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Comparison of BMI and the Body Mass/Body Surface Ratio: Is BMI a Biased Tool?

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ABSTRACT

For decades we are used to judge our body composition by using the body mass index (BMI). Since the BMI denominator can be considered as a substitute for body surface area (BSA), the body mass/ body surface ratio (BM/BSA) can be calculated. For a distribution of BM/BSA values comparable to the distribution of normal BMI values, the range 35.5–39.9 kg/m² is chosen as normal, although it covers BM range 50 to 90 kg. The proposed normal BM/BSA range suggests that heavy adults with less than 2 m of height are not obese only if they are less than 90 kg. If the described limitations of the BM/BSA ratio are valid, then the BMI should be regarded as a biased tool, less applicable to individuals with body masses outside the 55 to 90 kg BM range. If we consider many health problems related to the increased body mass, it is possible that the BMI should be used with caution in heavy individuals.

Key words: body mass index, body surface area, body constitution, obesity

Introduction

We are used to estimate our body composition by using the body mass index (BMI)^{1–3}. It was introduced by Adolphe Quetelet between 1830 and 1850, as a measure of human body constitution:

$$\text{BMI} = \frac{\text{BM}}{\text{height}^2}$$

where BM is body mass in kilograms and height is in meters. The WHO defined BMI normal range is 18.5–24 kg/m².

BMI is a human specific index, without an animal equivalent, used in wide range of anthropological and clinical medicine research activities. For instance, it has been recognized among factors related to inheritance of body composition in regionally^{4–7} or demographically^{8,9} defined populations. Other authors used BMI to estimate relation of adiposity and leptin secretion¹⁰.

Limitations of BMI are well known. Many people with a BMI below 30 kg/m² are obese and thus misclassified by BMI². The prevalence of obesity-associated co-morbidities is high in subjects with short stature in whom BMI as a diagnostic tool is poor and cannot be improved by decreasing BMI thresholds for overweight³. When used to

calculate the fat content, BMI can provide misleading information in many settings: infancy and childhood; ageing; racial differences; athletes; military and civil forces personnel; weight loss with and without exercise; physical training; and special clinical circumstances¹.

The proposed body mass/ body surface ratio (BM/BSA)

The BMI denominator can be described as an area wrapped around a cylinder as tall as the body, and wide height/π. BMI expressed in kg/m² is just another measure of thickness, similar to the paper thickness expressed in g/m² (i.e., ordinary printer paper is 80 g/m² thick).

If we consider the BMI denominator as an early substitute for the body surface area (BSA), it might seem surprising that BMI survived the publication of Dubois & Dubois formula for BSA in 1916, and the simple Mosteller formula in 1987¹¹:

$$\text{BSA} = \sqrt{\frac{\text{BM} \times \text{height}}{3600}}$$

where BM is body mass in kilograms and height is in meters.

TABLE 1
COMPARISON OF BMI AND THE BM/BSA RATIO IN EVALUATING OBESITY

BMI (kg/m ²) marked range: 18.5-24													
	Body mass in kg												
	50	55	60	70	75	80	85	90	95	100	105	110	
Body height in cm	150	22.22	24.44	26.67	28.89	31.11	33.33	35.56	37.78	40.00	42.22	44.44	46.67
	155	20.81	22.89	24.97	27.06	29.14	31.22	33.30	35.38	37.46	39.54	41.62	43.70
	160	19.53	21.48	23.44	25.39	27.34	29.30	31.25	33.20	35.16	37.11	39.06	41.02
	165	18.37	20.20	22.04	23.88	25.71	27.55	29.38	31.22	33.06	34.89	36.73	38.57
	170	17.30	19.03	20.76	22.49	24.22	25.95	27.68	29.41	31.14	32.87	34.60	36.33
	175	16.33	17.96	19.59	21.22	22.86	24.49	26.12	27.76	29.39	31.02	32.65	34.29
	180	15.43	16.98	18.52	20.06	21.60	23.15	24.69	26.23	27.78	29.32	30.86	32.41
	185	14.61	16.07	17.53	18.99	20.45	21.91	23.37	24.84	26.30	27.76	29.22	30.68
	190	13.85	15.24	16.62	18.01	19.39	20.78	22.16	23.55	24.93	26.32	27.70	29.09
	195	13.15	14.46	15.78	17.09	18.41	19.72	21.04	22.35	23.67	24.98	26.30	27.61
BM/BSA(kg/m ²) marked range: 35.5-39.9													
Body height in cm	150	34.64	36.33	37.95	39.50	40.99	42.43	43.82	45.17	46.48	47.75	48.99	50.20
	155	34.08	35.74	37.33	38.85	40.32	41.74	43.11	44.43	45.72	46.97	48.19	49.38
	160	33.54	35.18	36.74	38.24	39.69	41.08	42.43	43.73	45.00	46.23	47.43	48.61
	165	33.03	34.64	36.18	37.66	39.08	40.45	41.78	43.06	44.31	45.53	46.71	47.86
	170	32.54	34.13	35.65	37.10	38.50	39.85	41.16	42.43	43.66	44.85	46.02	47.15
	175	32.07	33.64	35.13	36.57	37.95	39.28	40.57	41.82	43.03	44.21	45.36	46.48
	180	31.62	33.17	34.64	36.06	37.42	38.73	40.00	41.23	42.43	43.59	44.72	45.83
	185	31.19	32.71	34.17	35.56	36.91	38.20	39.46	40.67	41.85	43.00	44.11	45.20
	190	30.78	32.28	33.72	35.09	36.42	37.70	38.93	40.13	41.29	42.43	43.53	44.60
	195	30.38	31.87	33.28	34.64	35.95	37.21	38.43	39.61	40.76	41.88	42.97	44.03

In the upper part with BMI values normal range for BMI (18.5–24 kg/m²) is marked in grey cells. In the lower part, the range 35.5–39.9 kg/m² is chosen since it gives distribution of normal values similar to the distribution of normal BMI values for individuals with body mass from 50 to 90 kg.

BMI and BSA concepts somehow remained separate for decades. The rare exception is calculation of antineoplastic chemotherapy doses in obese patients¹² where the BMI value is often used as a drug dose limiting marker.

A simple graph in Figure 1, compares the BMI denominator (height²) with the actual BSA values generated by the Mosteller formula. It shows that the squared body height is a poor substitute for the actual BSA data, particularly in taller persons.

Table 1 compares the BMI values with values of the body mass/body surface (BM/BSA) ratio calculated by the Mosteller formula¹¹.

The WHO proposed normal range values (18.5–24 kg/m² of BMI) form a characteristic distribution pattern in Table 1 that cannot easily be copied on BM/BSA values, due to the different formula denominators. Data in Table 1 suggest that the best suited range of BM/BSA values is 35.5–39.9 kg/m². Other, wider, or more narrow ranges produce distributions even less similar to the pat-

tern of normal BMI distribution. In comparison to BMI, here proposed range of normal BM/BSA values makes less allowance for adults with more than 90 kg, or adults with less than 55 kg and more than 150 cm, considering them to slim or to fat, while for BMI they are still in the normal range.

Possible consequences of comparison between BMI and BM/BSA

Here presented BM/BSA distribution suggests that 90 kg is the upper normal body mass for all people with height below 2 m and that BMI should be regarded as a biased tool, less applicable to individuals with body masses outside the 55 to 90 kg range. Considering many health problems related to the increased body mass. It is possible that the BMI should be used with caution in heavy individuals with more than 90 kg of body mass. Beside tradition, the BMI popularity might result from the fact that it makes certain allowances in very slim and in

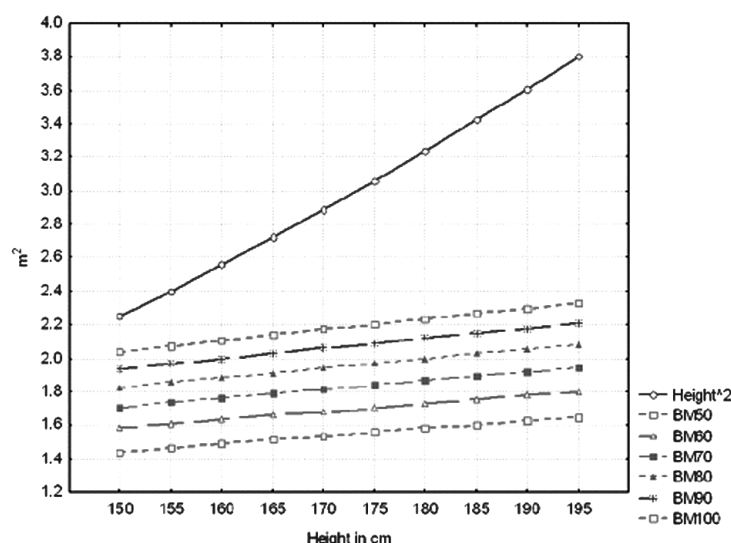


Fig. 1. Comparison of the BMI denominator (body height²), independent of the body mass, with body surface values ($BSA = (mass \times height / 3600)^{(1)}$) for different body masses (from 50 kg in BM50 to 100 kg in BM100). The BMI denominator (height²) is obviously a very poor substitute for BSA, particularly in taller persons.

heavy individuals. In clinical practice, allowing heavy adults to fit in the normal range after losing some weight,

might be more acceptable than explaining that all adults should aim to have less than 90 kg.

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USPOREDBA INDEKSA TJELESNE MASE (BMI) I OMJERA TJELESNA MASA/TJELESNA POVRŠINA: KOLIKO JE BMI NEOBJEKTIVAN?

SAŽETAK

Desetljećima je uobičajeno prosuđivati tjelesnu građu izračunom indeksa tjelesne mase (BMI). Kako je nazivnik formule BMI u stvari zamjena za tjelesnu površinu (BSA), moguće je izračunati omjer tjelesne mase (BM) i tjelesne površine (BM/BSA). Radi dobivanja razdiobe BM/BSA vrijednosti usporedive s razdiobom normalnog raspona BMI, raspon 35,5–39,9 kg/m² je odabran kao normalan, mada on pokriva sam tjelesnu masu u rasponu 50 to 90 kg. Odabrani normalni BM/BSA raspon sugerira da krupne odrasle osobe niže od 2 m nisu pretile samo ako imaju masu manju od 90 kg. Ukoliko je ovo ograničenje valjano, BMI bi trebalo smatrati neobjektivnim pokazateljem koji je manje primjenjiv u pojedinaca mase izvan raspona 55 do 90 kg. Uzevši u obzir sve zdravstvene probleme povezane s pretilošću, moguće je da BMI treba biti rabljen s oprezom u krupnih osoba.