous fat, visceral fat accumulation

has been shown to be closely associated with dyslipidemia, insulin resistance, diabetes and hypertension, all of which increase the risk of CVD[13–15]. Hence, it is of great significance to find a propagable and simple clinical tool for detecting visceral fat and diagnosing central obesity. As we expected, anthropometry just meets our requirements, that is, it is simple, cheap, non-invasive, and can be used for screening and early detection of obesity. At present, the traditional anthropometric indicators mainly include height, weight, body mass index (BMI), waist circumference (WC), hip circumference, Waist-to-height ratio (WHtR) and so on. However, previous studies have found that these indicators have some limitations, for instance, BMI can not reflect the fat distribution[14]. Although WC is generally considered to be a sign of central obesity, it still has some limitations, such as being disturbed by race and gender[16, 17]. Therefore, in order to overcome these limitations, Krakauer et al. developed a new nutritional index, namely a body shape index (ABSI), which is calculated from height, weight and WC[18]. And their study confirmed that ABSI was positively associated with visceral fat or central obesity, and they also found that the correlation between ABSI and premature death was higher than that of BMI and WC[18]. Since then, ABSI has received more and more attention. Subsequent studies revealed the relationship between ABSI and arterial stiffness[19], carotid atherosclerosis[20], hypertension[21], metabolic syndrome[22], diabetes and CVD[23–27].

However, as far as we know, data about the correlation between ABSI and AAC is currently lacking. Furthermore, there are no related studies to compare the relative strength of predictive efficiency of traditional anthropometric indicators and ABSI for AAC. Therefore, the present study was to explore the relationship between ABSI and AAC. Besides, we also tried to test the predictive ability of ABSI and anthropometric indicators for AAC in the general population aged 40–80 years from the 2013–2014 National Health and Nutrition Examination Survey (NHANES 2013–2014).

Methods

Study population

NHANES is a regular survey of representative samples of the general population in the United States, which aimed to investigate the health and disease status of the general population in the United States and provide perfect health guidance, the contents and survey data of which have been described in detail in other literatures[28]. The present study included 3140 participants aged 40–80 years from the NHANES 2013–2014. The study protocol of NHANES 2013–2014 was approved by the National Center for Health Statistics of the Center for Disease Control and Prevention Institutional Review Board, all participants of the present study provided written informed consent at the time of enrollment, and the study was consistent with the principles of the Declaration of Helsinki. Flow chart of participant selection of the present study was shown in the figure below (Fig. 1).

Survey And Measurement

After screening by inclusion and exclusion criteria, 3140 participants were enrolled in the present study. The demographic characteristics of all participants were obtained by standardized family interview questionnaire, including age, sex, race, smoking history, history of diabetes, hypertension, osteoporosis and sleep disorder. The race was divided into five groups: non-Hispanic White, non-Hispanic Black, Mexican American, other Hispanic and other races. Smoking history was divided into two groups: yes and no. Height, weight, systolic blood pressure (SBP), diastolic blood pressure (DBP) and WC were measured by medical trained professionals according to measurement procedures and standards, and the calculation method of the BMI was: weight (kg) divided into the square of the height (meter). The WHtR was defined as the ratio of WC to height. The parameter values of blood samples of participants were determined strictly according to operational procedures by medically trained technicians in standard basic laboratory, including blood lipid profile, fasting plasma glucose (FPG), hemoglobin A1c (HbA1c), serum electrolytes, kidney function, etc.

For the calculation of ABSI, we used the formula described by Krakauer et al. based on height, BMI and WC[18], that is:

$$ABSI = \frac{WC}{\text{height}^{\frac{1}{2}} \times \text{BMI}^{\frac{2}{3}}}$$

In our study, we divided participants into two groups based on the optimal cutoff point of ABSI: higher ABSI (> 0.84; n = 1264) and lower ABSI ($\leq$ 0.84; n = 1876).

AAC was gained by transverse scanning of the lumbar spine (vertebrae L1–L4) with dual-energy X-ray absorptiometry (DXA) (Densitometer Discovery A, Hologic, Marlborough, MA, USA) and semi-quantified by the Kauppila score system, with scores ranging from 0 to 24, and the specific scoring rules of AAC have been described in detail elsewhere[29, 30]. We divided AAC into two groups: no calcification (AAC = 0) and calcification (AAC > 0).

Statistical analysis

All Statistical tests were performed with SPSS 19.0 (SPSS Inc., Chicago, Illinois, USA), MedCalc version 19.1 (MedCalc Software, Belgium) and R Programming Language (version 3.6.3). Continuous variables were expressed as mean $\pm$ standard deviation or median (quartiles: Q1, Q3) depending on whether the data was normal distribution, and the independent-sample t-test or Mann-Whitney U test was used to examine the differences between the two groups. Categorical variables were presented as numbers (percentages), and Pearson chi-square test or Fisher's exact test was used to test the differences between groups. The effect of ABSI on AAC was evaluated by the Logistic regression in different models, including crude model and adjusted models. Further subgroup analyses were performed to test the consistence of the predictive significance of ABSI for AAC according to sex, age ($\leq$ 65 and > 65 years), smoking history, hypertension, diabetes, osteoporosis, sleep disorder, BMI (< 23 and $\geq$ 23 kg/m²), SBP (< 140 and $\geq$ 140 mmHg), DBP (< 90 and $\geq$ 90 mmHg), FPG (< 126 and $\geq$ 126 mg/dL), HbA1c (< 6.5 and $\geq$

6.5%) and low-density lipoprotein cholesterol (LDL-C) (≤ 130 and > 130 mg/dL). The model used in the subgroup analyses did not contain other covariates. Besides, possible modifications of the connection between ABSI and AAC were also assessed by interaction tests. C-statistics derived from receiver-operating characteristic (ROC) curve analysis were used to test the predictive potential of ABSI and traditional anthropometric indicators for AAC, and examine the incremental effects of ABSI on the predictive potential of the baseline risk model that including traditional risk factors. DeLong's test was performed to compare the area under the curve (AUC) of each prediction model. The optimal cutoff point of ABSI for predicting AAC were determine by ROC curve analysis. A two-tailed P value < 0.05 was regarded as statistically significant.

Results

The 3140 participants (median age: 58.0 years; 48.3% men) enrolled in the present study were divided into two groups based on the optimal cutoff point of ABSI: higher ABSI (> 0.84 ; $n = 1264$) and lower ABSI (≤ 0.84 ; $n = 1876$). Baseline characteristics of total population and participants stratified by the ABSI of 0.84 were displayed in Table 1 and Fig. 2. Compared with participants in lower ABSI group, those with higher ABSI appeared to be older, display higher levels of WC, WHtR, SBP and AAC score, and higher percentage of male, Non-Hispanic white and smoker, and higher prevalence of diabetes, hypertension, osteoporosis, sleep disorder and AAC, while lower BMI. Laboratory indices including FPG, triglycerides (TG), blood urea nitrogen (BUN), uric acid, creatinine, HbA1c, γ -glutamyl transpeptidase (GGT) and alkaline phosphatase (ALP) were significantly higher in participants with higher ABSI, while total cholesterol (TC), LDL-C and high-density lipoprotein cholesterol (HDL-C) levels were comparatively lower.

Table 1
Participants characteristics stratified by the optimal cutoff point of ABSI

variables	Total population (n = 3140)	Lower ABSI ($\leq$ 0.84; n = 1876)	Higher ABSI ($>$ 0.84; n = 1264)	P value
Age, years	58.0 (48.0, 68.0)	53.0 (46.0, 63.0)	64.0 (56.0, 73.0)	$<$ 0.001
Sex, male, n (%)	1518 (48.3)	821 (43.8)	697 (55.1)	$<$ 0.001
Race, n (%)				$<$ 0.001
Non-Hispanic white	1375 (43.8)	724 (38.6)	651 (51.5)	
Non-Hispanic black	620 (19.7)	439 (23.4)	181 (14.3)	
Mexican-American	412 (13.1)	253 (13.5)	159 (12.6)	
Other Hispanic	298 (9.5)	187 (10.0)	111 (8.8)	
Others	435 (13.9)	273 (14.6)	162 (12.8)	
Smoking history, n (%)	1452 (46.2)	765 (40.8)	687 (54.4)	$<$ 0.001
Diabetes, n (%)	648 (20.6)	290 (15.5)	358 (28.3)	$<$ 0.001
Hypertension, n (%)	1486 (47.3)	782 (41.7)	704 (55.7)	$<$ 0.001
Osteoporosis, n (%)	258 (8.2)	127 (6.8)	131 (10.4)	$<$ 0.001
Sleep disorder, n (%)	336 (10.7)	166 (8.8)	170 (13.4)	$<$ 0.001
Body mass index, kg/m ²	28.4 $\pm$ 5.6	28.8 $\pm$ 5.8	28.0 $\pm$ 5.1	$<$ 0.001
Waist circumference, cm	99.3 $\pm$ 13.6	96.2 $\pm$ 13.0	103.9 $\pm$ 13.0	$<$ 0.001
WHtR	0.6 $\pm$ 0.1	0.6 $\pm$ 0.1	0.6 $\pm$ 0.1	$<$ 0.001
SBP, mmHg	127.2 $\pm$ 18.3	125.1 $\pm$ 17.1	130.4 $\pm$ 19.4	$<$ 0.001

ABSI a body shape index, WHtR waist-to-height ratio, SBP systolic blood pressure, DBP diastolic blood pressure, LDL-C low-density lipoprotein cholesterol, HDL-C high-density lipoprotein cholesterol, FPG fasting plasma glucose, GGT γ -glutamyl transpeptidase, AAC abdominal aortic calcification

variables	Total population (n = 3140)	Lower ABSI ($\leq$ 0.84; n = 1876)	Higher ABSI ($>$ 0.84; n = 1264)	<i>P</i> value
DBP, mmHg	71.3 $\pm$ 10.8	72.0 $\pm$ 10.2	70.3 $\pm$ 11.5	0.221
Laboratory results				
Triglycerides, mg/dL	132.0 (86.0, 192.8)	121.0 (80.0, 176.0)	144.0 (97.0, 211.8)	$<$ 0.001
Total cholesterol, mg/dL	196.0 $\pm$ 42.7	198.0 $\pm$ 41.9	193.2 $\pm$ 43.7	0.002
LDL-C, mg/dL	114.8 $\pm$ 36.0	117.0 $\pm$ 35.2	111.4 $\pm$ 37.1	0.004
HDL-C, mg/dL	54.1 $\pm$ 16.5	55.6 $\pm$ 16.9	51.8 $\pm$ 15.6	$<$ 0.001
Blood urea nitrogen, mg/dL	14.3 $\pm$ 6.2	13.6 $\pm$ 5.3	15.3 $\pm$ 7.1	$<$ 0.001
Creatinine, mg/dL	0.9 (0.7, 1.0)	0.9 (0.7, 1.0)	0.9 (0.8, 1.1)	$<$ 0.001
Uric acid, mg/dL	5.5 $\pm$ 1.4	5.3 $\pm$ 1.3	5.6 $\pm$ 1.4	$<$ 0.001
FPG, mg/dL	98.0 (90.0, 110.0)	96.0 (89.0, 109.0)	102.0 (91.0, 119.0)	$<$ 0.001
Hemoglobin A1c, %	5.7 (5.4, 6.0)	5.6 (5.3, 5.9)	5.8 (5.4, 6.2)	$<$ 0.001
Total bilirubin, mg/dL	0.6 $\pm$ 0.3	0.6 $\pm$ 0.3	0.6 $\pm$ 0.3	0.663
GGT, U/L	21.0 (15.0, 30.0)	20.0 (14.0, 30.0)	21.0 (15.0, 31.0)	0.002
Alkaline phosphatase, IU/L	65.0 (53.0, 77.0)	64.0 (53.0, 75.0)	67.0 (54.0, 80.0)	$<$ 0.001
Total calcium, mg/dL	9.5 $\pm$ 0.4	9.4 $\pm$ 0.4	9.5 $\pm$ 0.3	0.226
Phosphorus, mg/dL	3.8 $\pm$ 0.6	3.8 $\pm$ 0.6	3.8 $\pm$ 0.6	0.164
25-OH-VitD3, nmol/L	63.8 (45.9, 81.0)	63.3 (46.2, 79.6)	64.9 (45.7, 83.1)	0.065
AAC, n (%)	947 (30.2)	444 (23.7)	503 (39.8)	$<$ 0.001
ABSI a body shape index, WHtR waist-to-height ratio, SBP systolic blood pressure, DBP diastolic blood pressure, LDL-C low-density lipoprotein cholesterol, HDL-C high-density lipoprotein cholesterol, FPG fasting plasma glucose, GGT γ -glutamyl transpeptidase, AAC abdominal aortic calcification				

In Logistic regression analysis, four models (crude model and Model 1–3) including covariables with statistically significance ($P < 0.1$) and clinical significance were established to assess the predictive

significance of ABSI for AAC. With the increase of confounding factors, the risk of participants with higher ABSI developing into AAC gradually decreased, while higher ABSI remained to be an independent risk predictor of AAC, whether ABSI was regarded as a categorical or continuous variable (all $P < 0.05$ in Model 1–3) (Table 2). Further subgroup analyses was performed to test the consistence of the predictive significance of ABSI for AAC (thirteen subgroups as mentioned above) (Fig. 3). The higher ABSI (regarding lower ABSI as reference) was consistently positively correlated with AAC in eleven subgroups, including sex, age, smoking history, hypertension, diabetes, sleep disorder, BMI, SBP, DBP, FPG and LDL-C (P for interaction > 0.05). However, in the osteoporosis and HbA1c subgroups, the correlation between the two was no longer synchronized (P for interaction < 0.05). Interestingly, the risk of participants with higher ABSI developing into AAC seemed to be more noticeable in participants without osteoporosis [OR (95% CI) without osteoporosis 2.157 (1.829–2.542) vs. with osteoporosis 1.504 (0.920–2.459), P for interaction < 0.001] and with HbA1c $< 6.5\%$ [OR (95% CI) HbA1c $< 6.5\%$ 2.251 (1.898–2.669) vs. HbA1c $\geq 6.5\%$ 1.297 (0.881–1.910), P for interaction = 0.011].

Table 2
Predictive value of ABSI for AAC in different logistic regression models

	ABSI as a continuous variable ^a			ABSI as a categorical variable ^b		
	OR	95% CI	P value	OR	95% CI	P value
Crude model	2.485	2.099–2.942	< 0.001	2.132	1.826–2.489	< 0.001
Model 1	1.378	1.150–1.653	0.001	1.257	1.057–1.494	0.010
Model 2	1.287	1.070–1.547	0.007	1.220	1.025–1.453	0.025
Model 3	1.259	1.046–1.516	0.015	1.201	1.008–1.430	0.041
Crude model: unadjusted						
Model 1: adjusted for age, smoking history, hypertension, diabetes, osteoporosis						
Model 2: adjusted for variables included in Model 1 and body mass index, systolic blood pressure						
Model 3: adjusted for variables included in Model 2 and triglycerides, total cholesterol, creatinine, fasting plasma glucose						
ABSI a body shape index, AAC abdominal aortic calcification, OR odds ratio, CI confidence interval						
^a The OR was examined by per 1-unit increase of ABSI						
^b The OR was examined regarding lower ABSI as reference (stratified by the optimal cutoff point of ABSI determined by ROC curve analysis)						

The comparative analysis of AUC of different models for predicting AAC showed that the discriminant ability of ABSI was significantly higher than that of other univariate predictive models, including height, weight, BMI, WC and WHtR (all P for comparison < 0.001). However, the addition of ABSI had no significant increasing effect on the AUC obtained by the baseline risk model composed of age, smoking

history, diabetes, hypertension, osteoporosis, SBP, TG, TC, FPG, HbA1c, creatinine, uric acid, ALP, total calcium and 25-OH-VitD3 (AUC: baseline risk model, 0.726 vs. baseline risk model + ABSI, 0.728, *P* for comparison = 0.098) (Table 3, Fig. 4).

Table 3
C-statistics for discrimination ability of different models

variables	AUC	95% CI	<i>P</i> value	Z value	<i>P</i> for comparison
Univariate model					
ABSI	0.625	0.608–0.642	< 0.001	Reference	Reference
Height	0.532	0.514–0.549	0.005	5.710	< 0.001
Weight	0.562	0.545–0.580	< 0.001	4.217	< 0.001
BMI	0.548	0.530–0.565	< 0.001	5.385	< 0.001
WC	0.505	0.487–0.523	0.652	6.841	< 0.001
WHtR	0.512	0.494–0.529	0.284	8.687	< 0.001
Combined variable model					
Baseline risk model ^a without ABSI	0.726	0.710–0.741	< 0.001	Reference	Reference
Baseline risk model ^a with ABSI	0.728	0.712–0.744	< 0.001	1.657	0.098
ABSI a body shape index, BMI body mass index, WC waist circumference, WHtR Waist-to-height ratio, AUC area under the curve, CI confidence interval					
^a The baseline risk model included age, smoking history, diabetes, hypertension, osteoporosis, systolic blood pressure, triglycerides, total cholesterol, fasting plasma glucose, hemoglobin A1c, creatinine, uric acid, alkaline phosphatase, total calcium and 25-OH-VitD3					

Discussion

As far as we know, the present study was the first report on the relationship between ABSI and AAC. In the present study, we retrospectively explored the predictive importance of ABSI derived from traditional anthropometric indicators for AAC. The main findings were as follows: (1) compared with participants in lower ABSI group, those with higher ABSI showed higher levels of AAC score and higher prevalence of AAC; (2) the higher ABSI (per 1-unit increase or regarding lower ABSI as reference) was a strong

independent risk predictor of AAC in our population, although after adjusting for possible interference factors; (3) the risk of participants with higher ABSI developing into AAC seemed to be more noticeable in participants without osteoporosis and with HbA1c < 6.5%; (4) the discriminant ability of ABSI for predicting AAC was significantly higher than that of other anthropometric indicators. These results suggest that ABSI may be essential for risk management of AAC.

AAC has been widely considered as an important risk factor for CVD, and it is very common in patients with CVD. Some studies have shown that AAC is significantly associated with incident myocardial infarction[2], stroke[31], osteoporosis[32], fracture[33], CVD mortality[2], all-cause mortality[3], etc. Therefore, for these patients, the identification of pathogenic factors of AAC is of great clinical significance for primary and secondary prevention of CVD. It has been reported that advanced age, smoking, diabetes, obesity and dyslipidemia may be the risk factors of AAC[4, 9–11]. However, there may be other risk factors for AAC, such as nutrition indices.

At present, BMI and WC are the most commonly used anthropometric indicators in clinical practice, but both of them have some limitations in fat distribution. First, BMI can't not only distinguish adipose tissue from non-adipose tissue, but also can't reflect fat distribution[34]. In fact, people with excess visceral fat or central obesity are more likely to develop CVD and metabolic syndrome[14, 15]. Unlike BMI, WC has always been regarded as an alternative indicator of central obesity[35]. Previous studies have shown that WC could predict the risk of death better than BMI[36, 37], but a comparative study showed that WC was weakly or negatively correlated with subclinical CVD[19]. This suggests that the ability of WC to predict metabolic-related diseases may be overrated. The reason for this may be that the WC can't distinguish between subcutaneous fat and visceral fat, and can't reflect the difference of height and race[17]. Therefore, the WC may not be enough to fully represent central obesity. In addition, although the WHtR derived from WC and height has also been shown to predict metabolic disorders[38], it can't reflect differences of weight between individuals. Therefore, it is essential to develop a better tool to assess central obesity. It is reported that imaging technology is the gold standard for the evaluation of central obesity, but it is difficult to be widely popularized because of its high cost, complex operation and radiation. Therefore, a simple evaluation method comes into being, that is, ABSI developed by Krakauer et al. in 2012[18].

ABSI is a recently developed nutritional index composed of height, weight and WC, which is reported to be positively correlated with central obesity, metabolic related diseases and death risks[18, 22]. A subsequent study found that among teenagers, ABSI was better at identifying hypertension than BMI and WC[39]. And in Chinese adults, ABSI was a better predictor of diabetes and metabolic syndrome than BMI and WC[25]. Recent studies have also found that ABSI had a stronger correlation with all-cause mortality and CVD mortality than WC, BMI and WHtR, and it might be an important marker of atherosclerosis in patients with type 2 diabetes[40, 41]. Similarly, studies by Geraci et al. have also shown that ABSI might be considered as a better predictor of carotid atherosclerosis in patients with hypertension than traditional nutrition indexes, including WC and BMI[20]. However, some studies have found that ABSI is not superior to BMI and WC in predicting the risk of related disease or death. For example, two studies

coincidentally found that in Chinese children, adolescents or adults and the elderly, the correlation between ABSI and pre-hypertension or hypertension was not higher than WC, BMI and WHtR, while the WHtR had the highest predictive power[21, 42]. In addition, another study found that although ABSI was positively correlated with arterial stiffness, its AUC value was significantly lower than that of WHtR in differentiating arterial stiffness, suggesting that ABSI might not be a better predictor of arterial stiffness in Chinese population[19]. Besides, A large European cohort study found that WC, BMI and WHtR were J-shaped correlated with all-cause mortality, while ABSI was positively correlated with all-cause mortality, and BMI was superior to ABSI in predicting CVD mortality[43]. Furthermore, a meta-analysis of 30 clinical studies showed that higher ABSI was associated with increased risk of hypertension, type 2 diabetes, CVD and all-cause death, which increased by 13%, 35%, 21% and 55%, respectively, and ABSI was superior to WC and BMI in predicting all-cause mortality, but performed poorly in predicting chronic diseases[23]. However, the studies mentioned above are aimed at exploring the relationship between ABSI and other diseases, and there is little evidence to compare ABSI with other anthropometric indicators in predicting the risk of AAC. Our research was the first to determine the ability of ABSI to recognize AAC. The results showed that there was a positive correlation between ABSI and AAC. Additionally, we found that ABSI was a better indicator of AAC than BMI, WC and WHtR, and it showed similar predictive power to baseline risk models including age, smoking history, diabetes, hypertension, osteoporosis, SBP, TG, TC, FPG, HbA1c, creatinine, uric acid, ALP, total calcium and 25-OH-VitD3 in the American population. Moreover, we also found for the first time that participants with higher ABSI had a higher risk of developing AAC in the HbA1c < 6.5% and non-osteoporosis subgroups. The reason for this might be that osteoporosis and HbA1c ≥ 6.5 were the interference factors of ABSI risk prediction model, which was also the focus of our future research. The homogenization and differentiation of the above studies may be explained by the differences in race, sample size and population characteristics.

Innovatively, our findings added to the evidence of ABSI and CVD from clinical to subclinical diseases. Moreover, we compared the predictive value of ABSI and other nutrition indexes for AAC for the first time. Therefore, this study provided additional information that the evaluation of ABSI might be of clinical significance in primary prevention to identify people at risk of CVD. In spite of this, several limitations still existed in this study. Firstly, the present study was a cross-sectional study, which could not identify the causal relationship between ABSI and AAC. Secondly, in Logistic regression analysis, we only controlled for several meaningful confounding factors, but there might be other confounding factors not included in our study, such as inflammatory indicators. Thirdly, ABSI with a very small variance was highly concentrated around the mean value, which made it difficult to define the best critical value of ABSI in clinical practice. Finally, The data of this study only came from the general population of NHANES 2013–2014, so the findings may not be applicable more populations broadly.

Conclusions

Taken together, our results showed that WC, BMI, WHtR and ABSI were significantly associated with AAC, and found that ABSI was an independent predictor of AAC. Furthermore, ABSI was superior to BMI, WC

and WHtR in predicting the risk of AAC in our study. However, whether ABSI is suitable for clinical practice needed to be further studied in different populations.

Abbreviations

ABSI: A body shape index; AAC: Abdominal aortic calcification; ROC: Receiver operating characteristic; CVD: Cardiovascular disease; BMI: Body mass index; WC: Waist circumference; WHtR: Waist-to-height ratio; NHANES 2013-2014: 2013-2014 National Health and Nutrition Examination Survey; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; FPG: Fasting plasma glucose; HbA1c: Hemoglobin A1c; DXA: Dual-energy X-ray absorptiometry; LDL-C: Low-density lipoprotein cholesterol; AUC: Area under the curve; TG: Triglycerides; BUN: Blood urea nitrogen; GGT: γ -glutamyl transpeptidase; ALP: Alkaline phosphatase; TC: Total cholesterol; HDL-C: high-density lipoprotein cholesterol; OR: odds ratio; CI: confidence interval.

Declarations

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Authors' contributions

ZWW collected, analyzed and interpreted the data and drafted the manuscript; ML, JX and JG revised the manuscript; NFL was the designer of the manuscript and approved to submit the manuscript finally. All authors read and approved the final version of the manuscript.

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Availability of data and materials

The NHANES database is available at: https://www.cdc.gov/nchs/nhanes/about_nhanes.htm. The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

The study of NHANES 2013-2014 was approved by the National Center for Health Statistics of the Center for Disease Control and Prevention Institutional Review Board. Informed consent was obtained from all participants included in the study.

Consent for publication

Not applicable.

Competing interests

The authors declare no conflict of interest.

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Figures

Figure 1

Flow chart of the study population enrollment

NHANES 2013-2014 2013-2014 National Health and Nutrition Examination Survey, **AAC** abdominal aortic calcification

Figure 2

Bar graph of mean value of AAC Score stratified by a body shape index (ABSI)

AAC abdominal aortic calcification

* Compared with lower ABSI group, participants in higher ABSI group had significantly higher AAC Score ($P < 0.001$)

Figure 3

Logistic regression analysis evaluating predictive implication of ABSI in different subgroups. The OR was examined regarding lower ABSI as reference (stratified by the optimal cutoff point of ABSI determined by ROC curve analysis)

ABSI a body shape index, **BMI** body mass index, **SBP** systolic blood pressure, **DBP** diastolic blood pressure, **FPG** fasting plasma glucose, **HbA1c** hemoglobin A1c, **LDL-C** low-density lipoprotein cholesterol, **OR** odds ratio, **CI** confidence interval

Figure 4

C-statistics evaluating incremental effect of different models

A: ABSI vs Height or Weight or BMI or WC or WHtR; B: Baseline risk model without ABSI vs Baseline risk model with ABSI

ABSI a body shape index, **BMI** body mass index, **WC** waist circumference, **WHtR** Waist-to-height ratio

The baseline risk model included age, smoking history, diabetes, hypertension, osteoporosis, systolic blood pressure, triglycerides, total cholesterol, fasting plasma glucose, hemoglobin A1c, creatinine, uric acid, alkaline phosphatase, total calcium and 25-OH-VitD3