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The impact of anthropomorphic indices on clinical outcomes in patients with acute ST-elevation myocardial infarction

Rajendra H. Mehta[1]*, Robert M. Califf[1], Jyotsna Garg[1], Harvey D. White[2], Frans Van de Werf[3], Paul W. Armstrong[4], Karen S. Pieper[1], Eric J. Topol[5], and Christopher B. Granger[1]

[1] *Duke Clinical Research Institute and Duke University Medical Center, PO Box 17969, Durham, NC 27715, USA;* [2] *Greenlane Cardiovascular Service, Auckland City Hospital, Auckland, New Zealand;* [3] *University Hospital Leuven, Leuven, Belgium;* [4] *University of Alberta, Edmonton, Canada; and* [5] *Case Western Reserve University, Cleveland, OH, USA*

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Aims Multiple studies have focused on the relationship of body anthropometric measures with clinical events in ST-elevation myocardial infarction (STEMI) patients, highlighting the 'obesity paradox'. However, the relative prognostic importance of these measures over other baseline variables is less known.

Method and results We performed a retrospective analysis of 94 108 STEMI patients from seven clinical trials evaluating various reperfusion strategies to study the relationship and prognostic importance of height, weight, body mass index (BMI), and body surface area (BSA) with 30-day death and in-hospital cardiogenic shock, major bleeding, and stroke. Main outcome measures of interest included 30-day death and in-hospital cardiogenic shock, major bleeding, and stroke. Weight, BMI, and BSA were inversely and independently related to all clinical events. Despite being statistically significant ($P < 0.0001$), the prognostic information contributed by weight beyond that conferred by baseline clinical factors was minimal (<1% of total prognostic information) making it of limited clinical relevance for predicting 30-day death and cardiogenic shock. In contrast, weight accounted for 8.4% and 4.3% of the prognostic information in the logistic regression models for major bleeding and for stroke. BMI or BSA added little incremental value over simple measure of weight.

Conclusion Although statistically significantly related to most outcomes in patients with STEMI including death and shock, body weight provided clinically relevant prognostic information only for the risk of major bleeding and of stroke. Furthermore, BMI or BSA contributed little incremental prognostic information beyond that provided by weight alone. Thus, the existing large body of information concerning the strong prognostic importance of anthropometric measures with outcomes after STEMI should be interpreted in the context of other more important risk factors.

Introduction

Height, weight, and body mass index (BMI) have been shown to be associated with the likelihood of developing coronary artery disease (CAD). An inverse relationship has been demonstrated between height and the incidence of coronary heart disease by both case-controlled[1,2] and cohort studies.[3,4] Similarly, obesity (increased weight as well as BMI) has been shown to be an independent predictor of the risk of coronary atherosclerosis[5,6] and directly linked to increased cardiovascular morbidity and mortality.[7–9] Both height and weight are influenced by genetic, environmental, and socioeconomic factors and are associated with other coronary risk factors, which influence the risk of coronary atherosclerosis and outcomes of patients with established CAD.

In the GUSTO trial,[10] both height and weight were found to be inversely associated with 30-day mortality among patients with ST-elevation myocardial infarction (STEMI) treated with fibrinolytic therapy. Thus, in contrast to the lower risk of death in patients with low body weight in the general population, a paradoxically higher mortality was shown to occur among patients with STEMI who were shorter or had lower body weight.[10,11] This inverse relationship of body anthropometric measures, particularly weight and BMI, has also been demonstrated among patients undergoing coronary artery bypass surgery or percutaneous

*Corresponding author. Tel: +1 919 668 8971; fax: +1 919 668 7056.
E-mail address: mehta007@dcri.duke.edu

coronary intervention (PCI).[12] The above studies along with all other investigations have consistently suggested that height, weight, and BMI are independently related to clinical events in patients with STEMI,[10,11,13–17] and therefore should be routinely considered while risk-stratifying these patients. Although a large amount of literature has been dedicated in reporting the relationship of body anthropometric measures with clinical outcome in patients with STEMI, the relative prognostic importance of these factors with respect to each other and with respect to other clinical variables remains less well known. Thus, it is unclear whether the contribution of any of these anthropometric measures provides clinically relevant independent prognostic information.

Accordingly, we examined the relationship of these anthropometric measures [height, weight, BMI, and body surface area (BSA)] with clinical outcomes in patients with STEMI receiving reperfusion therapy.[18–24] The objective of the study was to understand how these different anthropometric measures influence the outcomes of patients with STEMI when adjusted for confounders. More specifically, our goal was to quantify the prognostic information provided by these anthropometric variables in the risk assessment of different clinical events in patients with STEMI receiving reperfusion therapy.

Methods

Study population

Data on patients enrolled in seven large-scale randomized clinical trials, namely GUSTO I through III, ASSENT-2 and -3, ASSENT 3 plus, and HERO-2[18–24] were evaluated for this investigation. The methods and patient populations of these studies have been previously published. These trials evaluated the efficacy of different fibrinolytic or reperfusion therapies,[18–21] the adjunctive treatment regimens to fibrinolytic therapy,[19,22,24] or the safety and efficacy of pre-hospital fibrinolysis.[23] Patients were excluded if they had missing data on height or weight [$n = 7952$ (8%)]. The remaining patients constituted the study sample ($n = 94\,108$).

Data collection and clinical end-point definitions

Baseline demographics, medical history, medications, procedures, complications, and clinical events were collected prospectively on the case report form in all trials. The clinical end-points were similarly defined for all studies. Cardiogenic shock was defined as systolic blood pressure (SBP) <90 mmHg for ≥ 1 h that was not responsive to fluid administration alone, thought to be secondary to cardiac dysfunction, and associated with signs of hypoperfusion or a cardiac index (c-index) ≤ 2.2 L/min/m^2. All suspected strokes were adjudicated by blinded central clinical events committee using prospectively defined criteria. Major bleeding was defined as intracranial haemorrhage or bleeding that causes haemodynamic compromise.

Anthropometric measurements

Weight was expressed in kilograms (kg) and height in meters (m). These measurements were obtained from the patients' case-report form as noted by the enrolling sites. BMI was calculated as weight in kilograms divided by height in squared-meters (m^2). BSA was derived using the equation: surface area (m^2) = square root (kg $\times$ cm/3600).

Statistical methods

All analyses were performed with SAS® software (version 8.2, Cary, NC, USA). All categorical measures were reported as counts with percentages. All continuous measures were reported as median $\pm$ inter-quartile range (IQR) and overall range. In all cases, missing variables were not defaulted to negative and denominators reflect cases reported. The continuous relationships of weight, height, BMI, and BSA to various outcome measures were derived and displayed by generating logistic regression models adjusting for differences in the baseline characteristics found to influence the outcome of interest. If an association was found to be non-linear, appropriate transformations of these variables were generated based on the point of maximum change in slope using cubic splines. The higher and lower value for each anthropometric measure was chosen based on this 'hinge' point. Thus, the cut-points were different for the same anthropometric measures for different outcomes. Multivariable logistic regression models were used to determine factors independently associated with various outcomes. For each individual outcome, initial model included covariates similar to that used in the previously published models on 30-day death,[10] cardiogenic shock,[25] major bleeding,[26] and stroke.[27] Variables with a significant ($P < 0.05$) association with the event of interest were retained in the final models. The relative prognostic contributions of various body anthropometric measures in the risk assessment of 30-day mortality, cardiogenic shock, bleeding, and stroke were estimated as the relative increase in the χ^2 value of the model with addition of each of the measures, calculated by subtracting the χ^2 value of the reduced model (one with all other factors but no anthropometric measure in it) from the χ^2 value of the overall model (model in which the anthropometric measure of interest was added to the reduced model) divided by the χ^2 value of the overall model multiplied by 100 (Appendix I). The ability of each model to discriminate between the presence and absence of the given outcome was estimated based on c-index. Finally, to address if the results were significantly influenced by the missing anthropometric and other covariates, we imputed these missing values, in patients, using the Markov Chain Monte Carlo technique of multiple imputation and re-did our models for all events as described before.[28] The results from the first imputed data set were compared with the results from multiple imputations and the differences were negligible. Thus, the results of the first imputed data set were used.

Results

The clinical characteristics of the patient cohort are shown in *Table 1* and are representative of a typical patient population seen in large clinical trials. The associations of various anthropometric measures with individual clinical events are shown in *Tables 2–5*, which show the adjusted χ^2 value and odds ratio (OR) of each anthropomorphic measure, as well as the total model χ^2 with and without the anthropomorphic measure. Baseline variables adjusted for, in the respective multivariable models for an event are shown at the bottom of *Tables 2–5*. As noted, all anthropometric measures showed an inverse relationship with clinical events such as 30-day death and in-hospital cardiogenic shock, major bleeding, and stroke. The height–outcome relationships were almost completely attenuated with the adjustment for other predictive variables. Following multivariable adjustment, weight was no longer a significant predictor of 30-day mortality, stroke, or cardiogenic shock in the higher weight category, although significant inverse association of weight and major bleeding persisted in the higher weight category. In contrast, in the lower body weight category, a consistent statistically significant

Table 1 Overall baseline characteristics of the patient population

Characteristics	
N	94,108
Age (median [IQR]) (range), years	61.56 [52.00, 70.00] (15.68, 110.00)
Female sex (%)	23,662 (25.15)
Hypertension (%)	38,644 (41.11)
Diabetes mellitus (%)	14,325 (15.23)
Current smoking (%)	36,206 (38.71)
Elevated cholesterol (%)	22,919 (32.59)
Family history CAD (%)	18,782 (39.73)
Prior angina (%)	29,148 (40.81)
Prior myocardial infarction (%)	15,238 (16.21)
Prior stroke (%)	1,354 (1.89)
Prior angioplasty (%)	3,950 (4.20)
Prior coronary bypass surgery (%)	3,319 (3.53)
Killip class $\geq$ III (%)	1,978 (2.12)
Presenting heart rate (median [IQR]) (range), b.p.m.	74.00 [63.00, 86.00] (20, 250)
Presenting systolic blood pressure (median [IQR]) (range), mmHg	130.00 [116.00, 150.00] (30.00, 280.00)
Presenting diastolic blood pressure (median [IQR]) (range), mmHg	80.00 [70.00, 90.00] (20.00, 190.00)
Weight (median [IQR]) (range), kg	78.00 [69.00, 87.00] (31.00, 213.00)
Height (median [IQR]) (range), m	1.70 [1.65, 1.77] (1.02, 4.61)
BMI (median [IQR]) (range)	26.53 [24.18, 29.38] (4.00, 157.85)
BMI $\geq$ 30 kg/m^2 (%)	19,904 (21.15)
BMI $\leq$ 20 kg/m^2 (%)	2,676 (2.84)
Body surface area (median [IQR]) (range), m^2	1.92 [1.79, 2.06] (1.13, 3.29)
Myocardial infarction location–Anterior (%)	38,703 (41.49)
Myocardial infarction location–Inferior (%)	50,887 (54.55)
Myocardial infarction location–other (%)	3,698 (3.96)
N	993
Initial creatinine clearance (median [IQR]) (range), mL/min	76.86 [61.37, 99.40] (21.21, 177.86)

inverse relationship existed between weight and all outcomes measures. The relationship of BMI and BSA paralleled that seen for body weight for all outcome measures.

Tables 6 and *7* illustrate that although weight is an important prognostic factor for stroke and bleeding, other baseline variables besides weight are more strongly associated with 30-day death and cardiogenic shock. The prognostic information contributed by the anthropometric measure in the overall model for an individual clinical event varied from minimum ($<$1% for 30-day death and cardiogenic shock) to moderate (up to 5.5 and 8.5% for major bleeding and stroke, respectively, *Table 8*).

Discussion

Our study provides important insights into the relationship of various anthropometric measures with clinical outcomes in patients with STEMI treated with reperfusion therapy. Similar to that shown by other investigators,[10–17] our data suggest a consistent, strong, inverse relationship with all anthropometric measures and adverse clinical events such that patients who were shorter or with lower body weight were more likely to suffer adverse events after their STEMI compared to taller and heavier patients. However, as opposed to height, this relationship was stronger for weight or anthropometric measures that incorporate weight (BMI and BSA). In fact, most of the height–outcome relationship was accounted for by confounding.

In contrast, the relationships between weight and outcomes persisted, despite adjustment for confounding factors. However, unlike that shown by prior investigators, our data suggest that this relationship was not linear, but was observed mostly and consistently in patients in the lower weight category. Although an independent inverse relationship existed between weight and clinical events in the lower body weight group, among patients of higher body weight, most of the variation in clinical outcomes was accounted for by the differences in baseline clinical characteristics and weight remained a less important correlate of adverse outcomes. Thus, once adjusted for these confounders, weight was no longer independently associated with most patients' outcomes in this higher body weight cohort. Only major bleeding continued to demonstrate significant inverse association with weight and clinical events in the higher weight group.

More importantly, while these relationships of anthropometric measures with clinical events were highly statistically significant and interesting and thus, has been the focus of multiple studies in literature evaluating factors independently associated with clinical events in patients with STEMI,[10–17,29] our study suggests caution in the over-interpretation of the relevance of these relationships from the clinical perspective of day-to-day practice of medicine. The findings of prior investigations may give the impression that weight and BMI are important prognostic factors that should be routinely considered when assessing risk of adverse clinical events after STEMI.[10,12–14,16,17] Furthermore, although these studies have not explicitly implied that obesity may have some inherent advantage among patients with STEMI, the vast body of literature that has focused on the 'obesity paradox' may have some believing that this may be true. However, the present

Table 2 Anthropometric measures and death at 30 days in patients with STEMI

Death at 30 days	χ^2 (for individual variables)	OR	95% CI	*P*-value	Overall adjusted log-likelihood χ^2 for various models (DF)[a]	c-index
Model without any anthropometric measures					6597.99 (23)	0.822
+ Height (1.65) (m)	6.35			0.0418	6618.41 (25)	0.822
+ Height $\leq$ 1.65	1.46	1.058	0.966,1.159	0.2263		
+ Height $>$ 1.65	5.94	0.920	0.860,0.984	0.0148		
+ Weight (85) (kg)	20.56			$<$0.0001	6632.45 (25)	0.823
+ Weight $\leq$ 85	17.77	0.925	0.892,0.959	$<$0.0001		
+ Weight $>$ 85	0.02	0.996	0.943,1.052	0.8902		
+ Height (1.65) (m) and weight (85) (kg)	26.17			$<$0.0001	6638.09 (27)	0.823
+ Height $\leq$ 1.65	5.06	1.115	1.014,1.223	0.0244		
+ Height $>$ 1.65	1.11	0.962	0.896,1.033	0.2913		
+ Weight $\leq$ 85	18.54	0.918	0.883,0.954	$<$0.0001		
+ Weight $>$ 85	0.03	1.005	0.950,1.062	0.8732		
+ BMI_25 kg/m^2	28.45			$<$0.0001	6616.34 (25)	0.822
+ BMI $\leq$ 25	23.45	0.950	0.931,0.970	$<$0.0001		
+ BMI $>$ 25	0.07	0.9999	0.989,1.009	0.7855		
+ BSA_1.7 (m^2)	17.59			0.0002	6629.51 (25)	0.823
+ BSA $\leq$ 1.7	4.3893	0.550	0.314,0.962	0.0362		
+ BSA $>$ 1.7	8.2302	0.721	0.577,0.902	0.0041		

Note that the 'hinge' in the spline transformation determines the cut-point for the higher and lower values of the anthropometric measures.

[a]Adjusted for age, gender, Killip class, age $\times$ Killip class, SBP, heart rate, location of MI, previous MI, symptom duration, diabetes, smoking, prior coronary artery bypass surgery, hypertension (HTN), prior stroke. Additional anthropometric measures are as indicated: height (increment of 0.1 m), weight (increment of 10 kg), height and weight, BMI (increment of 5 kg/m^2), and BSA (increment of 1 m^2) were added as two continuous variables (one below and one above the cut-point) to the baseline-adjusted model to evaluate their prognostic importance.

Table 3 Anthropometric measures and cardiogenic shock in patients with STEMI

Cardiogenic shock	χ^2 (for individual variables)	OR	95% CI	*P*-value	Overall adjusted log-likelihood χ^2 for various models (DF)[a]	c-index
Model without any anthropometric measures					5133.2305 (20)	0.796
+ Height (1.75) (m)	1.37			0.5039	5134.6001 (22)	0.796
+ Height $\leq$ 1.75	1.28	0.966	0.909,1.026	0.2573		
+ Height $>$ 1.75	0.38	1.036	0.927,1.158	0.5364		
+ Weight (85) (kg)	9.09			0.0106	5144.1411 (22)	0.797
+ Weight $\leq$ 85	8.63	0.946	0.912,0.982	0.0033		
+ Weight $>$ 85	0.14	1.009	0.961,1.059	0.7127		
+ Height (1.75) (m) and weight (85) (kg)	9.89			0.0423	5144.8931 (24)	0.797
+ Height $\leq$ 1.75	0.001	0.999	0.936,1.066	0.9727		
+ Height $>$ 1.75	0.78	1.052	0.940,1.178	0.3768		
+ Weight $\leq$ 85	7.99	0.944	0.908,0.983	0.0047		
+ Weight $>$ 85	0.03	1.004	0.956,1.056	0.8656		
+ BMI (25) (kg/m^2)	13.9127			0.0010	5149.3183 (22)	0.797
+ BMI $\leq$ 25	12.93	0.824	0.741,0.916	0.0003		
+ BMI $>$ 25	0.18	1.010	0.963,1.060	0.6709		
+ BSA (20) (m^2)	7.5416			0.0230	5142.6311 (22)	0.797
+ BSA $\leq$ 2.0	6.75	0.712	0.552,0.920	0.0094		
+ BSA $>$ 2.0	0.00	1.000	0.683,1.463	0.9995		

Note that the 'hinge' in the spline transformation determines the cut-point for the higher and lower values of the anthropometric measures.

[a]Adjusted for age, SBP, DBP, heart rate, Killip class, location of MI, previous MI, previous coronary bypass surgery, female gender, HTN, and previous PCIs. Additional anthropometric measures are as indicated: height (increment of 0.1 m), weight (increment of 10 kg), height and weight, BMI (increment of 5 kg/m^2), and BSA (increment of 1 m^2) were added as two continuous variables (one below and one above the cut-point) to the baseline-adjusted model to evaluate their prognostic importance.

Table 4 Anthropometric measures and major bleeding in patients with STEMI

Major bleeding	χ^2 (for individual variables)	OR	95% CI	*P*-value	Overall adjusted log-likelihood χ^2 for various models (DF)[a]	c-index
Model without any anthropometric measures					2333.6275 (19)	0.703
+ Height (1.70) (m)	47.93			<0.0001	2381.3252 (21)	0.705
+ Height ≤ 1.70	16.46	0.880	0.828,0.936	<0.0001		
+ Height > 1.70	20.02	0.856	0.799,0.916	<0.0001		
+ Weight (70) (kg)	208.14			<0.0001	2537.7290 (21)	0.711
+ Weight ≤ 70	59.25	0.797	0.752,0.844	<0.0001		
+ Weight > 70	86.78	0.870	0.845,0.896	<0.0001		
+ Height (1.70) (m) and weight (70) (kg)	211.64			<0.0001	2540.3040 (23)	0.711
+ Height ≤ 1.70	1.05	0.966	0.903,1.032	0.3055		
+ Height > 1.70	1.24	0.960	0.893,1.032	0.2647		
+ Weight ≤ 70	51.34	0.803	0.757,0.853	<0.0001		
+ Weight > 70	69.11	0.877	0.850,0.904	<0.0001		
+ BMI (25) (kg/m^2)	140.0026			<0.0001	2472.7807 (21)	0.708
+ BMI ≤ 25	25.77	0.785	0.714,0.862	<0.0001		
+ BMI > 25	63.93	0.829	0.791,0.868	<0.0001		
+ BSA (19) (m^2)	212.1867			<0.0001	2539.5441 (21)	0.711
+ BSA ≤ 1.9	96.01	0.247	0.187,0.327	<0.0001		
+ BSA > 1.9	54.99	0.366	0.281,0.477	<0.0001		

Note that the 'hinge' in the spline transformation determines the cut-point for the higher and lower values of the anthropometric measures.

[a]Adjusted for age, black race, sex, DBP, pulse, HTN, current smoker, location of MI, USA (country), Killip class, USA × Killip class. Additional anthropometric measures are as indicated: height (increment of 0.1 m), weight (increment of 10 kg), height and weight, BMI (increment of 5 kg/m^2), and BSA (increment of 1 m^2) were added as two continuous variables (one below and one above the cut-point) to the baseline-adjusted model to evaluate their prognostic importance.

Table 5 Anthropometric measures and stroke in patients with STEMI

Stroke	χ^2 (for individual variables)	OR	95% CI	*P*-value	Overall adjusted log-likelihood χ^2 for various models (DF)[a]	c-index
Model without any anthropometric measures					442.1505 (7)	0.698
+ Height (1.75) (m)	1.1606			0.5597	442.3905 (9)	0.694
+ Height $\leq$ 1.75	0.07	0.987	0.896,1.088	0.7938		
+ Height $>$ 1.75	0.72	0.902	0.711,1.145	0.3966		
+ Weight (90) (kg)	26.1558			$<$0.0001	472.4628 (9)	0.701
+ Weight $\leq$ 90	22.60	0.863	0.812,0.917	$<$0.0001		
+ Weight $>$ 90	0.03	0.988	0.862,1.132	0.8601		
+ Height (1.70) (m) and weight (90) (kg)	30.9523			$<$0.0001	476.6353 (11)	0.701
+ Height $\leq$ 1.75	4.76	1.133	1.013,1.267	0.0291		
+ Height $>$ 1.75	0.001	1.004	0.787,1.282	0.9739		
+ Weight $\leq$ 90	26.88	0.827	0.769,0.888	$<$0.0001		
+ Weight $>$ 90	0.02	0.991	0.861,1.139	0.8935		
+ BMI (25) (kg/m^2)	32.4682			$<$0.0001	479.9420 (9)	0.702
+ BMI $\leq$ 25	16.10	0.672	0.554,0.816	$<$0.0001		
+ BMI $>$ 25	4.82	0.881	0.788,0.987	0.0282		
+ BSA (22) (m^2)	21.0866			$<$0.0001	466.1781 (9)	0.700
+ BSA $\leq$ 2.2	19.73	0.443	0.310,0.635	$<$0.0001		
+ BSA $>$ 2.2	0.02	1.117	0.199,6.266	0.9002		

Note that the 'hinge' in the spline transformation determines the cut-point for the higher and lower values of the anthropometric measures.

[a]Adjusted for age, SBP, DBP, HTN, previous stroke, age $\times$ HTN. Additional anthropometric measures are as indicated: height (increment of 0.1 m), weight (increment of 10 kg), height and weight, BMI (increment of 5 kg/m^2), and BSA (increment of 1 m^2) were added as two continuous variables (one below and one above the cut-point) to the baseline-adjusted model to evaluate their prognostic importance.

Table 6 Multivariable logistic regression model showing important independent correlates of 30-day mortality and cardiogenic shock

30-Day death				Cardiogenic shock			
Variables	OR	95% CI	χ^2	Variables	OR	95% CI	χ^2
Intercept			87.49	Intercept			2.74
Age (years)	1.077	1.074–1.080	2701.86	Age (years)	1.042	1.039–1.045	761.65
SBP (mmHg)[a]	0.967	0.964–0.969	714.60	SBP (mmHg)	0.954	0.952–0.956	1352.76
Heart rate $\leq$ 50 b.p.m.	1.008	0.986–1.029	0.48	Killip class 2	2.051	1.898–2.217	326.96
Heart rate $>$ 50 b.p.m.	1.019	1.017–1.020	601.49	Killip class 3	4.374	3.788–5.050	404.69
MI–anterior vs. other	1.623	1.531–1.720	266.69	Killip class 4	25.493	20.752–31.318	951.43
Killip class 2	2.012	1.880–2.154	407.25	Heart rate $\leq$ 50 b.p.m.	0.996	0.975–1.017	0.15
Killip class 3	3.591	3.131–4.117	335.03	Heart rate $>$ 50 b.p.m.	1.020	1.018–1.021	554.73
Killip class 4	8.566	7.057–10.399	471.64				
c-index	0.81			c-index	0.78		

[a]Truncated at SBP of 120 mmHg.

Table 7 Multivariable logistic regression model showing important independent correlates of stroke and moderate or major bleeding

Major bleeding				Stroke			
Variables	OR	95% CI	χ^2	Variables	OR	95% CI	χ^2
Intercept			188.00	Intercept			101.28
Age (years)	1.029	1.026–1.031	467.81	Age (years)	1.058	1.049–1.067	166.50
US patients	2.975	2.817–3.141	1544.10	Previous CVA	2.799	2.156–3.635	59.61
Female gender	1.259	1.184–1.339	53.74	Weight $\leq$ 90 kg	0.980	0.973–0.988	28.74
Weight $\leq$ 70 kg	0.974	0.969–0.979	98.98	Weight $>$ 90 kg	0.999	0.984–1.013	0.04
Weight $>$ 70 kg	0.986	0.984–0.989	100.91	Diastolic BP (mmHg)	1.009	1.005–1.014	16.45
Current smoker	0.950	0.895–1.009	2.81	History of HTN	3.012	1.304–6.954	6.67
				Height $\leq$ 175 cm	1.012	1.002–1.025	5.39
				Height $>$ 175 cm	1.001	0.977–1.026	0.01
				Age $\times$ HTN	0.988	0.977–1.000	3.59
c-index	0.70			c-index	0.71		

CVA, cerebrovascular accident; age $\times$ HTN, interaction term for age and HTN.

study demonstrates that, in fact, the prognostic information of any of these anthropometric measures is so small relative to other factors that it is less likely to be clinically meaningful. Consistent with prior studies and as noted earlier, multivariable logistic regression analysis in our study identified weight, BMI, and BSA as highly statistically significant independent predictors of 30-day death and shock. However, the inclusion of any of these anthropometric measure to these prediction models added $<$1% of prognostic information beyond that already provided by other variables in the models. Thus, obesity should not be considered as a somewhat favourable prognostic marker in any population, but rather as demonstrated in multiple prior studies, an important public health hazard directing epidemiological efforts towards reducing obesity epidemic among the general population beginning early in childhood or adolescence.

Only for the outcomes of major bleeding and stroke, weight and weight-based anthropometric measures (BMI and BSA) provided some clinically relevant quantitative prognostic information over and above that provided by other baseline variables. These variables contributed between 5 and 8% of prognostic information in the overall risk-prediction models for these two outcomes. In fact, the awareness of the importance of the prognostic value of patients' body weight has been well recognized and highlighted by investigators as important factors in assessing risk and guiding therapy. Among patients treated with similar doses of tenecteplase, investigators from ASSENT-3 trial have shown that the strict weight-based lower adjunctive dosing of unfractionated heparin resulted in lower rates of major bleeding without any significant increase in ischaemic events compared with the higher dose of adjunctive unfractionated heparin used in ASSENT-2 trial [adjusted OR 0.49; 95% confidence interval (CI) 0.35–0.67].[30] Therefore, it is not surprising that this importance of weight with the risk of bleeding and stroke is also reflected in the recommendations of American College of Cardiology/American Heart Association/European Society of Cardiology guidelines for the treatment of patients with STEMI, where particular emphasis is placed on weight-based dosing of fibrinolytic therapy and other adjunctive treatments, particularly heparin.[31]

It seems logical that BMI and BSA were found to have similar relationship with most clinical events as observed with body weight, because of the incorporation of weight in the calculation of these anthropometric measures. However, it appears from our data that the proportion of prognostic information provided for any outcomes (including

Table 8 Independent incremental proportional prognostic information contributed by anthropometric measures in the overall model for various clinical events

Variable	30-Day death (%)	Cardiogenic shock (%)	Major bleeding (%)	Stroke (%)
+Height (m)	0.31	0.02	1.90	0.00
+Weight (kg)	0.52	0.15	8.42	4.29
+Height (m) and weight (kg)	0.61	0.16	8.54	4.94
+BMI (kg/m^2)	0.28	0.21	5.74	5.28
+BSA (m^2)	0.48	0.12	8.46	3.22

major bleeding and stroke) by BMI and BSA is similar to that imparted by body weight. This finding suggests that rather than using anthropometric measures derived using complex formula such as BMI and BSA, a simple measure of body weight should be used, as it provides almost all the anthropometric measures-related prognostic information for most outcomes in STEMI patients.

Our study findings should be viewed in light of its strengths and limitations. The large number of patients in our study with greater than 7000 deaths and equally large number of other events observed, allowed for robust adjustments that were not possible in prior studies involving small number of patients. However, our study included patients with STEMI treated with reperfusion, and the applicability of its findings to unselected patients with STEMI or not receiving reperfusion need to be confirmed in the future study, although there appears to be no reason to contemplate that the relationship would be different in these populations. Like most studies evaluating anthropomorphic measures in large acutely ill populations, missing data that were more common among patients with early death may reduce the confidence of our findings, particularly with regards to early death. Although we cannot be certain of the influence of these missing variables on the results of our study, our findings remained unchanged after imputation of missing covariates suggesting that there was no major impact on our findings. In addition, effects of unmeasured confounders may influence our results. Finally, we did not have information on waist-to-hip ratio in our patients that had been previously shown to be an important risk factor for adverse cardiovascular outcomes.[32] Thus, we could not assess the prognostic importance of this anthropometric measure.

In summary, our study provides an important quantitative perspective on the previously well-described qualitative prognostic value of various anthropometric factors among patients with STEMI treated with reperfusion. Our data indicate that while body weight is statistically significantly related to major clinical events in patients with STEMI, weight provides independent clinically relevant prognostic information only for the risk of major bleeding and stroke. Furthermore, these findings support the use of simple measure of body weight over the more complex measures of BMI and BSA for risk-stratification of patients with STEMI, as these factors provide little incremental prognostic information beyond that conferred by weight alone. This information should be kept in context while assessing risks and when interpreting the existing large body of information that emphasizes the strong prognostic inverse relationship of anthropometric measures with adverse outcomes after STEMI.

Conflict of interest: none declared.

Appendix I

Estimation of prognostic information contributed by an anthropometric measure for a given outcome in the full model (%) = [χ^2 (log-likelihood) for the model with anthropomorphic measure − χ^2 (log-likelihood) for the model without anthropomorphic measure/ χ^2 (log-likelihood) for the model with anthropomorphic measure × 100. For example, for the outcome of death at 30 days, the factor body weight contributes 6632.45 − 6597.99/ 6632.45 × 100 or 0.52% to the prognostic information in the overall model.

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