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Development of a Consistent Body Mass Index

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Development of a Consistent Body Mass Index

Abstract

A new body mass index, termed Consistent Body Mass Index CBMI=$\sqrt{m/h^3}$, is developed from first principles. Customarily used Body Mass Index (BMI = m/h^2) or its variant Tri-ponderal Mass Index (TMI = m/h^3) or other measures serving to the purpose of classifying the anthropometric status of a person have repeatedly been demonstrated to be unsatisfactory in various aspects. A new index inclusive of all ages, body sizes, and sexes is therefore needed. A non-dimensional hence scalable index CBMI, which correlates well with waist-to-height ratio, w/h, is developed from fundamental relations. Correlation levels of CBMI and TMI against waist-to-height ratio w/h are

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compared for measurements comprising participants ranging from 1-day-old to 75-year-old male and female infants, children, and adults. Waist-to-height ratio w/h, which correlates well, $r = 0.84$, with CBMI is a reliable measure of the anthropometric status of a person. New criteria and relevant charts, based on w/h and CBMI, are established for classifying anthropometric status levels. CBMI can also be used as an estimator for ideal body weight for a definite CBMI value and a given height h from $m = (CBMI)^2 h^3$.

Keywords: Public health; Obesity; Non-dimensional new body mass index; Waist-to-height ratio; New classifications of body anthropometric status levels; Ideal body weight estimation.

1. Introduction

In his book L'homme moyen (The average man) Quetelet (1796-1874) introduced a measure, body mass divided by height squared, m/h^2, which was much later termed as the Body Mass Index, BMI [1]. Despite the worldwide usage of Quetelet's body mass index, it has the serious drawback of not being directly applicable to children and youth, let alone infants. Likewise, the index is unreliable for relatively short or tall people. This particular defect originates from the dimensional form of BMI (kg/m^2), which renders it unscalable. Drawbacks associated with BMI are discussed in several studies [2-4].

Such and similar problems have led to various different indexes such as the one proposed by Rohrer (1888–1926), the Corpulence Index (CI), also termed Ponderal Index (PI) or Tri-ponderal Mass Index (TMI), defined as mass per cubic height m/h^3. Being essentially non-dimensional, TMI provides some improvements as reported in various studies [5, 6]; however, it still lacks general applicability.

Trefethen [7] suggested to use m/h^E with $E = 2.5$ and scaling factor 1.3 so that the new BMI reads $1.3\, m/h^{2.5}$. Obviously, the new BMI inherits the

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fundamental problem of dimensionality and cannot be related to a physically meaningful non-dimensional parameter.

WHO Expert Consultation published a report [8], which emphasizes the importance of waist circumference and waist-to-hip ratio measures in identifying metabolic diseases and risk factors concerning cardiovascular diseases, hypertension, diabetes, various cancer types, and mortality. All these risks are associated with and classified according to the BMI and waist circumference. Classifications based on the dimensional BMI (kg/m^2) and waist circumference (m) cannot be relied on for wide range of body sizes. Clearly, while a waist circumference of 0.90 m for a person of 1.80 m height may be classified fit, the same waist size would not be considered so for a person of 1.60 m height. A non-dimensional parameter would be much more reliable in such classifications as dimensional analysis teaches us [9]. Indeed, relatively recent studies consider non-dimensional measures such as waist-to-hip ratio [10, 11] and more appropriately waist-to-height ratio [12-14] rather than the body mass index BMI for predicting various health risks and years of life lost due to obesity.

The present derivation process is based on relating a geometric ratio; namely, waist-to-height ratio w/h, to a physical non-dimensional quantity based on mass, density, and height. The selection of waist-to-height ratio instead of some other dimensionless ratio such as waist-to-hip ratio, has its justification in two essential points. First, waist-to-height ratio is in accord with the general geometric description of fullness or slimness; that is, width divided by length or transverse axis divided by longitudinal axis. Waist-to-hip ratio on the other hand is a ratio of two slightly different transverse sections and therefore incapable of determining fullness or slimness of an object. Second, the relevance of waist-to-height ratio to health risks associated with obesity has been clinically observed in studies [12-14] to the extent that a very strong claim concerning mortality due to obesity-related cardiovascular diseases is made in [14]. Thus, after identifying w/h as the principal geometric parameter

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representing fullness or slimness it is related to the newly derived body mass index CBMI by using the well-known definition that mass is equal to density times volume. To place BMI and TMI within the same framework, in line with the WHO report which attempts to correlate waist circumference w to BMI, a proportionality between w and BMI/density is assumed and after a division by h, waist-to-height ratio w/h is directly connected to TMI/density, both non-dimensional quantities. Once CBMI and TMI are related to w/h their performances may be compared in equal terms. It is clear that these comparisons do not constitute a true validation of CBMI as a measure of "anthropometric status"; however, supposing that BMI or equivalently TMI is regarded as a *somewhat acceptable measure* of adiposity or related health risks, the relatively better performance of CBMI against TMI may be considered as a promising aspect in favor of CBMI. Thus, the performance assessment of CBMI presented here is relative and not absolute; for a future work it is planned to check the validity of CBMI in absolute sense by performing direct measurements of adiposity.

1. Methodology

1.1. Formulation of Consistent Body Mass Index from First Principles

A universally applicable body index must be scalable, or equivalently non-dimensional, and relatable to another non-dimensional quantity geometrically describing the fullness or slenderness of an object; namely, width-to-length ratio. Starting from first principles, the present work now develops a non-dimensional body mass index termed CBMI, directly related to waist-to-height ratio w/h that can be used for all body sizes and ages, including infants. To this end, we begin with the elementary definition that mass is equal to density times volume:

$$m = \rho V \quad (1)$$

where m is mass in kg, ρ density in kg/m^3, and V volume in m^3 according to the SI units. Due to the necessity of mathematical modelling the human body

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is approximated as a circular cylinder whose height is the same as a person's height h and whose radius r is equal to an imaginary overall average radius as schematically depicted in Figure 1. Although mathematically quite convenient, such a representation is obviously a daring simplification which necessarily implies potential drawbacks associated with changes in body proportions due to sex, ethnicity, age, and adiposity levels. Despite these concerns, the lumped approach adopted here proves to be both useful in representing the standard transverse measure of waist circumference w and accurate enough in formulating a body mass index as revealed by results in Section 3. The cylindrical volume V is

$$V = \pi r^2 h = \pi(w/2\pi)^2 h = \frac{1}{4\pi} w^2 h \quad (2)$$

where $w = 2\pi r$ is taken as the average waist circumference corresponding to radius r defined above. Substituting V into the definition of mass gives

$$m = \rho V = \frac{\rho}{4\pi} w^2 h \quad (3)$$

Solving for w yields

$$w = 2\sqrt{\frac{\pi}{\rho}\frac{m}{h}} \quad (4)$$

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In order to formulate a dimensionless measure, both sides of the above equation are divided by h so that

$$\frac{w}{h} = 2\sqrt{\frac{\pi}{\rho}\frac{m}{h^3}} \quad (5)$$

Finally, to account for differences in forms of human bodies from that of a circular cylinder we define a dimensionless coefficient α^*, which may be termed as the *form factor*, so that

$$\frac{w}{h} = 2\alpha^*\sqrt{\frac{\pi}{\rho}\frac{m}{h^3}} = \alpha\sqrt{\frac{m}{h^3}} \quad (6)$$

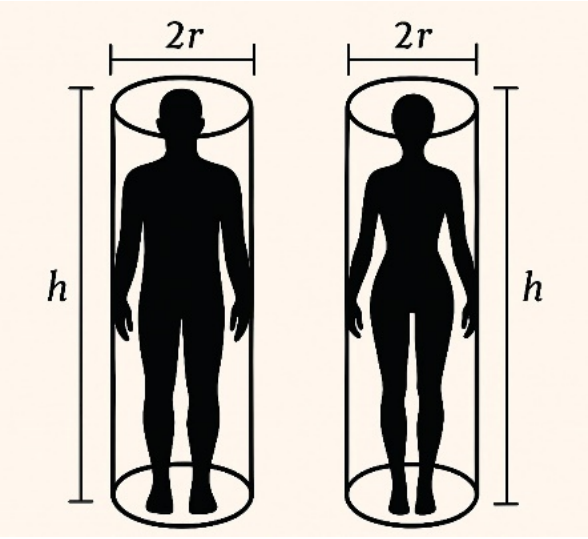
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where $\alpha = 2\alpha^*\sqrt{\pi/\rho}$ is a dimensional constant introduced to factor out the relatively smaller effect of changes in body density from person to person. Thus, the Consistent Body Mass Index CBMI is defined as

$$\text{CBMI} = \sqrt{\frac{m}{h^3}} \quad (7)$$

which is directly related to the ratio of waist circumference to height, $w/h = \alpha \bullet \text{CBMI}$. The new index does not appear non-dimensional; but this is only apparent because if the body density ρ were kept, $\sqrt{m/\rho h^3}$, it would be explicitly non-dimensional.

Human body density shows variations depending on sex and percentages of fatty, muscular, and bone tissues; therefore, the dimensional constant $\alpha = 2\alpha^*\sqrt{\pi/\rho}$ would in principle differ according to sex, tissue composition, and to some extent, age. For simplicity, taking the human body density approximately $\rho = 1000$ kg/m^3 gives $\alpha = 0.11 \bullet \alpha^*$ where the multiplier 0.11 is a dimensional quantity making both sides of equation (6) non-dimensional. Using the average value $\alpha = 0.129$ obtained in §3.1, $\alpha^* = \alpha/0.11$ becomes $\alpha^* = 1.17$, which indicates that the constructed model is good because the proportionality factor or form factor is $\alpha^* \sim O(1)$.



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Figure 1. Representation of human body as a circular cylinder with radius r and height h. Geometric measure of slenderness or fullness of an object: Waist-to-height ratio $w/h = \pi(2r/h)$ (width/height), where waist circumference $w = 2\pi r$.

1.2. Standard BMI Expressed as TMI and Related to Waist-to-Height Ratio

The standard $BMI = m/h^2$ has the dimension of mass over length squared (kg/m^2) and cannot be linked to non-dimensional waist-to-height ratio. To cast BMI into a dimensionless form, first it is divided by the presumably constant body density ρ so that $m/\rho h^2$ attains the dimension of length (m). This length may be assumed *proportional* to the waist circumference w, as implied in the WHO report (World Health Organization, 2011) so that

$$w \propto \frac{m}{\rho h^2} \quad (8)$$

where both sides of the above expression are *dimensionally in accord* and may be written as an equality by introducing a dimensionless proportionality constant or form factor, say β^*:

$$w = \beta^* \frac{m}{\rho h^2} \quad (9)$$

Due to the advantages of using non-dimensional quantities as well as performing consistent comparisons of BMI with CBMI we now rewrite (9) as w/h by simply dividing both sides by h:

$$\frac{w}{h} = \beta \frac{m}{h^3} \quad (10)$$

where $\beta = \beta^*/\rho$ is a dimensional constant absorbing the body density ρ as in the definition of α. The right-hand side of equation (10) is nothing other than the tri-ponderal mass index TMI. Now that BMI and TMI are clearly related we are ready to compare equation (6) with (10) in terms of their performances

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in predicting measured w/h values from the computed $CBMI = \sqrt{m/h^3}$ and $TMI = m/h^3$ values. CBMI differs from TMI by the square root only; but this fine difference results in remarkable improvements in correlation coefficients computed for w/h versus CBMI values.

2. Measurements

2.1. Ethical Approval

The required ethical permission to conduct the data collection part of the study was approved and issued by Biruni University Ethics Commission (Ruling no. 2024-BIAEK/09-59, 21 April 2025). Verbal informed consent of the participants was obtained and all measurements were performed in accordance with relevant guidelines and regulations. Hospital staff working at Biruni University Hospital, healthy volunteers, patients' relatives and/or children accompanying the patients and infants in the neonatal unit were included in the study. Participants were not subjected to any prioritized selection criterion other than being healthy without any chronic or other diseases. The process was naturally randomized based on available and consenting individuals. Weight, used interchangeably with mass, was measured with a scale placed on a level surface while participants were wearing light clothes without shoes, height was measured in upright position, infants in supine position, and waist circumference was measured with measuring tape, the midpoint between the lower border of the rib cage and the iliac crest at the end of normal expiration.

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2.2. Statistical Analyses

Basic statistical analyses were carried out on the Excel data files established for the subgroups and entire participants. Using G*Power 3.1, the required sample size was calculated to be 400 participants based on a two-tailed analysis with an effect size (Cohen's d) of 0.17, a significance level (α) of 0.05, and a statistical power of 0.90. 400 participants were measured in four subgroups: teenage and adult females, teenage and adult males, female

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children and male children with 100 participants in each subgroup. Teenagers and adults were classified together as adults for ages 10 years and older; consequently, less than 10-year-olds were categorized as children. The separation of participants into two main categories as children (<10 years) and adults (≥10 years) is basically for emphasizing that the applicable range of CBMI covers a wide range of age groups including infants. In the end all the data, regardless of sex and age, are evaluated and compared together; calculations are done in exactly the same way for all the sex and age groups. In order to show that there are no substantial differences in results across different sexes and ages, results for different groups are also included. Table 1 gives the relevant statistical figures as averages ±standard deviations for the measured data.

Table 1. Basic statistical characteristics of measured data as averages±standard deviations.

Group	Age range (year)	Age (year)	Mass (kg)	Height (cm)	Waist (cm)	Waist/Height
Female adults	10-70	30±12	63±15	163±10	80±14	0.49±0.081
Male adults	10-75	33±18	69±21	168±15	84±15	0.50±0.065
Female children	0-9	5±3	18±8	103±25	51±8	0.51±0.068
Male children	0-9	6±3	21±8	110±21	54±8	0.50±0.063
All	0-75	18±17	43±27	136±35	67±18	0.50±0.068

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2.3. Application of Method of Least Squares

The present work assumes a direct proportionality between waist-to-height ratio w/h and the newly introduced body mass index $CBMI = \sqrt{m/h^3}$. Both these quantities are non-dimensional and that CBMI is termed *consistent* because it accords with the geometric parameter w/h. In order to

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quantitatively determine the degree of correlation between w/h and CBMI as well as between w/h and TMI we first recall equations (6) and (10)

$$w/h = \alpha\sqrt{m/h^3} \qquad\qquad w/h = \beta(m/h^3) \quad (11)$$

The method of least-squares is employed to determine α and β separately for the measured data by minimizing the sum of errors squared with respect to the proportionality constant. Once the proportionality constants α and β are computed, the predicted values are obtained from the right-hand sides of the equations in (11). Since the measured w_i/h_i values are known, the total residual error S_r for CBMI is computed from $S_r = \sum_{i=1}^{N}\left[w_i/h_i - \alpha\sqrt{m_i/h_i^3}\right]^2$ while the residual error of the measured w_i/h_i values, S_t, is obtained from $S_t = \sum_{i=1}^{N}[w_i/h_i - (w_i/h_i)_{mean}]^2$. Accordingly, the extent of the improvement provided by the model equation is quantified by the correlation coefficient $r = \sqrt{1 - S_r/S_t}$. Note that when the residual error $S_r = 0$, the correlation coefficient $r = 1$ hence the model represents the data perfectly. On the other hand, if $S_r \geq S_t$ the model completely fails to represent the data. For TMI exactly the same approach is applied to obtain β; only m_i/h_i^3 is used in place of $\sqrt{m_i/h_i^3}$. The following results are computed according to these formulations by using a FORTRAN software developed specifically for this application.

3. Results

3.1. Waist-to-Height versus CBMI and TMI

α and β values connecting CBMI and TMI to w/h are obtained as described above. Then, measured w/h values versus corresponding CBMI and TMI values computed from (11) are plotted separately and relevant correlation coefficients are calculated. In accord with the SI units, weights are taken in kilogram (kg), heights and waist circumferences in meter (m). Computations

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are carried out for four subgroups of 100 participants each and for entire 400 participants, separately. Statistical results for α·CBMI and β·TMI are summarized in Table 2 and Table 3, respectively.

Table 2. Correlation coefficients of w/h versus CBMI for different groups.

CBMI	Form factor α	Residual error (model) S_r	Residual error (data) S_t	Correlation coefficient r
Female adults	0.128	0.159	0.540	0.840
Male adults	0.133	0.185	0.415	0.744
Female children	0.128	0.082	0.463	0.907
Male children	0.128	0.099	0.391	0.864
All	0.129	0.555	1.851	0.837

Table 2 shows the results for CBMI. Except for male adults, r = 0.744, correlation coefficients are all above 0.8. A plausible argument and some trial computations for explaining this exceptional case are included in the discussion.

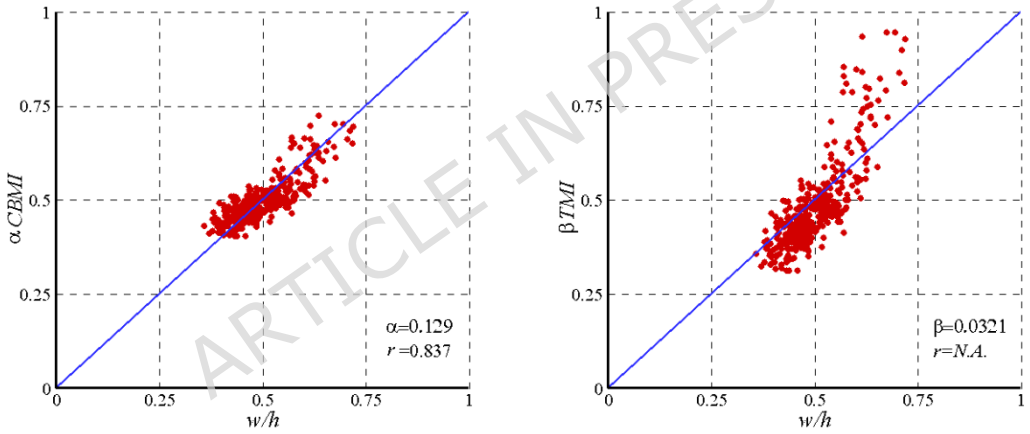
Table 3. Correlation coefficients of w/h versus TMI for different groups.

TMI	Form factor β	Residual error (model) S_r	Residual error (data) S_t	Correlation coefficient r
Female adults	0.0327	0.279	0.540	0.695
Male adults	0.0351	0.209	0.415	0.704
Female children	0.0304	0.747	0.463	N.A.
Male children	0.0310	0.833	0.391	N.A.
All	0.0321	2.373	1.851	N.A.

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Table 3 shows the results for TMI. Note that since the same data is used in computations, S_t values are the same both for Table 2 and Table 3. Correlation coefficients could be obtained only for the subgroups of female and male adults; for the remaining subgroups and the complete data, r could not be computed (marked as Not Available) because $S_r > S_t$ hence $r^2 < 1$. Thus, from the mathematical point of view, TMI does not correlate with w/h; a conclusion graphically observed as well.

Figures 2a and 2b show w/h - CBMI and w/h - TMI plots for the complete data set. The relatively good performance of CBMI with correlation coefficient r = 0.837 as a body mass index quantitatively representing the geometric measure w/h is obvious.



Figures 2a and 2b. Waist-to-height ratio w/h versus α • CBMI (left, r = 0.837) and β • TMI (right, r = N.A.) for entire data set.

3.2. Waist-to-Height Ratio and CBMI

Table 4 gives the basic statistical results, average ±standard deviation, for the measured waist-to-height ratios w/h and computed CBMI = $\sqrt{m/h^3}$ values. A nearly constant proportionality factor between w/h and CBMI is obvious for all the groups, as expected from the direct correspondence established in the derivation process.

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Table 4. Basic statistical characteristics of w/h and CBMI for different groups.

Group	Age range (year)	Age (year)	Mass (kg)	Height (cm)	Waist/Height	CBMI
Female adults	10-70	30±12	63±15	163±10	0.49±0.081	3.79±0.39
Male adults	10-75	33±18	69±21	168±15	0.50±0.065	3.75±0.27
Female children	0-9	5±3	18±8	103±25	0.51±0.068	3.97±0.55
Male children	0-9	6±3	21±8	111±21	0.50±0.063	3.88±0.52
All	0-75	18±17	43±27	136±35	0.50±0.068	3.85±0.45

3.3. Criterion Based on Waist-to-Height Ratio

For the complete data set Table 1 gives an average waist-to-height ratio $w/h = 0.50 \pm 0.068$. This average is obtained for 400 participants aged between 0-75 years, residing in the city of Istanbul; a very small group of a definite region. More importantly, the average ratio $w/h = 0.50$ cannot not be taken as indicative of desired level of anthropometric status as it is well-known that across the globe in the past 30 years or so there is an uptrend in average body weight due to increased availability of food supplies and varieties combined with unhealthy eating habits [15]. Despite all these concerns, definite classification levels for waist-to-height ratio and CBMI are set according to relevant statistics computed from the measurements of the present work. In the future, data comprising considerably larger groups may be used to classify anthropometric status levels more accurately.

The starting point is the main clinical observation indicated in [12-14] that $w/h = 0.5$ is the critical value in assessing health risks. In particular, the note [14] asserts that mortality associated with obesity-related cardiovascular diseases could be reliably related to w/h being greater than 0.5 or less. Accordingly, the *upper limit of normal* is set as $w/h = 0.5$. The remaining

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cutoffs are established in a semi-empirical manner with the aid of standard deviation computed for measured w/h values. Thus, adopting a conservative viewpoint, the w/h value as obtained by subtracting the standard deviation from the mean value, $w/h = 0.5 - 0.04 = 0.46$, is set as the *mean normal* or *ideal normal* so that $w/h = 0.50$ becomes the *upper limit of normal* as intended. Further, for ease of use in terms of integers, the values are re-scaled by using $100 \bullet w/h$ instead of w/h. In calculations, taking the waist circumference in centimeter and height in meter produces the desired result without the necessity of multiplying by 100.

Table 5 shows the classification levels valid for any age and sex except for infants less than 1-year-old. A different scale, possibly one level shifted up (e.g., Normal range: 50-58) must be used for infants as their average $w/h \approx 0.60$, regardless of sex. Once again, all these levels are tentatively proposed and may be redefined according to extended measurements of different groups and more importantly judgement of involved professionals. At present, no claims are made regarding the general applicability of the defined cutoffs. Figure 3, visual representation of Table 5, depicts the classification of anthropometric status levels for definite waist-to-height ratios.

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Table 5. Anthropometric status levels according to waist-to-height ratios.

Classification	$100 \bullet w/h$
Underweight	<42
Normal	42-50
Overweight	50-58
Obese	58-66
Adipositas	>66

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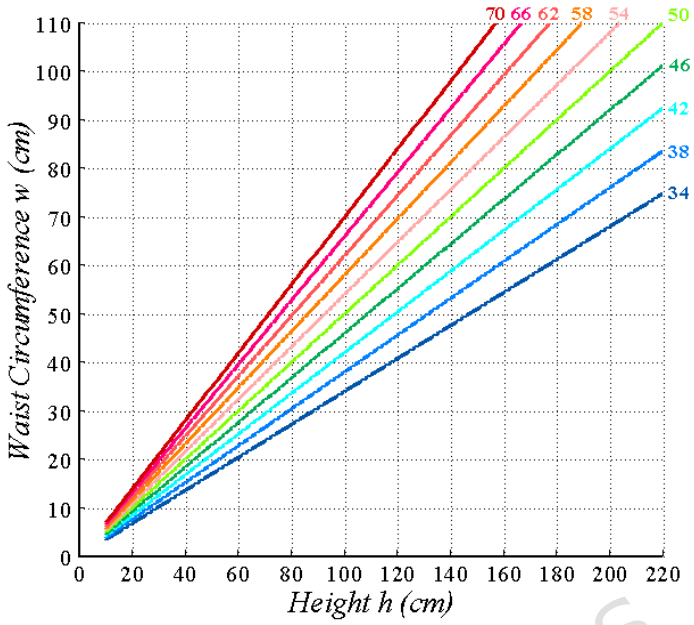


Figure 3. Classification of anthropometric status levels according to 100•waist-to-height ratios. Interval between 42 to 50 normal levels with ideal average 46.

3.4. Criterion Based on Consistent Body Mass Index CBMI

For the complete data set Table 4 gives the overall average for $CBMI = \sqrt{m/h^3}$ as 3.85, which may be rounded off to 3.9 and set as the *upper limit of normal* in line with the average of waist-to-height ratios. The intervals are arranged according to the waist-to-height classification levels with appropriate rounding of values. The ideal normal is then the mid-value $CBMI = 3.6$ between 3.3 - 3.9. For the sake of using integers, $10 \bullet CBMI$ is used in place of CBMI. Table 6 gives the classification levels according to CBMI values and the corresponding waist-to-height ratios as computed from $100 \bullet w/h = 100 \bullet \alpha \bullet CBMI$ with $\alpha = 0.129$. Clearly, the intervals computed from $100 \bullet \alpha \bullet CBMI$ are in good agreement with those of $100 \bullet w/h$ given in Table 5. Figure 4 shows the anthropometric status levels according to $10 \bullet CBMI$ values.

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Table 6. Anthropometric status levels according to 10 • CBMI and corresponding 100 • w/h as computed from 100 • α·CBMI with α = 0.129.

Classification	10 • CBMI	100 • α • CBMI = 100 • w/h
Underweight	<33	<42.6
Normal	33-39	42.6-50.3
Overweight	39-45	50.3-58.1
Obese	45-51	58.1-65.8
Adipositas	>51	>65.8

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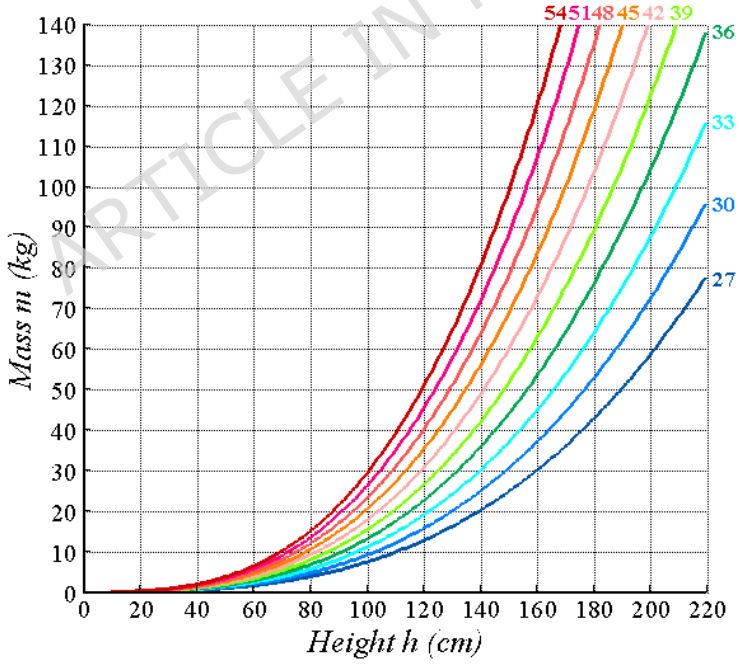


Figure 4. Classification of anthropometric status levels according to 10•CBMI values. Interval between 33 and 39 normal levels with ideal average 36.

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3.5. Graphical Application Based on Waist-to-Height Ratio

A sample graphical application of waist-to-height ratio for a 10-year-old female participant with 40 kg mass, 147 cm height, 67 cm waist circumference is given in Figure 5. The waist-to-height ratio is $100 \bullet w/h = 45.6$, which is very slightly below the ideal level of 46. The classic body mass index on the other hand gives $BMI = 18.5\ kg/m^2$, which is the lower limit of the normal range ($18.5\ kg/m^2$-$24.9\ kg/m^2$), almost underweight.

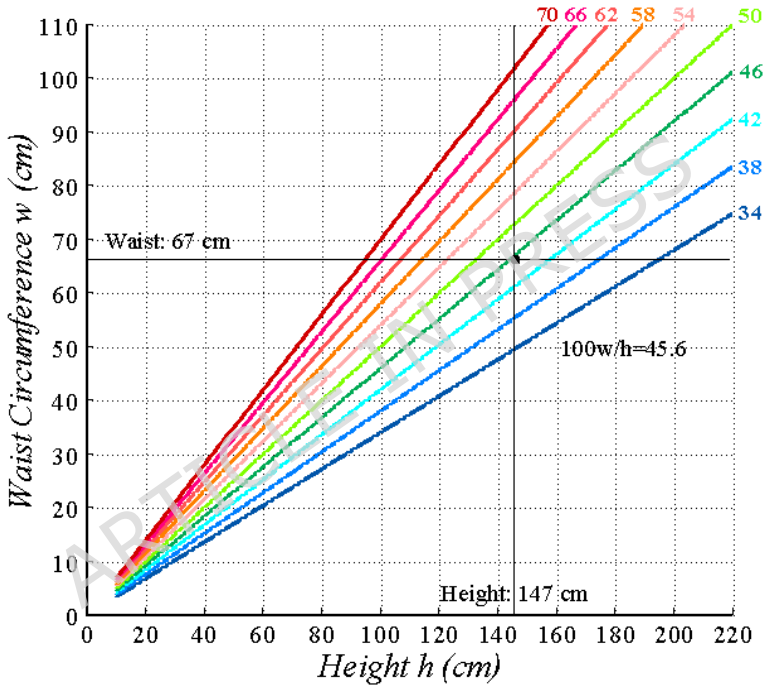


Figure 5. A sample graphical assessment of anthropometric status level for a 10-year-old female: 147 cm height and 67 cm waist circumference. Assessed normal with $100 \bullet w/h = 45.6$, nearly equal to ideal normal 46.

3.6. Graphical Application Based on CBMI Index

CBMI classification is graphically demonstrated in Figure 6 for the same 10-year-old female: 40 kg, 147 cm height, 67 cm waist circumference.

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Accordingly, the consistent body mass index is $10 \bullet CBMI = 35.5$, which, as observed for waist-to-height ratio, indicates very nearly perfect normal body anthropometric status level of 36, based on the scale set in Table 6. Note that for this case the classic body mass index as calculated before gives $BMI = 18.5\ kg/m^2$, which is the lower limit of the normal range ($18.5\ kg/m^2$ - $24.9\ kg/m^2$) or the upper limit of the underweight category.

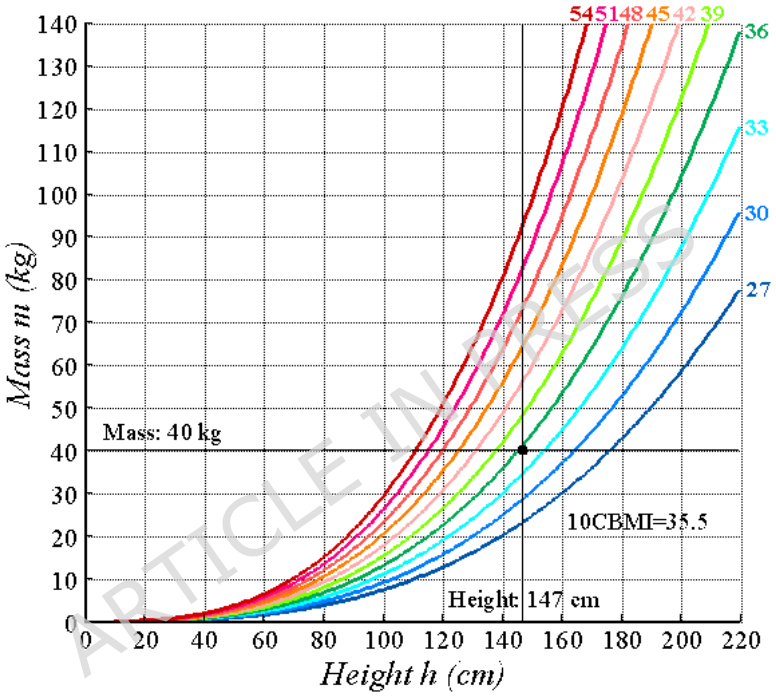


Figure 6. A sample graphical assessment of anthropometric status level for a 10-year-old female: 40 kg mass, 147 cm height. Assessed normal with 10•CBMI=35.5 slightly less than ideal normal 36.

4. Discussion

The present study has theoretically derived from first principles a new index termed Consistent Body Mass Index ($CBMI = \sqrt{m/h^3}$), which is in accord with waist-to-height ratio w/h, a key parameter identifying body anthropometric status level. The new index is non-dimensional, valid for all ages, body sizes,

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and sexes. General applicability of the new index and its satisfactory correlation with waist-to-height ratio render it a relatively better measure of anthropometric status level for all ages, sexes, and body sizes.

Besides serving as an anthropometric status measure, body mass index $BMI = m/h^2$ and tri-ponderal mass index $TMI = m/h^3$ are frequently used in pediatric growth assessment. However, evidence suggests that both measures misclassify adiposity, especially for children and relatively short or tall adults. BMI typically underestimates adiposity for shorter persons while overestimates for taller ones. The non-dimensional TMI overcomes the scalability issue but does not correlate well with waist-to-height ratio, an important geometric measure. Systematic reviews and cohort comparisons consistently show that TMI performs similar to or slightly better than BMI in estimating body fat percentage; neither being completely reliable for all heights and ages [16]. Conversely, when compared with BMI, waist-to-height-ratio w/h is found to have better longitudinal agreement with fat-mass measured directly by Dual X-ray Absorptiometry DXA (DEXA) in a cohort of children and adolescents, a finding underscoring the limitations of BMI as a proxy for adiposity [17, 18]. TMI does not correlate with w/h for children and infants, especially for the higher range $w/h > 0.6$ as demonstrated here. This finding is naturally interpreted as the failure of TMI for children and infants. Refined body composition phenotyping such as DXA, or Bioelectrical Impedance Analysis BIA, or related modalities should be used for accurate quantification of fat and fat-free compartments, especially for individuals with “normal-BMI, high-fat”, or relatively taller/shorter adults and children, or sarcopenic profiles, where BMI is the least informative [19]. However, these modalities are neither easily nor frequently applicable in practice.

To address and subsequently resolve the issues enumerated, a readily accessible body composition indicator, the consistent body mass index $CBMI = \sqrt{m/h^3}$ is suggested here. The consistency of the new index is attributed to

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three main points: 1) it is non-dimensional, 2) it is directly proportional to w/h, and 3) it is applicable for all body sizes and age groups starting from newborns, regardless of sex. The existence of a direct proportionality between w/h and CBMI indicates that *any one* of these quantities may be used as a classifier of body anthropometric status level.

Relatively low correlation coefficient $r = 0.744$ of CBMI versus w/h for male adults, especially when compared with female children $r = 0.907$, is basically attributed to increase/decrease of body mass density ρ due to decrease/increase (lower/higher adipose) in w/h ratio. This hypothesis was tested by retaining the body density in the CBMI formulation as $\sqrt{m/\rho h^3}$ and empirically increasing mass density ρ for men with $w/h < 0.5$, keeping the same for $w/h = 0.5$ (mean waist-to-height ratio), and decreasing for $w/h > 0.5$. This empirical rectification of ρ by approximately $\pm 3\%$ on the average increased the correlation coefficient of the same data from $r = 0.744$ to $r = 0.800$ (7.5% improvement) for male adults. A similar trial performed for female adults increased the correlation coefficient from $r = 0.840$ to $r = 0.877$ (4.4% improvement). These results are encouraging for introducing a more accurate CBMI in a future work with the inclusion of ρ computed according to $\rho = \rho(w/h)$ or equivalently $\rho = \rho(\mathrm{CBMI})$. Furthermore, CBMI can be used as an estimator for ideal body weight for a targeted CBMI value and a given height h from $m = (\mathrm{CBMI})^2 h^3$. Finally, a full account of the development and testing procedure along with the measurement data and FORTRAN code used in the present work is available as a technical report [20].

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Author contributions

Serdar Beji conceived the original idea for the study and did the theoretical formulation. Prepared the software, worked out the numerical and statistical details for correlation computations and visualizations. Drafted the original version of the manuscript. Reviewed the final manuscript.

Nezihe Kizilkaya Beji arranged the ethical permission documents and the team for data collection. Curated the raw data and ensured its quality. Suggested references and commented on the statistical results and correlations. Reviewed the draft and the final version of the manuscript.

Ümmü Mutlu identified the important main parameters and suggested references. Provided a preliminary data set for trial computations. Commented on the statistical results and correlations. Drafted and reviewed the final version of the manuscript.

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All the authors reviewed and revised the manuscript for improving and clarifying its content. The authors approved the final version of the manuscript for publication.

Data Availability Statement

The measured data used in this study and the FORTRAN program developed for application of method of least squares and computation of relevant statistics are available and may be obtained freely from the corresponding author on request via e-mail.

Competing Interests: The authors declare no competing interests.

Ethical Standards: Verbal informed consent was obtained from all participants. Verbal consent was witnessed and formally recorded.

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