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Body Mass Index and Major Adverse Cardiovascular Events: A Secondary Analysis Based on a Retrospective Cohort Study

Authors' Contribution:
Study Design A
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Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
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Background: The association between body mass index (BMI) and major adverse cardiovascular events (MACE) has not been clarified and is controversial. Therefore, the purpose of present study is to explore the association between BMI and MACE.

Material/Methods: This was a secondary analysis of a retrospective cohort study in which 204 participants who were diagnosed with stable coronary artery disease (CAD) and received elective percutaneous coronary intervention (PCI) were recruited. According to the BMI, patients were divided into 3 categories – underweight (BMI <18.5 kg/m^2), normal BMI (18.5 ≤BMI <25 kg/m^2), and overweight (BMI ≥25 kg/m^2)], and the patients were followed up. The primary endpoint was MACE.

Results: After a median follow-up of 783 days, MACE events had occurred in 18 participants. After controlling for potential confounding factors, no difference was observed in MACE between the underweight group and the normal BMI group (OR=1.73, 95% CI 0.42 to 7.17); but there were significantly fewer MACE in the overweight group than in the normal BMI group (OR=0.17; 95% CI: 0.03 to 0.84). Pearson correlation analysis showed that BMI was positively correlated with hemoglobin (r=0.2102) and albumin (r=0.2780), but negatively correlated with high-density lipoprotein cholesterol (r=–0.2052). The receiver operating characteristic curve (ROC) showed that the best threshold for BMI to predict MACE was 24.23, the area under the curve was 0.729, sensitivity was 0.893, and the specificity was 0.460.

Conclusions: Our study shows that overweight patient with stable CAD have lower risk of MACE after PCI, and the optimal threshold for predicting MACE is 24.23.

MeSH Keywords: Body Mass Index • Cardiovascular Abnormalities • Percutaneous Coronary Intervention

Full-text PDF: https://www.medscimonit.com/abstract/index/idArt/919700

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Background

In recent years, due to the modernization of lifestyle and the change of dietary structure, the prevalence rate of obesity or overweight is on the rise in both developed and developing countries [1–3]. Similarly, with this rapid development, the incidence of obesity or overweight in China has also increased rapidly [4–6]. According to previous studies, the prevalence rate of overweight and obesity in China has increased 5-fold in the past 10 years. It is accepted that obesity is not only a chronic disease that seriously endangers people's health, it is also an important risk factor leading to type 2 diabetes mellitus [7,8], hypertension [9,10] and coronary heart disease [11–13]. In the United States, nearly 10 000 people die from obesity-related diseases every year [14]. The worldwide prevalence and spread of obesity not only significantly increase the prevalence and mortality of a variety of chronic diseases, but also significantly increases health care system expenditures.

At present, predecessors have paid attention to the impact of BMI on the prognosis of patients after percutaneous coronary intervention (PCI), and many studies on cardiovascular events after PCI have been published [15,16]. Nevertheless, the effect of BMI on cardiovascular events is still controversial. The NCVD-PCI registry [17] is a retrospective cohort study in which 28 742 participants were recruited. After adjusting for potential confounding factors using a COX proportional risk model, no difference was observed in MACE between the normal BMI group and the underweight group, while the risk of 1-year death in the overweight group was significantly lower compared to the normal BMI group (HR=1.02, p=0.952). Similarly, a meta-analysis of 22 studies [18] evaluated the short-term and long-term prognostic effects of obesity on patients with coronary artery revascularization, and the results showed that compared with individuals with normal BMI, obese patients who received PCI had lower short-term (OR=0.63, 95% CI: 0.54 to 0.73) and long-term mortality (OR=0.65, 95% CI: 0.51 to 0.83). On the other hand, the short-term mortality (OR=0.63, 95% CI: 0.56 to 0.71) of obese patients treated with coronary artery bypass graft (CABG) was lower than that of individuals of normal BMI, but no significant difference was observed in long-term mortality between the 2 groups. However, some scholars hold different views, and their results show that BMI has no effect on cardiovascular events in patients after PCI. A retrospective study in Iran included 3948 participants who received PCI treatment [19]. The results showed that there was no difference in hospital mortality rates among patients in different BMI groups. After 9-month follow-up, the incidence rates of MACE in patients in different BMI groups were similar.

The information provided above shows that the impact of BMI on MACE is still controversial. The therefore conducted this secondary analysis based on a retrospective cohort study to explore the effect of BMI on MACE. In addition, considering that previous studies have not determined the optimal threshold of BMI for predicting MACE, we also investigated the optimal threshold of BMI for predicting the occurrence of MACE in patients after PCI.

Material and Methods

The Dryad database (*http://datadryad.org/*), managed by a non-profit organization, is a place to store high-quality data resources, so that the data used in scientific publications can be discovered, reused, and referenced. The objective of the Dryad database is to form an academic exchange system with academic communities, publishing, research, educational institutions, funding institutions, and other stakeholders to coordinate, maintain, and promote the protection and reuse of scientific data. In addition, for the purpose of reusing data, the data stored on the Dryad database is unlimited and free to download. Using the data stored in the Dryad database, researchers or scientists can obtain the data free of charge and conduct studies based on various research assumptions. The Sho Suzuki study [20] (*https://datadryad.org/resource/doi:10.5061/dryad.fn6730j*) is a retrospective cohort study conducted in a single center in Japan, in which 204 participants were recruited, all of whom were diagnosed with coronary artery disease (CAD).

The data we used from the Sho Suzuki study [20] included sex, age, body mass index (BMI), hemoglobin, albumin, estimated glomerular filtration rate (eGFR), total cholesterol, triglyceride, high-density lipoprotein (HDL), low-density lipoprotein (LDL), hemoglobin A1c (HbA1c), systolic blood pressure (SBP), diastolic blood pressure (DBP), left ventricular ejection fraction (LVEF), and history of medication and disease. All the data used in the present research were originally collected by Sho Suzuki et al. [20] (*https://datadryad.org/resource/doi:10.5061/dryad.fn6730j*). In brief, the Sho Suzuki study [20] is a cohort study conducted in a single center (Shinonoi General Hospital) in Japan. All patients were evaluated by clinical symptoms, auxiliary examinations, electrocardiogram, and coronary angiography. Finally, stable coronary heart disease was diagnosed by a clinician. Our study is a secondary analysis based on previously collected data, and all patients' information is anonymous. Therefore, patient informed consent and ethics committee approval were not required for this study.

Primary endpoints and treatment

The primary endpoint of our study was MACE, which consists of all-cause death, non-fatal myocardial infarction, and non-fatal stroke. Detailed definitions have been described in the Sho Suzuki study [20]. In our study, the exposure factor was

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Table 1. Baseline characteristics of 3 groups.

BMI	Underweight	Normal BMI	Overweight	P-value
N	17	118	69	
Age (year)				0.565
Age <45	0 (0.00%)	1 (0.85%)	1 (1.45%)	
45≤ age <65	3 (17.65%)	18 (15.25%)	17 (24.64%)	
Age ≥65	14 (82.35%)	99 (83.90%)	51 (73.91%)	
Hemoglobin (g/dL)	12.41±2.16	13.48±2.04	14.04±1.78	0.007
Albumin (g/dL)	3.56±0.62	3.89±0.54	4.08±0.42	<0.001
EGFR (mL/min/1.73 m^2)	50.41±29.15	61.99±22.76	62.86±26.16	0.158
Total cholesterol (mg/dL)	187.80±39.27	186.02±35.44	183.81±35.79	0.900
Triglyceride (mg/dL)	84.06±47.14	127.64±99.30	158.62±99.42	0.010
HDL (mg/dL)	60.35±19.14	50.15±12.01	47.61±12.17	0.002
LDL (mg/dL)	105.82±29.55	111.09±28.92	109.40±27.94	0.758
HbA1c (%)	6.39±1.29	6.24±1.03	9.18±22.52	0.364
SBP (mmHg)	136.41±25.74	135.50±20.25	137.59±19.58	0.797
DBP (mmHg)	78.00±14.50	77.31±13.46	77.49±12.64	0.979
LVEF (%)	57.61±13.96	62.92±10.11	65.19±7.11	0.014
Sex (Male)				0.775
No	6 (35.29%)	37 (31.36%)	19 (27.54%)	
Yes	11 (64.71%)	81 (68.64%)	50 (72.46%)	
OCI (n,%)				0.995
No	14 (82.35%)	98 (83.05%)	57 (82.61%)	
Yes	3 (17.65%)	20 (16.95%)	12 (17.39%)	
PAD (n,%)				0.591
No	11 (64.71%)	87 (73.73%)	53 (76.81%)	
Yes	6 (35.29%)	31 (26.27%)	16 (23.19%)	
Atrial fibrillation (n,%)				0.990
No	15 (88.24%)	103 (87.29%)	60 (86.96%)	
Yes	2 (11.76%)	15 (12.71%)	9 (13.04%)	
Dyslipidemia (n,%)				0.061
No	13 (76.47%)	55 (46.61%)	32 (46.38%)	
Yes	4 (23.53%)	63 (53.39%)	37 (53.62%)	
Past smoking (n,%)				0.702
No	9 (52.94%)	62 (52.54%)	32 (46.38%)	
Yes	8 (47.06%)	56 (47.46%)	37 (53.62%)	
Diabetes mellitus (n,%)				0.777
No	10 (58.82%)	78 (66.10%)	43 (62.32%)	
Yes	7 (41.18%)	40 (33.90%)	26 (37.68%)	
Aspirin (n,%)				0.479
No	0 (0.00%)	2 (1.69%)	0 (0.00%)	
Yes	17 (100.00%)	116 (98.31%)	69 (100.00%)	

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Table 1 continued. Baseline characteristics of 3 groups.

BMI	Underweight	Normal BMI	Overweight	P-value
Thienopyridines (n,%)				0.226
No	0 (0.00%)	4 (3.39%)	0 (0.00%)	
Yes	17 (100.00%)	114 (96.61%)	69 (100.00%)	
Warfarin (n,%)				0.555
No	16 (94.12%)	116 (98.31%)	67 (97.10%)	
Yes	1 (5.88%)	2 (1.69%)	2 (2.90%)	
PPI (n,%)				0.407
No	8 (47.06%)	37 (31.36%)	25 (36.23%)	
Yes	9 (52.94%)	81 (68.64%)	44 (63.77%)	
Statins (n,%)				0.986
No	8 (47.06%)	54 (45.76%)	31 (44.93%)	
Yes	9 (52.94%)	64 (54.24%)	38 (55.07%)	
ACEI (n,%)				0.045
No	13 (76.47%)	106 (89.83%)	66 (95.65%)	
Yes	4 (23.53%)	12 (10.17%)	3 (4.35%)	
ARB (n,%)				0.772
No	11 (64.71%)	67 (56.78%)	38 (55.07%)	
Yes	6 (35.29%)	51 (43.22%)	31 (44.93%)	
Beta-blocker (n,%)				0.294
No	11 (64.71%)	91 (77.12%)	47 (68.12%)	
Yes	6 (35.29%)	27 (22.88%)	22 (31.88%)	
MRA (n,%)				0.524
No	16 (94.12%)	110 (93.22%)	67 (97.10%)	
Yes	1 (5.88%)	8 (6.78%)	2 (2.90%)	
Mace (n,%)				<0.001
No	11 (64.71%)	98 (83.05%)	67 (97.10%)	
Yes	6 (35.29%)	20 (16.95%)	2 (2.90%)	

Data is represented by median (interquartile range, or number (%). ACEI – angiotensin-converting enzyme inhibitor; ARB – angiotensin-receptor blocker; BMI – body mass index; eGFR – estimated glomerular filtration rate; HbA1c – hemoglobin A1c; SBP – systolic blood pressure; DBP – diastolic blood pressure; HDL – high-density lipoprotein; LDL – low density lipoprotein; LVEF – left ventricular ejection fraction; MRA – mineralocorticoid receptor antagonist; OCI – old cerebral infarction; PAD – peripheral artery disease; PPI – proton pump inhibitor; Mace – major adverse cardiovascular events.

BMI. Except BMI and MACE, other variables were considered as covariates (potential confounders).

All patients were given standard medication and intervention by clinicians according to recommended guidelines.

Statistical analysis

In the present study, patients were divided into 3 categories – underweight (BMI <18.5 kg/m^2), normal BMI (18.5 ≤BMI <25 kg/m^2), and overweight (BMI ≥25 kg/m^2) – according to BMI value. Mean and standard deviations were used for continuous variables and LSD analysis of variance was used for comparisons. Numbers (%) were used for classification variables, and the chi-square test was used for comparisons. In addition, we compared the differences between groups by odds ratio (OR) and 95% confidence interval (CI). In univariate analysis and least absolute shrinkage and selection operator (Lasso) [21] regression, we use MACE as the dependent variable and other variables as independent variables to explore which variables were related to MACE. In multivariate regression analysis, we used MACE as the dependent variable and BMI as the independent

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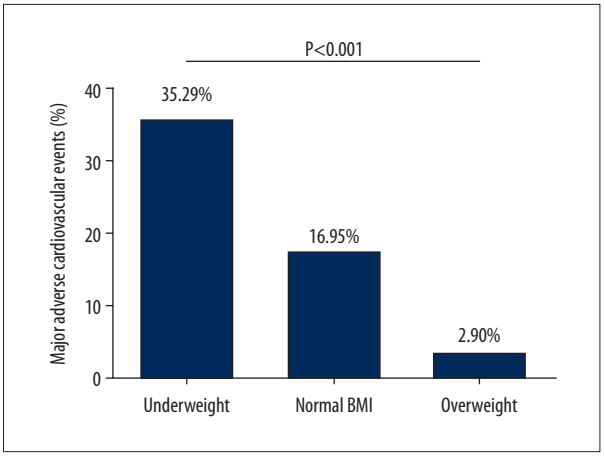

Figure 1. Comparison of MACE among the 3 BMI groups.

variable. The variables selected from univariate analysis and Lasso regression analysis were used as covariates, and then we observed the independent effect of BMI on MACE.

We used receiver operating characteristic (ROC) [22] curves to observe the optimal threshold of BMI to predict MACE, and used the area under the curve (AUC), sensitivity, and specificity to evaluate the stability of the prediction model. Pearson correlation analysis was used to evaluate the correlation between BMI and hemoglobin, albumin, total cholesterol, high-density lipoprotein, and low-density lipoprotein. P<0.05 was considered to indicate a statistically significant difference. In this study, we used SPSS 24 statistical software, R software, GraphPad Prism 6, and EmpowerStats to analyze the data.

Results

Baseline characteristics of the 3 groups

With the increased BMI grade, there was an increasing trend (all P<0.05) for hemoglobin, albumin, triglyceride, and LVEF. In contrast, HDL showed a downward trend with increasing BMI grade (all P<0.05). No difference was observed in age, sex, EGFR, total cholesterol, LDL, HbA1c, SBP, DBP, and history of medication and disease, except for angiotensin-converting enzyme inhibitor (ACEI). After a median follow-up of 783 days, 6 participants in the underweight group had experienced a MACE, with a MACE incidence rate of 35.29% (6/17); 20 participants in the normal BMI group had MACE, with an incidence rate of 16.95% (20/118); and 2 participants in the overweight group had MACE, with an incidence rate of 2.90% (2/69) (P for trend<0.001 (Table 1, Figure 1).

Univariate analysis

We used MACE as the dependent variable and other variables as independent variables to observe the factors related to MACE. Univariate analysis showed that age (45≤ age <65 *vs.* age <45: OR=0.03, 95% CI 0.00 to 0.82), hemoglobin (OR=0.64, 95% CI 0.51 to 0.79), albumin (OR=0.16, 95% CI 0.07 to 0.34), total cholesterol (OR=0.98, 95% CI 0.97 to 1.00), LDL (OR=0.98, 95% CI 0.97 to 1.00), PAD (yes *vs.* no: OR=2.95, 95% CI 1.30 to 6.70), PPI (yes *vs.* no: OR=0.39, 95% CI 0.18 to 0.88), and BMI (underweight *vs.* normal BMI: OR=2.67, 95% CI 0.89 to 8.07; overweight *vs.* normal BMI: OR=0.15, 95% CI 0.03 to 0.65) were associated with MACE. Other variables were not associated with MACE (Table 2).

Lasso regression analysis

Because there are many variables included in our study, and some variables have statistical significance but no clinical significance with MACE, we used Lasso regression to select data reduction and feature variables. The results of Lasso regression analysis showed that age, BMI, hemoglobin, albumin, peripheral artery disease, diabetes mellitus, warfarin, and proton pump inhibitor were correlated with MACE. The formula used to calculate the score was=0.67126*age+0.14111*BMI –0.14604*hemoglobin–0.99928*albumin–0.47701*peripheral artery disease+0.13917*diabetes mellitus–0.07581* warfarin+0.35068*proton pump inhibitor (Figures 2, 3).

Multivariate regression analysis

In multivariate logistic regression analysis, we used MACE as the dependent variable, BMI categories as the independent variable, and the variables (age, BMI, hemoglobin, albumin, peripheral artery disease, diabetes mellitus, warfarin and proton pump inhibitor) selected from the Lasso regression analysis as the covariant to observe the independent effect of BMI categories on MACE. In adjusted model I, age, peripheral artery disease, diabetes mellitus, and warfarin were adjusted, and the outcome indicates that BMI categories are associated with MACE (underweight *vs.* normal BMI: OR=2.34, 95% CI 0.67 to 8.20; overweight *vs.* normal BMI: OR=0.14, 95% CI 0.03 to 0.67). In adjusted model II, we adjusted for age, peripheral artery disease, diabetes mellitus, warfarin, proton pump inhibitor, hemoglobin, and albumin. Similar to the previous analysis presented above, BMI categories were still correlated with MACE (underweight *vs.* normal BMI: OR=1.73, 95% CI 0.42 to 7.17; overweight *vs.* normal BMI: OR=0.17, 95% CI 0.03 to 0.84) (Table 3).

Receiver operating characteristic curve

We used ROC curves to evaluate the optimal threshold of BMI for predicting MACE. The results show that the optimal threshold of BMI for predicting MACE is 24.23. Under these circumstances, the area under the curve (AUC) was 0.729, sensitivity was 0.893, and the specificity was 0.460, which indicates

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Table 2. Univariate analysis.

	Major adverse cardiovascular events
Age (year)	
Age <45	Reference
45≤ age <65	0.03 (0.00, 0.82) 0.0379
Age ≥65	0.19 (0.01, 3.11) 0.2432
Sex (Male)	
No	Reference
Yes	0.91 (0.39, 2.14) 0.8284
Hemoglobin (g/dL)	0.64 (0.51, 0.79) <0.0001
Albumin (g/dL)	0.16 (0.07, 0.34) <0.0001
EGFR (mL/min/1.73 m^2)	0.99 (0.97, 1.01) 0.2012
Total cholesterol (mg/dL)	0.98 (0.97, 1.00) 0.0115
Triglyceride (mg/dL)	1.00 (1.00, 1.00) 0.8758
HDL (mg/dL)	0.99 (0.96, 1.02) 0.5146
LDL (mg/dL)	0.98 (0.97, 1.00) 0.0185
HbA1c (%)	0.99 (0.94, 1.05) 0.7962
SBP (mmHg)	1.00 (0.98, 1.02) 0.8182
DBP (mmHg)	0.99 (0.96, 1.02) 0.5898
LVEF (%)	0.99 (0.95, 1.02) 0.4884
OCI (n,%)	
No	Reference
Yes	2.21 (0.88, 5.52) 0.0905
PAD (n,%)	
No	Reference
Yes	2.95 (1.30, 6.70) 0.0100
Atrial fibrillation (n,%)	
No	Reference
Yes	2.13 (0.77, 5.87) 0.1452
Dyslipidemia (n,%)	
No	Reference
Yes	0.48 (0.21, 1.11) 0.0863
Past smoking (n,%)	
No	Reference
Yes	0.43 (0.19, 1.01) 0.0523

	Major adverse cardiovascular events
Diabetes mellitus (n,%)	
No	Reference
Yes	0.68 (0.28, 1.64) 0.3933
Aspirin (n,%)	
No	Reference
Yes	0.15 (0.01, 2.54) 0.1910
Thienopyridines (n,%)	
No	Reference
Yes	0.47 (0.05, 4.67) 0.5177
Warfarin (n,%)	
No	Reference
Yes	4.44 (0.71, 27.82) 0.1118
PPI (n,%)	
No	Reference
Yes	0.39 (0.18, 0.88) 0.0239
Statins (n,%)	
No	Reference
Yes	0.58 (0.26, 1.31) 0.1897
ACEI (n,%)	
No	Reference
Yes	1.20 (0.33, 4.42) 0.7839
ARB (n,%)	
No	Reference
Yes	1.38 (0.62, 3.06) 0.4311
Beta-blocker (n,%)	
No	Reference
Yes	0.71 (0.27, 1.85) 0.4792
MRA (n,%)	
No	Reference
Yes	1.43 (0.29, 6.98) 0.6603
BMI (kg/m^2)	
Normal BMI	Reference
Underweight	2.67 (0.89, 8.07) 0.0812
Overweight	0.15 (0.03, 0.65) 0.0113

Data is represented as OR (95% CI) P value. ACEI – angiotensin-converting enzyme inhibitor; ARB – angiotensin-receptor blocker; BMI – body mass index; eGFR – estimated glomerular filtration rate; HbA1c – hemoglobin A1c; HDL – high-density lipoprotein cholesterol; LDL – low density lipoprotein cholesterol; LVEF – left ventricular ejection fraction; MRA – mineralocorticoid receptor antagonist; OCI – old cerebral infarction; PAD – peripheral artery disease; PPI – proton pump inhibitor.

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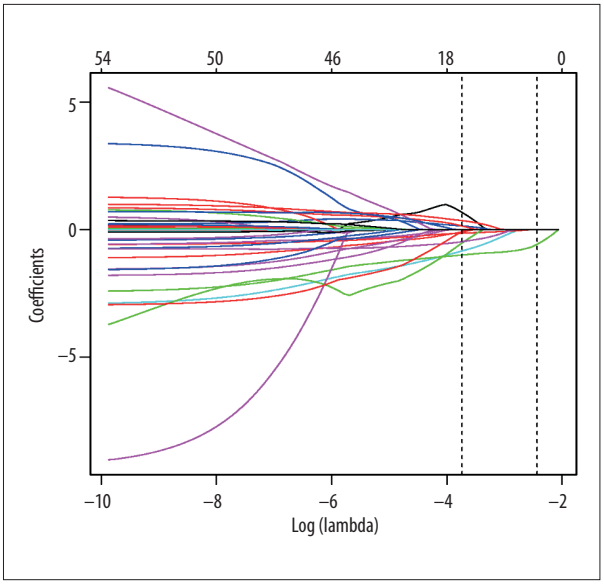

Figure 2. Lasso regression Analysis of factors related to MACE

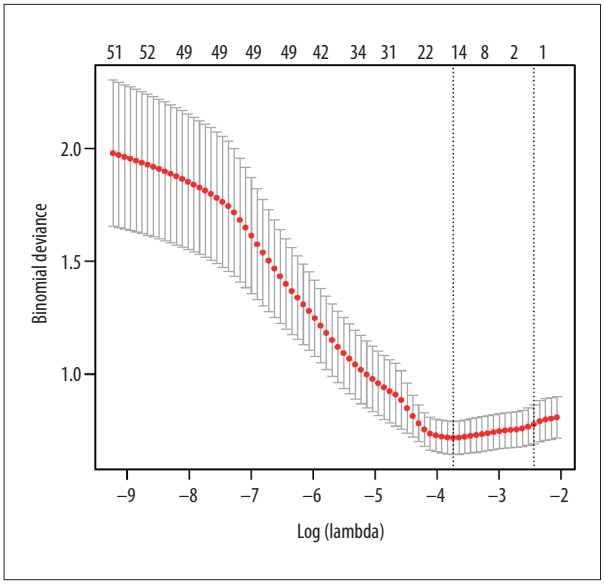

Figure 3. Lasso regression Analysis of factors related to MACE.

Table 3. Multivariate regression analysis.

Exposure	Non-adjusted	Adjust I	Adjust II
BMI			
Normal BMI	Reference	Reference	Reference
Underweight	2.67 (0.89, 8.07) 0.0812	2.34 (0.67, 8.20) 0.1826	1.73 (0.42, 7.17) 0.4529
Overweight	0.15 (0.03, 0.65) 0.0113	0.14 (0.03, 0.67) 0.0134	0.17 (0.03, 0.84) 0.0297

Data is represented as OR (95% CI) P value. Outcome variable: major adverse cardiovascular events. Exposure variables: body mass index. Non-adjusted model adjust for: None. Adjust I model adjust for: age; peripheral artery disease; diabetes mellitus and warfarin. Adjust II model adjust for: age; peripheral artery disease; diabetes mellitus and warfarin, proton pump inhibitor, hemoglobin and albumin.

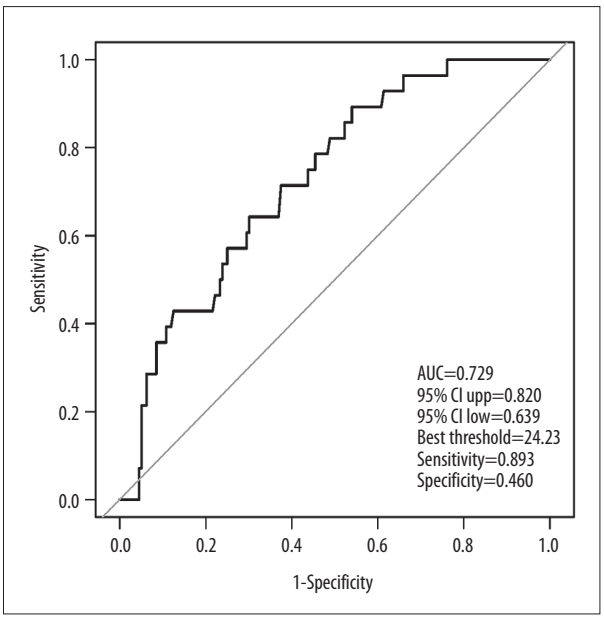

Figure 4. ROC curve for predicting the optimal threshold of MACE.

that predicting MACE with a BMI threshold of 24.23 has high reliability (Figure 4).

Pearson correlation analysis comparing BMI and other variables

We used Pearson correlation analysis to explore the association between BMI and nutritional indexes and blood lipid indexes. Pearson correlation analysis showed that BMI was positively correlated with hemoglobin (r=0.2102, P<0.05) and albumin (r=0.2780, P<0.05), but negatively correlated with high-density lipoprotein (r=–0.2052, P<0.05). However, Pearson correlation analysis showed that BMI was not associated with total cholesterol or low-density lipoprotein (Table 4, Figure 5).

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Table 4. Pearson correlation analysis between BMI and other variables.

Variable	Variables	Correlation	95% CI low	95% CI upp	P value
Body mass index	Hemoglobin	0.2102	0.0750	0.3378	0.0025
Body mass index	Albumin	0.2780	0.1462	0.4001	0.0001
Body mass index	Total cholesterol	0.0146	–0.1358	0.1643	0.8499
Body mass index	High density lipoprotein	–0.2052	–0.3354	–0.0673	0.0038
Body mass index	Low density lipoprotein	0.0783	–0.0618	0.2154	0.2730

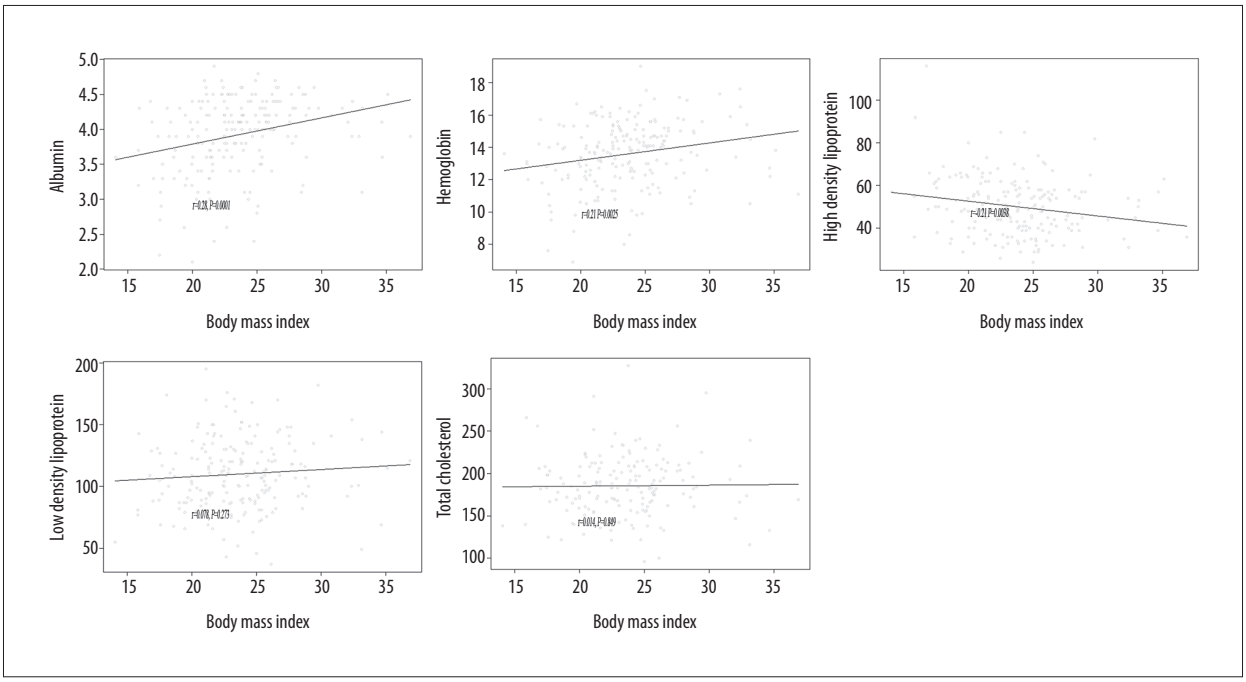

Figure 5. Pearson correlation analysis between BMI and other variables.

Discussion

This study observed the effect of BMI on the prognosis of patients with stable CAD after PCI. The patients were divided into 3 groups according to their BMI scores. Our results indicate that although the confounding factors were adjusted, increased BMI (overweight group) was associated with lower MACE compare to the normal BMI group (OR=0.17, 95% CI 0.03 to 0.84). There was no difference in MACE between the lower BMI group (underweight group) and the normal BMI group (OR=1.73, 95% CI 0.42 to 7.17). The ROC curve shows that the best threshold for BMI to predict MACE is 24.23 kg/m^2. On this condition, the sensitivity (0.893) and specificity (0.460) are at a high level, indicating that the prediction result of this model is reliable. In further analysis, Pearson correlation analysis showed that BMI was positively correlated with hemoglobin (r=0.2102) and albumin (r=0.2780), but negatively correlated with high-density lipoprotein (r=–0.2052), which indicates that increased BMI was associated with better nutritional status and lower HDL levels.

Previous studies have shown that elevated BMI is a risk factor for a range of chronic diseases. A prospective cohort study recruited 37 674 healthy young male participants, with an average follow-up of 17.4 years, showing that increased BMI was associated with higher risk of diabetes and coronary heart disease [23]. Similarly, a study conducted in China found that elevated BMI was associated with a 2.35-fold increase in the incidence of hypertension compared with a normal BMI group (OR=2.35, 95% CI 2.18 to 2.50) [24]. However, researchers have found an interesting phenomenon (obesity paradox), in which elevated BMI is associated with lower MACE in patients with coronary heart disease after PCI. Secondary analysis based on the APPROACH registry reported that overweight patients had lower mortality rates after CABG and PCI than those with normal BMI, especially in those with high-risk coronary artery anatomy but without diabetes mellitus [25]. A multicenter, prospective, real-world study in Japan recruited 10 142 participants, with an endpoint of MACE during hospitalization. Despite controlling for potential confounding factors, elevated

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BMI was also associated with fewer bleeding events (OR=0.98, p=0.033) [26]. On the contrary, some scholars pointed out that BMI was not associated with MACE in patients with coronary artery disease after PCI, and this opinion has been validated in their clinical trials [27]. Similar to most previous studies, our study also found that elevated BMI was associated with lower incidence of MACE.

The pathological mechanism of elevated BMI and lower MACE has not yet been elucidated, and we present 3 possible theoretical assumptions about this phenomenon:

(1) Atherosclerosis: Atherosclerosis is an important process in the development of coronary heart disease, involving many biological responses. Rupture of atherosclerotic plaques and thrombosis can lead to acute occlusion of coronary vessels, leading to myocardial infarction [28]. There were significant clinical differences between obese patients who underwent coronary angiography and those with normal weight. Obese patients tended to be younger and were associated with a variety of chronic diseases such as high blood pressure and diabetes. Previous results showed that coronary artery diameter in obese patients who underwent coronary angiography was significantly larger than in patients with normal weight [29], meaning that the coronary artery diameter increased with the increase of BMI. In addition, previous results also confirmed that small vessels were an independent predictor of 12-month MACE [30,31].

(2) Inflammation: Previous results have shown that BMI is closely related to inflammatory response. In people with normal weight, C-reactive protein is associated with coronary artery calcification, and inflammation and vascular endothelial injury play an important role in the pathogenesis of coronary heart disease. However, in obese people, this correlation was significantly reduced, and the measured CRP levels did not really reflect high levels of coronary artery calcification.

(3) Endothelial cells: Previous studies have shown that obese people have better endothelial protection than non-obese people. A study involving healthy people assessed the correlation among vascular function, inflammatory factors, and endothelial proliferating cells [32]. The results showed that blood flow-mediated diastolic function was higher in obese people than in normal-weight people, and intima-media thickness decreased with the increase of obesity grade.

Our study has the following advantages. First, Lasso regression analysis was used to select characteristic variables, and the selected variables were more representative in clinical practice. Second, we adjusted the covariates by 2 models, and the results were consistent, which shows that they were reliable. Finally, this study determined, for the first time, the optimal threshold (BMI=24.23 kg/m^2) for predicting MACE by BMI, which is similar to the values used in clinical practice to diagnose overweight (BMI ≥25 kg/m^2). The AUC, sensitivity, and specificity were all high, which shows that the predicted values have high reliability.

The present study has the following shortcomings. First, this was a secondary analysis of previous studies. We lacked data on the characteristic variables of coronary angiography, such as stent type, stent length, contrast agent dosage, angiographic time, number of lesions, and diameter of vessels. Second, this was a retrospective cohort study, with inevitable selection bias and follow-up bias. Finally, it is well known that the economic status and income of patients are closely related to MACE, but we lacked accurate data on patient income. Therefore, we were unable to assess whether BMI is associated with economic status or income.

Conclusions

Our study shows that overweight patients with stable CAD have lower MACE after PCI, and the optimal threshold for predicting MACE is 24.23. This conclusion still needs to be further confirmed by more multicenter trials.

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