

What is wrong with the Body Mass Index?

I have recently been seeing a large number of elderly people, but have been struck by the poor relationship between the Body Mass Index (BMI) and my overall impression of the person's health. I heard, not for the first time, BMI being promoted on Radio 4 as a good measure of the population's health. I raised the question with Charles.

'Charles, recently I have been examining a large number of elderly individuals and am not very impressed by BMI as a measure of the healthy individual. Yet we are told on the radio, and elsewhere, that the average BMI has increased in the population, and this forebodes increasing morbidity and mortality, both at vast expense to the health service.'

'Well, Coe, as we have discussed before, although morbidity increases health service expenditure, mortality certainly doesn't. What in particular had you noticed?'

'I have seen several big healthy chaps with only a bit of a tummy with BMIs above 30, which is supposed to be the critical level, and weedy individuals, but with gross abdominal obesity, whose BMIs are within the normal range.'

'What precisely is BMI?'

'It's weight/height²,' I replied.

'That's a contradiction in terms,' he replied.

'Indices are dimensionless.'

'What do you mean?'

'Well comparative measures work best when they are the ratios of values with the same dimensions, for example, specific gravity is weight/weight. Provided the density is uniform, mass has the effective dimensions of length³ and therefore body mass index should be mass/height³, not mass/height².'

'I have often wondered about it myself, but why is it used?'

'I once mentioned this to an expert in obesity and he was only able to give me the pragmatic explanation that BMI worked better in assessing risk than the natural or 'ponderal' index, weight/height³.'

'Can you do better, Charles? Why is BMI more closely associated with the observed risk than ponderal index, the better indicator of the assumed hazard, body fat?'

'Let's look at the implications! BMI is the same as ponderal index multiplied by height. Therefore, the taller you are, the less bulky you have to be for the same risk and *vice versa*.'

'So that means that there is a disproportionate disadvantage in being tall and fat and, or, a reduced advantage in being short and thin.'

'You've got it, Coe!'

'Go on.'

'Let's start with the short and thin! Think of the problems of smaller warm-blooded animals in winter. They have more surface area per unit body mass, so they require disproportionately greater fat stores or insulation. Why not small people? You might say they have to be thick-skinned to survive till spring!'

'I see what you are getting at,' I replied, and made a further suggestion. 'The energy stores required at times of crisis during prolonged illness might be more or less absolute and so not depend much on the size of the individual. But why might being tall and heavy be particularly bad?'

'Of course that is the other possibility,' he said adding with a wry smile, 'But I thought you might know the answer, so it's over to you for the tall, Coe!'

I was taken aback but much relieved when I found myself responding: 'Actually, I do have an idea. Do you know about the two metabolic types of muscle?'

It was his turn to say, 'Go on!'

'There is the bulky, strong type and the wiry endurance type. Dominance of the latter is associated with longer survival, so the anomaly may reflect the fact that the big burly person who has excess of strong muscle as well as fat is at particular disadvantage.'

'We've answered the conundrum, but that does not change the fact that BMI is not an index.'

'Why does that matter?'

'It may work within a population but it cannot be used to compare populations or generations.'

'So when the obesity lobby says our BMI is rising, so we must be getting fatter, that's wrong?'

‘It ain’t necessarily so!’

‘Because we’re getting taller?’ I guessed.

‘Yes, each increase of 1 cm in adult height means an increase in BMI of more than one half of one percent, or about one and a half percent for every inch. That equates to an absolute increase of about 0.5 in BMI per generation during the twentieth century, and probably more so for children.’

‘I agree that that is a substantial increase, but is it enough to explain away the obesity epidemic?’

‘One only has to look around to be sure that it isn’t, but, nevertheless, using the BMI exaggerates the trend. It also means that ideal values cannot be transferred across generations, particularly in children.’

‘Fair enough, but we’ve drifted off the original point.’

‘Yes, the simple view – the greater the index, the greater the ill health – does not recognise the value of good nutrition. Whether the ‘index’ is ponderal or BMI is immaterial.’

‘How do you overcome the problem, Charles?’

‘One can manipulate the data to produce U-shaped curves, but it would be nice to see a linear association.’

‘Waist/height ratio is becoming more fashionable, particularly as it seems abdominal obesity is the critical thing.’

‘Much better, it is a true index, being dimensionless, and may well be the simplest answer. However, aside from a simple direct relationship, I am also more attracted by the positive than the negative. I remember you told me some time ago that, much to some people’s surprise, when they looked at survival of old ladies after a hip fracture the heavy ones did better than the thin ones. I can think of reasons for this other than nutrition, but having adequate fat stores must help to survive the perioperative period, as must having good muscle with which to cough and to mobilise quickly. So, let’s start

with the proposition that health positively co-relates with adequate nutrition or its surrogate, body mass.’

‘But that’s against all conventional teaching!’ I said.

‘Not if you were in Belsen! Abdominal obesity is the trouble, and much of strong muscle is abdominal. Look at weight lifters! Let’s allow for a slim abdomen by dividing by the waist measurement.’

‘Fair enough,’ I said. ‘But wouldn’t you have to divide by waist cubed?’

‘True, that would make it an index, but might over-compensate. Waist squared (to reflect cross-sectional area) is the natural power and the scaling could be completed by the inclusion of height.’

‘So, the Charles Index is $\text{weight}/(\text{waist}^2 \times \text{height})$.’

‘I am flattered by the eponym, but would like to call it the Health Index.’

‘Implying the greater it is the better?’

‘Yes,’ he insisted.

‘But, I say again, this goes against all conventional teaching.’

‘Perhaps, but those who are attached to the BMI should remember the warning, in another sphere, that comes with all financial advice, “Past experience is not necessarily a guide to future performance!”’

I wonder whether anyone will ever put these ideas to the test. The Charles Index would certainly appear to reflect the health of the old men that I have been examining much better than the conventional BMI.

After the conversation, Charles worked out the BMI of a large range of individuals of varying proportions, including those Gulliver might have met in his travels, and sent me the table below.

Coemgenus

Table to illustrate the effects of height and body weight distribution on BMI, the ponderal index and the Charles index.

	Height m	Weight kg	Waist cm		Ponderal Index (both)	BMI (both)	Charles Index	
			normal	obese			normal	obese
Tom Thumb	0.05	0.0018	0.023	0.028	14.3	0.71	68.4	43.8
Pigmy	1.00	14.3	46	57	14.3	14.3	68.4	43.8
Short Man	1.55	53.3	71	90	14.3	22.1	68.4	43.8
Average Man	1.75	76.6	80	100	14.3	25	68.4	43.8
Tall Man	1.95	106	89	111	14.3	27.9	68.4	43.8
Goliath	10	14285	457	571	14.3	142.8	68.4	43.8

‘Obese’ in the above table is shorthand for ‘obese with poor musculature and skin nutrition’. The calculations of the indices are exact and therefore may differ slightly from those calculated from the rounded figures in the table. In this table, the difference in BMI between a short man and a tall man is 5.8. However, if a short man with a BMI of 25 was used as the model, he would weigh 60 kg and have a ponderal index of 16.1. A tall man of the same proportions (ponderal index 16.1) would weigh 119 kg and would appear to be obese with a BMI of 31.5 (exact calculation).