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Research Paper

Interaction between body mass index and blood pressure on the risk of vascular stiffness : A community-based cross-sectional study and implications for nursing

Yiyan Wang [a,1], Hao Wang [b,1], Jie Zhou [a], Jiaqi Wang [a], Hengjing Wu [c], Jing Wu [a,*]

[a] School of Nursing, Shanghai University of Traditional Chinese Medicine, Shanghai, China
[b] Department of Critical Care Medicine, West China Hospital of Sichuan University, Sichuan, China
[c] Clinical Center for Intelligent Rehabilitation Research, Shanghai Yangzhi Rehabilitation Hospital (Shanghai Sunshine Rehabilitation Center), Yangzhi Rehabilitation Hospital, Tongji University, Shanghai, China

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A B S T R A C T

Objective: This study aimed to analyze associations between body mass index (BMI) and vascular measurements (brachial ankle pulse wave velocity [baPWV] and ankle-brachial index [ABI]), whether blood pressure (BP) was involved in the relationship, and implications for nursing.
Methods: A cross-sectional study was conducted, including 1,894 middle-aged and older adults who underwent routine health screening at a community medical center in the Zhangjiang community in Shanghai, China. Participants were divided into three groups based on BMI: normal weight (n = 1,202), overweight (n = 480), and obese (n = 212). Multivariate linear regression models and smooth curve fittings were used to evaluate the associations between BMI and indices of vascular stiffness. Mediation analysis examined whether blood pressure mediate the association between BMI and vascular stiffness.
Results: Multiple linear regression analysis showed that BMI to be significantly and negatively associated with baPWV ($\beta = -0.06$ [-0.10, -0.03]) and ABI ($\beta = -0.004$ [-0.005, -0.003]), respectively. The interaction test results of systolic blood pressure (SBP) in the relationship between BMI and baPWV were significant (P for interaction = 0.01). After adjusting for age and sex, mediation analyses showed that BMI and baPWV were correlated ($\beta = 0.090$, $P < 0.001$) and mediated by SBP ($\beta = 0.533$, $P < 0.001$) and diastolic blood pressure (DBP) ($\beta = 0.338$, $P < 0.001$). A negative association was found between BMI and ABI ($\beta = -0.135$, $P < 0.001$), which appeared to be partially mediated by SBP ($\beta = 0.124$, $P < 0.001$) and DBP ($\beta = 0.053$, $P < 0.001$). Additional subgroup analysis based on blood pressure levels did not revealed statistically significant mediating effects.
Conclusions: Our findings showed conflicting associations between BMI and non-invasive vascular measurements of arterial stiffness. BP may have a biological interaction in the relationship between BMI and baPWV. Managing blood pressure and weight through comprehensive clinical care is crucial for preventing stiffness or blockage of vessels in middle-aged and older adults.

What is known?

- Vascular stiffness is a significant pathological factor for cardiovascular disease (CVD) and is strongly linked to the morbidity and mortality of CVD.
- Vascular stiffness, measured by brachial ankle pulse wave velocity (baPWV) and ankle-brachial index (ABI), is independently associated with body weight status and blood pressure.
- A positive correlation was found between blood pressure and baPWV, but there were inconsistent outcomes for the relationship between BMI and baPWV.

* Corresponding author.
E-mail address: jingwuclose@126.com (J. Wu).
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[1] These authors contributed equally to this work.

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What is new?

- The study revealed a negative correlation between BMI and two vascular stiffness parameters (baPWV and ABI), among hypertensive patients, which contrasts with clinical experience.
- Even though baPWV was greater in individuals with high blood pressure regardless of BMI, a negative correlation was observed between BMI and baPWV in the high blood pressure group.
- One possible explanation for this phenomenon is that in hypertensive obese patients, aortic elasticity may increase adaptively, leading to an unfavorable association between BMI and baPWV.

1. Introduction

Vascular impairment, characterized by increased arterial stiffness and atherosclerotic vessel changes, is a subclinical pathological phenotype of peripheral arterial disease (PAD) [1,2]. For decades, nurse practice in PAD contributed significantly to catheter-directed thrombolytic therapy [3]. In recent years, nurse practitioners have also helped provide better healthcare advice to patients to reduce the risk of PAD progression [4]. In the clinical setting, the symptom that nurses may most often associate with vascular impairment is claudication or chest pain [5]. However, vascular lesions with significant clinical symptoms usually indicate irreversible vascular dysfunction and are associated with poor patient prognosis. The main indicators of vascular stiffness can be assessed noninvasively through the measurement of pulse wave velocity (PWV) and ankle-brachial index (ABI) [6,7]. Recent research suggests that older persons in the community with elevated PWV or ABI have an increased of all-cause mortality [8]. Atherosclerotic vascular impairment often remains undiagnosed; hence, people at risk of the symptoms associated with the disorder are frequently left untreated [9]. For nurses, managing vascular stiffness necessitates a greater emphasis on detection and risk assessment, which can improve patient survival and allow the early implementation of risk factor management or mitigation strategies [10].

It has been established that atherosclerotic vascular impairment develops with age, and several risk factors for cardiovascular disease (CVD), including hyperlipidemia, diabetes, and smoking, can also accelerate this progression [11,12]. Obesity is another common risk factor for CVD, and the relationship between obesity and vascular stiffness has drawn increasing attention, although with contradictory conclusions. Several studies have reported no association between BMI and arterial stiffness [13,14], while others have shown a clear association of obesity with accelerated arterial stiffness [15]. Moreover, studies have reported obesity as a potentially protective factor associated with improved vascular function [16,17]. One explanation for this paradoxical relationship may be that arterial blood pressure (BP) was not considered [18]. This is because BMI may have a blunting effect on the increment of PWV associated with rising BP [19]. Although the association between BMI and CVD is frequently reported in middle-aged and older adults, its relationship with the indicators of vascular stiffness remains unclear.

Because BP and body weight are crucial risk factors for atherosclerosis, exploring the interaction between these factors on vascular stiffness is crucial for facilitating comprehensive CVD prevention and control programs. Considering the simplicity and reduced burden for patients, the measurement of brachial ankle pulse wave velocity (baPWV) was chosen for this study. Thus, our present study aimed to investigate the association between BMI and two non-invasive measures of vascular stiffness (baPWV and ABI) and examine the interaction between BMI and BP on vascular stiffness in a community-based middle-aged and elderly population.

2. Methods

2.1. Study design and participants

A cross-sectional study was conducted in the Zhangjiang community in Shanghai, China from March to December 2019. Middle-aged and older adults undergoing routine health examinations at the Community Healthcare Center were recruited using a whole-group sampling methodology. The inclusion criteria were: 1) participants were aged 55 years or older; 2) participants provided voluntary informed consent; 3) participants had basic language comprehension, as well as normal cognitive and consciousness levels. Exclusion criteria were those participants with a medical history of malignant disease and a lack of written informed consent. Linear regression was the primary statistical methodology for this study, and the sample size of the data needed 5–10 times the number of independent variables. As our study involved testing 27 independent variables, the sample size required to be at least 270 [20].

2.2. Instruments

2.2.1. General information questionnaire

We collected general demographic information of patients, including their gender, age, and education level, using a self-designed questionnaire.

2.2.2. Physical examination

Physical examination and a short interview were performed to assess the current health status of each participant. Clinical and anthropometrical variables, including BMI, heart rate (HR), systolic blood pressure (SBP), and diastolic blood pressure (DBP), were measured or assessed. The smoking, alcohol drinking, physical activity, and medication status were collected during the face-to-face interview. Physical activity levels were evaluated based on self-reported data [21]. Individuals who reported no exercise habits were categorized as sedentary. At the same time, those who engaged in physical activity below the benchmark of 150 min of moderate aerobic activity or 75 min of vigorous aerobic activity per week were classified as having mild physical activity levels. On the other hand, those who met or exceeded these benchmarks were classified as having high levels of physical activity. Self-reported medical conditions were recorded, including diabetes, dyslipidemia, and chronic kidney disease (CKD).

2.2.3. Indices of vascular stiffness

PWV is most commonly measured using baPWV and carotid-femoral pulse wave velocity (cfPWV). Compared with cfPWV, baPWV is simpler to perform, less time-consuming, and less stressful for the patient [22,23]. Therefore, baPWV was used to assess arterial stiffness in this study.

We used a volume plethysmographic device (PWV/ABI, Omron Corp., Tokyo, Japan) to measure baPWV and ABI by a previously reported method. The baPWV and ABI were measured with the participant in a supine position after 5 min of rest. Using an oscillometric method, the device simultaneously recorded the bilateral pulse waves of the brachial and posterior tibial arteries. Electrocardiography electrodes were placed on the participants' arms (above the wrists), a microphone for detecting heart sounds was placed on the sternum, and cuffs were wrapped around the upper arms and ankles. For the analysis, the mean value of the baPWV values on the right and left sides baPWV value was used to get the total baPWV value. The ABI value was calculated by dividing the maximum ankle SBP by the higher brachial SBP.

2.3. Data collection

After receiving formal training, the study group members collaborated with nurses from the physical examination center to distribute the questionnaire to participants. Before conducting the physical examination, the study group obtained informed consent from the participants after explaining the study's purpose and precautions. Demographic information was also collected from the participants by the study group. The physical examination results were obtained from the physical examination center one week after completion.

2.4. Statistical analysis

The statistical analyses were conducted with R (http://www.R-project.org, The R Foundation) and EmpowerStats software (http://www.empowerstats.com, X&Y Solutions, Inc., Boston, MA). Categorical data are expressed as numbers and percentages and compared using the chi-square test. Continuous variables that conformed to a normal distribution were presented as the *Mean* ± *SD* and analyzed using one-way ANOVA; whereas, non-normal distributed variables were presented as *Median* (P_{25}, P_{75}) and tested by the Krukal-Wallis *H* test. Comparisons between two groups were performed using the least significant difference (LSD). Multivariate linear regression models and smooth curve fittings were used to evaluate the associations between BMI, baPWV, and ABI. The other variables were considered potential effect modifiers. We performed tests for linear trends by entering the median value of each category of BMI as a continuous variable in the models. Stratified and interaction analyses were conducted according to gender (male and female), age (<60, 60–80, and >80 years), and SBP (<130, 130–140, and ≥140 mmHg, 1 mmHg = 0.133 kPa). Mediation analysis was conducted using the PROCESS macro of SPSS (SPSS, Chicago, IL, USA) to explore whether blood pressure variables could mediate the association between BMI and vascular function variables.

2.5. Ethical consideration

The ethical aspects of this study were reviewed and approved by the Ethical Committee of the Shanghai Yangzhi Rehabilitation Hospital (YZ 2019-051). All participants provided signed, informed written consent forms.

3. Results

3.1. Baseline characteristics

The baseline characteristics of 1,894 participants are shown in Table 1. Participants were stratified into three groups according to BMI (18.5–24.9 kg/m^2, normal weight; 25–27.9 kg/m^2, overweight; and ≥28 kg/m^2, obese) based on published values for the Chinese population [24,25]. The mean age of study participants was 64.95 ± 8.44 years, of which 32.21% were males. Significant differences occurred between weight groups in SBP, DBP, baPWV, and ABI. The normal weight group had lower mean values of SBP, DBP, and baPWV, while the mean value of ABI was higher. 21.22% of the participants had a history of smoking, 13.88% of the participants had a history of drinking, 8.08% of the participants had diabetes, 22.55% of the participants had dyslipidemia, and 2.87% of the participants had chronic kidney disease (CKD).

3.2. Association between BMI and baPWV and ABI

Table 2 presents the association between BMI and baPWV, and ABI. In model 1 (unadjusted model), we observed a positive association between BMI and baPWV [0.11 (0.07, 0.16)]. However, a negative association was observed between BMI and baPWV in model 2 (adjustment for age, sex, and SBP) [−0.06 (−0.09, −0.02)]. Similar results were found in model 3 (fully adjusted model) [−0.06 (−0.10, −0.03)]. Stratified by BMI, the trend test remained significant between them (P = 0.015). We also performed generalized additive models and smooth curve fittings to evaluate their associations (Appendix A).

Moreover, in model 1 (unadjusted model), we observed a negative association between BMI and ABI [−0.003 (−0.004, −0.002)]. Similar results were obtained by model 2 (adjustment for age, sex, SBP) [−0.004 (−0.005, −0.003)] and model 3 (fully adjusted model) [−0.004 (−0.005, −0.003)] (Appendix A). Trend estimates remained significant across analyses stratified by BMI (P < 0.001).

3.3. Interaction of blood pressure

Age and gender are known factors that influence the association between BMI and baPWV, while SBP is a factor that has been shown to affect this association in the literature. Therefore, age, gender, and SBP were included in the subgroup analysis, and their potential interactions were examined regarding the association between BMI and vascular stiffness indicators. SBP was categorized based on the Management of Hypertension in Primary Health Care in China (2020) [26] and relevant previous studies, using cut-off values of 130 mmHg and 140 mmHg. Table 3 examined population subgroups stratified by sex, age, and SBP to investigate the association between BMI and atherosclerotic indicators. The association between BMI and baPWV remained negative only in the hypertensive group (SBP ≥130 mmHg) (Table 3, Appendix B). In addition, the association between BMI and ABI was consistent in different sex groups, age groups, and SBP groups (Table 3, Appendix B). No significant interaction effect was found.

Grouping was done by SBP (<130 and ≥ 130 mmHg) and BMI(<25 and ≥ 25 kg/m^2) (Table 4; Appendix C). The baPWV was higher in groups BMI (−)/SBP (+) and BMI (+)/SBP (+), indicating that regardless of BMI, baPWV was higher in hypertensive (Appendix C). The baPWV in group BMI (+)/SBP (-) was smaller than in the other three groups. Statistically significant differences were found in the baPWV and ABI between blood pressure and BMI subgroups (Appendix C).

Mediation analysis diagrams are shown in Fig. 1. BP variables mediated the relationship between BMI and vascular stiffness variables in the total population (P < 0.05). Further subgroup analysis based on SBP showed a positive effect between BMI and baPWV in participants with SBP < 130 mmHg, while the opposite was true in participants with high blood pressure levels. BMI's total and direct effects on ABI were consistently negative across all subgroups analyzed. Still, the regression coefficients between BMI and vascular variables did not achieve statistical significance in almost subgroup analyses.

4. Discussion

In this study, we discovered a negative association between BMI and two essential indicators of vascular stiffness (baPWV and ABI) among middle-aged and elderly individuals. Nevertheless, this association varied across subpopulations categorized based on blood pressure levels. Further sensitivity and mediating effect analyses supported the hypothesis that BP potentially mediates the

Table 1
Baseline characteristics of the total participants according to different BMI groups.

Variables	Total (n = 1,894)	Normal weight (n = 1,202)	Overweight (n = 480)	Obese (n = 212)	$F/\chi^2/H$	P
Age (years)	64.95 ± 8.44	64.58 ± 8.47	65.68 ± 8.38	65.38 ± 8.28	1.703	0.038
Gender					4.377	0.106
Male	610 (32.22)	374 (31.11)	173 (36.04)	63 (29.72)		
Female	1,284 (67.79)	828 (68.89)	307 (63.96)	149 (70.28)		
HR (beat/min)	73.54 ± 10.71	73.17 ± 10.18	73.81 ± 11.94	75.06 ± 10.60	3.924	0.060
SBP (mmHg)	134.45 ± 21.95	130.91 ± 21.98	139.02 ± 19.32	144.13 ± 22.55	49.712	<0.001
DBP (mmHg)	75.87 ± 11.69	73.44 ± 11.01	79.12 ± 10.87	82.24 ± 12.97	84.439	<0.001
baPWV (m/s)	15.17 (13.41, 17.55)	14.83 (13.18, 17.27)	15.81 (13.74, 17.99)	15.74 (14.21, 18.13)	31.440	<0.001
ABI	1.11 ± 0.08	1.12 ± 0.08	1.10 ± 0.08	1.09 ± 0.09	17.555	<0.001
Smoking	402 (21.22)	250 (20.79)	108 (22.50)	44 (20.75)	2.760	0.738
Drinking	263 (13.88)	163 (13.56)	76 (15.83)	24 (11.32)	10.473	0.285
Physical activity					3.983	0.496
Sedentary	105 (5.54)	70 (5.82)	28 (5.83)	7 (3.30)		
Mild level	1,393 (73.55)	872 (72.56)	357 (74.38)	164 (77.36)		
High level	396 (20.91)	260 (21.63)	95 (19.79)	41 (19.34)		
Diabetes	153 (8.08)	84 (6.98)	38 (7.92)	30 (14.15)	16.363	0.002
Dyslipidemia	427 (22.54)	238 (19.80)	123 (25.63)	66 (31.13)	16.113	<0.001
CKD	54 (2.85)	31 (2.58)	13 (2.71)	10 (4.72)	5.803	0.212
Statins	36 (1.90)	20 (1.66)	9 (1.88)	7 (3.33)	25.540	0.270
Anti-diabetic medication	128 (6.76)	7 (0.58)	29 (6.04)	28 (13.21)	20.854	<0.001
Anti-hypertensive medication	414 (21.86)	247 (20.55)	112 (23.33)	55 (25.94)	10.825	0.172

Note: Data are n (%), *Mean* ± *SD*, or *Median* (P_{25}, P_{75}). 1 mmHg = 0.133 kPa. BMI = body mass index. SBP = systolic blood pressure. DBP = diastolic blood pressure. HR = heart rate. baPWV = brachial ankle pulse wave velocity. ABI = ankle-brachial index. CKD = chronic kidney disease.

Table 2
The multivariate linear regression analyses between BMI and baPWV and ABI.

Variables	baPWV			ABI		
	Model 1 β (95% CI)	Model 2 β (95% CI)	Model 3 β (95% CI)	Model 1 β (95% CI)	Model 2 β (95% CI)	Model 3 β (95% CI)
BMI	0.11 (0.07, 0.16)	−0.06 (−0.09, −0.02)	−0.06 (−0.10, −0.03)	−0.003 (−0.004, −0.002)	−0.004 (−0.005, −0.003)	−0.004 (−0.005, −0.003)
P for trend	<0.001	0.004	<0.001	<0.001	<0.001	<0.001
BMI categories						
18.5–25 kg/m^2	Reference	Reference	Reference	Reference	Reference	Reference
25–28 kg/m^2	0.63 (0.27, 0.98)	−0.19 (−0.45, 0.07)	−0.20 (−0.46, 0.05)	−0.014 (−0.022, −0.005)	−0.018 (−0.027, −0.010)	−0.017 (−0.025, −0.008)
≥28 kg/m^2	0.82 (0.33, 1.31)	−0.33 (−0.69, 0.02)	−0.40 (−0.76,-0.04)	−0.032 (−0.044, −0.020)	−0.038 (−0.049, −0.026)	−0.035 (−0.047, −0.022)
P for trend	<0.001	0.035	0.015	<0.001	<0.001	<0.001

Note: Model 1, no covariates were adjusted; Model 2, age, gender, SBP were adjusted; Model 3, age, gender, SBP, HR, smoking, drinking, physical activity, diabetes mellitus, dyslipidemia, CKD, anti-hypertensive medication, anti-diabetic medication, anti-dyslipidemia medication were adjusted. ABI = ankle-brachial index. BMI = body mass index. baPWV = brachial ankle pulse wave velocity. SBP = systolic blood pressure. HR = heart rate. CKD = chronic kidney disease.

Table 3
Stratified and interaction analyses between BMI and arterial stiffness.

Variables	baPWV (m/s)		ABI	
	Adjusted β (95% CI)	P for interaction	Adjusted β (95% CI)	P for interaction
Gender				
Male	−0.07 (−0.14, −0.01)	0.71	−0.004 (−0.006, −0.002)	0.93
Female	−0.06 (−0.10, −0.02)		−0.004 (−0.005, −0.002)	
Age (years)				
<60	−0.03 (−0.10, 0.04)	0.20	−0.004 (−0.006, −0.002)	0.38
60 - 80	−0.07 (−0.11, −0.03)		−0.004 (−0.005, −0.002)	
>80	−0.18 (−0.34, −0.02)		−0.007 (−0.012, −0.002)	
SBP (mmHg)				
<130	0.03 (−0.03, 0.09)	0.01	−0.004 (−0.006, −0.002)	0.85
130 - 140	−0.05 (−0.12, 0.02)		−0.004 (−0.006, −0.002)	
≥140	−0.10 (−0.16, −0.04)		−0.003 (−0.005, −0.001)	

Note: Each stratification adjusted for all the factors (age, gender, SBP, HR, smoking, drinking, physical activity, diabetes mellitus, dyslipidemia, CKD, anti-hypertensive medication, anti-diabetic medication, anti-dyslipidemia medication) except the stratification factor itself. The P values presented in the table reflect the statistical analysis of whether subgroup factors had an interaction and effect on BMI and atherosclerotic indexes. 1 mmHg = 0.133 kPa. BMI = body mass index. baPWV = brachial-ankle pulse wave velocity. ABI = ankle-brachial index. SBP = systolic blood pressure. HR = heart rate. CKD = chronic kidney disease.

biological effect in the relationship between BMI and baPWV. These findings indicate that BP might modify the impact of weight on vascular stiffness, and early integrated care for weight and BP indicators might improve vascular health in middle-aged and older individuals.

Several other studies [17,27,28] also found a negative association between BMI and baPWV after adjusting for confounding factors. This negative correlation was considered a possible explanation for the obesity paradox. Several population-based samples found that obesity in older subjects and patients with multiple chronic

Table 4
The baPWV and ABI among different groups.

Variables	BMI (−)/SBP (−)[a] ($n = 628$)	BMI (−)/SBP (+)[b] ($n = 563$)	BMI (+)/SBP (−)[c] ($n = 236$)	BMI (+)/SBP (+)[d] ($n = 452$)	*H/F*	*P*
baPWV (m/s)	13.90 ± 2.27	17.47 ± 3.49	14.31 ± 2.27	17.28 ± 3.20	553.14	<0.001 (a < b, d; c < b, d)
ABI	1.11 ± 0.08	1.13 ± 0.08	1.08 ± 0.08	1.11 ± 0.09	17.34	<0.001 (c < a < b; b > c, d; c < d)

Note: Data are *Mean* ± *SD*. Group BMI (−)/SBP (−), BMI 18.5–25 kg/m^2 and SBP ≤130 mmHg; Group BMI (−)/SBP (+), BMI 18.5–25 kg/m^2 and SBP >130 mmHg; Group BMI (+)/SBP (−), BMI >25 kg/m^2 and SBP ≤130 mmHg; Group BMI (+)/SBP (+), BMI >25 kg/m^2 and SBP >130 mmHg. 1 mmHg = 0.133 kPa. BMI = body mass index. baPWV = brachial ankle pulse wave velocity. ABI = ankle-brachial index.

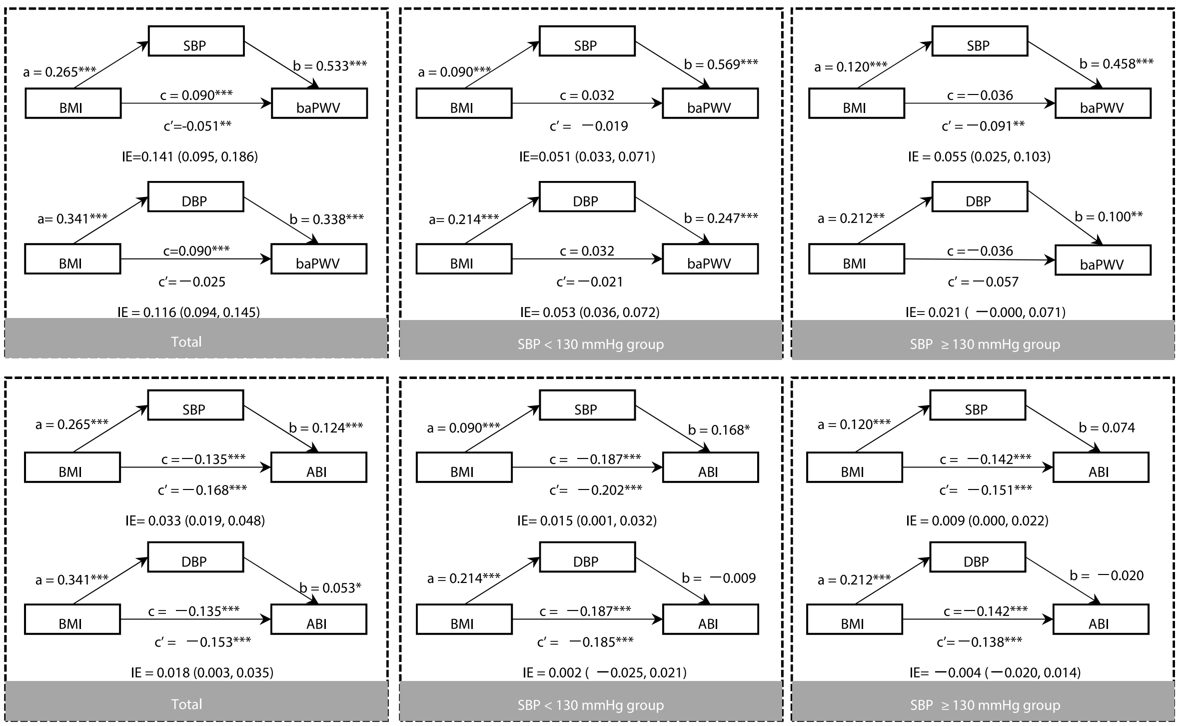

Fig. 1. Blood pressure mediation model of the relationship between BMI and vascular stiffness variables, controlling for age and sex. The total (c) and direct effects (a, b, c′) are reflected by the standardized regression coefficients and significance between the independent and dependent variables in each model. The indirect effect (IE) indicates the changes in vascular stiffness variables in each standardized unit change in BMI mediated by the proposed mediator. 1 mmHg = 0.133 kPa *P < 0.05; **P < 0.01; ***P < 0.001. BMI = body mass index. SBP = systolic blood pressure. DBP = diastolic blood pressure. baPWV = brachial ankle pulse wave velocity. ABI = ankle-brachial index.

diseases may be protective and associated with reduced mortality [29]. This counterintuitive association has been recognized as the obesity paradox [30]. In this study, we found a stable negative correlation between BMI and ABI, while BMI was also negatively associated with baPWV after adjusting for possible confounders. Different metrics measure a conflicting relationship between BMI and vascular stiffness. To explore the causes of this paradoxical association, we analyzed sex, age, and BP as stratified variables. A negative association between BMI and baPWV was observed only in participants with an SBP ≥130 mmHg. We concluded that a negative correlation between BMI and baPWV does not align with the concept of the obesity paradox.

One possible explanation for the finding that the association between BMI and baPWV varies with BP levels is the influence of medications. The majority of the participants in the hypertensive group may have been receiving more aggressive medical treatments. The baPWV is a biomarker of arterial stiffness, and some medical treatments may slow the progression of arterial stiffness in hypertensive patients [31,32]. Nevertheless, despite adjusting for medication use across different regression models and BP groups, we still observed a negative correlation between BMI and baPWV in the hypertensive participants.

Another possible explanation for this phenomenon is the vascular adaptation of obese patients to elevated BP. Obese patients tend to have elevated cardiac output (CO), reduced peripheral vascular resistance, and elevated left ventricular end-diastolic pressure [33]. However, hemodynamic adaptation varies in obese patients with different BP levels. Although total and central blood volumes are elevated in hypertensive obese individuals, they are lower than in normotensive individuals with similar levels of obesity [34,35]. In addition, CO left ventricular stroke volumes and peripheral vascular resistance are usually higher in hypertensive obese individuals than in hypertensive individuals of normal weight [35,36]. In hypertensive obese patients, aortic elasticity may be adaptively increased, resulting in a negative correlation between BMI and baPWV in hypertensive individuals. This may not indicate that BMI reduces the risk of arterial stiffness in individuals because left ventricular end-diastolic pressure and pulmonary capillary wedge pressure are more severely elevated in hypertensive obese individuals. A 30-year cohort study found long-term obesity and hypertension still harm vascular function [37].

In this study, the baPWV was higher in hypertensive than hypotensive individuals, regardless of BMI. This may be because elevated BP is a mechanical factor contributing to arterial stiffness [38,39], with BP having a greater effect on baPWV than BMI [40]. Therefore, it is possible that managing BP has a greater benefit on vascular stiffness than controlling BMI in preventing vascular damage among middle-aged and older individuals. Healthcare professionals need to pay attention to the weight and BP profile of middle-aged and older adults at risk for vascular stiffness. The concerned nurse practitioners can provide information to patients about the role of weight and BP management in the risk of vascular stiffness, recommend healthy lifestyle practices, and implement suitable measures to prevent further development of vascular stiffness or occlusion [41]. Community nurses possess the capacity to utilize a range of self-management models to enhance the proactive engagement of the older adults, foster the development of healthy behavioral habits, and actively engage in the management of blood pressure and weight to improve overall health levels. Moreover, multidisciplinary cooperation can be considered for comprehensive blood pressure and weight management to reduce the risk of vascular stiffness [42].

The present study included a larger sample size than previous similar studies, and it considered the interaction between BMI and BP on vascular stiffness. However, it has several limitations. First, this was a cross-sectional study, which prevents any causal inference. Second, unmeasured confounders may influence the results, such as detailed medical history and laboratory values. Third, our population had more female than male participants, which may have affected the study results. Zuo et al. [43] showed that females are more susceptible to weight-related atherosclerosis and increased blood pressure. Fourth, this was a single-center study, so the results still need to be further verified in a multi-center context. Finally, due to the limitations of BMI as a measure of adiposity, BMI may not reflect the specific distribution of body fat mass.

5. Conclusion

We found conflicting results regarding the associations between BMI and non-invasive vascular measurements of arterial stiffness and atherosclerosis. This phenomenon may be due to the biological interaction of BP in the relationship between BMI and baPWV. Additionally, more research is needed to comprehensively evaluate the potential for managing blood pressure to confer greater vascular benefits than managing BMI among middle-aged and older adults.

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CRediT authorship contribution statement

Yiyan Wang: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Writing - original draft, Writing - review & editing, Project administration. **Hao Wang**: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Writing - original draft, Writing - review & editing, Project administration. **Jie Zhou**: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources, Data curation, Writing - review & editing. **Jiaqi Wang**: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Writing - review & editing. **Hengjing Wu**: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources, Supervision, Writing - review & editing, Project administration. **Jing Wu**: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Funding acquisition, Writing - review & editing, Supervision, Project administration.

Data availability statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declaration of competing interest

The authors have declared no conflict of interest.

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Appendices. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijnss.2023.06.008.

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