# Ideal Body Weight Formulas in Relation to Body Mass Index and Reference Heights

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***Abstract***

*Body mass index (BMI) is frequently used in the medical sciences as a measure of adiposity. BMI is the weight (in kg) divided by the square of the height (in meters). In contrast, formulas for ideal body weight (IBW) exist that are linear in the height. Here we obtain new formulas for ideal body weight for height by choosing a more mathematically appropriate reference height. We compare the BMI and IBW formulas by means of the ANSURII database, and show that the IBW formula presented here leads to lower percentage discrepancies in the calculation of the IBW compared to previous formulas.*

**Keywords: Body mass index; Ideal body weight; Obesity; Anthropometry; Biometry**

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**Introduction**

In the medical community, ideal body weights provide a foundation upon which important clinical practices rely, such as medication selections; anesthetic dosages; and disease designations. Much more than just a personal reference of health, these values define standards in the medical community that can greatly influence the care that patients receive.

In practice, ideal body weight serves a variety of functions. Adult and pediatric ICU standards recommend basing mechanical ventilation tidal volumes (VT) on patients' IBWs as the lung capacity is a culmination of a patient's age, height, sex, and chest cavity dimensions . As the risks of improper tidal volumes include organ-failure, increased mortality, and longer ICU stays, it is of significant importance to accurately extrapolate patient body dimensions. Furthermore, diagnoses of various eating disorders partly rely upon IBW. Previously, the DSM-IV diagnosed anorexia using percentages of expected IBW . Currently, the DMS-V has switched to BMI values to function as cutoffs that differentiate between patients with anorexia nervosa purging subtype or bulimia depending on whether their BMI meets the specified criteria . Within the subcategory of anorexia nervosa, BMI values are further utilized to categorize the illness as mild, moderate, severe, or extreme. These designations greatly alter treatment courses, and as many medications are contra-indicated in patients with eating disorders due to increased seizure risks, these parameters are important for all practitioners to account for when prescribing medications in these patient populations.

Perhaps best known for its role in defining the recent obesity epidemic, ideal body weights are not only important in defining weight class designations and obesity. Additionally, these measurements in the overweight and obese populations can be used to correlate risks of developing associated comorbidities such as diabetes, cancer, and cardiovascular disease amongst others.

A major clinical application and an ongoing area of research in clinical medicine, ideal body weights provide important insight when determining appropriate dosages of medications in all patients. The pharmacokinetics of a drug depend on a great number of factors, with an important one being distribution. As distribution depends upon the drugs ability to enter various tissues, the amount and type of tissue present will influence drug concentration, duration of action, and efficacy. For example, elderly patients experience a decrease in lean body mass and total body water over time; therefore, water-soluble drugs will have a greater concentration as there is a smaller volume of distribution available to these drugs. Common water-soluble drugs in elderly patients, such as plasma circulating anti-coagulants, will then be more effective and may need to have a reduced dosage. Conversely, these same patients will see an increase in adipose tissue, leading to less active lipid-soluble drugs as the volume of distribution for these drugs has increased, effectively decreasing the concentration of these agents. Just as in the elderly, the ideal body weight should be understood in all patients in order to prescribe safe, effective doses of medication. As IBW provides a much better understanding of total body weight distribution, it could prove to be a better diagnostic tool in clinical medicine.

Typical formulas for IBW are linear equations in which the IBW is some constant plus some multiple of the subject's height. In contrast, a given "ideal" BMI will also generate an ideal body weight, one that is quadratic in the height. Peterson et al. have shown how to reconcile linear and quadratic formulas, based on Taylor-series expansions. Here we follow a similar path but rely instead simply on the property of squaring two numbers. More important, we argue that any IBW formula should be based on a realistic choice of reference height. Hamwi, Devine, Robinson et al., Miller et al., and Hammond et al. all use a height of 60 inches, or 150 cm, in their formulas for ideal body weight. However, given that the height of an average male adult is considerably higher than this, the ideal body weight formulas are likely to be inaccurate when describing the male population. In addition, Moreault, Lacasse, and Bussières as well as Shah et al. argue in favor of using a value of 22 for the ideal BMI and determining ideal body weight from that formula. Hence we shall adopt a BMI of 22 as ideal in what follows.

**Method**

Consider the BMI for a subject of height H and weight W. Then, by definition:

$$BMI = W/H^2. \quad (1)$$

If, now, we assume the subject has the ideal body mass index, call it B, the subject will also have the idea body weight (IBW) for their height. By rearranging (1),

$$IBW = B*H^2. \quad (2)$$

Suppose a subject is of height H = H(0) + h. Here, we assume that H(0) is large compared to h, such as the average height for the subjects in a given population. Then from Equation (2), the ideal body weight for such a subject is:

$$IBW = B* [H(0) + h]^2 \quad (3)$$

Expanding the term in brackets:

$$IBW = B*H(0)^2 + 2B*H(0)*h + B*h^2 \quad (4)$$

This can be rewritten in the form:

$$IBW = B*H(0)^2 + 2B*H(0)*h*[1 + h/H(0)] \quad (5)$$

We have assumed, however, that h is small compared to H(0), and as a consequence the last term in Equation (5) can be ignored. This is an extremely important condition, and if one chooses an inappropriate reference height H(0), then the accuracy of the approximation may be poor.
But assuming an appropriate reference height, this approximation leads to the linear equation

$$IBW = B*H(0)^2 + 2*B*H(0)*h \quad (6)$$

Or, in terms of the subject's actual height H,

$$IBW = B*H(0)^2 + 2B*H(0)*[H – H(0)] \quad (7)$$

As a simple justification, consider 11^2 = 121. If we write 11^2 = [10 + 1]^2, in essence choosing 10 to be our reference height, then the approximation introduced above says that 11^2 = 10^2 + 20 = 120, which is within 1% of the exact answer. If instead we chose a reference point of 8, we have 11^2 = [8 + 3]^2 = 64 + 48 = 112, which is far less accurate. The choice of reference height, then, is crucial.

Heretofore, the reference heights for almost all IBW formulas has been 152 cm, or 5 feet, for both men and women. To determine whether these choices are optimal, we explored the ANSURII data of 4,081 US male military personnel. Only one subject was less than 1.52 m in height. The maximum recorded height was 1.993 m. The average height of the 4,081 men in the ANSUII survey was 1.75621m with a standard deviation of 0.06855, and so the standard reference height of 1.52 m is more than two standard deviations below the mean for the ANSURII data.

For women, the ANSURII data give an average height of 1.628m (with a standard deviation of 0.0642) for the 1,986 female military personnel, hence the choice of 1.52m as a standard reference height is more accurate for women than for men, though it is still more than one standard deviation below the mean.

Following Moreault, we use B = 22 for the ideal BMI for both men and women. For the ANSURII data, we select a reference height of H(0) = 1.75 m for men and H(0) = 1.63 m for women. Inserting these two formulas into Equation (7) gives the following IBW formulas:

IBW = 22*[1.75]^2 + 2*22*1.75*[H(m) – 1.75] (men)
(8)

And

IBW = 22*[1.63]^2 + 2*22*1.63*[H(m) – 1.63] (women)
(9)

Numerically, and converting the heights from meters into centimeters, these yield:

IBM (kg) = 67.375 + 0.77*[H(cm) – 175] (men)
(10)

IBM (kg) = 58.45 + 0.72*[H(cm) – 163] (women)
(11)

These are the results obtained for our sample population, which should be good approximations for the United States population. Body shapes and average heights vary from culture to culture, however, and as a consequence "local" IBW equations can be developed by inserting the best values for ideal body mass index and average heights into Equation (7).

Moreault et al argue for using a BMI of 22, as we have here, and employing the quadratic expression for ideal body weight that results. Our equations (10) and (11) are, in keeping with ideal body weights, linear functions of the height. The quadratic and linear equations should yield similar results provided that the reference height selected is a good measure of the average height of a given population. To compare our equation with the standard BMI formula and those presented in Refs. [N-M], we computed the sums of the squares of the differences predicted by the various formulas.

We also use a least-squares fit to obtain another IBW equation. For men, with heights in the range from 1.5 to 2.0 meters, and for women in the height range 1.4 to 1.9 meters, we obtained:

IBM (kg) = 101.75 + 0.38*[H(cm) – 175] (men)
(12)

IBM (kg) = 58.97 + 0.726*[H(cm) – 163] (women)
(13)

To compute these, we set the BMI = 22 and calculated BMI*H^2 over the range of heights with increments equal to 0.01 meters. We then used the LINEST function in Excel to generate the line of best fit through these data.

**Results and discussion**

The two equations derived in this paper (10) and (11) were used to predict ideal body weights for men in the height range of 1.5 to 2.0 meters, in intervals of 0.01 meters. These were compared with the ideal body weight as determined from the BMI formula for an ideal BMI of 22. They were also compared with the ideal body weight formulas of Ref {N-M].

Of all of the ideal body weight formulas, the ones in this paper, and the ones of Peterson, were by far the most accurate. The sums of squares for Lipscombe and Lipscombe were just over 9.95 in the height range from 1.5 to 2.0 m. These both compare well with the least-squares fit, which has 9.26. For Peterson, the sums of squares was just over 11.33. In stark contrast, the next best predictors are the formulas of Hamwi and Devine, where the variance was more than 787 and 1,384 respectively.

For women, for the range of heights of 1.4 to 1.9 meters, the sum of squares for Lipscombe and Lipscombe was again the best estimator, with a total of just under 22.22, compared to the least squares estimate of 9.26, with Peterson the next most accurate predictor at just under 227.

Hence, in terms of accuracy, the formulas (10) and (11) presented in this paper are the most accurate when compared to those predicted by the BMI equation directly. This excludes the least-squares fits, for two reasons. First, should one need to predict values for a different body mass index, one can go directly to Equation (7) here and compute the result; to use the least-squares method, one would need laboriously to go and enter the new data in a spreadsheet. Second, the line of best fit is drawn across all the heights used within the entire range. Formulas (10) and (11) presented here are intended to be highly accurate in the middle of the range, close to the average height of the sample population. It is true that this means they will be less accurate at heights far from the average. However, a least squares fit might be more accurate at the extremes and less accurate for the majority of the population. Indeed, in the height range for women of 1.53 to 1.73 meters (corresponding approximately to the 5th to 95th percentile) , the least-squares variance was 3.317, compared with the Lipscombe and Lipscombe value of 0.25. Likewise, for men, the least squares fit for heights in the range of 1.65 to 1.85 meters (approximately equal to between the 5th and 95th percentile respectively) was 3.4, whereas for Equation (10) it was only 1.7.

One logical objection might be that we have assumed for our formula that the ideal body mass index is 22, and we have used this same value for calculating ideal body weight from the BMI equation. But, as with the equations of Peterson, one can choose any body mass index as the ideal, and then adjust Equations (10) and (11) accordingly. In each case, the ideal body weight predicted in this paper should be closest to that given by the BMI formula, for the reason that the percentage errors are less, due to the more-optimal choice of reference heights.

Need to cite Shah. Comparison of ideal body weight equations and published height-weight tables with body mass index tables for healthy adults in the United States.

Shah B, Sucher K, Hollenbeck CB
Nutr Clin Pract. 2006 Jun; 21(3):312-9.

**Conclusion**

Following the example of Peterson, Hamwi, Devine and others we sought a simple expression for ideal body weight given a subject's height. To do so, we chose as a reference height not the 152 cm used in those articles, but ones equal the average height in the population being studied. The formulas derived from first principles in this paper are more accurate than pre-existing formulas, and are comparable to the accuracy of least-squares formulas derived numerically on an ad hoc basis.

Caution should be exercised by physicians in using the Hamwi or Devine expressions, in particular for males, as they routinely have a higher value for ideal weight than the BMI itself, or the expressions used here. Given the current obesity epidemic, it is better to use the formulas presented in this paper, which are closer to the BMI predictions for ideal weight.

Furthermore, the derivation presented here allows researchers to select the ideal BMI of their choice and a good estimate for the average height of the subjects in a study, to determine their own accurate, linear formula for ideal body weight for their sample population.

**Resumo**

*Korpa maso-indekso (BMI) estas ofte uzata en la medicinaj sciencoj kiel mezuro de obezeco. BMI estas la pezo (en kg) dividita per la kvadrato de la alteco (en metroj). Kontraŭe, ekzistas formuloj por ideala korpa pezo (IBW) kiuj estas linearaj en la alteco. Ĉi tie ni akiras novajn formulojn por ideala korpo pezo por alteco elektante pli matematike taŭgan*

*referencan altecon. Ni komparas la BMI kaj IBW-formulojn per la ANSURII datumbazo, kaj oni montras, ke la IBW-formulo prezentita ĉi tie kondukas al malpli altaj procentaj diferencoj en la kalkulo de la IBW kompare al antaŭaj formuloj.*

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