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Association between the oxidative balance score and estimated pulse wave velocity from the National Health and Nutrition Examination Survey (2005–2018)

Yumeng Shi[1,3,4] and Wei Zhou[1,2,3,4*]

Abstract

Background No research report has been conducted to investigate the impact of oxidation balance score (OBS) on the estimated pulse wave velocity(ePWV).We aimed to examine the association between OBS and ePWV.

Method We evaluated data for 13,073 patients from the National Health and Nutrition Examination Survey (NHANES). The exposure variable was OBS. The outcome variables was combination of ePWV and arterial stiffness.

Results We observed a significant negative correlation between OBS (Per 1SD increase) and ePWV in the gradually adjusted models. Based on the aforementioned results, a two-piecewise logistic regression adjusted model was subsequently employed to establish the association between OBS and elevated ePWV, and the inflection point was determined as 5. The increased risk of elevated ePWV (OR:0.70; 95%CI:0.51–0.94) gradually decreases with the increase of OBS on the left side of the inflection point; however, when OBS exceeds 5, this decrease in risk of elevated ePWV(OR:1.00; 95%CI:0.96–1.04) is no longer observed (P for log likelihood ratio test = 0.028).

Conclusions There exists a significant association between OBS and ePWV in the context of American adults. Specifically, OBS exhibits a negative correlation with ePWV; however, when considering an elevated ePWV, a saturation effect is observed in relation to OBS.

Keywords Oxidative balance score, Estimated pulse wave velocity, NHANES, Arterial stiffness, Vascular aging

Introduction

The findings from large-scale population-based studies have demonstrated a robust association between arterial stiffness and an elevated risk of cardiovascular events. Moreover, arterial stiffness has been closely linked to hypertension, diabetes, kidney disease, dementia, and mortality [1, 2]. The index of carotid–femoral pulse wave velocity (cfPWV) is commonly employed to quantify arterial stiffness [3]. However, the widespread implementation of cfPWV in clinical practice is hindered by the high cost of equipment, the need for trained personnel, and a lack of standardized methodologies; therefore,

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researchers have devised methods to estimate pulse wave velocity (ePWV) based on age and blood pressure through functional [4]. Additionally, several studies have demonstrated that the predicted arterial stiffness of ePWV exhibits similarity to the predicted value of cfPWV [5]. The ePWV index, calculated based on age and average blood pressure, accurately reflects the degree of vascular aging by capturing changes in vascular biology over time. Moreover, ePWV serves as a surrogate marker for arterial stiffness, indirectly reflecting the state of arterial structure and function. Arterial stiffness, being an important manifestation of vascular aging, is considered a hallmark of the aging process [6].The process of vascular aging is a complex interplay involving oxidative stress, chronic inflammation, and cellular senescence [7]. Specifically, vascular aging is characterized by the senescence of endothelial cells. Senescent endothelial cells secrete reactive oxygen species (ROS) and inflammatory factors, which in turn promote their own aging through DNA damage and activation of DNA damage response [8]. Moreover, this positive feedback loop induces the senescence of surrounding healthy cells, thereby creating an inflammatory microenvironment within arterial blood vessels [9]. In fact, the oxidative stress represented by ROS in the above physiological process can be adjusted in clinical practice to maintain the health of human blood vessels. The term "oxidative stress" refers to the imbalance between exposure to pro-oxidants and antioxidants. In this scenario, the role of pro-oxidersedes that of antioxidants, potentially resulting in cellular damage and oxidation [10]. On the other hand, mitigating exposure to oxidative factors can potentially mitigate the risk of arterial stiffness; however, quantifying individual-level exposure to oxidation factors alone remains challenging.

Therefore, the oxidation balance score (OBS) serves as a robust solution to address the aforementioned issues, representing a comprehensive assessment of oxidative stress-related exposure based on the cumulative intake of diverse pro-oxidants and antioxidants, the higher the score, the lower the level of oxidative stress [11, 12]. OBS integrates dietary and lifestyle factors to quantitatively assess the degree of oxidative balance. The efficacy of OBS has been demonstrated in cancer [13, 14], diabetes [15], osteoarthritis [16], and cardiovascular diseases [17] through extensive research. However, the previous literature solely encompasses cardiovascular diseases such as chronic congestive heart failure, nonfatal myocardial infarction, and stroke. Furthermore, the observed increase in OBS merely substantiates the protective effect on cardiovascular diseases in unadjusted models .Due to the pathophysiological basis of cardiovascular diseases being oxidative stress, there is currently no research report on the relationship between OBS and arterial stiffness. However, considering arterial stiffness as an intermediate variable and risk predictor of cardiovascular diseases, it is expected to have a biological effect with OBS. Therefore, we propose two research hypotheses: firstly, there exists a correlation between OBS and arterial stiffness; secondly, there may be a nonlinear correlation between OBS and arterial stiffness. To examine the aforementioned research hypotheses, this study employed a large-scale dataset obtained from the National Health and Nutrition Examination Survey (NHANES).

Methods

Data source and participants

Participants in this cross-sectional analysis were drawn from the population enrolled in the NHANES database spanning from 2005 to 2018. NHANES, a nationally representative population study conducted by the Centers for Disease Control and Prevention (CDC) [18], employed a stratified multi-stage probability and oversampling design to recruit participants for assessing their health and nutritional status, the data is published biennially [19]. Prior to participation, all participants provided informed consent and obtained ethical approval from the research ethics review committee of the National Center for Health Statistics (NCHS). A comprehensive exposition of NHANES research and its corresponding statistical analysis can be found at https://www.cdc.gov/nchs/nhanes/.

In the NHANES cohort from 2005 to 2018 year, we included a total of 38,544 participants aged over 18 years with complete OBS and ePWV data. We excluded 25,471 patients due to covariate deletion, resulting in a final sample size of 13,073 participants for this data analysis.

Definition of the OBS and ePWV

The OBS in this cross-sectional analysis comprises two components: the dietary OBS and the lifestyle OBS. Sixteen nutrients and four lifestyle factors are utilized for calculating the OBS. The components comprising the dietary OBS include dietary fiber (g/d), carotene (RE/d), riboflavin (mg/d), niacin (mg/d), vitamin B6 (mg/d), total folate (mcg/d), Vitamin B12 (mcg/d), Vitamin C (mg/d), Vitamin E (ATE) (mg/d), calcium (mg/d), magnesium (mg/d), zinc (mg/d), copper (mg/d) selenium (mcg/d), total fat (g/d) and iron (mg/d). Additionally, the lifestyle OBS encompasses physical activity (MET-minute/week), BMI (kg/m^2), alcohol (g/d) and cotinine (ng/mL). We further categorized these 20 components into 5 types of oxidants and 15 types of antioxidants, with the latter being further divided into 3 groups and assigned scores ranging from 0 to 2. Conversely, pro-oxidant scores were inverted, with a maximum score of 0 and a minimum score of 2. Consequently, we obtained the final comprehensive OBS by considering both antioxidant and pro-oxidant component scores [20].

The outcome variable was ePWV. We used a formula derived from the Reference Values for Arterial Stiffness' Collaboration [21]as described in the study by Greve et al [5]. ePWV was calculated by age and mean blood pressure (MBP); $ePWV = 9.587 - 0.402 \times age + 4.560 \times 10^{-3} \times age^2 - 2.621 \times 10^{-5} \times age^2 \times MBP + 3.176 \times 10^{-3} \times age \times MBP - 1.832 \times 10^{-2}$. MBP = DBP + 0.4 (SBP-DBP). In this study, 0.4 was used to calculate MBP instead of 0.33, because a coefficient of 0.4 is more in line with the change of pulse contour with age and its relationship with target organ damage [22, 23].

Covariates

Baseline questionnaires were utilized to collect covariate information, encompassing age, gender, race/nationality, smoking status, poverty income ratio, body mass index (BMI), and self-reported baseline medical history including diabetes mellitus (DM), hypertension, cardiovascular diseases(CVD), and drug use. BMI was determined by measuring height and weight. Blood biochemical markers comprised glycosylated hemoglobin levels, estimated glomerular filtration rate (eGFR), total cholesterol (TC), high-density lipoprotein levels (HDL), and C-reactive protein (CRP). The eGFR was calculated using the chronic kidney disease epidemiological cooperation (CKD-EPI) formula [24]. DM is defined as having a fasting blood glucose level of ≥7 mm/L, being diagnosed with diabetes by a medical professional, or currently using medication to manage high blood glucose levels [25]. The definition of hypertension entails a mean systolic blood pressure (SBP) equal to or exceeding 140 mmHg and/or a mean diastolic blood pressure (DBP) equal to or exceeding 90 mmHg, or the presence of self-reported hypertension diagnosis accompanied by antihypertensive [26]. Cardiovascular diseases in our study were defined as any reported diagnosis of coronary heart disease, angina pectoris, myocardial infarction, chronic heart failure, and stroke [27]. Detailed information of the above indicators can be found on www.cdc.gov/nchs/nhanes/.

Statistical analysis

Mean and standard deviation (SDs) or medians (interquartile ranges) (IQRs) are used to represent continuous variables, while percentages are used for representing classified variables. The differences in OBS among the four groups of continuous variables are compared using a one-way analysis of variance test or the Mann-Whitney test of nonparametric, whereas the differences in categorical variables are assessed using a chi-square test.

Previous literature has demonstrated a significant association between ePWV ≥ 10 m/s and an increased risk of cardiac events [28]. Therefore, in this cross-sectional analysis, we define the elevated ePWV as ePWV ≥ 10 m/s. Pearson's correlation coefficient was used to to assess the association of OBS and ePWV with cardiovascular risk factors. Beta coefficients (β) and 95% confidence interval (CI) used to investigate the association between OBS and ePWV were calculated using multivariate linear regression; Odds ratios (OR) and 95%CI used to investigate the association between OBS and elevated ePWV in participants were calculated using multivariate logistic regression for three models. Model 1 was adjusted for none; model 2 was adjusted for age, sex, BMI, race, poverty income ratio; model 3 was adjusted for age, sex, BMI, race, poverty income ratio, SBP, DBP, smoking status, HbA1c, CRP, TC, HDL, eGFR, DM, CVD, Hypertension, antihypertensive drugs, Lipoprotein-lowering drugs, hypoglycemic drugs. The dose-response relationship between OBS and ePWV and elevated ePWV visually demonstrated by employing a generalized additive model (GAM) and fitting a smooth curve using the penalty. If nonlinearity was detected, we first used a recursive algorithm to calculate the inflection points and then constructed a two-segment binary logistic model on both sides of the inflection points.

The statistical significance of all two-tailed $P < 0.05$ was observed. The data analysis was conducted using the Empower (R; www.empowerstats.com; X&Y Solutions, Inc., Boston, MA, USA) and the R statistical software package (http://www.R-project.org, The R Foundation).

Results

Demographic and clinical characteristics of the study population

In the final analysis, a total of 13,073 participants were included in this study. The patients' average age (standard deviation: SD) was 49.84 (17.82) years, constituting 50.26% males. Additionally, diabetes was present in 13.98% of the patients and hypertension prevalence stood at 41.59%. The ePWV mean and standard deviation (SD) were present as 8.43 ± 2.29 m/s. Table 1 presents a comprehensive description of baseline data characteristics based on the OBS fourth-class grouping. The findings indicate that, in comparison to participants in the highest OBS group (24 < OBS < 37), those in the lowest OBS group (0 < OBS < 11) primarily consist of elderly males, predominantly belonging to non-Hispanic black and Mexican American ethnicities. Additionally, a higher prevalence of current smokers was observed. In addition, participants in the lowest OBS group exhibit higher levels of BMI, SBP, HbA1c, CRP, a higher prevalence of hypertension, DM and CVD, as well as a higher medication rate compared to those in the highest OBS group. Furthermore, they have lower poverty-income ratio values along with decreased HDL and eGFR values. However, there was no statistically significant difference observed between DBP and TC in the OBS grouping ($P > 0.05$).

Table 1 Baseline characteristics of the study population according to the quartile of OBS[a]

Characteristics	OBS				*P* value
	Quartile 1	Quartile 2	Quartile 3	Quartile 4	
OBS range	0 to<11	11 to<19	19 to<24	24 to < 37	
N	2953	3465	3212	3443	
Males, N(%)	1611 (54.55%)	1738 (50.16%)	1529 (47.60%)	1693 (49.17%)	< 0.001
Age, year	49.19 ± 18.34	51.40 ± 18.23	49.80 ± 17.52	48.85 ± 17.10	< 0.001
BMI, kg/m^2	29.21 ± 7.10	29.59 ± 6.61	29.25 ± 6.61	27.85 ± 6.23	< 0.001
Race					< 0.001
Non-Hispanic White, N(%)	1241 (42.03%)	1615 (46.61%)	1708 (53.18%)	2080 (60.41%)	
Non-Hispanic Black, N(%)	741 (25.09%)	802 (23.15%)	535 (16.66%)	402 (11.68%)	
Mexican American, N(%)	571 (19.34%)	631 (18.21%)	583 (18.15%)	559 (16.24%)	
Other Hispanic, N(%)	244 (8.26%)	275 (7.94%)	259 (8.06%)	255 (7.41%)	
Other races, N(%)	156 (5.28%)	142 (4.10%)	127 (3.95%)	147 (4.27%)	
Current smoking, N(%)	935 (31.66%)	872 (25.17%)	652 (20.30%)	461 (13.39%)	< 0.001
SBP, mmHg	124.87 ± 19.71	124.09 ± 18.79	122.95 ± 18.24	120.99 ± 17.06	< 0.001
DBP, mmHg	69.95 ± 12.59	69.41 ± 12.16	70.02 ± 12.30	70.09 ± 11.34	0.081
Poverty income ratio	2.19 ± 1.54	2.38 ± 1.55	2.71 ± 1.61	2.97 ± 1.65	< 0.001
HbA1c,%	5.77 ± 1.13	5.76 ± 1.04	5.66 ± 0.96	5.58 ± 0.90	< 0.001
TC, mg/dL	195.85 ± 43.76	196.10 ± 41.48	197.29 ± 40.59	196.25 ± 40.47	0.528
HDL, mg/dL	51.74 ± 16.84	51.57 ± 15.20	52.65 ± 15.91	54.66 ± 16.25	< 0.001
CRP, mg/dL	0.21 (0.01-20.00)	0.22 (0.01–17.50)	0.20 (0.01–11.32)	0.15 (0.01–13.90)	< 0.001
eGFR, mL/min/1.73 m^2	94.07 ± 24.44	91.24 ± 25.16	93.14 ± 22.61	94.11 ± 21.36	< 0.001
ePWV, m/s					< 0.001
< 10	2211 (74.87%)	2466 (71.17%)	2449 (76.25%)	2705 (78.57%)	
≥ 10	742 (25.13%)	999 (28.83%)	763 (23.75%)	738 (21.43%)	
Comorbidities, N (%)					
DM	468 (15.85%)	575 (16.59%)	431 (13.42%)	354 (10.28%)	< 0.001
CVD	412 (13.95%)	486 (14.03%)	327 (10.18%)	256 (7.44%)	< 0.001
Hypertension	1275 (43.18%)	1621 (46.78%)	1312 (40.85%)	1229 (35.70%)	< 0.001
Medication use, N (%)					
Antihypertensive drugs	897 (30.38%)	1239 (35.76%)	970 (30.20%)	920 (26.72%)	< 0.001
Lipoprotein-lowering drugs	513 (17.37%)	793 (22.89%)	608 (18.93%)	613 (17.80%)	< 0.001
hypoglycemic drugs	341 (11.55%)	421 (12.15%)	326 (10.15%)	241 (7.00%)	< 0.001

[a]Values are mean ± SD, median [IQR] for skewed variables, or n (%) for categorical variables

Abbreviations OBS: Oxidative Balance Score; BMI body mass index, SBP systolic blood pressure, DBP diastolic blood pressure, HbA1c, glycosylated hemoglobin; TC, total cholesterol; HDL, high-density lipoprotein cholesterol; eGFR, estimated glomerular filtration rate; DM, Diabetes mellitus; CVD, Cardiovascular diseases

Table 2 Pearson correlation between the OBS index and cardiovascular risk factors

	OBS	
	R	*P* Value
BMI, kg/m^2	-0.0854	<0.001
SBP, mmHg	-0.0804	<0.001
DBP, mmHg	0.0013	0.880
HbA1c,%	-0.0752	<0.001
TC, mg/dL	0.0067	0.442
HDL-C, mg/dL	0.0723	<0.001

Table 3 Pearson correlation between the ePWV and cardiovascular risk factors

	ePWV	
	R	*P* Value
BMI, kg/m^2	0.0221	0.011
SBP, mmHg	0.6640	<0.001
DBP, mmHg	0.1343	<0.001
HbA1c,%	0.2456	<0.001
TC, mg/dL	0.0858	<0.001
HDL-C, mg/dL	0.0701	<0.001

Abbreviations OBS: Oxidative Balance Score; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; HbA1c, glycosylated hemoglobin; HDL-C, high-density lipoprotein cholesterol; TC, total cholesterol

Pearson correlation analysis between OBS, ePWV, and cardiovascular risk factors

The Pearson correlation analysis of OBS, ePWV, and cardiovascular risk factors is presented in Tables 2 and 3. The results demonstrate a negative correlation between the OBS index and BMI, SBP, and HbA1c. Additionally,

a negative correlation is observed between the OBS index and HDL-C; however, no significant correlation is found with DBP and TC. Table 3 reveals that ePWV exhibits significant correlations with BMI, SBP, DBP, HbA1c, TC, and HDL-C.

Association between OBS and ePWV

We aim to investigate the potential impact of OBS on ePWV employing a linear regression model that accounts for various confounding factors. The association between OBS and ePWV is presented in Table 4. We observed a significant negative correlation between OBS (Per 1SD increase) and ePWV in the gradually adjusted models. However, when OBS was utilized as a classification variable in model 3, with Q1 group serving as the reference group, there was a gradual decrease in the β value of ePWV across Q2, Q3, and Q4 groups. This finding indicates a significant linear negative correlation (p for trend < 0.001). The dose-response relationship between OBS and ePWV is observed through the application of a generalized additive model and fitting curve as visual representations, which also demonstrate a linear negative correlation (See Fig. 1).

Table 4 The association between OBS and ePWV in diferent models

OBS Index	ePWV, m/s, β (95%CI)		
	Model 1	Model 2	Model 3
Per 1SD increase	-0.10 (-0.13, -0.06)	-0.05 (-0.07, -0.04)	-0.04 (-0.05, -0.03)
Quartiles			
Q1 (0 to<11)	0	0	0
Q2 (11 to<19)	0.18 (0.06, 0.29)	-0.06 (-0.10, -0.01)	-0.01 (-0.04, 0.02)
Q3 (19 to<24)	-0.06 (-0.17, 0.06)	-0.07 (-0.12, -0.02)	-0.05 (-0.08, -0.01)
Q4 (24 to < 37)	-0.24 (-0.35, -0.12)	-0.13 (-0.17, -0.08)	-0.09 (-0.12, -0.06)
P for trend	< 0.001	< 0.001	< 0.001

Model 1 was adjusted for none

Model 2 was adjusted for age, sex, BMI, race, poverty income ratio

Model 3 was adjusted for age, sex, BMI, race, poverty income ratio, SBP, DBP, smoking status, HbA1c, CRP, TC, HDL, eGFR, DM, CVD, Hypertension, antihypertensive drugs, Lipoprotein-lowering drugs, hypoglycemic drugs

Association between OBS and elevated ePWV

The results of the multivariate logistic regression model in Table 5 indicate that there is no significant linear correlation between OBS and elevated ePWV, even after adjusting for all confounding factors. Comparing to the OBS Q1 group, the odds ratios (OR) for elevated ePWV in Q2-Q4 groups were 0.76 (95%CI:0.39–1.46), 0.57(95%CI:0.28–1.15), and 0.69 (95%CI:0.33–1.45) respectively; however, their corresponding 95% CI all exceeded 1, indicating no statistical difference (p for trend > 0.05). The nonlinearity of the dose-response

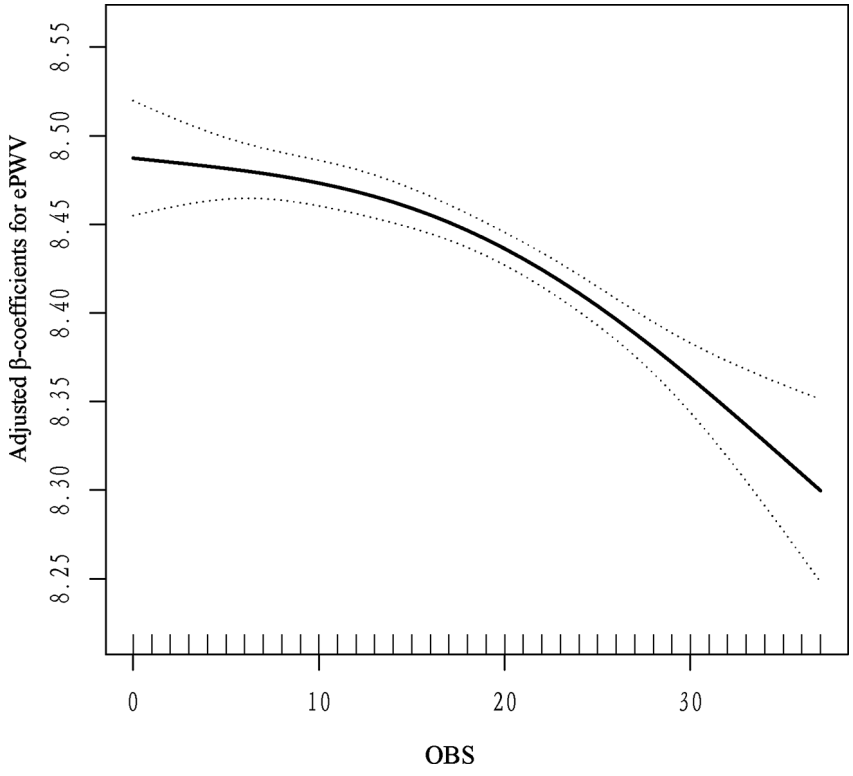

Fig. 1 Dose-response relationship between OBS and ePWV. Models were adjusted for age, sex, BMI, race, poverty income ratio, SBP, DBP, smoking status, HbA1c, CRP, TC, HDL, eGFR, DM, CVD, Hypertension, antihypertensive drugs, Lipoprotein-lowering drugs, hypoglycemic drugs

Table 5 The association between OBS and elevated ePWV in diferent models

OBS Index	Event (%)	Elevated ePWV, OR (95%CI)		
		Model1	Model 2	Model 3
Per 1SD increase	3242 (24.80%)	0.91 (0.88, 0.95)	0.96 (0.89, 1.05)	0.81 (0.62, 1.06)
Quartiles				
Q1 (0 to<11)	742 (25.13%)	1	1	1
Q2 (11 to<19)	999 (28.83%)	1.21 (1.08, 1.35)	1.02 (0.82, 1.27)	0.76 (0.39, 1.46)
Q3 (19 to<24)	763 (23.75%)	0.93 (0.83, 1.04)	0.97 (0.77, 1.22)	0.57 (0.28, 1.15)
Q4 (24 to < 37)	738 (21.43%)	0.81 (0.72, 0.91)	1.01 (0.80, 1.27)	0.69 (0.33, 1.45)
P for trend		< 0.0001	0.929	0.220

Model 1 was adjusted for none

Model 2 was adjusted for age, sex, BMI, race, poverty income ratio

Model 3 was adjusted for age, sex, BMI, race, poverty income ratio, SBP, DBP, smoking status, HbA1c, CRP, TC, HDL, eGFR, DM, CVD, Hypertension, antihypertensive drugs, Lipoprotein-lowering drugs, hypoglycemic drugs

relationship between OBS and elevated ePWV, as depicted in Fig. 2, is evident. Based on the aforementioned results, a two-piecewise logistic regression adjusted model was subsequently employed to establish the association between OBS and elevated ePWV (Table 6), and the inflection point was determined as 5. The increased risk of elevated ePWV (OR:0.70; 95%CI:0.51–0.94) gradually decreases with the increase

Table 6 Results of two-piecewise logistic regression model

OBS Index	Elevated ePWV, OR (95%CI)[#], *P* value	
Inflection point (K)	Unadjusted models	Adjusted models[#]
≤ 5	1.11 (1.06, 1.17) *P* < 0.0001	0.70 (0.51, 0.94) *P* = 0.019
> 5	0.98 (0.98, 0.99) *P* < 0.0001	1.00 (0.96, 1.04) *P* = 0.945
P for log likelihood ratio test	< 0.001	0.028

Two-piecewise logistic regression model was used to calculate the threshold effect of the OBS. If the log likelihood ratio test>0.05, it means the two-piecewise logistic regression model is not superior to the single-line logistic regression model

[#]Adjusted for age, sex, BMI, race, poverty income ratio, SBP, DBP, smoking status, HbA1c, CRP, TC, HDL, eGFR, DM, CVD, Hypertension, antihypertensive drugs, Lipoprotein-lowering drugs, hypoglycemic drugs

of OBS on the left side of the inflection point; however, when OBS exceeds 5, this decrease in risk of elevated ePWV(OR:1.00; 95%CI:0.96–1.04) is no longer observed (*P* for log likelihood ratio test = 0.028).

Discussion

In this extensive cross-sectional study involving American adults, we observed a significant association between higher OBS levels and lower ePWV levels, while also noting a non-linear L-shaped correlation between OBS and

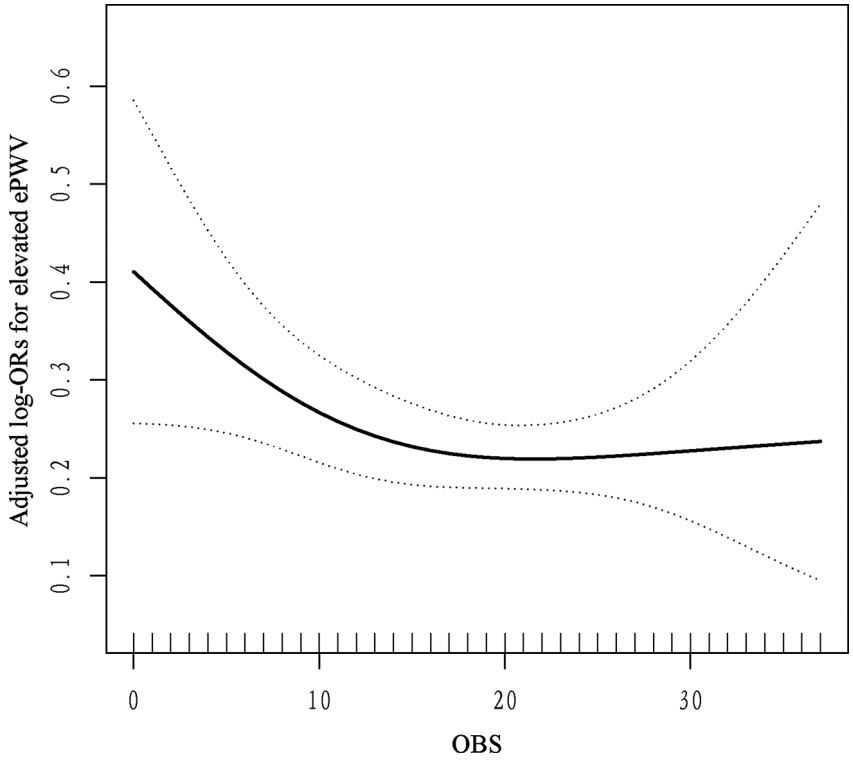

Fig. 2 Dose-response relationship between OBS and elevated ePWV . Models were adjusted for age, sex, BMI, race, poverty income ratio, SBP, DBP, smoking status, HbA1c, CRP, TC, HDL, eGFR, DM, CVD, Hypertension, antihypertensive drugs, Lipoprotein-lowering drugs, hypoglycemic drugs

arterial stiffness.The inflection point of OBS was also determined to be 5, and it was observed that a significant reduction in the risk of arterial stiffness occurred only when OBS≤5.

The relationship between OBS and ePWV, as well as arteriosclerosis, has not been investigated in previous studies, with only one study assessing the impact of OBS on cardiovascular events [17]. Titilayo's team utilized the chronic renal Insufficiency cohort to investigate the association between OBS and cardiovascular diseases (CVD). The findings revealed that among 3233 CKD patients, while an unadjusted original model demonstrated a protective effect of increased OBS on CVD, this relationship was not observed in the fully adjusted model (*P* for trend=0.93) [17]. The aforementioned research confirms the absence of a linear association between OBS and CVD; however, it does not delve into investigating any potential nonlinear correlation between them. Therefore, this study bridges the gap in the examination of OBS and cardiovascular diseases by exploring their nonlinear relationship with arterial stiffness.

This study represents the first attempt to assess the impact of oxidative stress-related exposure using OBS as a comprehensive measurement method on ePWV in American adults, classified ePWV was an indicator of arterial stiffness. The impact of OBS elevation in various disease states on diverse outcomes is not concurrent. We observed a consistent negative linear correlation between OBS and ePWV levels, regardless of whether they were treated as continuous or categorical variables. Moreover, the effect size of ePWV decreased progressively with increasing OBS levels. However, when considering elevated ePWV as a classified variable in the disease, the benefits of increasing OBS are limited. The results demonstrate a saturation effect OBS and elevated ePWV, with an cutoff point of OBS to be 5. On the left side of the inflection point, there is a negative correlation between OBS and elevated ePWV, while on the right side of the inflection point, there is no association between increased OBS and decreased arterial stiffness. Therefore, in clinical practice, it is imperative to ascertain the patients' oxidative balance and provide efficacious dietary and lifestyle guidance to further mitigate the incidence of arterial stiffness.

With the increase of OBS, the mechanism of ePWV level decrease may be due to the effective action of antioxidants. The ePWV is derived from a coefficient formula incorporating age and blood vessel data, enabling the estimation of blood vessel age. There is compelling evidence suggesting the efficacy of OBS in mitigating the aging process. A cross-sectional study conducted by Zhang et al [20]. on a cohort of 3220 American adults reveals a significant positive correlation between OBS and telomere length, specifically observed in women only. Given the positive correlation between telomere attrition and the heightened incidence of age-related diseases [29–32], it is widely acknowledged that telomere wear significantly contributes to increased morbidity and mortality. Furthermore, this study demonstrates that augmenting OBS levels can potentially modulate biological aging and age-related diseases through regulation of telomere length.

The current research also has certain limitations. Firstly, the cross-sectional nature of the data poses challenges in establishing causality. Secondly, the dietary composition of OBS is derived from self-reported 24-hour data, which may errors and deviations; that self-reported data has been validated in published studies [33]. Although the analysis has been adjusted for several potential confounders, residual confounding is still likely. Thirdly, we deleted more than 20,000 subjects with missing variables in this study, but the balance of data distribution will not change the results of the study. Lastly, this study lacks oxidative stress biomarkers to validate the efficacy of OBS in assessing oxidation equilibrium.

Conclusions

In summary, there exists a significant association between OBS and ePWV in the context of American adults. Specifically, OBS exhibits a negative correlation with ePWV; however, when considering an elevated ePWV, a saturation effect is observed in relation to OBS. Notably, only when OBS≤5 does an increase in OBS levels demonstrate a protective impact on arterial stiffness.

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Author contributions

YMS participated in literature search, study design, data collection, data analysis, data interpretation, and wrote the manuscript. YMS and WZ conceived of the study, and participated in its design, coordination, data collection and analysis. WZ participated in study design and provided the critical revision. All authors read and approved the final manuscript.

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Data availability

Publicly available datasets were analyzed in this study. This data can be found here: https://www.cdc.gov/nchs/nhanes/index.htm.

Declarations

Ethics approval and consent to participate

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

Informed consent

Informed consent was obtained from all individual participants included in the study.

Competing interests
The authors declare no competing interests.

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