

BMJ Open Cross-sectional association between body fat percentage and arteriosclerosis assessed by Cardio-Ankle Vascular Index in a Chinese population: a retrospective observational study

Linfeng He,¹ Lijuan Bai,¹ Lihua Liu,¹ Yun Liu,¹ Ruiyun Wang,¹ Yaoling Wang,¹ Man Liao,¹ Yizhou Wan,² Benling Qi ¹

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LH and LB contributed equally.

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¹Department of Geriatrics, Union Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, Hubei, China

²Department of Orthopaedics, Union Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, Hubei, China

Correspondence to

Benling Qi;
qibenlingok_2015@163.com

ABSTRACT

Objective To evaluate arteriosclerosis using Cardio-Ankle Vascular Index (CAVI) and to explore the relation between the body fat percentage (BFP) and CAVI.

Design A retrospective observational study.

Setting and participants A total of 1152 patients admitted to a geriatric unit and general practice at a mega hospital in Wuhan, China, from November 2018 to November 2019 were included in this study.

Primary outcome Association between BFP and CAVI.

Results Multiple linear regression analysis showed that BFP was positively correlated with CAVI after correction for potential confounding variables ($\beta=0.03$; 95% CI: 0.01 to 0.05); this association persisted after BFP was treated by quartile categorical variables and the trend test was statistically significant (p for trend=0.002). Meanwhile, the generalised additive model showed a non-linear association between BFP and CAVI. When BFP<20.6%, BFP is not associated with CAVI for ($\beta=-0.02$; 95% CI: -0.06 to 0.03), but when BFP \geq 20.6%, there is a linear positive association between BFP and CAVI ($\beta=0.05$; 95% CI: 0.02 to 0.07). Subgroup analysis showed that there was an interaction between BFP and CAVI in the age stratification (p interaction=0.038).

Conclusion BFP was non-linearly correlated with CAVI, with a 0.05 increase in CAVI for every 1% increase in BFP when BFP \geq 20.6% and a 0.03 increase in CAVI in those >65 years of age.

INTRODUCTION

Obesity and cardiovascular disease are two major threats to the world's public health. It was reported that in 2019, around 55.4 million people died worldwide and one-third of these deaths were due to cardiovascular disease, with the proportion in China even reaching over 47%.¹ In addition, obesity is also prevalent worldwide, with the number of overweight and obese people increasing from 921 million in 1980 to 2.1 billion in 2013.² A 2015 study in China found that the number of overweight and obese people in the country

Strengths and limitations of this study

- We used a generalised linear model to clarify the true association between body fat percentage (BFP) and Cardio-Ankle Vascular Index (CAVI).
- Subgroup analysis reduces heterogeneity across populations.
- This study does not follow-up the population to observe the effect of changes in BFP on CAVI.
- We were unable to include confounding factors such as exercise, diet and lipid-lowering medication use for analysis due to the retrospective nature of the study.

reached a staggering 600 million.³ What are brought by obesity are cardiovascular diseases such as coronary heart disease (CHD), hypertension and heart failure,^{4 5} with over two-thirds of obesity-related deaths resulting from cardiovascular disease.⁶ Obesity and cardiovascular diseases are closely linked, while the main bridge between the two is atherosclerosis (AS).⁷

Arteriosclerosis, as an atherosclerotic process, has been shown to be associated with obesity. Studies by Tang *et al*⁸ and Vianna *et al*⁹ showed that brachial-ankle pulse wave velocity (bapwv) increased with body mass index (BMI), but the opposite result was seen in studies by Rodrigues *et al*¹⁰ and Yang *et al*.¹¹ Clearly, this falls into the so-called obesity paradox,^{12 13} making the relationship between obesity and arteriosclerosis controversial. In contrast to previous studies, we speculate that this controversy may be due to the fact that BMI does not reflect the true picture of adiposity and the vulnerability of bapwv to blood pressure.¹⁴ Therefore, this study uses body fat percentage (BFP), which is a more accurate assessment of obesity, and

Cardio-Ankle Vascular Index (CAVI), which is more accurate than *bapwv* and is independent of blood pressure for analyses.^{15 16} In this study, we explored the relationship between BFP and CAVI and analysed other factors that may influence CAVI as well.

PARTICIPANTS AND METHODS

Study participants

A retrospective collection of 1152 patients who met the following two conditions at the same time: (a) those who were admitted to our geriatrics and general medicine departments from November 2018 to November 2019 and (b) those who had both arterial elastance and BFP measurements. Patients who met the following criteria were excluded: (1) unable to provide BFP and CAVI; (2) acute infection; (3) acute myocardial infarction; (4) stroke; (5) heart failure; (6) Cushing's syndrome; (7) primary aldosteronism; (8) nephrotic syndrome; (9) malignancy and (10) hormone therapy.

Study methods

Clinical characteristics and blood indicators

Information including age, gender, history of tobacco or alcohol consumption, diuretic use and comorbidities including hypertension, CHD, peripheral artery disease (PAD, defined as imaging tests such as Doppler ultrasound suggesting AS formation in the peripheral arteries and a discharge diagnosis of peripheral AS), diabetes, osteoporosis, chronic kidney disease (CKD), chronic obstructive pulmonary disease (COPD) and fatty liver at the time of hospitalisation were obtained from the hospital electronic medical record system. Blood indices such as total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C) and fasting glucose were collected by an automated biochemical analyzer from patients after 8 hours of fasting.

Measurements of BFP and CAVI

Subjects rested quietly in the supine position for about 5 min with hands placed flat on both sides of the body; cuffs were placed upper side of the elbow joints of both upper arms and both ankle joints; heart sound sensors were placed at the second intercostal sternum and ECG electrodes were placed at both wrists. All parts were checked to be connected properly, which took about 5 min. The CAVI values of the right and left sides of the subjects were measured using the VS-1500 arterial elastometer from Fukuda, Japan, and the mean values of the CAVI values on both sides were included in the study. The height, weight, BMI and BFP of the examinees 2 hours after meal were measured using Tsinghua Tongfang BCA-2A bioelectrical impedance body composition analyzer. The above-related operations were performed by professionals.

Statistical analysis

First, comparisons were made between BFP quartile groups, with continuous variables expressed as

mean±SD or median (Q1–Q3) and categorical variables as *n* (%). One-way ANOVA, Kruskal-Wallis and χ^2 tests were employed to elaborate the differences between these groups. Second, univariate linear regression was adopted to analyse the relationship between variables and CAVI. Third, BFP was included in the linear regression as a continuous variable and categorical variable to make clear the relationship between BFP and CAVI. Non-adjusted model, adjust I model and adjust II model were also constructed in the case of uncorrected variables and corrected variables, respectively. Besides, trend test was conducted to illustrate the group differences with BFP as a categorical variable. Fourth, the generalised additive model (GAM) was used to fit the curve of BFP and CAVI. Fifth, the two-segment linear regression model was used to calculate the best inflection point of the fitted curve. Finally, subgroups were made to observe the relationship between BFP and CAVI in different populations and their interactions were referenced to figure out the differences between such populations. A two-sided *p* value less than 0.05 was statistically significant. All statistical analyses were performed using R V.3.6.3.

Patient and public involvement

Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

RESULTS

Baseline characteristics

A total of 1152 people participated in this study, ranging from 18 to 95 years, of whom 798 were male, accounting for 69.3%. According to results, age, BMI, BFP, systolic blood pressure (SBP), HDL-C, TG, fasting glucose, gender, the prevalence of hypertension, diabetes, osteoporosis and fatty liver were statistically different among BFP quartile groups. So was the number of smokers and drinker. Compared with other three groups, participants in the Q4 group had higher age, BMI, BFP, SBP, fasting glucose, female proportion and fatty liver prevalence, and this group had fewer smokers and drinkers. More details are shown in [table 1](#).

Relationship between age, BMI and BFP

Spearman correlation analysis showed that age ($r=0.200$, $p<0.001$) and BMI ($r=0.410$, $p<0.001$) were positively correlated with BFP ([figure 1](#)). In [figure 1A](#), locally estimated scatterplot smoothing showed that age was negatively correlated with BFP in people older than 70 years. [Figure 1B](#) shows that, in contrast to the situation when $BMI>22$, a rapid increase was observed in BFP when $BMI<22$.

Univariate linear regression

According to univariate linear regression, age, gender, SBP, fasting glucose and the prevalence of hypertension, diabetes, PAD, CHD, osteoporosis, CKD, and COPD were

Table 1 Baseline characteristics

BFP	Q1	Q2	Q3	Q4	P value
N	277	296	289	290	
Age (years, mean±SD)	54.80±14.47	56.46±13.60	58.46±13.86	61.66±13.65	<0.001
BMI (kg/m ² , mean±SD)	22.12±2.59	24.38±2.61	25.16±3.12	26.05±3.70	<0.001
BFP (% , mean±SD)	18.83±3.80	24.01±0.97	27.26±1.10	33.27±3.16	<0.001
SBP (mm Hg, mean±SD)	125.09±15.75	128.98±16.54	130.16±17.48	134.37±18.98	<0.001
DBP (mm Hg, mean±SD)	81.13±10.33	83.54±10.80	82.45±10.20	81.73±10.84	0.040
CAVI (m/s, mean±SD)	8.06±1.35	8.17±1.36	8.21±1.58	8.27±1.47	0.359
TC (mmol/L, mean±SD)	4.32±1.08	4.39±1.05	4.47±1.12	4.45±1.14	0.355
TG (mmol/L, median (Q1–Q3))	1.15 (0.83–1.75)	4.45 (3.75–5.04)	4.37 (3.61–5.23)	1.40 (1.03–2.00)	<0.001
HDL-C (mmol/L, mean±SD)	1.25±0.36	1.14±0.33	1.17±0.34	1.24±0.34	<0.001
LDL-C (mmol/L, median (Q1–Q3))	2.49 (1.97–3.06)	2.63 (1.98–3.18)	2.61 (2.03–3.25)	2.60 (1.92–3.30)	0.255
Fasting glucose (mmol/L, median (Q1–Q3))	4.83 (4.49–5.36)	4.94 (4.61–5.60)	5.00 (4.57–5.62)	5.13 (4.69–5.73)	<0.001
Gender (n, %)					<0.001
Female	26 (9.39%)	42 (14.19%)	78 (26.99%)	208 (71.72%)	
Male	251 (90.61%)	254 (85.81%)	211 (73.01%)	82 (28.28%)	
CHD (n, %)					0.842
No	226 (82.78%)	230 (80.42%)	229 (80.07%)	231 (80.49%)	
Yes	47 (17.22%)	56 (19.58%)	57 (19.93%)	56 (19.51%)	
Hypertension (n, %)					<0.001
No	154 (56.41%)	110 (38.46%)	116 (40.42%)	112 (38.89%)	
Yes	119 (43.59%)	176 (61.54%)	171 (59.58%)	176 (61.11%)	
Diabetes (n, %)					0.001
No	196 (71.79%)	175 (60.55%)	191 (66.55%)	164 (56.94%)	
Yes	77 (28.21%)	114 (39.45%)	96 (33.45%)	124 (43.06%)	
PAD (n, %)					0.303
No	72 (26.37%)	71 (24.83%)	69 (24.13%)	57 (19.86%)	
Yes	201 (73.63%)	215 (75.17%)	217 (75.87%)	230 (80.14%)	
CKD (n, %)					0.486
No	260 (95.24%)	267 (93.36%)	272 (95.10%)	267 (92.71%)	
Yes	13 (4.76%)	19 (6.64%)	14 (4.90%)	21 (7.29%)	
COPD (n, %)					0.420
No	265 (97.07%)	277 (96.85%)	277 (96.85%)	273 (94.79%)	
Yes	8 (2.93%)	9 (3.15%)	9 (3.15%)	15 (5.21%)	
Osteoporosis (n, %)					0.042
No	231 (84.62%)	250 (87.41%)	245 (85.66%)	228 (79.17%)	
Yes	42 (15.38%)	36 (12.59%)	41 (14.34%)	60 (20.83%)	
Fatty liver (n, %)					<0.001
No	196 (71.27%)	164 (56.36%)	154 (53.66%)	139 (48.26%)	
Yes	79 (28.73%)	127 (43.64%)	133 (46.34%)	149 (51.74%)	
Smoking (n, %)					<0.001
No	163 (59.27%)	172 (59.11%)	200 (69.69%)	251 (87.15%)	
Yes	112 (40.73%)	119 (40.89%)	87 (30.31%)	37 (12.85%)	
Drinking (n, %)					<0.001
No	190 (69.09%)	175 (60.14%)	204 (71.08%)	255 (88.54%)	
Yes	85 (30.91%)	116 (39.86%)	83 (28.92%)	33 (11.46%)	
Diuretic use (n, %)					0.388
No	261 (94.22%)	271 (91.55%)	265 (91.70%)	262 (90.34%)	
Yes	16 (5.78%)	25 (8.45%)	24 (8.30%)	28 (9.66%)	

BFP, body fat percentage; BMI, body mass index; CAVI, Cardio-Ankle Vascular Index; CHD, coronary heart disease; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; DBP, diastolic blood pressure; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; PAD, peripheral artery disease; SBP, systolic blood pressure; TC, total cholesterol; TG, triglycerides.

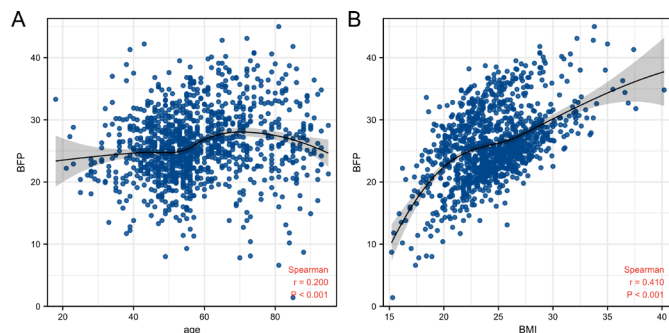


Figure 1 Scatterplot of age, BMI and BFP. (A) Age. (B) BMI. BFP, body fat percentage; BMI, body mass index.

positively correlated with CAVI; BMI, TC and TG were negatively correlated with CAVI and BFP, diastolic blood pressure (DBP), HDL-C, LDL-C and the prevalence of fatty liver, smoking and drinking were not correlated with CAVI. More details are shown in [table 2](#).

Different linear regression models

The relationship between BFP and CAVI was elaborated by constructing the non-adjusted model, adjust I model and adjust II model. According to the non-adjusted model, BFP was not correlated with CAVI ($\beta=0.00$; 95% CI: -0.01 to 0.02). According to adjust I model where age, BMI and gender were corrected, BFP was positively correlated with CAVI ($\beta=0.03$; 95% CI: 0.01 to 0.05), which was also true when BFP was employed as a categorical variable (p for trend=0.002). According to adjust II model, BFP was also positively correlated with CAVI. More details are shown in [table 3](#).

Generalised additive model

The non-linear relationship between BFP and CAVI was observed using GAM ([figure 2](#)). BFP was not correlated with CAVI ($\beta=-0.02$; 95% CI: -0.06 to 0.03) on the left side of the inflection point (<20.6) of the fitted curve. However, they were positively correlated ($\beta=0.05$; 95% CI: 0.02 to 0.07) on the right side of the inflection point (≥ 20.6). More details are shown in [table 4](#).

Subgroup analysis

The interaction among subgroups revealed that BFP had an interaction with age (p interaction=0.011). The interaction between BFP and CAVI was weaker in those >65 years ($\beta=0.03$) than those ≤ 65 years ($\beta=0.05$). Such interaction was less significant in subgroups including gender, BMI, SBP, hypertension, diabetes, PAD, CHD, osteoporosis, CKD, COPD, fatty liver, smoking, drinking, DBP, TC, HDL-C, TG, fasting glucose and LDL-C (p interaction >0.05). More details are shown in [table 5](#).

DISCUSSION

The relationship between BFP and CAVI was explored in this retrospective study on the Chinese population. We found a non-linear correlation between BFP and CAVI. At first, in a multiple linear regression analysis, our findings

Table 2 Univariate linear regression analysis

	Statistics	β (95% CI)	P value
Age	57.87 \pm 14.11	0.06 (0.06 to 0.07)	<0.001
Gender			
Female	354 (30.73%)	Reference	
Male	798 (69.27%)	0.32 (0.14 to 0.50)	<0.001
BMI	24.46 \pm 3.36	-0.06 (-0.09 to -0.04)	<0.001
BFP	25.91 \pm 5.80	0.00 (-0.01 to 0.02)	0.612
SBP	129.70 \pm 17.53	0.02 (0.02 to 0.03)	<0.001
DBP	82.23 \pm 10.57	0.01 (-0.00 to 0.02)	0.075
TC	4.41 \pm 1.10	-0.23 (-0.31 to -0.16)	<0.001
TG	1.84 \pm 1.76	-0.07 (-0.12 to -0.02)	0.005
LDL-C	2.82 \pm 6.30	-0.01 (-0.02 to 0.01)	0.443
HDL-C	1.20 \pm 0.35	-0.22 (-0.47 to 0.02)	0.078
Fasting glucose	5.46 \pm 2.19	0.05 (0.01 to 0.09)	0.011
Hypertension			
No	492 (43.39%)	Reference	
Yes	642 (56.61%)	0.70 (0.54 to 0.87)	<0.001
Diabetes			
No	726 (63.85%)	Reference	
Yes	411 (36.15%)	0.66 (0.48 to 0.83)	<0.001
PAD			
No	269 (23.76%)	Reference	
Yes	863 (76.24%)	0.84 (0.64 to 1.03)	<0.001
CHD			
No	916 (80.92%)	Reference	
Yes	216 (19.08%)	1.05 (0.84 to 1.25)	<0.001
Osteoporosis			
No	954 (84.20%)	Reference	
Yes	179 (15.80%)	0.56 (0.34 to 0.79)	<0.001
CKD			
No	1066 (94.09%)	Reference	
Yes	67 (5.91%)	1.09 (0.74 to 1.44)	<0.001
COPD			
No	1092 (96.38%)	Reference	
Yes	41 (3.62%)	1.18 (0.74 to 1.63)	<0.001
Fatty liver			
No	653 (57.23%)	Reference	
Yes	488 (42.77%)	-0.15 (-0.32 to 0.02)	<0.001
Smoking			
No	786 (68.89%)	Reference	
Yes	355 (31.11%)	0.09 (-0.09 to 0.27)	0.347
Drinking			
No	824 (72.22%)	Reference	
Yes	317 (27.78%)	-0.17 (-0.36 to 0.01)	0.068

BFP, body fat percentage; BMI, body mass index; CHD, coronary heart disease; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; DBP, diastolic blood pressure; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; PAD, peripheral artery disease; SBP, systolic blood pressure; TC, total cholesterol; TG, triglycerides.

showed BFP was positively correlated with CAVI ($\beta=0.03$; p=0.013) even after correction of potential confounders. Such positive relationship persisted even after treating BFP as a quadratic categorical variable. However, the

Table 3 Different linear regression models analysis between BFP and CAVI

Exposure	Non-adjusted (β , 95% CI, p)	Adjust I (β , 95% CI, p)	Adjust II (β , 95% CI, p)
BFP	0.00 (−0.01 to 0.02, 0.612)	0.03 (0.01 to 0.05, 0.011)	0.03 (0.00 to 0.05, 0.022)
BFP (quartile)			
Q1	Reference	Reference	Reference
Q2	0.11 (−0.13 to 0.35, 0.344)	0.23 (0.03 to 0.42, 0.024)	0.20 (0.00 to 0.40, 0.049)
Q3	0.15 (−0.09 to 0.39, 0.216)	0.29 (0.07 to 0.51, 0.010)	0.29 (0.06 to 0.51, 0.012)
Q4	0.21 (−0.03 to 0.45, 0.081)	0.52 (0.22 to 0.82, <0.001)	0.49 (0.18 to 0.80, 0.002)
P for trend	0.07 (−0.01 to 0.14, 0.081)	0.15 (0.06 to 0.25, 0.002)	0.15 (0.05 to 0.25, 0.002)

Non-adjusted model adjusts for: none.

Adjust I model adjusts for: age; gender and BMI.

Adjust II model adjusts for: age, gender, BMI, SBP, hypertension, diabetes, PAD, CHD, osteoporosis, CKD, COPD, fatty liver, smoking, drinking, DBP, TC, HDL-C, TG, fasting glucose, LDL-C and diuretic use.

BFP, body fat percentage; BMI, body mass index; CAVI, Cardio-Ankle Vascular Index; CHD, coronary heart disease; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; DBP, diastolic blood pressure; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; PAD, peripheral artery disease; SBP, systolic blood pressure; TC, total cholesterol; TG, triglycerides.

increase in the effect size (β) between Q2 and Q3 subgroups was not significant, leading to the speculation that there was a non-linear relationship between BFP and CAVI, which could be clarified using GAM. The results showed a non-linear curve between BFP and CAVI after correcting confounding variables, with no correlation

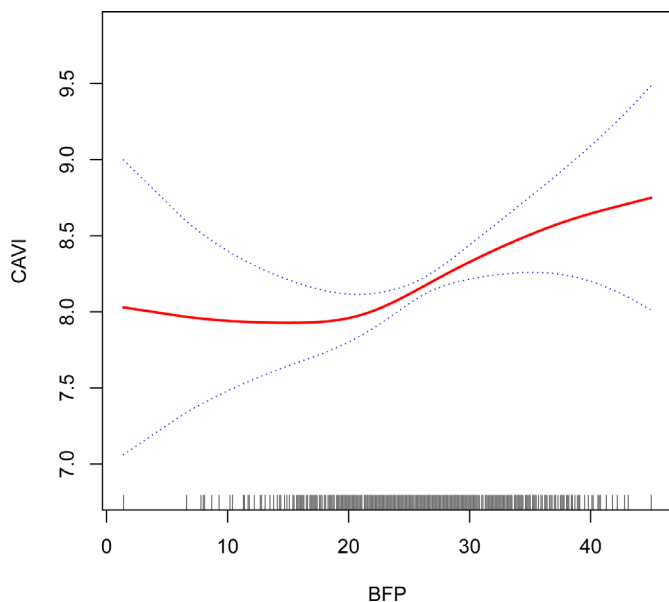


Figure 2 Fitting curve between BFP and CAVI. A non-linear relationship between BFP and CAVI after adjusting for age, gender, BMI, SBP, hypertension, diabetes, PAD, CHD, osteoporosis, CKD, COPD, fatty liver, smoking, drinking, DBP, TC, HDL-C, TG, fasting glucose, LDL-C and diuretic use. BFP, body fat percentage; BMI, body mass index; CAVI, Cardio-Ankle Vascular Index; CHD, coronary heart disease; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; DBP, diastolic blood pressure; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; PAD, peripheral artery disease; SBP, systolic blood pressure; TC, total cholesterol; TG, triglycerides.

between BFP and CAVI when $BFP < 20.6$ ($p=0.424$), while a positive correlation when $BFP \geq 20.6$ ($\beta=0.05$; $p=0.001$). Subgroup analysis revealed a weaker interaction between BFP and CAVI among those >65 years compared with those ≤ 65 years.

To clarify the correlation between BFP and CAVI, ‘body fat percentage’ and ‘cardio-ankle vascular index’ were searched as keywords on PubMed and only one report on BFP and CAVI was found. According to Czippelova *et al.*,¹⁷ BFP was negatively correlated with CAVI among young obese people, but not statistically significant, which could be partly explained by its small sample (29 subjects) and uncorrected confounding variables. This study, which examined the correlation between BFP and CAVI, included more subjects (1152) and corrected potential confounding variables. Previous studies have proved the correlation between obesity and arteriosclerosis.^{18 19} Studies by Tang *et al.*⁸ and Vianna *et al.*⁹ demonstrated a positive correlation between BMI and baPWV, while studies by Rodrigues *et al.*,¹⁰ a Brazilian scholar, and Yang *et al.*,¹¹ a Chinese scholar, advocated that BMI

Table 4 Threshold analysis between BFP and CAVI

Inflection point of BFP	Effect size (β)	95% CI	P -value
<20.6	−0.02	−0.06 to 0.03	0.424
≥ 20.6	0.05	0.02 to 0.07	0.001

Adjusted: age, gender, BMI, SBP, hypertension, diabetes, PAD, CHD, osteoporosis, CKD, COPD, fatty liver, smoking, drinking, DBP, TC, HDL-C, TG, fasting glucose, LDL-C and diuretic use. BFP, body fat percentage; BMI, body mass index; CAVI, Cardio-Ankle Vascular Index; CHD, coronary heart disease; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; DBP, diastolic blood pressure; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; PAD, peripheral artery disease; SBP, systolic blood pressure; TC, total cholesterol; TG, triglycerides.

**Table 5** Association between BFP and CAVI in subgroups

Characteristic	No. of participants	Effect size (95% CI)	P interaction
Age (years)			0.038
18–48	287	0.05 (0.01 to 0.09)	
49–54	245	0.05 (0.01 to 0.09)	
55–65	319	0.05 (0.02 to 0.08)	
66–95	301	0.03 (0.01 to 0.06)	
Gender			0.873
Female	346	0.03 (–0.00 to 0.06)	
Male	766	0.03 (0.00 to 0.06)	
Hypertension			0.348
No	479	0.02 (–0.00 to 0.05)	
Yes	633	0.03 (0.01 to 0.06)	
Diabetes			0.879
No	707	0.03 (0.00 to 0.05)	
Yes	405	0.03 (–0.00 to 0.06)	
PAD			0.964
No	262	0.03 (–0.00 to 0.06)	
Yes	850	0.03 (0.00 to 0.05)	
CHD			0.900
No	902	0.03 (0.00 to 0.05)	
Yes	210	0.03 (–0.01 to 0.06)	
Osteoporosis			0.065
No	939	0.03 (0.01 to 0.06)	
Yes	173	0.01 (–0.02 to 0.04)	
CKD			0.255
No	1047	0.03 (0.01 to 0.06)	
Yes	65	0.01 (–0.04 to 0.05)	
COPD			0.908
No	1073	0.03 (0.00 to 0.05)	
Yes	39	0.03 (–0.04 to 0.09)	
Fatty liver			0.121
No	633	0.02 (–0.00 to 0.05)	
Yes	479	0.04 (0.01 to 0.07)	
Smoking			0.240
No	763	0.03 (0.01 to 0.06)	
Yes	349	0.02 (–0.02 to 0.05)	
Drinking			0.166
No	804	0.03 (0.01 to 0.06)	
Yes	308	0.01 (–0.03 to 0.05)	
BMI			0.173
<18.5	32	–0.07 (–0.14 to 0.00)	
≥18.5, <25	602	–0.00 (–0.03 to 0.02)	
≥25	478	–0.00 (–0.03 to 0.02)	
Fasting glucose (tertile)			0.437
Low	371	0.02 (–0.00 to 0.05)	
Middle	364	0.04 (0.01 to 0.07)	
High	377	0.03 (–0.00 to 0.06)	

Above subgroups were adjusted for age, gender, BMI, SBP, hypertension, diabetes, PAD, CHD, osteoporosis, CKD, COPD, fatty liver, smoking, drinking, DBP, TC, HDL-C, TG, fasting glucose, LDL-C and diuretic use, except for its stratified variables.

BMI, body mass index; CHD, coronary heart disease; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; DBP, diastolic blood pressure; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; PAD, peripheral artery disease; SBP, systolic blood pressure; TC, total cholesterol; TG, triglycerides.

was negatively correlated with baPWV. Their results are apparently contradictory. The study concluded a negative correlation between BMI and CAVI, which shares the results of some prior studies^{20 21} and echoes the ‘obesity paradox’^{12 13} that high BMI may benefit people with cardiovascular disease.

Such paradoxical relationship between BMI and arteriosclerosis may be explained by the following two aspects: first, bapwv is susceptible to blood pressure,¹⁴ which undermines the accuracy of AS evaluated by bapwv and second, BMI fails to reflect the true picture of obesity, for example, a higher BMI can be found in a strong athlete. However, BFP is a more accurate, reliable and significant indicator to assess overall obesity.¹⁵ In addition, the CAVI that is immune to blood pressure introduced in this study can better reflect systemic arteriosclerosis, thus outperforming baPWV in evaluating arteriosclerosis.¹⁶ As a result, the relationship between BFP and CAVI is taken as priority in this study and results reveal the threshold curve between them, which may be attributed to the role of adipose tissue in producing hormones and cytokines.²² Different adipose tissues secrete different factors that exert anti-AS and pro-AS effects. Physiologically, the anti-AS and pro-AS factors secreted by adipose tissue are in balance. Under such state, adiponectin inhibits macrophage autophagy²³ and reduces oxidative stress caused by oxidised low-density lipoprotein and high glucose to better protect vascular endothelial cells,²⁴ leptin exacerbates endothelial cell dysfunction through the proteinase C-β pathway²⁵ and visfatin promotes AS by inducing phenotypic alterations in macrophage that leads to insulin resistance.²⁶ However, in the case of obesity, such balance is disrupted when the adipose tissue within the body increases to a certain critical value, resulting in the impairment of protective adipokines, more secretion of inflammatory adipokines and the occurrence of AS. The critical value was found to be BFP=20.6% in the study, with no difference among males and females. However, more large-scale and multicentre clinical studies are still required to provide more evidence.

In addition, BFP was found to be more weakly interacted with CAVI among people >65 years. Existing studies reveal that age is a contributing factor to AS. A study by Di *et al*²⁷ proved the positive correlation between age and CAVI even after the correction of factors including gender, blood pressure and heart rate. Previous studies^{28 29} also made clear the positive correlation between age and bapwv. Therefore, it is speculated that the reason for the weaker interaction between BFP and CAVI among people >65 years may be the greater effect of age on CAVI than BFP. Meanwhile, TC, TG and LDL were found to be negatively correlated with CAVI, which was obviously unreasonable and contradicted with the results of the aforementioned studies.^{28 29} This may be explained by the use of lipid-lowering drugs among participants. However, due to the limitation of retrospective study, the use of lipid-lowering drugs could not be included for analysis.

Limitations

First, this study is a cross-sectional analysis, which is not able to infer the causal relationship between BFP and CAVI. Besides, this study did not follow the population to see the effect of changes in BFP on CAVI. We were unable to include confounding factors such as exercise, diet and lipid-lowering medication into the analysis due to the retrospective nature of the study. The gender differences in the population involved in this study were large and the effect could not be completely eliminated even after correction. Finally, this study is a single-centre study, which lacks some representativeness, and we hope that this will be supported by future multicentre studies with larger samples.

CONCLUSION

Taken together, among the Chinese population included in the study, CAVI increased by 0.05 for every 1% increase in BFP when $BFP \geq 20.6\%$ and by 0.03 among those >65 years.

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Competing interests None declared.

Patient consent for publication Not applicable.

Ethics approval This study was conducted in accordance with the contents of the Declaration of Helsinki. Since this study was a retrospective anonymous study, no identifying information was included, informed consent from the patients was waived. The study was approved by the Institutional Review Board of Union Hospital, Tongji Medical College, Huazhong University of Science and Technology (UHCT20168).

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ORCID iD

Benling Qi <http://orcid.org/0000-0003-3149-5707>

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