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When is sitting height a better measure of adult body size than total height – and why? The contrasting examples of body mass, waist circumference and lung volume

Running title: Body mass, waist circumference, lung volume

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Abstract

Objectives:

We aimed to establish which of sitting height (SH) and total height (Ht) is most appropriately used in the scaling of adult body mass (BM), waist circumference (WC) and forced vital capacity (FVC), considering likely explanations and proposing a suitable index for each.

Methods:

Data were from the U.S. Third National Health and Nutrition Survey for white and black American women and men aged 20-50 years. Statistical analysis involved mainly correlation coefficients, the multiple regression of BM, WC or FVC on SH and leg length (LL), and fitting of allometric regression equations relating each of BM, WC and FVC to SH or Ht.

Results:

BM and WC correlated more strongly with SH than with Ht, and FVC correlated more strongly with Ht. Associations with LL were negative for WC, negative or non-significant for BM and positive for FVC. Using round-number exponents for Ht and SH, the allometric relationships indicated that appropriate indices are BM/SH^3**,** WC/SH and FVC/Ht^2.

Conclusions:

Contrary to usual practice, BM and WC are better scaled in relation to SH than to Ht. FVC is slightly better scaled in relation to Ht, as is conventional. Interpretations involve the small influence of LL on BM and the influence both of gluteo-femoral fatness on measured SH and of childhood health and nutrition on adult LL, WC and FVC. It is evident that SH should be measured more often for research purposes.

1 | INTRODUCTION

Total body height or stature (Ht) has long been used as a measure of linear body size against which to assess other variables. Yet there are situations in which the use of sitting height (SH) has been shown to be more appropriate, or might be suspected of being so. Here we consider relationships to Ht and SH of body mass (BM), waist circumference (WC) and lung volume quantified as forced vital capacity (FVC).

To begin with BM, several indices relating it to Ht have been introduced, including BM/Ht^3 (Rohrer, 1908) and the body mass index, BM/Ht^2 (Davenport, 1920; Khosla, & Lowe, 1967). As for SH, this was used a century ago in various other indices of BM status (Walker, 1916; von Pirquet, 1916, 1918; Dreyer, 1919; Bardeen, 1923). Walker (1916) chose SH rather than Ht because SH is more comparable to the body lengths of quadrupeds. The 'sitting height index of build', calculated as BM/SH^3 ($kg/m^{3)}$, has since been shown to be a better index of BM status than the BMI for children, adolescents and young adults (Burton, 2015, 2018), but this left open the question of whether BM is more closely correlated with Ht or with SH in adults more generally. WC is generally related to Ht, rather than to SH (e.g. Browning, Hsieh, & Ashwell, 2010; Burton, 2010; Nevill, Duncan, Lahart, & Sandercock, 2017). That is generally true of lung volumes also (see Discussion), although Dreyer (1919) related FVC to SH because of an assumed relationship of both to trunk volume.

The SH is commonly expressed in terms of the ratio SH/Ht (or 100 × SH/Ht), sometimes called the 'cormic index'. Gray (1923) discussed it in relation to skeletal anomalies and endocrine disorders and argued for it to be given more attention. Since then, although both SH and SH/Ht have played important roles in anthropometry, especially in regard to children, they have too often been neglected. Indeed, although values of SH were recorded in the United States 'National Health and Nutrition Examination Survey' of 1988-1994 (NHANES III, see below), they have not been recorded in the subsequent NHANES surveys. Relationships between leg length (LL) and SH in adults of various ethnic groups have been discussed elsewhere (Burton, Nevill, Stewart, Daniell, & Olds, 2013).

Although Ht is much more often used as a linear measure of body size than is SH, our initial hypothesis was that this is not always appropriate. Relevant questions to be answered included: (1) Do BM, WC and FCV correlate more strongly with SH than with Ht, which would make the former three variables more usefully standardized in relation to SH than to Ht? (2) For a given SH, is LL a significant predictor of those variables? (3) For BM, WC and FCV, what are appropriate indices in which each one is divided by some function of Ht or SH (as in the BMI)? Questions 1 and 2 have already been answered for BM, but inadequately for adults older than 20 years (Burton, 2015, 2018). Also to be considered were possible causal explanations of the observed relationships. This paper focuses on these issues and is not about other correlates and predictors of BM, WC and FCV, nor about possible ethnic differences.

2 | MATERIALS AND METHODS

2.1 | Subjects

The data were from the U.S. Department of Health and Human Services (National Center for Health Statistics. Third National Health and Nutrition Examination Survey, 1988-1994, NHANES III Laboratory Data File. Public Use Data File Documentation Number 76200. Hyattsville, MD: Centers for Disease Control and Prevention, 1996), relevant aspects of which are described by Hankinson, Odencrantz and Fedan (1999). The data were for individual men and women coded as DMARACER 1 (“white”) and DMARACER 2 (“black”). (These categories include individuals designated ‘Mexican American’ as well as ‘African-American’ and ‘European-American’.) The main data were for ages 20-50 years, with 50 being chosen as the maximum age for reasons given by Bogin and Varela-Silva (2008): (1) that this largely avoids the age-related changes in height and SH which, in the

NHANES III sample, tend to decrease more rapidly after age 50 years than before, and (2) that 50 years is a convenient cut-off point for fatness changes. Data for ages 51-90 years were also analysed for comparison and briefly reported.-The measurement procedures are described in the NHANES procedures manual (National Health and Nutrition Examination Survey III). Leg length (LL) is defined as Ht minus SH. The NHANES data are published with weightings that improve the estimation of nationally representative statistics for the US, but, as that is not the present objective, these weightings are not used here.

2.2 | Statistics

The data were analyzed for four cohorts: white women, black women, white men and black men. Means and standard deviations (SDs) were calculated for SH, LL, Ht, SH/Ht, BM, WC and FVC. Pearson correlation coefficients (*r*) were calculated for LL and SH ($r_{\mathrm{LL.SH}}$), for BM and Ht ($r_{\mathrm{BM.Ht}}$), for BM and SH ($r_{\mathrm{BM.SH}}$), for WC and Ht ($r_{\mathrm{WC.Ht}}$), for WC and SH ($r_{\mathrm{WC.SH}}$), for FVC and Ht ($r_{\mathrm{FVC.Ht}}$) and for FVC and SH ($r_{\mathrm{FVC.SH}}$). Over the relevant age range of 20-50 years, FVC falls markedly and approximately linearly with age, as illustrated for NHANES III data by Hankinson, Odencrantz and Fedan (1999). Therefore, the last two of those correlation coefficients, relating to FVC, were also calculated with adjustment for variations in age, that is to say as partial correlation coefficients that exclude the influence of age. Where appropriate, differences between correlation coefficients were tested by Steiger's method (Lee, & Preacher, 2013) with probabilities (*P*) given as 'two-tailed' values.

The relative importance of SH and LL as predictors of BM, WC and FVC was assessed in terms of the following regression equation (Burton, 2015, 2018):

$$Y = a \times \mathrm{SH} + b \times \mathrm{LL} + c \qquad (1)$$

The dependent variable, *Y*, was taken variously as $\mathrm{BM}^{1/3}$, WC and $\mathrm{FVC}^{1/3}$. The cube roots were used on dimensional grounds. (Masses, at constant density, are proportional to volumes and cube roots of volumes have units of length.) The individual values of *a*, *b* and *c* are of little interest and are not recorded here, but only the ratio [b/a], which quantifies the contribution of LL to the prediction of Y relative to that of SH. In order to obtain its standard error (SE) and the significance of its difference from zero, Equation 1 was modified as follows (Burton, 2018):

$$Y = a \times (\mathrm{SH} + [b/a] \times \mathrm{LL}) + c \qquad (2)$$

with the ratio [b/a], rather than b, being the second regression coefficient. It can be shown by Monte-Carlo modelling that correlations between Y and Ht are greater than between Y and SH when [b/a] exceeds about 0.3. That is more obviously the case when [b/a] = 1, because (SH + [b/a] × LL) then equals Ht.

Relationships between Y and either SH or Ht were expressed in terms of the following allometric regression equations, in which d, e, p and q are the regression parameters:

$$Y = d \times \mathrm{SH}^{p} \qquad (3)$$

$$Y = e \times \mathrm{Ht}^{q} \qquad (4)$$

Values of d and e are of no interest here and are not recorded. Equations 2-4 were fitted by non-linear regression.

Statistical relationships between FVC and WC and between FVC and BM, were assessed in terms of partial correlation coefficients that exclude the effects of SH and age. The numbers of subjects were as in Table 1.

Statistical analyses were carried out using Excel 2007 (Microsoft Corporation, Redmond, Washington, USA), Datafit 8.0 (Oakdale Engineering, Oakdale, PA, USA) and R (R Core Team, 2019) using the package ppcor (Kim, 2015).

3 | RESULTS

Table 1 shows some characteristics of the four cohorts as used in relation to both BM and WC. Because of missing data, most analyses for FVC used different subsets, but with similar characteristics. Tables 2-4 show other results for BM, WC and FVC. Values of *p*, *q* or both are given in Tables 3 and 4 as appropriate.

For each cohort, both BM and WC were more strongly correlated with SH than with Ht ($P < 0.00001$). In contrast, the correlation coefficients for FVC are slightly higher for Ht than for SH whether or not they were adjusted for age. For the white men and women, these differences were highly significant ($P < 0.00001$). For the black men the differences were less significant ($P = 0.03$ for FVC) and for the black women they were not significant ($P > 0.05$).

Several correlations exist between items in Tables 2-4 that are noted next. To avoid confusion, because some of those items are themselves correlation coefficients (*r*), the correlation coefficients relating them are here designated *R*. Values of [*b*/*a*] are strongly correlated with each of the tabulated correlation coefficients $r_{\mathrm{BM.Ht}}$ ($R = 0.98$), $r_{\mathrm{BM.SH}}$ ($R = 0.99$), $r_{\mathrm{WC.Ht}}$ ($R = 0.98$), $r_{\mathrm{WC.SH}}$ ($R = 0.98$), $r_{\mathrm{FVC.Ht}}$ ($R = 1.00$), and $r_{\mathrm{FVC.SH}}$ ($R = 0.94$). All of these *R* values were statistically significant ($P \leq 0.03$, one-tailed, $n = 4$).

There are other patterns to the correlation coefficients in Tables 2 and 3. For example, $r_{\mathrm{BM.Ht}}$ correlates with $r_{\mathrm{BM.SH}}$ ($R = 0.96$), $r_{\mathrm{BM.Ht}}$ correlates with $r_{\mathrm{WC.Ht}}$ ($R = 0.94$), $r_{\mathrm{WC.Ht}}$ correlates with $r_{\mathrm{WC.SH}}$ ($R = 0.96$), $r_{\mathrm{BM.SH}}$ correlates with $r_{\mathrm{WC.SH}}$ ($R = 0.94$) and $r_{\mathrm{FVC.Ht}}$ correlates with $r_{\mathrm{FVC.SH}}$ ($R = 0.95$). All are significant, despite the small numbers ($P < 0.04$, one-tailed).

For all four cohorts combined ($n = 8541$), WC and BM were strongly correlated ($r = 0.90$), with the reduced major axis regression relationship between them being as follows:

$$\mathrm{WC} = 3.30 \times \mathrm{BM}^{0.77}. \qquad (5)$$

The tabulated SH exponents, *p*, for WC and BM are also highly correlated with each other ($n = 4$; $R = 0.998$).

For FVC and WC and for FVC and BM, the partial correlation coefficients controlling for SH and age were all significantly negative. In the case of the black men, the coefficient for FVC and BM was -0.07 ($P = 0.016$). All the other seven coefficients were more significant ($P \leq 0.00004$), with values ranging from -0.14 to -0.18 for FVC and WC and from -0.08 to -0.16 for FVC and BM—always less for FVC and BM than for FVC and WC.

Data on forced expiratory volume in one second (FEV_1) were analysed in the same way as those for FVC, the results showing essentially the same patterns of correlation as FVC.

The results for ages 51-90 years were so like those for ages 20-50 years as not to merit detailed reporting. Those most relevant are summarized in the Appendix.

4 | DISCUSSION

The correlation coefficients for each of the variables BM, WC and FVC with SH and with Ht constitute the most straightforward evidence on which of the latter is the better linear measure of body size in each context. For ages 20-50 years, the findings were that both BM and WC correlated more strongly with SH than with Ht, while the opposite was marginally true of FVC. This was also true for the women of 51-90 years, but not for the men in that age group (see Appendix). How far these findings match general expectations is unclear from the literature. Other related issues are treated below for BM, WC and FVC under separate headings. One of these is the choice of indices analogous to the BMI and taking the form BM/SH^p, WC/SH^p and FVC/Ht^q. These are discussed in Section 5 followed in Section 6 by a consideration of causal interpretations involving other published information.

4.1 | Body mass (BM)

With BM regressed on SH and LL, the coefficient $[b/a]$ in Equation 2 was positive, but not significantly so, for men, and small, but significantly negative, for women. Near-zero values have previously been found for ages 8 to 20 years (Burton, 2018), and also for the overall range of 1-25 years using year-by-year averages rather than individual data (Burton, 2015). The key point here is that all four values of $[b/a]$ in Table 2 are small (i.e. -0.20 to +0.05 and much less than +0.3), meaning that, in the context of Equations 1 and 2, LL is a trivial predictor of BM compared with SH. This accords with the stronger correlation between BM and SH than between BM and Ht.

4.3 | Waist circumference (WC)

Because WC and SH both relate to the upper body, one might suppose them to be somewhat correlated with each other. We found no published evidence on this, but it was true of all four cohorts (Table 3). Moreover, the correlations between them ($r_{\mathrm{WC.SH}}$) were stronger than between WC and Ht ($r_{\mathrm{WC.Ht}}$). All four values of [*b*/*a*] were negative (-0.18 to -0.77).

4.4 | Forced vital capacity (FVC)

It might be expected that both trunk size and FVC would correlate better with SH than with Ht, with LL being irrelevant (Dreyer 1919), but the opposite was found to be true, although the differences in correlation coefficients were insignificant for the black women (Table 4). That Ht is slightly better than SH as a predictor of FVC accords with fact that all four values of [*b*/*a*], ranging from 0.46 to 0.75, exceeded 0.3.

The published evidence is weak. Relating FVC to Ht is commonplace and some studies have also included SH. However, the only example we have found of Ht and SH being compared as separate predictors of FVC is provided by McDonnell and Seal (1991), though without quantitative details. They found SH to predict FVC somewhat less well than Ht, although not always doing so significantly. Hankinson, Odencrantz and Fedan (1999) also measured SH, but merely noted that addition of SH to a prediction model including Ht produced little improvement. The data of Dreyer (1919) and Aslett, Hart and McMichael (1939) are too few for significance. Suggestively, ethnic differences in lung volumes have been found to relate to SH/Ht for ages 7-20 years (Hsi, Hsu, & Jenkins, 1983) and for adults (Yap, Chan, Chan, & Wang, 2001).

That FVC correlated only slightly more strongly with Ht than with SH may seem to be of little practical consequence, except inasmuch as Ht is more convenient. Of more interest is the matter of causal explanation (Section 6).

5 | Indices analogous to the BMI

Although statistical analysis produces precise values for p and q for any given sample, the exact value chosen in defining an index can be of little practical consequence, as illustrated by Benn (1971) and Hwaung et al. (2019). Indeed, the definition of the BMI is accepted as BM/Ht^2 despite the fact that estimates of the exponent, q, are highly variable (even more so than in Table 2) and can be as low as 1.1 in women when BM and Ht are weakly correlated (Burton, 2007). There is therefore minimal disadvantage in making p and q round numbers.

That BM correlates more strongly with SH than with Ht implies that the body mass index (BM/Ht^2) should be theoretically less satisfactory than an index of form BM/SH^p. For the examples in Table 2, p is 1.84-2.96. However, a dimensionally appropriate value of 3 may be preferable as it gives the sitting height index of build, BM/SH^3 (see Introduction).

As indicators of adiposity, indices based on WC presently take the form of WC/Ht^q, with q being taken as the round-number values of 0, 0.5 or 1.0 (Browning et al., 2010; Burton, 2010; Nevill et al., 2017). However, exact values of q vary considerably with age range and fatness as is the case for BM (Hwaung et al., 2019). A q value of 1.0 is both dimensionally appropriate and convenient and that is true also of p in the index WC/SH^p. That is the p value obtained for black women and also the average of the two values for men (Table 3). The lower value for the white women (0.36) relates to the low correlation coefficient for WC and SH in that cohort (0.005) (*cf* Burton, 2010). When a single p is desirable, then 1.0, and thus the index WC/SH, are recommended.

With FVC correlating more strongly with Ht than with SH, an appropriate index would be FVC/Ht^2, in which the exponent 2 approximates to the mean values of q in Table 4 (i.e. 2.29). McDonnell and Seal (1991) obtained a value of 2.21. Indices including also age have also been derived (e.g. Jędrychowski, & Księżyk, 1973).

6 | Causal interpretations

The emphasis so far has been on prediction and the choice of appropriate indices, but the statistical relationships need also to be interpreted as far as possible in terms of causality.

That LL is a weak predictor of BM compared with SH, as shown by the low or negative values of [*b*/*a*], presumably relates to the fact that longer legs tend to be narrower for a given upper body mass (Burton, Nevill, Stewart, Daniell, & Olds, 2012). However, there is no obvious theoretical (e.g. biomechanical) reason why [*b*/*a*] should be exactly zero.

Measurements of SH, and so of LL, are biased by gluteo-femoral fat thickness, even though the tissue is somewhat compressed by sitting. Bogin and Varela-Silva (2008) have quantified this for NHANES III data. Their Figures 1 and 2 show positive correlations between SH/Ht and percentage body fat for black American and Mexican-American men and women and for white American women, but not significantly for white American men. An increase in buttock tissue thickness with general fatness must augment measured SH—with a consequent decrease in calculated LL. The effect should typically be larger for women as they tend to have higher average percentages of fat than men and greater thicknesses of buttock tissue (Bogin, & Varela-Silva, 2008). This may be relevant to the fact that [*b*/*a*] for BM was found to be more negative for women than for men (Table 2) and it would be equally relevant to the data on WC (Table 3). There is insufficient information for the effect to be quantified here.

There is probably a more salient explanation for the negative values of [*b*/*a*] in Tables 2 and 3. Poor nutrition in childhood can lead in adults to shorter legs (Wadsworth, Hardy, Paul, & Cole, 2002; Frisancho, 2007; Bogin, & Beydoun, 2007; Bogin, & Varela-Silva, 2008) and also a tendency in adults to higher fat content and therefore BM and WC

(Velásquez-Meléndez, Silveira, Allencastro-Souza, & Kac, 2005; Frisancho, 2007; Said-Mohamed et al., 2018; Vilar-Compte, Macinko, Weitzman, & Avendaño-Villela, 2019) especially in women (Asao et al., 2006; Henriques, Teixeira, Cardoso & Azevedo, 2018). Some of these studies used WC as a measure of fatness, but BM was only used, together with Ht, as a component of BMI. Equations 1 and 2 were not used.

That WC and BM correlate strongly with each other ($r = 0.90$) must relate to the fact that each one correlates with both Ht and fatness. A much stronger correlation between WC and BM is not to be expected, given the variability of body shape (especially as between men and women). Tables 2 and 3 show clear differences between WC and BM in regard to the tabulated values for each; yet there are similar patterns in the variations from cohort to cohort.

The issue of FVC is more straightforward in that measurements of Ht are uninfluenced by buttock fatness. That Ht is a good predictor of FVC implies that the latter correlate positively with LL as well as with SH. (Recall that all four values of $[b/a]$ are positive and exceed 0.3.) It may therefore be relevant that childhood ill health or poor nutrition can result in smaller forced expiratory volume in one second (FEV_1) (Barker et al., 1991; Packard et al., 2011) as well as in shorter legs as noted above.

On the assumption for adults that FVC, WC and BM are all influenced by a common factor such as childhood nutrition and health, the partial correlation coefficients for FVC and WC and for FVC and BM should be negative. This was shown to be so. Lazarus, Gore, Booth and Owen (1998) found FVC (adjusted for age, Ht, smoking and bronchial symptoms) to be negatively associated with subscapular skinfold thickness in both men and women and with WC in men, but not with BM. For elderly men, Santana et al. (2001) found significant negative correlations between WC and FVC.

These results do not rule out the possibility that FVC is directly influenced by BM or fatness (as reflected in WC). Indeed, Lazarus et al. (1998) suggested that breathing might be influenced mechanically by fat deposits. Resolving this issue is beyond the scope of this paper, but detailed analysis of such situations might be aided by considering SH.

7 | CONCLUSIONS

The main findings were that BM and WC correlated more strongly with SH than with Ht, while FVC correlated slightly more strongly with Ht. Thus, either SH or Ht can be the better linear measure of body size depending on context. It is a natural supposition that variables relating to trunk size would correlate most strongly with SH, as is the case with WC. Despite current practices, that might also be expected to apply to FVC, but factors, relating perhaps to early health, make LL relevant too, so that the correlations are slightly stronger with Ht. Researchers' expectations may differ, but, given that legs have mass, the findings for BM may be unexpected also.

The statistical relationships are most often considered in the context of prediction and, in that context, some differences between pairs of correlation coefficients (for example, between $r_{\mathrm{FVC.Ht}}$ and $r_{\mathrm{FVC.SH}}$) are too small to be of much practical significance. However, questions of causation are also important. Then Equations 1 and 2, together with the associated estimates of $[b/a]$, have proved more suggestive of mechanisms than are correlations with Ht and SH. Interpreting the statistical results in terms of causality requires knowledge from other studies and, because the published information does not exactly and quantitatively match what is required, some of the causal interpretations here must be regarded as tentative. A clear lesson from these three diverse examples is that more attention needs to be given to SH and LL, especially in the context of future research. Nevertheless, measurement of SH in clinical settings is unlikely to become more widespread, despite both its simplicity (see Appendix) and its usefulness in relation to children and adolescents (Burton 2018).

8 | APPENDIX

8.1 | Analysis of data for ages 51-90 years

Means and SDs of BM, WC, Ht, SH and LL were closely similar in the two age categories, although mean values of FVC were all about 1 litre less in the older groups. Most relevant are the comparisons of the correlation coefficients in Table 5 between each of BM, WC and FVC and each of Ht and SH (i.e. $r_{\mathrm{BM.Ht}}$, $r_{\mathrm{BM.SH}}$, $r_{\mathrm{WC.Ht}}$, $r_{\mathrm{WC.SH}}$, $r_{\mathrm{FVC.Ht}}$ and $r_{\mathrm{FVC.SH}}$). In each case, BM and WC both correlated slightly more strongly with SH than with Ht— significantly so for all but the black women. The results for FVC were inconsistent and, taken with the corresponding results for 20-50 years, indicate that FVC correlates about equally with Ht and SH for the whole age range.

8.2 | Measurement methods for WC, FVC and SH

Various abdominal levels have been specified in the literature for the measurement of WC (Santana et al. 2001; Goyal and Gupta 2020). It is therefore important that the protocol used for the NHANES data was standardised. In papers already cited here, the measurement of FVC is described by Jędrychowski and Księżyk (1973), McDonnell and Seal (1991), Lazarus et al. (1998) Hankinson et al. (1999) and Santana et al. (2001).

Measurement of SH is cheap and simple (e.g. Yap et al. 2001), requiring only a flat-topped seat and a vertical scale such as that of a stadiometer. With the subject seated with the lower back and shoulders against a wall and looking straight ahead, SH is measured as the distance from the highest point on the head to the surface of the seat.

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DISCLOSURE OF INTERESTS

The authors report no conflict of interest. They alone are responsible for the content and writing of the paper.

AUTHOR CONTRIBUTIONS

Authors' contributions to manuscript were as follows:

RFB conducted the research. RFB and FLB analysed data and wrote the paper.

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TABLE 1 Characteristics of subjects from the NHANES III Laboratory Data File as used in BM and WC analyses.

	White women	Black women	White men	Black men
Number of subjects	2940	1680	2628	1293
SH (mean ± SD), m	0.86 ± 0.04	0.85 ± 0.03	0.91 ± 0.04	0.90 ± 0.04
LL (mean ± SD), m	0.75 ± 0.04	0.79 ± 0.04	0.82 ± 0.05	0.87 ± 0.05
Ht (mean ± SD), m	1.61 ± 0.07	1.63 ± 0.06	1.73 ± 0.08	1.77 ± 0.07
SH/Ht (mean ± SD)	0.53 ± 0.01	0.52 ± 0.01	0.53 ± 0.01	0.51 ± 0.01
SH/Ht (range)	0.45-0.58	0.46-0.56	0.48-0.56	0.46-0.56
$r_{\mathrm{LL.SH}}$	0.53	0.39	0.56	0.35

Abbreviations: BM, body mass, kg; WC, waist circumference, m; SH, sitting height, m; LL, leg length, m; Ht, height, m; SD, standard deviation; $r_{\mathrm{LL.SH}}$, correlation coefficient for LL and SH (all significant, $P < 0.00001$).

TABLE 2 Analysis of data relating to body mass (BM)

	White women	Black women	White men	Black men
BM (mean ± SD), kg	68.9 ± 16.7	76.8 ± 20.3	80.0 ± 16.2	83.0 ± 19.1
$r_{\mathrm{BM.Ht}}$	0.23	0.28	0.43	0.40
$r_{\mathrm{BM.SH}}$	0.32	0.40	0.49	0.51
$[b/a] \pm$ SE	-0.20 ± 0.04	-0.10 ± 0.04	0.05 ± 0.04	0.05 ± 0.04
Significance of $[b/a]$	$P < 0.00001$	$P = 0.01$	$P = 0.17$	$P = 0.10$
$p \pm$ SE	1.84 ± 0.10	2.65 ± 0.15	2.30 ± 0.08	2.96 ± 0.10
$q \pm$ SE	1.26 ± 0.10	1.93 ± 0.16	2.00 ± 0.08	2.34 ± 0.15

Numbers of subjects as in Table 1. Abbreviations: SD, standard deviation; SE, standard error; $r_{\mathrm{BM.Ht}}$, correlation coefficients for body mass and height; $r_{\mathrm{BM.SH}}$, correlation coefficients for body mass and sitting height; $[b/a]$, see Equation 2; p and q are the exponents in Equations 3 and 4. The correlation coefficients are all highly significant ($P < 0.00001$).

TABLE 3 Analysis of data relating to waist circumference (WC)

	White women	Black women	White men	Black men
WC (mean ± SD), m	0.88 ± 0.15	0.91 ± 0.17	0.93 ± 0.13	0.90 ± 0.15
$r_{\mathrm{WC.Ht}}$	0.004	0.11	0.18	0.19
$r_{\mathrm{WC.SH}}$	0.09	0.23	0.25	0.32
$[b/a]$ ± SE	−0.77 ± 0.09	−0.35 ± 0.07	−0.25 ± 0.06	−0.18 ± 0.06
Significance of $[b/a]$	$P < 0.00001$	$P < 0.00001$	$P = 0.0001$	$P = 0.001$
p ± SE	0.36 ± 0.07	1.11 ± 0.12	0.79 ± 0.06	1.26 ± 0.10

Numbers of subjects as in Table 1. Abbreviations: SD, standard deviation; SE, standard error; $r_{\mathrm{WC.Ht}}$, correlation coefficients for waist circumference and height; $r_{\mathrm{WC.SH}}$, correlation coefficients for waist circumference and sitting height; $[b/a]$, see Equation 2; p is are the exponent in Equations 3. The correlation coefficients (r) are highly significant ($P < 0.0001$), excepting $r_{\mathrm{WC.Ht}}$ for white women, which is not significant.

TABLE 4 Analysis of data relating to forced vital capacity, FVC

	White women	Black women	White men	Black men
Number of subjects	2987	1716	2661	1320
FVC (mean ± SD), litres	3.64 ± 0.59	3.21 ± 0.58	5.08 ± 0.77	4.49 ± 0.75
$r_{\mathrm{FVC.Ht}}$	0.59 (0.61)	0.52 (0.53)	0.62 (0.65)	0.54 (0.55)
$r_{\mathrm{FVC.SH}}$	0.54 (0.56)	0.51 (0.53)	0.56 (0.59)	0.50 (0.51)
$[b/a]$ ± SE	0.63 ± 0.06	0.38 ± 0.05	0.75 ± 0.07	0.46 ± 0.06
q ± SE	2.21 ± 0.07	2.48 ± 0.11	2.13 ± 0.06	2.33 ± 0.11

Abbreviations: SD, standard deviation; SE, standard error; FVC, forced vital capacity, litres; $r_{\mathrm{FVC.Ht}}$, correlation coefficients for FVC and height; $r_{\mathrm{FVC.SH}}$, correlation coefficients for FVC and sitting height; $[b/a]$, see Equation 2; q is the exponent in Equations 4. The correlation coefficients are all highly significant ($P < 0.00001$). Those in brackets are age-adjusted, i.e. partial correlation coefficients. The values of $[b/a]$ are all highly significant ($P < 0.00001$).

TABLE 5 Analysis of data for ages 51-90 years.

	White women	Black women	White men	Black men
Number of subjects	2347	643	2205	607
$r_{\mathrm{BM.Ht}}$	0.34	0.28	0.49	0.44
$r_{\mathrm{BM.SH}}$	**0.40**	**0.33**	**0.54**	**0.53**
Significance of difference (*P*)	< 0.00001	0.00004	0.00005	0.00004
$r_{\mathrm{WC.Ht}}$	0.06	0.13	0.22	0.19
$r_{\mathrm{WC.SH}}$	**0.10**	**0.16**	**0.25**	**0.31**
Significance of difference (*P*)	0.0001	0.1	0.01	< 0.00001
$r_{\mathrm{FVC.Ht}}$	0.54	0.43	**0.53**	**0.55**
$r_{\mathrm{FVC.SH}}$	**0.60**	**0.47**	0.51	0.48
Significance of difference (*P*)	< 0.00001	0.07	< 0.05	0.005

This shows the correlation coefficients (*r*) for body mass (BM), waist circumference (WC) and forced vital capacity (FVC), each with height (Ht) and sitting height (SH). For each pair, the largest is shown bold, together with the significance of each difference.