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Association between body mass index and outcomes after percutaneous coronary intervention in multiethnic South East Asian population: a retrospective analysis of the Malaysian National Cardiovascular Disease Database—Percutaneous Coronary Intervention (NCVD-PCI) registry

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ABSTRACT

Objective To examine the relationship between body mass index (BMI) and outcomes after percutaneous coronary intervention (PCI) in a multiethnic South East Asian population.

Setting Fifteen participating cardiology centres contributed to the Malaysian National Cardiovascular Disease Database—Percutaneous Coronary Intervention (NCVD-PCI) registry.

Participants 28 742 patients from the NCVD-PCI registry who had their first PCI between January 2007 and December 2014 were included. Those without their BMI recorded or BMI <11 kg/m^2 or >70 kg/m^2 were excluded.

Main outcome measures In-hospital death, major adverse cardiovascular events (MACEs), vascular complications between different BMI groups were examined. Multivariable-adjusted HRs for 1-year mortality after PCI among the BMI groups were also calculated.

Results The patients were divided into four groups; underweight (BMI <18.5 kg/m^2), normal BMI (BMI 18.5 to <23 kg/m^2), overweight (BMI 23 to <27.5 kg/m^2) and obese (BMI ≥27.5 kg/m^2). Comparison of their baseline characteristics showed that the obese group was younger, had lower prevalence of smoking but higher prevalence of diabetes, hypertension and dyslipidemia. There was no difference found in terms of in-hospital death, MACE and vascular complications after PCI. Multivariable Cox proportional hazard regression analysis showed that compared with normal BMI group the underweight group had a non-significant difference (HR 1.02, p=0.952), while the overweight group had significantly lower risk of 1-year mortality (HR 0.71, p=0.005). The obese group also showed lower HR but this was non-significant (HR 0.78, p=0.056).

Conclusions Using Asian-specific BMI cut-off points, the overweight group in our study population was independently associated with lower risk of 1-year mortality after PCI compared with the normal BMI group.

Strengths and limitations of this study

- ► Our data were obtained from a real-world multicentre registry, with a study population comprising three major ethnic groups.
- ► We used the more appropriate lower body mass index (BMI) classification recommended for Asian population.
- ► There was a potential for unmeasured confounding due to the retrospective nature of our study.
- ► BMI may not be the most accurate indicator for obesity.

INTRODUCTION

Obesity is defined as the state of being grossly fat or overweight. Body mass index (BMI) has been traditionally used to define obesity, in which according to WHO classification a BMI between 25 to 29.9 kg/m^2 is considered overweight, while a BMI of ≥30 kg/m^2 is considered obese.[1] Obesity has been strongly associated with higher cardiovascular morbidity and mortality.[2 3] It has been found previously in large collaborative analyses of individual data from multiple prospective observational studies that each 5 kg/m^2 higher BMI was associated with about 40% higher ischaemic heart disease mortality.[3] The most likely mechanism of this association is excess body weight contributes directly to cardiovascular risk factors such as diabetes mellitus, hypertension and hypercholesterolaemia.[3]

Despite the general belief that obesity is associated with higher morbidity and mortality, some studies have demonstrated the protective effect of obesity in certain disease settings. This includes chronic obstructive pulmonary disease, diabetes, end-stage renal failure and HIV/AIDS.[4] This interesting phenomenon is called 'obesity paradox'. From cardiovascular perspective, it was first reported in 1996 by Ellis *et al* that obesity may be protective in patients undergoing percutaneous coronary interventions (PCI).[5]

Malaysia is a multicultural, multiethnic Asian country which consists of three major ethnic groups: Malay, Chinese, Indian, and also a smaller group of other ethnicities. The prevalence of overweight and obesity in Malaysia has been increasing steadily for the past years. According to the National Health and Morbidity Survey (NHMS) 2015, a population-based survey involving all the states in Malaysia, the national prevalence of overweight, obesity and abdominal obesity had increased by 0.6%, 2.6% and 2.0%, respectively, compared with previous findings in 2011.[6] The prevalence of obesity in Malaysia was reported as 17.7%, which was even higher than the 13% prevalence of obesity globally in 2014 based on WHO 1998 BMI classifications.[6]

As obesity is a major health problem in Malaysia, it is interesting to see whether obesity paradox also exists in our population. In this study, we examined the prevalence of obesity among patients undergoing PCI from the Malaysian National Cardiovascular Disease Database—Percutaneous Coronary Intervention (NCVD-PCI) registry and the differences on demographic, clinical and angiographic findings among the different BMI groups. We also examined the association between BMI groups and outcomes after PCI in our multiethnic Malaysian population.

METHODS

Study design

We performed a retrospective analysis of anonymised prospectively collected data for patients who underwent PCI between January 2007 and December 2014. The data were obtained from the Malaysian NCVD-PCI registry. This registry, which was established since 2007, is an ongoing observational prospective registry of patients who underwent PCI initially from eight participating centres and for the last report data were obtained from 15 participating centres in Malaysia.[7,8] Consecutive patients aged >18 years undergoing PCI were included in the database. The cases were initially notified using data abstraction form, completed at each site by interventional cardiologists, medical officers, nurses or lab technicians.[9] These were compiled and later transcribed into an online web-based centralised database which was encrypted with security passwords unique to each user.[9]

The initial notification comprised information including demographics, clinical status, clinical examination and baseline investigations, previous revascularisation, cardiac status at the time of PCI, catheterisation laboratory visit (including adjunctive pharmacotherapy), PCI procedural details, procedural outcome and clinical status at discharge.[9] Subsequent follow-ups were made via phone calls at 30 days, 6 months and 12 months after the index procedure. The status of the patient (dead or alive) at follow-up was recorded and any death status reported was cross-checked with the national death registry.

In our study, 36 010 patients who had their first PCI done between January 2007 and December 2014 were identified. The indications for PCI included both for acute coronary syndrome (ACS) and non-acute coronary syndrome (non-ACS). ACS was defined as either unstable angina, non-ST-elevation myocardial infarction (NSTEMI) or ST-elevation myocardial infarction (STEMI). Non-ACS included those who had stable angina, positive functional ischaemia test or positive cardiac imaging test.

Those with BMI (derived automatically from height and weight) recorded in the database were included in the study, and for those patients who had repeated PCI done at later date, only their first PCI were included in the analysis. We divided the eligible patient into four different BMI categories: underweight (<18.5 kg/m^2), normal BMI (18.5 to <23 kg/m^2), overweight (23 to <27.5 kg/m^2) and obese (≥27.5 kg/m^2). The cut-off values for these different BMI groups were based on the classification suggested by WHO for Asian population which is also used by our local Malaysian obesity clinical practice guideline.[10,11] BMI values <11 kg/m^2 or >70 kg/m^2 were considered 'implausible' and therefore excluded from the analysis. From the initial 36 010 patients identified, 7268 patients were excluded from analysis due to either missing BMI values or having implausible BMI. In total, 28 742 patients then remained and were included for analysis.

Data variables

Data were collected for demographic characteristics (age, gender, ethnicity, BMI, smoking status), premorbid conditions and cardiovascular history (histories of PCI, coronary artery bypass graft (CABG) surgery, myocardial infarction and heart failure). Indications for PCI and the angiographic findings for all the PCI procedures during the patient's first admission were recorded. Multivessel disease was defined as having two or more coronary arteries with ≥50% stenosis. The medications on discharge were also recorded. The outcomes of interest were in-hospital complications and all-cause mortality during admission and within 1 year after the index PCI.

Statistical analysis

Patients were categorised into four groups according to their calculated BMI. Data for each BMI groups were compared for their differences. Continuous variables were expressed as mean±SD, and their differences were compared using one-way analysis of variance if they were normally distributed. Normality was examined by SPSS skewness and kurtosis. Categorical variables were expressed as frequencies and percentages, and their differences were analysed using χ^2 test.

To evaluate the association between BMI categories and mortality within 1 year, their respective multivariable-adjusted HRs were calculated using Cox proportional-hazards regression model. The BMI category 18.5 to <23.0 kg/m^2 (normal BMI) was considered the reference group. Variables included in the model were chosen by separate univariate analyses; those with p value of <0.05 were included in the final model, as well as those that were of clinical importance. To avoid biases in the estimates and loss of power, missing data for the included variables (except for BMI) were imputed using multiple imputation by chained equations and multivariable Cox proportional-hazards regression analysis was then performed with the imputed data set. Multicollinearity between the included variables was examined using SE of b coefficient. All tests were two sided and a p value of <0.05 was considered to be statistically significant. The assumption of proportional hazards for each covariate was reviewed separately by the means of log-minus-log survival plots. HRs were reported together with the 95% CI values. All statistical analyses were performed using SPSS V.23.

RESULTS

Patient characteristics

Between January 2007 and December 2014, we identified 28 742 patients with BMI range between 11 and 70 kg/m^2 that underwent their first PCI from our NCVD-PCI database. The patients were divided into four groups according to their BMI values as shown in table 1. There were more males than females in all four BMI groups. Overweight and obese groups had significantly higher percentages of males (84.1% and 82.1%, respectively) compared with underweight (80%) and normal BMI (81.2%) groups. Among the three major ethnic groups, Malay showed significantly higher percentages recorded in the higher BMI groups, while Chinese showed the opposite. Comparing the mean age between the four

Table 1 Patients' baseline characteristics and clinical presentation on admission

	Underweight (n=435)	Normal weight (n=5168)	Overweight (n=12 605)	Obese (n=10 534)	p Value	Missing values, n (%)
Gender, n (%)					<0.001	0 (0)
Male	348 (80.0)	4198 (81.2)	10 601 (84.1)	8653 (82.1)		
Female	87 (20.0)	970 (18.8)	2004 (15.9)	1881 (17.9)		
Ethnicity, n (%)					<0.001	24 (0.1)
Malay	199 (45.7)	2183 (42.3)	5967 (47.4)	5977 (56.8)		
Chinese	118 (27.1)	1500 (29.1)	3030 (24.1)	1795 (17.1)		
Indian	78 (17.9)	1077 (20.9)	2649 (21.0)	2029 (19.3)		
Others	40 (9.2)	403 (7.8)	950 (7.5)	723 (6.9)		
Age (mean±SD)	61.4±11.0	60.2±10.4	57.9±10.0	55.5±10.0	<0.001*	0 (0)
Blood pressure on admission (mean±SD)					<0.001*	1366 (4.8)
Systolic	134.6±28.1	136.6±26.5	136.6±24.8	138.6±24.4		
Diastolic	72.8±13.0	74.6±12.5	76.7±12.2	78.9±12.6		
Current smoker, n (%)	122 (32.2)	1227 (27.2)	2922 (26.7)	2360 (25.7)	0.012	3715 (12.9)
Dyslipidemia, n (%)	285 (69.9)	3431 (70.3)	8678 (72.6)	7617 (76.0)	<0.001	1479 (5.1)
Hypertension, n (%)	288 (67.9)	3438 (68.7)	8788 (71.7)	8088 (78.4)	<0.001	743 (2.6)
Diabetes mellitus, n (%)	127 (30.0)	2043 (41.1)	5521 (45.3)	5213 (50.8)	<0.001	911 (3.2)
Renal impairment, n (%)	21 (4.9)	332 (6.6)	607 (4.9)	577 (5.6)	<0.001	664 (2.3)
Heart failure, n (%)	23 (5.5)	218 (4.3)	441 (3.6)	411 (4.0)	0.035	759 (2.6)
Previous myocardial infarction, n (%)	196 (47.5)	2298 (46.8)	5457 (45.3)	4537 (44.8)	0.104	1250 (4.3)
Previous cerebrovascular accident, n (%)	11 (2.6)	94 (1.9)	262 (2.1)	204 (2.0)	0.549	686 (2.4)
Previous percutaneous coronary intervention, n (%)	49 (11.3)	719 (13.9)	1836 (14.6)	1544 (14.7)	0.155	8 (0.0)
Previous coronary artery bypass graft, n (%)	15 (3.4)	182 (3.5)	485 (3.8)	392 (3.7)	0.755	12 (0.0)

*p value based on one-way analysis of variance test.

Table 2 Cardiac status at PCI

	Underweight (n=435)	Normal weight (n=5168)	Overweight (n=12 605)	Obese (n=10 534)	p Value	Missing values, n (%)
Indication, n (%)					<0.001	50 (0.2)
ACS	164 (37.7)	1851 (35.9)	4418 (35.1)	3366 (32.0)		
Non-ACS*	271 (62.3)	3301 (64.1)	8161 (64.9)	7160 (68.0)		
ACS type, n (%)					0.320	99 (1.0)
STEMI	86 (53.1)	996 (54.4)	2439 (55.7)	1776 (53.4)		
NSTEMI	50 (30.9)	583 (31.8)	1390 (31.7)	1082 (32.5)		
UA	26 (16.0)	253 (13.8)	550 (12.6)	469 (14.1)		
Killip† class, n (%)					0.022	998 (18.8)
I and II	60 (85.7)	720 (88.8)	1822 (91.5)	1312 (92.0)		
III and IV	10 (14.3)	91 (11.2)	170 (8.5)	114 (8.0)		
PCI post STEMI, n (%)					0.071	–
Primary	3 (7.7)	51 (11.7)	131 (13.4)	91 (14.4)		
Rescue	25 (64.1)	313 (72.0)	715 (73.2)	465 (73.3)		
Delayed	11 (28.2)	71 (16.3)	131 (13.4)	78 (12.3)		

ACS, acute coronary syndrome; NSTEMI, non-ST-elevation myocardial infarction; PCI, percutaneous coronary intervention; STEMI, ST-elevation myocardial infarction; UA, unstable angina.
*Included stable angina, positive functional ischaemia test and positive cardiac imaging test.
†Killip class for patients with STEMI only.

groups, it can be seen that there was a significant trend of decreasing mean age as we move to higher BMI groups. The opposite was true for systolic and diastolic blood pressure, in which the lower BMI groups had significantly lower mean systolic and diastolic blood pressure. The number of current smokers was also significantly higher in the underweight group (32.2%) compared with the obese group (25.7%).

In terms of previous medical illness and cardiovascular history, obese patients were more likely to have diabetes mellitus, hypertension and dyslipidemia compared with the lower BMI groups. They were however less likely to have heart failure compared with the leaner patients. There was no significant difference noted between the different BMI groups in terms of previous myocardial infarction (MI), cerebrovascular accident (CVA) and previous PCI or CABG.

Indications and cardiac status at PCI

In general, there were more PCIs conducted for non-ACS indication compared with ACS in all four BMI groups (table 2). The percentages for ACS were higher in the lower BMI groups while the percentages for non-ACS were higher in the overweight and obese groups. Further breakdown of types of ACS showed no difference among the BMI groups in terms of diagnosis of unstable angina, NSTEMI or STEMI. However, in those with STEMI, the obese group was more likely to have lower Killip class compared with the lower BMI groups.

Angiographic profile

Procedural characteristics are tabulated in table 3. In terms of number of vessels involvement, the obese group had a tendency towards more multivessel involvement, and the underweight group had a tendency towards single-vessel involvement. However, this finding needs to be interpreted with caution as the number of missing data for this variable was quite high from our study (37.3% of the data were missing for this variable).

The characteristics of the lesions did not differ significantly among the groups. There was no significant pattern noted in terms of lesion type and lesion length. Left anterior descending (LAD) artery was the most commonly involved vessel compared with the other sites. Among the different BMI groups, the obese and overweight group however showed significantly lesser involvement of the LAD compared with their leaner counterparts. Besides this, the obese group also had a higher proportion of drug-eluting stent (DES) used and was also associated with higher chance of using the radial artery approach for vascular access.

Discharge medications

On discharge from the hospital, the rates of prescribing aspirin, clopidogrel and statin were the same for all groups. Usage of other evidence-based therapies such as beta-blocker, ACE inhibitor (ACE-I) or angiotensin receptor blocker (ARB) were higher in the obese and overweight group compared with the lower BMI groups (table 4).

Outcomes

Table 5 shows the in-hospital complications after PCI. There was a trend of lower rate of in-hospital death in the overweight and obese groups, almost reaching statistical significance (p=0.057). There

Table 3 Angiographic profile and lesion characteristics

Angiography findings	Underweight	Normal weight	Overweight	Obese	p Value
Coronary disease, n (%)					<0.001
SVD*	140 (50.5)	1669 (51.9)	3945 (49.9)	3124 (47.2)	
MVD†	137 (49.5)	1546 (48.1)	3961 (50.1)	3499 (52.8)	
Lesion type, n (%)					0.248
A and B1	181 (37.1)	2252 (39.6)	5298 (38.1)	4459 (38.3)	
B2 and C	307 (62.9)	3442 (60.4)	8606 (61.9)	7191 (61.7)	
Lesion length, n (%)					0.485
<20 mm	207 (45.1)	2424 (45.3)	5759 (44.1)	4863 (44.3)	
>20 mm	252 (54.9)	2929 (54.7)	7314 (55.9)	6109 (55.7)	
Target vessel, n (%)					
LMS	11 (2.2)	121 (2.1)	278 (2.0)	188 (1.6)	0.480
LAD	256 (51.2)	2564 (44.4)	6222 (44.0)	5226 (44.0)	0.017
LCX	48 (9.6)	689 (11.9)	1731 (12.3)	1454 (12.3)	0.309
RCA	121 (24.2)	1358 (23.5)	3368 (23.8)	2897 (24.4)	0.551
Type of stent used, n (%)					<0.001
DES	296 (65.1)	3545 (67.1)	8785 (68.2)	7533 (69.9)	
BMS	97 (21.3)	1100 (20.8)	2675 (20.8)	2174 (20.2)	
Other	62 (13.6)	638 (12.1)	1422 (11.0)	1071 (9.9)	
Vascular access, n (%)					<0.001
Radial	185 (44.3)	2520 (50.4)	6492 (53.3)	5520 (54.4)	
Femoral	239 (57.2)	2551 (51.0)	5897 (48.4)	4884 (48.1)	

BMS, bare metal stent; DES, drug-eluting stent; LAD, Left anterior descending; LCX, Left circumflex; LMS, Left main stem; MVD, multivessel disease; RCA, right coronary artery; SVD, single-vessel disease.
*SVD: lesion of >50% stenosis in one coronary system.
†MVD: lesion of >50% stenosis in two coronary systems.

was no significant difference seen in terms of major adverse cardiovascular events (MACEs) and vascular complications.

We performed Cox proportional-hazards regression analysis to compare the HRs for 1-year mortality between the four BMI groups. Using the normal BMI group as the reference, the unadjusted HRs for overweight and obese groups were significantly lower at 0.63 (CI 0.50 to 0.80, p<0.001) and 0.69 (CI 0.54 to 0.87, p=0.002), respectively (table 6). The underweight group had a higher HR of 1.06 but this was not statistically significant. After adjustment for the covariates, the overweight group remained to have significantly lower HR of 0.71 (CI 0.55 to 0.90, p=0.005) compared with the normal BMI group (table 7). The obese group also had a lower HR of 0.78 but this failed to reach statistical significance (CI 0.61 to 1.01, p=0.056). From our analysis, we also found that other significant predictors of 1-year mortality after PCI were age >60 years, gender, diabetes, dyslipidemia, heart failure, renal failure, ethnicity and ACS as the indication for PCI (table 7).

DISCUSSION

In this study, we examined the prevalence of obesity and overweight among patients who underwent PCI over a

Table 4 Medications at discharge

Medication on discharge, n (%)	Underweight (n=435)	Normal weight (n=5168)	Overweight (n=12 605)	Obese (n=10 534)	p Value
Aspirin	391 (96.3)	4682 (95.8)	11 493 (95.7)	9674 (95.8)	0.898
Clopidogrel	391 (96.3)	4548 (93.4)	11 188 (93.3)	9416 (93.5)	0.122
Ticlopidine	5 (1.4)	168 (3.7)	356 (3.1)	286 (3.0)	0.031
Beta-blocker	263 (68.0)	3394 (71.8)	8645 (73.6)	7312 (74.0)	0.003
ACE inhibitor/angiotensin II receptor blocker	235 (61.4)	2948 (63.1)	7701 (66.1)	6837 (69.7)	<0.001
Statin	369 (93.4)	4480 (93.4)	11 182 (94.3)	9345 (93.6)	0.104

Table 5 In-hospital complications

Complications, n (%)	Underweight (n=435)	Normal weight (n=5168)	Overweight (n=12 605)	Obese (n=10 534)	p Value
Death	6 (1.4)	50 (1.0)	89 (0.7)	68 (0.7)	0.057
Major adverse cardiovascular event*	5 (1.2)	70 (1.4)	154 (1.2)	128 (1.2)	0.879
Vascular complications†	1 (0.2)	28 (0.5)	71 (0.6)	56 (0.5)	0.823

*Major adverse cardiovascular event included periprocedural myocardial infarction, emergency percutaneous coronary intervention, emergency coronary artery bypass graft, cardiogenic shock, arrhythmia, transient ischaemic attack/stroke, cardiac tamponade, new or worsening heart failure.
†Vascular complications included bleeding, access site occlusion, loss of distal pulse, dissection, pseudoaneurysm.

period of 8 years from 2007 to 2014. Most of the patients were in the overweight group (44%), followed by the obese (37%), normal BMI (18%) and underweight group (1%). This pattern was similar to the distribution of BMI in the general Malaysian population as reported in the NHMS 2015, in which 33.4% were overweight, 30.6% were obese, 29.3% were having normal BMI and 6.7% were underweight.[6] In terms of the demographic characteristics, even though the obese group had lesser prevalence of smoking and were younger than their leaner counterparts, in general they had more cardiovascular risk factors such as diabetes, dyslipidemia and hypertension. The higher prevalence of these comorbidities in obese people is a well-established observation, and the proposed pathophysiology was obesity is associated with beta cell dysfunction, abnormal lipids metabolism and activation of sympathetic nervous system.[12–14]

Regarding the angiographic profile of the patients, we found that obese patients in our population were more likely to have multivessel disease. This can be explained by the fact that obese patients have more cardiovascular risk factors which would predispose to more extensive coronary vessels involvement. We also found that in our study population, the leaner patients had higher rate of involvement of LAD artery compared with the obese group. This might contribute to the poorer outcome in the underweight and normal BMI group patients, as we know that LAD supplies more amount of myocardium in the majority of patients. However, this is an assumption that we are not able to validate in this study.

Despite having higher prevalence of cardiovascular risk factors, our study showed that overweight and obese patients were 29% and 22%, respectively, less likely to die within 1 year after PCI compared with the normal BMI group. This survival advantage however was only statistically significant in the overweight group (p=0.005) but less so in the obese group (p=0.056). This means that in our study population the protective effect of higher-than-normal BMI was only significant in the overweight group but was lost once BMI increased further into the obese range. Our study used a lower cut-off values for overweight and obese groups compared with other studies which used the international WHO-recommended values, and these findings might suggest that the protective effect of being overweight in Asian population occurs at lower BMI values compared with their Western counterparts. The standard classification recommended by WHO for non-Asian population defined overweight as BMI of 25 to <30 kg/m^2 and obese as BMI ≥30 kg/m^2, as opposed to BMI of 23 to <27.5 kg/m^2 for overweight and BMI of ≥27.5 kg/m^2 for obese in Asian population.[1 10]

Table 6 Unadjusted HR for 1-year mortality risk after percutaneous coronary intervention between different body mass index (BMI) groups

BMI group*	HR	95% CI	p Value
Underweight	1.06	0.55 to 2.02	0.868
Overweight	0.63	0.50 to 0.80	<0.001
Obese	0.69	0.54 to 0.87	0.002

*Normal BMI group was the reference group.

Table 7 Multivariate Cox regression analysis for predictors of 1-year mortality after percutaneous coronary intervention

Variables	HR	95% CI	p Value
Body mass index group*			
Underweight	1.02	0.53 to 1.95	0.952
Overweight	0.71	0.55 to 0.90	0.005
Obese	0.78	0.61 to 1.01	0.056
Male gender	0.74	0.59 to 0.93	0.011
Age >60 years	2.08	1.70 to 2.54	<0.001
Diabetes mellitus	1.40	1.13 to 1.73	0.002
Dyslipidemia	0.72	0.58 to 0.89	0.003
Acute coronary syndrome	2.04	1.68 to 2.48	<0.001
Heart failure	1.74	1.24 to 2.44	0.002
Chronic renal failure	3.45	2.71 to 4.39	<0.001
Ethnicity†			
Chinese	0.67	0.52 to 0.87	0.002
Indian	0.71	0.55 to 0.92	0.009

The HRs were adjusted for gender, age group, ethnicity, diabetes, hypertension, dyslipidemia, smoking status, previous myocardial infarction, heart failure, cerebrovascular disease, renal impairment, previous coronary artery bypass graft and acute coronary syndrome.
*Normal body mass index group was the reference body mass index group.
†Malay ethnicity was the reference ethnic group.

The underweight group in our study however did not show any significant difference compared with the normal BMI group in terms of 1-year mortality. The rate of in-hospital complications (MACE and vascular complications) also did not differ significantly among all the BMI groups.

Our findings were similar to those reported by Gruberg *et al*, in which overweight patients had a lower mortality at 1-year follow-up.[15] In contrast to our findings, their obese population also had significantly better 1-year outcome, and their in-hospital complication rates were found to be lower in these two groups.[15] Meanwhile, Gregory *et al* found that obese patients had lower vascular complications post PCI, but no differences found in terms of in-hospital MACE and death.[16] These two studies however were conducted within Western population, and they also used higher cut-off BMI values for overweight and obese groups compared with ours.

In general, Asians have a smaller physique compared with the Westerners, and ethnicity is known to be a confounding factor in determining cardiovascular outcomes.[17] Asian population also has been shown to have higher prevalence of cardiovascular risk factors at lower BMI values compared with the Western population.[18] WHO expert committee therefore suggested using lower values for BMI classification in Asian population.[10] With regards to obesity and outcomes after PCI in Asian people, previously Numasawa *et al* and Kaneko *et al* did show that leaner Japanese patients were associated with higher complications post PCI.[19,20] Their studies however used BMI definition based on Western population instead of the one proposed for Asian population. Another study involving Asian population was by Kang *et al* from Korea, and they used lower BMI range for obese group, similar to our study. They found that obese patients with STEMI who underwent PCI were also associated with lower rate of 1-year mortality.[21]

The advantages of our study compared with these previous studies were (1) our study population was a multiethnic Asian population, comprising three different major ethnic groups (Malay, Chinese and Indian); and (2) we used the more appropriate BMI classification for Asian population as suggested by WHO. The findings from our study and all other studies mentioned above show that having BMI above the normal range does confer some protective effects in patients undergoing PCI, irrespective of their ethnic origin and the BMI classification used. However, the degree of protection conferred by having higher BMI demonstrated in our study might not be applicable to other Asian populations, mainly because of the differences in their ethnic distribution, and the level of PCI expertise between the countries might differ as well.

From our study findings, we also suspected that the relationship between BMI and mortality may not be linear. Previously, Byrne *et al* and Angeras *et al* in their large registry studies further subdivided the obese groups into smaller subgroups, and they found that the relationship between BMI and mortality was actually U-shaped.[22,23] Their studies showed that the mortality rates were lowest in the overweight and mildly obese groups, and highest in the underweight and the extremely obese group.[22,23] As we only used four BMI groups to classify our study population, this bimodal relationship was not very apparent from our result. Despite this, the survival advantage of the overweight group and the non-significant difference in survivals at BMI range above and below the overweight range seen in our study may point towards a U-shaped relationship between BMI and outcomes after PCI. This however needs to be validated from further research using smaller ranges to divide the BMI values.

From a practical perspective, however, we would like to emphasise that we do not promote either overweight or obesity. The current recommendations that every patient should aim to achieve normal BMI and practice healthy lifestyle remained. The result from this study is merely an observation found in this specific cohort and should not be misquoted. The health benefits of losing weight are still much more overall compared with the protective effects of being overweight in certain disease settings.

Mechanism of obesity paradox

The potential underlying mechanism responsible for obesity paradox is still poorly understood. It has been postulated that debilitating chronic disease and older age are usually associated with compromised nutrition, impaired physical function and reduction in lean body mass hence lower BMI.[24] Therefore, this group of patients may have lower tolerance towards the stressful state related with PCI and the complications afterward. Overweight and obese patients are also more likely to be adequately treated with intensive pharmacotherapy due to their higher prevalence of comorbidities and younger age, and this would lead to better outcomes compared with their leaner counterparts.

Adipose tissue itself is an endocrine organ which secretes various biological mediators called 'adipokines' and some of these may explain the cardioprotective effects in obese people. For example, lower level of adiponectin, which is seen in obese people, has been shown to be associated with better outcomes in patient with pre-existing ischaemic heart disease.[25] Adipose tissue also produces tumour necrosis factor (TNF) receptor that is thought to neutralise the deleterious effect of TNF alpha on the myocardium.[26,27]

Limitations

We have identified a few limitations to our study. First, this is a retrospective data analysis which was obtained from the NCVD-PCI registry database. There were missing data in most of the parameters studied, and there were patients who were lost to follow-up after discharge. As with other observational studies, there is also a possibility of unmeasured or residual confounding.

Second, we did not divide further the obese group into smaller subgroups (mild, moderate, severe obesity) as per classified in obesity guidelines.[11] This may introduce bias when analysing them as a single group because as mentioned before it has been shown in some studies that severe obesity (BMI >40 kg/m^2) had poorer outcomes than the normal and mildly obese groups.[22 23]

Third, despite being widely used as a surrogate for obesity, BMI may not be the best proxy for central adiposity. Instead, waist circumference, waist-to-hip ratio (WHR) and waist-to-stature ratio have been shown to be a better predictor of abdominal obesity compared with BMI, and our registry did not include any of these measurements.[28] Previous studies have also shown that central obesity measurement such as WHR was an independent predictor for cardiovascular outcomes, and combining such measurement with BMI might be superior than using BMI alone.[29 30]

Fourth, the BMI calculated in our registry was taken at one point in time only, and this failed to take into consideration any recent weight loss, which could be triggered by declining health status of the patient. Fifth, our study analysed 8 years of collected data, and in the current era of rapidly evolving interventional cardiology field, the tools and technique of PCI have undergone significant changes within this wide timeframe, hence may affect the way that patients were generally treated and their outcomes.

Finally, as our data were collected from up to 15 different centres, there was some clustering nature of the data, with more data collected from the larger and more well-equipped tertiary centres. This clustering effect was not accounted for in our analysis and might have resulted in bias to the outcomes.

CONCLUSIONS

Our study showed that except for smoking the traditional cardiovascular risk factors such as diabetes mellitus, hypertension and dyslipidemia were more prevalent in overweight and obese people undergoing PCI. Despite these findings, overweight patients were found to have lower risk of death within 1 year after PCI compared with patients with normal BMI. The obese group however failed to show any significant survival benefit in this study. This advantage of being overweight needs to be interpreted carefully as we also noted that higher BMI patients in our cohort were younger, had more PCI for non-ACS indication and lesser LAD involvement.

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Competing interests None declared.

Ethics approval The NCVD-PCI has received ethical approval from the Medical Research and Ethics Committee (MREC) under the Ministry of Health Malaysia and is registered with the National Medical Research Register of Malaysia (ID: NMRR-07-20-250).

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