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Latitudinal Gradient in the Body Mass Index (BMI), and the BMI's Geometric and Statistical Relationships to the Surface Area: Volume Ratio and Body Shape

Brandy Lea O'Neil
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To the Graduate Council:

I am submitting herewith a thesis written by Brandy Lea O'Neil entitled "Latitudinal Gradient in the Body Mass Index (BMI), and the BMI's Geometric and Statistical Relationships to the Surface Area: Volume Ratio and Body Shape." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Anthropology.

Andrew Kramer, Major Professor

We have read this thesis and recommend its acceptance:

Lyle W. Konigsberg, Richard L. Jantz

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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A Thesis
Presented for the
Master of Arts
Degree
The University of Tennessee, Knoxville

Brandy Lea O'Neil
August 1998

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Dedication

This thesis is dedicated to my mother, Kathleen O'Neil, and to Nana.

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My sincere appreciation goes to my MA committee, Drs. Andrew Kramer (Chair), Lyle W. Konigsberg, and Richard L. Jantz. As a whole, I thank them for their time spent in my three years at UT, and for their time waived in the process of this thesis.

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Abstract

The body mass index (BMI), weight/height^2 (W/H^2), is currently the index of choice for assessment of nutritional status. Statements in the literature about the BMI as a potential expression of "cold adaptation" or "Bergmann's Rule" beg the question: What does that BMI measure in terms of size, shape, and the surface area:volume (SA:V) ratio? Geometric modeling shows that the BMI captures both size and shape and is inversely related to the SA:V ratio. This admixture of size/shape information, combined with the unmeaningful absolute value of the BMI, preclude precise understanding of what it measures. A new weight-height-based variable was derived -the mean effective breadth (MEB)- which more clearly relates to the SA:V ratio and heuristically represents what weight-for-height does: it alters body breadth.

Previous findings of a geographical cline in the BMI in Native Americans were expanded to a worldwide sample of 328 adult populations. The BMI and MEB increased with increasing latitude, while the SA:V ratio decreased. All three ratios were also correlated with variables that alter the biological SA:V ratio: sitting height, relative sitting height, and bi-acromial and bi-iliac breadths. The MEB showed higher correlations with latitude, weight, height, sitting height, relative sitting height, and bi-acromial breadth than did the BMI, though coefficients were similar to those of the SA:V ratio.

The BMI's geometric and statistical associations with the SA:V ratio and

measures of proportion or shape corroborate and amplify others' findings that the BMI is not a shape-independent index of body size or nutritional status. The W/H^2 ratio was originally conceived by Quetelet as a "proof" of body proportionality. Nutritional epidemiologists should beware these associations when using BMI cutoff categories to diagnose chronic energy deficiency or obesity.

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Introduction

The body mass index (BMI), or "Quetelet's Index" (weight in kg/(height in m)^2), is used in many clinical and anthropological contexts to compare individuals' or groups' weights "independent of" or "unbiased by" their heights (Keys et al., 1972; Shetty and James, 1994:9). In adults, the BMI is usually correlated with weight, but not with height: it is therefore preferred over other weight-height indices as a measure of body size or nutritional status (e.g. Keys et al., 1972; Shetty and James, 1994). However, a number of studies have shown that the BMI does not truly represent size independent of body *shape.* The BMI is correlated with several measures of body shape or proportion such as relative sitting height (Garn et al., 1986; Norgan, 1994a,b), bony chest breadth (Garn et al., 1986), and the sum of humerus and femur breadths (Ross et al., 1988). These correlations are not surprising given the BMI's origin as a ratio of body proportionality (Quetelet, 1835).

In a different context, researchers have cited (Johnston and Schell, 1979:282) or predicted (Beall and Goldstein, 1992:747,752) high BMI values in cold-climate groups as evidence of "Bergmann's Rule" or cold adaptation. Bergmann's Rule (Bergmann, 1847; Mayr, 1956) refers to the intraspecific tendency for body size to increase in colder parts of the geographic range. The complementary "Allen's Rule" (Allen, 1877, 1906) predicts temperature-related clines in body (or limb) shape. Together, both rules reflect the fact that larger and less linear organisms have a lower body surface area to volume (SA:V) ratio, and are thus better able to conserve heat (Roberts, 1978:29-30). In heat-adapted organisms, the opposite is true (reviewed in Mayr, 1956; Ruff, 1994). The BMI's precise relationships to size and shape -and hence to these "rules"- are unclear. If the BMI is to be cited as an expression of "cold adaptation", what it measures in terms of the SA:V ratio must be understood.

Here, I develop a geometric model after Ruff (1991) to show that the BMI does indeed capture shape as well as size and varies inversely with the SA:V ratio. However, the absolute value of the BMI -in mixed units of "kgm"- is not informative in intuiting what it measures. As a clearer alternative, I introduce a new weight-and-height-derived variable -the mean effective breadth (MEB)- that heuristically represents the effects of weight-for-height in terms of its effects on the SA:V ratio and body breadth.

Next, in a worldwide sample of 328 means, I assess the BMI and SA:V ratio's correlations with geographic latitude (as a proxy variable for climate), and with anthropometric variables known to positively cline with latitude and affect the SA:V ratio (bi-iliac breadth, bi-acromial breadth, sitting height, relative sitting height, and body surface area). The MEB is included in the correlation analyses for exploratory purposes.

Results accord with and expand prior researchers' findings of both a geographic cline in the BMI (Johnston and Schell, 1979), and the BMI's association with measures of body proportion or shape (Garn et al., 1986; Ross et al., 1988; Norgan, 1994a,b). Results strongly suggest that the BMI is not a shape-independent index of body size or nutritional status. Despite its popularity as a proxy of fatness, the BMI is shown to be Quetelet's (1835) index of proportions after all.

Chapter 1: What is the BMI? A measure of "fatness" or body proportions?

The BMI is arguably the most popular of weight-height ratios as a measure of nutritional status or fatness. The BMI has become the "index of choice" for nutritional epidemiology (Shetty and James, 1994:9), and BMI cutoffs are used to diagnose both chronic energy deficiency and obesity (James et al., 1988; Shetty and James, 1994; reviewed in Henry, 1994). The Food and Agriculture Organization of the United Nations endorses the BMI as the worldwide standard for nutritional status assessment (Shetty and James, 1994), as have some National Institutes of Health-sponsored conferences (reviewed in Weigley, 1989:16). Body mass index nomograms can be found in texts and professional reference sources for clinical nutritionists (e.g. Whitney and Rolfes, 1996; Shils et al., 1994:A-49). The BMI has even been used to measure obesity or relative nutritional status in macaques, taking crown-rump length (C-R) as the squared linear dimension, i.e., $W/C\text{-}R^2$ (Jen et al., 1985, "Obesity Index Rh"; Berman and Schwartz, 1988; Bercovitch, 1992; Schwartz et al., 1993; Bodkin et al., 1993). (Laber-Laird et al., 1991 used trunk length instead of C-R.)

The BMI became popular as a measure of nutritional status largely due to a series of correlation analysis papers that showed that the BMI most consistently met three criteria: it was highly correlated with weight, minimally correlated with or "independent" of height (Billewicz et al., 1962; Florey, 1970; Lee et al., 1981; Frisancho and Flegel, 1982), and highly correlated with fatness

(Shetty and James, 1994:7; Keys et al., 1972; see also Micozzi et al., 1986). Keys et al. (1972:341), in a seminal paper wherein the W/H^2 ratio was named the "body mass index", designated the BMI as the weight-height index applicable "to all populations at all times".

However, other researchers have questioned the BMI's ability to discriminate fatness, since it is only a gross measure of weight, and have also disputed its supposed "independence" from height and body proportions. Many have demonstrated what Garn et al. (1986) have called "the three limitations of the body mass index". First, the BMI is not "unbiased by height" (Shetty and James, 1994:9) in all ages and all populations, especially in children (Garn et al., 1986), and women (Florey, 1970; Lee et al., 1981; Micozzi et al., 1986). Second, the BMI is a proportionality index, in that it is correlated with relative sitting height (Garn et al., 1986; Norgan, 1994a,b) and bony breadths (Garn et al., 1986; Ross et al., 1988). Third, as a gross measure of ponderosity, it is as correlated with measures of lean mass as it is with fatness (Garn et al., 1986; Ross et al, 1988; Norgan, 1990), and is often a poor predictor of fatness (Florey, 1970; Frisancho and Flegel, 1982; Roche, 1992:206).

The fact that the BMI correlates well with measures of body proportions is not surprising given its historical origins as a ratio to express such proportions (Quetelet, 1835; Ross et al., 1988). This is characteristic of weight-height indices generally, as they were devised in the nineteenth century in the context of growth and body proportionality studies (Keys et al., 1972:340). Of the ratios, weight (W) divided by height (H) is the simplest. However, because weight is a volumetric measurement and height a linear one, a number of "power indices" were developed in an attempt to accommodate the different exponents of weight and height (Keys et al., 1972).

The BMI was the first such index, and is credited to statistician and anthropometrist L. Adolph J. Quetelet (1835; 1833, in Ross et al., 1988). Subsequent indices were created to more accurately represent relative weight, it was believed, by adjusting the three powers of weight with linear height in a 1:1 ratio (Micozzi et al., 1986; Keys et al, 1972). Thus, Livi's (1898) *indice ponderale*, or ponderal index ($W^{.33}/H$), Rohrer's (1921) "index of body build" (W/H^3), and their respective inversions by Sheldon (1940:52, $H/W^{.33}$) for use in somatotyping and by Pirquet (1913, H^3/W) for growth studies all reflect this concern with dimensionality (Livi, Rohrer, and Pirquet in Krogman, 1941:9, 14, 12).

The development of the BMI was uniquely motivated by Quetelet's particular goals and historical context. Quetelet was a pioneer in growth studies and in the application of "physical" statistics and probability theory to the social or "human" sciences (see Jolly and Dagnelie, 1967; Jelliffe and Jelliffe, 1979; Tanner, 1981; Weigley, 1989). In these veins, he collected a large amount of anthropometric data and characterized their variability in terms of the "normal law of errors" -what we would now call the "normal distribution" (Jolly and Dagnelie, 1967:173). Quetelet's key preoccupation was understanding *l'homme* *moyen*, or "the average man", and in deducing general "law-like" principles of the human body and character based on the central tendencies of his data (Jolly and Dagnelie, 1967; Tanner, 1981:138). Body proportionality and its changes with growth were chief amongst Quetelet's traits of interest (Tanner, 1981:136), and herein lies the origin of the W/H^2 ratio.

The W/H^2 ratio first saw substantial exposure in Quetelet's widely-read 1835 compilation of essays. Based upon his observations of height and weight data, Quetelet (Diamond, 1969:66,67; facsimile reproduction of the 1842 English translation of Quetelet, 1835) said that, in children, the square of weight is proportioned to the fifth power of stature; in adults, weight is in proportion to the square of stature. Consequently, "increase in height is greater than the transverse increase, including breadth and thickness", and "proportion being attended to, width predominates in individuals of small stature" (Diamond, 1969:67,66).

Ross et al. (1988) have explained that Quetelet was simply trying to make a general statement about the growth of human proportionality: height-weight proportionality differs between children and adults, and between "extremes" of adults. In brief, he was saying that short people are relatively wider than tall people (Ross et al., 1988), an observation that Ross et al. (1987, in Ross et al., 1988) have shown to be true.

It has been said that Quetelet "adhered to the school of Procrustes, and the consequences of imperfections in his analogies he left to others" (Porter

1994:347). No statement is truer of the W/H^2 ratio. It is clear neither from his proof nor his explanation how the quotient of W/H^2 could itself convey the greater relative breadth of shorter people. However, it can be shown that Quetelet's index roughly expresses the surface area:volume ratio in inverse form, given that $height^2$ represents an areal measurement, and weight a volumetric one. Regardless, Quetelet's basic point about body proportionality has been lost to most who use the W/H^2 ratio as the "body mass index" today.

The twentieth century saw increasing use of the BMI and other W/H indices as measures not so much of proportionality, but of "nutritional status" (Keys et al, 1972; Garn and Pesick, 1982). The title of Krogman's (1941:5-16) 12-page listing of partially or wholly weight/height-derived ratios -"Indices of nutritional status, proportion and body type"- is revealing about this transitional phase when W/H indices were seen as proxies of both proportionality and nutritional status. By the 1960s and 1970s, intensified interest in the study of obesity in Westerners and chronic energy deficiency in developing countries led to a shift in the perception of W/H indices as predominantly measures of nutritional status (cf. Jelliffe and Jelliffe, 1979).

The use and conceptualization of the BMI as an idealized proxy of nutritional status represents a curious departure from Quetelet's (1835) and other early anthropometrists' intents. As priority of use shifted from the description of body proportions to the assessment of nutritional status, the fact that the BMI, and W/H indices in general, are also proportionality indices has been largely forgotten. BMI proponents emphasize its supposed independence from the height-aspect of size, and its correlations with the weight-aspect of size and fatness (e.g. Keys et al., 1972; Shetty and James, 1994). BMI detractors point to its correlations with measures of body shape, build, or proportion (e.g. Garn et al., 1986; Ross et al., 1988; Norgan, 1994a,b). In the next section, I will show with a geometric model how the BMI captures both size and shape, how it is not independent of height, and how it relates to the surface area:volume ratio.

Chapter 2: Geometric model of the BMI and the surface area:volume ratio

The easiest way to demonstrate the effects of weight relative to height is with a geometric model of the human body. After Ruff (1991, 1994) and others (e.g. Abernethy, 1793; Roussy, 1925 in Boyd, 1935; Quetelet, 1848), I will use a cylindrical model. One can conceptualize a cylinder as simply a wrapped-up rectangle with two circles on the ends, which is taken to represent the two-dimensional surface area of the human body, and its closed shape, the volume. Here, "volume" and "weight" are used interchangeably. Such an assumption is required without actual measurements of body density.

Simple logic predicts that increased weight relative to height will produce a relatively wider body (Roberts, 1978:30). This can be visualized by comparing two cylinders of the same height, but different volumes. The one with the greater volume will necessarily be wider. In addition, since areal dimensions scale with the $^2/_3$ power of volume, the wider cylinder will have a larger surface area but a lower SA:V ratio. Thus, increased weight relative to height increases surface area, but more strongly decreases the SA:V ratio.

The physiological implications of this scaling are apparent when one considers surface area and volume as each representing two different components of body size, and the SA:V ratio as containing some shape information derived from the relative proportions of these two different aspects of physiological body size.

Body weight is often referred to as the "metabolic size" because of Kleiber's Law, which states that across species, basal metabolic rate -the amount of heat produced to maintain basic biologic functions- varies with the ¾ power of body weight (Kleiber, 1961; Reiss, 1989).

External body surface area (i.e., of the skin) is often referred to as "body size" in reference to physiological processes that take place across organ surfaces (internal or external), and represents an energy "assimilation and loss" measure of size. Many assimilation/loss processes occur across organ surfaces of the body, such as nutrient and drug absorption; gaseous exchange; renal functions; conductive, evaporative, and radiative heat loss; and so forth (Reiss, 1989:16,20; Haycock et al., 1978:62,65; Turner and Reilly, 1995; Brozek et al., 1987). In clinical medicine and physiology, such functions are often "corrected for body size" by expressing them per unit body surface area, the assumption being that relevant organ surface areas parallel that of the skin (reviewed in Nwoye, 1989; Mosteller, 1987; Takai and Shimaguchi, 1986; Haycock et al., 1978; Brozek et al., 1987; Turner and Reilly, 1995).

Thus, weight grossly represents heat or energy requirements and production (Kleiber, 1961; Reiss, 1989:15,20), and surface area represents the substrate of energy assimilation or loss (Reiss, 1989:15,20). The SA:V ratio, then, is one of energetics and is a ratio of potential energy loss to production, of potential energy assimilation to energy requirements (Roberts, 1978; Reiss, 1989). Therefore, weight-for-height -via its link with the SA:V ratio- is not just a measure of physical proportions, as noted by Quetelet and others reviewed in the previous section, but of physiological proportions of "gross energetics" as well.

The BMI's relationship to the SA:V ratio can be easily modeled geometrically. Ruff (1991) developed a cylindrical model of the human body to demonstrate that changes in body breadth, but not changes in height, alter the lateral SA:V ratio. Here, I adapt and expand his model to include total surface area, and compare it to a geometric model of the BMI equation (Figure 1[*]). The geometric model is also useful for examining size/shape aspects of the BMI, independent of the potential collinearity and spurious correlation that can arise when ratios are used in statistical analyses with their component parts (Tanner, 1949), as is characteristic of many previous statistical assessments of the BMI (e.g. Keys et al, 1972; Norgan, 1994a,b).

Geometry shows that the BMI is inversely related to both the lateral and total SA:V ratios, but contains additional confusing information about size and shape. From Figure 1 (where D = diameter and L = height), the BMI can be broken down as follows:

$$\text{BMI} = \pi D^2/(4L)$$

$$=(D/4)\,(\pi D)\,(1/L)$$

=(inverse lateral SA:V ratio)(circumference)(inverse height)

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[*] All tables and figures may be found in Appendix A.

The BMI would be the exact inverse of the lateral SA:V ratio in an individual with a circumference equal to its height:

$$\pi D^2/4L = (D/4)\ (\pi D/L) = (D/4)(1/1) = D/4$$

The BMI's relation to the total SA:V ratio cannot be so neatly or easily decomposed, though the two ratios contain some similar information in the inverse. Referring to Figure 1, two contrasts between the BMI and the total SA:V ratio (hereafter denoted "SA:V ratio") deserve note, since they also point to shape and size information subsumed in the BMI. First, the BMI gives greater or exponential "weight" (*sensu* importance) to body breadth than does the SA:V ratio, given the squared diameter term in the BMI's numerator. Second, because of this D^2 term, the BMI gives greater importance to breadth than it does to height, versus the SA:V ratio where the diameter and height terms are both arithmetic.

However, the BMI is certainly not "independent" of height according to the geometric model. The model suggests a differential influence of height on the BMI in people of different shapes. Since the diameter-based BMI numerator increases exponentially, while the height-based denominator increases arithmetically, height should have less of an impact on the BMI quotient in wider people. Height should have a greater impact on the BMI in absolutely narrower people, such as children. Thus, according to the geometric model, the BMI is heavily shape-dependent (defining diameter as shape), and differentially height-dependent.

These implications may at first not seem intuitive, since the real BMI formula, W/H^2, contains H^2 in the denominator. This relates to a larger issue about the BMI (and ratios generally): What does it measure? Abstractly, it measures both size and shape, and "how much" of each it measures seems to vary with size and shape themselves. Concretely, the absolute value of the BMI represents a one-dimensional mixed unit of measurement, "kgm". This only provides further confusion regarding what the BMI measures. Knowing that someone has a BMI of, say, 25.9 is not meaningful in and of itself, but only in relation to reference standards (e.g. BMI cutoff categories, in James et al., 1988). Supposedly, one main purpose in using W/H indices is to *avoid* the use of referents (Keys et al., 1972; Shetty and James, 1994). Yet the BMI is difficult to understand at face value.

For use in the present paper, I will derive a new weight-height variable that is heuristically clearer than the BMI, and relates to the SA:V ratio. This variable, called the "mean effective breadth" (MEB), is the diameter of a cylindrical "person" with mass, and therefore all possible breadths, equalized per unit height (Figure 2). This variable represents what, for example, increased weight relative to height does: it increases breadth.

As shown in Figure 2, the MEB is derived with the formula for the volume of a cylinder, by substituting weight for volume and using known weight and height to solve for diameter. This diameter is what I have called the MEB.

From Figure 2:

MEB (in cm) = sq. root [(weight in kg x 1000)/(height in cm x .785)]

or 35.69 $(W^{.5}/H^{.5})$

The purpose of multiplying weight in kilograms by 1,000 (to convert it to cubic centimeters) is to resolve the mixed-unit-quotient problem seen in the BMI. The MEB represents a one-dimensional mean diameter, in centimeters, which makes its absolute value easy to understand. This conversion is based on the fact that one kilogram of water equals 1,000 cubic centimeters. Humans, of course, are not water, though water does comprise 60-80% of human body weight (Marieb, 1992:11). Regardless, this conversion is simply intended to make the MEB readily comprehensible. For statistical purposes, use of this constant would have no impact on any results.

Heuristically and mathematically, the MEB measures *mean diameter or shape* per unit height. By this statement, I do not imply or claim that the MEB is independent of size. Rather, it is a means of expressing weight-size per unit height-size in a quotient that equals mean diameter, with an absolute value that is simple to understand. Further, two individuals with the same height, weight, and MEB could be shaped differently (i.e., one could have a wider body, the other a narrower body with greater sitting height). Yet each has the same mean shape, and each should have similar SA:V ratios. Their *effective breadths*, therefore, are the same.

It is predicted that both the BMI and MEB will show the same patterns of correlations with other variables as the SA:V ratio, but in the inverse. I will test these predictions in the worldwide data analysis to follow. First, though, I will review the limited previous findings about weight-for-height and the BMI in morphological adaptation to climate research.

Chapter 3: Weight-for-height and the BMI in morphological adaptation to climate research

Research on climate-related clines in anthropometric characters seeks to document and explain worldwide human variability in terms of two "ecogeographic rules": Bergmann's (1847) and Allen's (1877) Rules. Bergmann's Rule refers to the intraspecific tendency in homeotherms for body size to increase in colder parts of the geographic range (Mayr, 1956). The complementary Allen's Rule states that their "peripheral parts" tend to be relatively elongated in warmer parts of the geographic range (Allen, 1906). Together, both rules reflect the fact that larger and less linear organisms have a lower SA:V ratio, and are thus better able to conserve heat. In heat-adapted organisms, the opposite is true (see Mayr, 1956; and Ruff, 1994 for discussion). This thermoregulatory aspect of the SA:V ratio is highlighted in such studies, where it is emphasized as a ratio of heat loss to heat production (e.g. Roberts, 1978:29-30).

The extensive body of literature in this area (thoroughly reviewed in Ruff, 1993;1994) has shown temperature-related morphological clines in a number of measures of body proportion or shape that physically relate to the SA:V ratio. The SA:V ratio itself varies with climate in human populations as would be predicted by the physiological explanation (Schreider, 1950, 1964; Ruff, 1994). Roberts (1978:13-29,94-97) has shown negative correlations between mean annual temperature and sitting height, relative sitting height, chest girth, relative biacromial and bi-iliac breadths, and calf circumference. He obtained positive correlations between mean annual temperature and relative span of the upper limbs, and lengths of the distal segments of the upper and lower limbs (Roberts, 1978:95-96). Ruff (1991, 1994) found a highly significant correlation between bi-iliac breadth and latitude in 56 modern human populations, and as summarized in the previous section, has shown via cylindrical modeling that body breadth, but not height, drives the lateral SA:V ratio. (However, Figure 1 here demonstrates that height *does* play an important role in the total SA:V ratio.)

Given the predictions above about the BMI (and weight-for-height generally) and its inverse relation with the SA:V ratio, one would expect that prior researchers would have studied weight-for-height in that context. However, the topic has received scant attention, and is usually only mentioned in passing in analyses that focus on related variables such as weight and height.

In a worldwide sample of 116 male and 33 female populations, Roberts (1953) reported correlations between weight and mean annual temperature of -.600 for males, and -.809 for females. The partial coefficients for weight and temperature exclusive of stature were -.538 and -.704 for males and females, respectively. Significant correlations between height and mean annual temperature disappeared when weight was partialed out. Roberts (1953:537) plotted his groups on a map according to "weight per unit stature", but did not include it in his reported statistical analyses.

Roberts (1978:17), when reviewing his clinal weight results as above, noted that "the effect of stature (on weight) can be partly overcome by examining weight per unit stature, and the same pattern appears". No statistical results accompany this comment.

Similarly, Newman (1960) reported negative correlations between weight and mean temperature of the coldest month in a sample of 60 adult Native American male groups (r = -.729). When stature was held constant, the partial correlation between weight and temperature was -.670, while the correlation between height and temperature when weight was partialed became non-significant. In his discussion, Newman (1960:307) briefly mentions that the $H/W^{.33}$ ratio "is independent of temperature", but other than presenting mean values for the index in a table, he does not elaborate.

In their analysis of climatic influences on cranial morphology, Beals et al. (1984) note a correlation of -.46 between a "ponderal index" and their five climatic zones (ranked 1-5, from "dry heat" to "dry cold"), but do not give the formula they used for "ponderal index". Some authors define the ponderal index as Livi's (1898, in Krogman, 1941:9) $W^{.33}/H$ (Keys et al., 1972; Micozzi et al., 1986; Shephard, 1991:17), while others give the formula H/W.33 (Florey, 1970; Lee et al., 1981). Shetty and James (1994:8) define it as the latter formula, or as W/H^3.

Ruff (1994:85), in his study of the correlation between bi-iliac breadth and geographic latitude, regressed body weight on stature in a sample of 56 male and female means. Points for cold-climate modern populations and fossils (e.g. Neanderthals) tended to fall above the regression line, i.e., they had relatively more weight per unit height. Tropical moderns and fossils (e.g. KNM-WT 15000; see Walker and Leakey, 1993) showed the opposite trend.

In the only explicit test of the BMI and climate, Johnston and Schell (1979) assessed geographic variation in the BMI in a Native American sample of 16 groups. ANOVA results showed a significant main effect for geographic region, with BMI means highest for northern North American Indians, followed by Eskimos, South American Indians, and Mesoamerican Indians. They explained the paradoxically lower BMI values of the Mesoamericans in comparison to the South Americans as due to the "well-documented" nutritional stress characteristic of Mesoamerican populations (Johnston and Schell, 1979:282). While they were cautious about overextending their interpretations, they did "point to the increased adaptation to low temperature afforded by a high weight-for-height" (Johnston and Schell, 1979:282).

More recently, Beall and Goldstein (1992:747,752) predicted -but did not find- high BMI values in Tibetan Nomads as evidence of "cold adaptation" or "Bergmann's Rule". While their statement is logically valid, no worldwide study has been done to show such an empirical association.

Thus, given Johnston and Schell's (1979) limited findings of a geographic BMI cline in Native Americans, and the geometric predictions about the BMI's inverse relation to the SA:V ratio, it is of interest to test the BMI's relationship to climate and the SA:V ratio in a worldwide sample. In a correlation analysis, I will assess the BMI's associations with geographic latitude (as a proxy variable for climate), and anthropometric variables known to positively cline with latitude (bi-iliac breadth, biacromial breadth, sitting height, relative sitting height, and body surface area). The BMI's associations will be compared to those of the MEB and the SA:V ratio.

Chapter 4: Tests of correlation between the BMI, MEB, SA:V ratio, latitude, and clinal anthropometrics

Materials and Methods

Sex-specific adult mean height and weight data were obtained from primary and secondary (e.g. the compilations of Eveleth and Tanner, 1976,1990) literature sources, and by personal communication of unpublished data (Armenian data from R.L. Jantz). Sitting height and bi-iliac and biacromial breadths were collected if also reported. Populations specifically noted to be "pathological" (e.g. obese) were not included. However, this criterion was not strictly observed regarding some Pacific Islanders and Eskimos, who have occasionally been defined as "obese" by BMI-cutoff standards, yet actually have little fat mass (cf. Houghton, 1990; So, 1980). In an effort to sample groups that were relatively long-lived in their present environments, New World populations except American Indians were excluded. Migration, though, was impossible to control (cf. Stinson, 1990).

Sampling criteria represent several compromises similar to those of other researchers doing large-scale studies based on grab sampling (e.g. Stinson, 1990; Ruff, 1991,1994). The "adult" age criterion was bent for some groups where height and weight means included 17- and 18-year-olds pooled with the adults. Large original sample sizes were preferred, and a minimum criterion of

20 observations was generally observed. The sample size criterion could not be evaluated for some of the (mainly European) listings in Eveleth and Tanner (1976, 1990). The criterion was mildly violated for a small number of ethnographic populations for whom means from larger sample sizes could not be obtained, largely due to small population size.

Where given a choice between urban versus rural or "traditional" groups of the same population, the latter were chosen (cf. Schmitt and Harrison, 1988:353). The former were usually being studied for pathological processes associated with Westernization, so they were also excluded on that basis. For similar reasons, older rather than more recent data sets of the same group were used, if available. Most of the data were originally collected and published in the 1960s, 1970s, and early 1980s. Initial efforts to control the age ranges represented by the samples were abandoned, due to the variability in reporting of summary statistics.

An initial sample of 400 was collected and then reduced to 333 according to these criteria (a procedure similar to Roberts, 1953) (Appendix B; summarized in Table 1). This method left a disproportionate number of Pacific Islanders in the sample (N=70, pooled with the Australian Aborigines in Table 1) with no reason for exclusion. In addition, Europeans predominate at the higher latitudes. Thus, in order to rule out biases due to these characteristics of the sample, analyses were performed on sample subsets excluding Pacific Islanders and excluding Europeans. Separate analyses were also performed by sex, by pole, and by population classification (after Eveleth and Tanner, 1976, 1990; as summarized in Table 1). Due to missing data for some groups, the number of observations for each variable-by-group classification is also given in Table 1 and in summaries of statistical analyses (cf. Stinson, 1990). The maximum sample size for latitude and weight/height-variable comparisons was 328. Finally, to rule out unintentional experimenter bias due to nonrandom sampling, separate analyses were performed with the data set published in Ruff (1994:75; Appendix C).

After Johnston and Schell (1979), the sample mean BMI was calculated from reported mean height and weight. This method was found to be accurate in estimating mean BMI -as if it were calculated from the true individual values- as long as height was reported to the millimeters place. The accuracy of this procedure could not be evaluated for most groups, though, and it should be noted that unless there is isometry, the ratio of averages (BMI as calculated here) is not equal to the average of ratios (BMI calculated the correct way) (see discussion in Konigsberg et al., 1998:19-20; Welsh et al., 1988). Latitudes were estimated to the nearest degree from Espenshade (1995), Murdock (1967), or by authors' reports. Midpoint latitudes were used for larger geographic ranges. After Ruff (1994), body surface area was estimated with the widely-used linear formula of DuBois and DuBois (1916) {surface area $cm^2 = 71.84 \cdot W^{.425} \cdot H^{.725}$ (W in kg, H in cm)}. The SA:V ratio was calculated by dividing surface area by body weight (kg). Relative sitting height was calculated as (sitting height/height) ·

100. Sitting height was calculated from relative sitting height and height in seven cases.

Statistical analyses were done with SAS Release 6.12 for Windows (© SAS Institute, Cary NC). Since all variables were not normally distributed in all subgroups, Spearman rank-order correlation coefficients (r_s) were used to assess strengths of association. The number of tests is large (N=121). However, due to different sample sizes for different observations (and hence variable power for each of the tests), I did not use the conservative Bonferroni's experiment-wise protected alpha. Instead, I adopted a significance level of $p < .01$, so there is a chance that the null hypothesis was incorrectly rejected for one or two of the tests.

Post-hoc testing of whether selected pairwise comparisons of r_s values were significantly different was done by the Fisher *z* transformation of selected coefficients (Neter et al., 1996:642; McCall, 1986:388 Table D). After the coefficients were *z*-transformed, the test statistic "*z* observed" (z_{obs}) was found by the following formula: $z_{obs}= (zr_1 - zr_2)$/square root$((1/N_1-3)+(1/N_2-3))$, where zr_1 and zr_2 are the *z* scores of the two coefficients, and N_1 and N_2 are their respective sample sizes (McCall, 1986:238). If $z_{obs} \leq -1.96$ or if $z_{obs} \geq 1.96$, then the null hypothesis is rejected at $p < .05$: the r_s values are significantly different (McCall, 1986:238).

In addition, partial correlations holding weight or height constant were done for the worldwide sample and by pole.

Results

Correlations with latitude for the BMI, MEB, weight, height, surface area (SA), and SA:V ratio are presented overall and by sex, group, and pole in Table 2. Table 3 includes results for the samples excluding Pacific Islanders, excluding Europeans, and Ruff's (1994) sample. Plots of the BMI, MEB, and SA:V ratio by latitude are shown in Figure 3a-c. The Pacific Islander/Australian Aborigine group was divided into three subgroups for the plots: Australian Aborigines, Polynesians, and other Pacific Islanders.

The BMI, MEB, weight, height, and SA were all moderately positively correlated with latitude, and the SA:V ratio negatively so. These latitudinal gradients were seen in the overall sample, and for the following subsamples: males, females, Asians, Native Americans, Pacific Islanders/Australian Aborigines, North latitudes, South latitudes, the sample excluding Europeans, and the sample excluding Pacific Islanders. Africans showed no significant within-group correlations with latitude, though near-significant trends were similar. In Europeans, only height was significantly correlated with latitude, and in Indo-Mediterraneans, only the MEB, BMI, and SA:V were significantly correlated with latitude. The BMI was not significantly correlated with latitude in Pacific Islanders/Australian Aborigines and in the South latitudes.

The same patterns in the worldwide sample were seen in Ruff's (1994) sample: none of the correlations between the two data sets was significantly different (z_{obs} = -1.88, 1.53, 1.24, 0.47, 1.70, and 1.24 for BMI, MEB, weight, SA, SA:V, and height, respectively). In the worldwide sample, the MEB was more highly correlated with latitude than was the BMI (z_{obs} = 2.12); coefficients for the MEB, weight, height, SA, and SA:V ratio were similar. Also in the worldwide sample, after partial correlation with weight held constant, none of the coefficients remained significant. When height was partialed out, the coefficients were reduced but remained significant (r_s = .3329, .3540, .3428, .3195, and -.3541 for BMI, MEB, weight, SA, and SA:V respectively, $p<.0001$).

Latitudinal gradients were generally stronger in North latitudes than in South latitudes: the BMI, MEB, weight, and SA:V ratio were all more highly correlated with latitude in the North subsample (z_{obs}=3.04, 2.81, 0.42, 1.62, and 3.06 for BMI, MEB, weight, height, SA, and SA:V, respectively). Partial correlations with weight held constant were also calculated by pole. As in the full sample, none of the correlations remained significant after partialing out shared variation in weight. Partialing out height reduced the correlations in the North latitudes; it eliminated them in the South latitudes (data not shown).

Correlations between the BMI, MEB, weight, height, SA, and SA:V ratio with sitting height, relative sitting height, and bi-acromial and bi-iliac breadths are presented in Table 4. Most of the variables were correlated. The MEB was more highly correlated than the BMI with weight, height, sitting height, and bi-acromial breadth (z_{obs} = 13.47, 5.78, 2.64, and 2.86, respectively). Negative correlations for the SA:V ratio with weight, height, sitting height, relative sitting height, and bi-acromial and bi-iliac breadths tended to be intermediate to and similar to the positive ones for the BMI and MEB. There was some indication that the three ratios (BMI, MEB, SA:V) might differ in their correlations by sex, with higher correlations with sitting height and relative sitting height in females, and higher correlations with bi-acromial and bi-iliac breadths in males. However, the between-sex coefficients were not significantly different, likely due to the small within-sex sample sizes for these variables (data not shown).

Chapter 5: Discussion

The BMI and MEB increased with increasing latitude, and the SA:V ratio decreased. These latitudinal gradients appear to be robust since they were seen in the worldwide sample, and in subsamples by sex, by pole, and by most population groupings. Further, results were similar when the analysis was done with the independently-selected data set of Ruff (1994). While his and this sample overlap (due to the use of common data sources), he did not select his sample with the present purposes in mind, so unintentional experimenter bias (due to non-random sampling) can be ruled out as an explanation for the gradients. Further, results cannot be attributed to high-latitude Europeans driving the correlations, as similar results obtained when Europeans were excluded from the sample. The same can be said about the disproportionate number of Pacific Islanders in the sample: similar results obtained when they were excluded from the sample as well.

Thus, Johnston and Schell's (1979) findings of higher BMI values in colder-climate Native Americans may be expanded and stated as a general worldwide trend. Beall and Goldstein's (1992) prediction of high BMI values in Tibetan Nomads as a means of "cold adaptation" may not be inaccurate, as higher latitude populations tend to have higher BMI values as well, and lower SA:V ratios. Previous findings of geographic gradients in weight (Roberts, 1953; Newman, 1960) and the SA:V ratio (Schreider, 1950, 1964; Ruff, 1994) were also confirmed. Partial correlations alternately holding weight or height constant reinforced the primary association of weight with climate (Roberts, 1953; Newman, 1960; Ruff, 1994): when weight was partialed out, neither the BMI, MEB, SA:V ratio, nor height remained significantly correlated with latitude, while controlling for height had little effect on the same correlations in the worldwide and North latitudes samples.

The higher correlations seen in the North as opposed to the South latitudes are not unexpected. Temperature range increases with increasing latitude generally, but less so in the South latitudes because of the higher proportion of ocean mass to land mass (Hammel, 1964:415). The North latitudes also have higher mean annual temperatures at any given parallel (Hammel, 1964:414,415). Thus, North and South latitudes are neither isothermic, nor equally variable. Given these differences, plus the fact that South latitudes were sampled at a more restricted range than North ones (1-30 degrees, versus 1-70 degrees, respectively; Table 1), the lower correlations in South latitudes are not surprising.

These polar discrepancies in temperature point to several potential limitations of latitude as a proxy variable for climate. The use of latitude here may have obscured more complex trends, as latitude may be insensitive to the climatic factors with which morphology "truly" clines. Allen (1906:377) observed that species' distributions (which in turn relate to morphological clines) are "found to agree, not generally with the arbitrary parallels of the geographer, but with isothermal lines". Further, different authors have advocated different aspects of temperature as more or less important. Roberts (1953, 1978) emphasized mean annual temperature as driving clines in many anthropometric traits, while Newman (1960:294) found that "mean coldest month temperatures correlate more highly with body weights".

Also, other attributes of climate such as humidity play significant roles in morphological clines. In addition to variable anthropometric clines between the sexes with different aspects of temperature, Stinson (1990) found that height varies with levels of precipitation in South American Indians. Populations are relatively shorter in the areas with the wettest climates, especially the tropical forest (Stinson, 1990:43,47). Stinson cites Hiernaux and Froment's (1976, in Stinson, 1990:47-48) similar observations in sub-Saharan African populations. While this may explain the non-significant correlations found here in the African sample, it is likely that the limited temperature variation around the equator and in the South latitudes also influenced the results.

A different type of latitude-climate divergence is seen in the case of some Pacific Islanders. Houghton (1990) has shown that the effective temperature faced by Polynesian ocean-goers and small island-dwellers is decidedly not tropical. The combined effects of winds, wetness, and the greater thermal conductivity of water make it "one of the coldest global environments" (Houghton, 1990:29). Figure 3a-c clearly shows Polynesians' outlying status with regard to the BMI, MEB, and SA:V ratio and latitude as compared with other groups. Polynesian means for these variables accorded more with those for high-latitude, cold-climate groups than with those of their low-latitude counterparts. Despite the Polynesians' unusual body proportions, the pooled Pacific Islander/Australian Aborigine sample still showed within-group latitudinal clines in the three ratios.

To the degree that it was not practical to control for all of these complex patterns on a worldwide basis, latitude was a good proxy variable. It should be noted that stronger or different trends could have been observed if other, more sensitive climatic variables were used. However, it is noteworthy that clines were present despite all of this underlying variability.

As Mayr (1956) has explained, geographical character gradients are simply empirical associations. Explanation of such trends is a separate process, and the gradients remain independent of the reasons for explaining them. The SA:V ratio is the favored physiological explanation for the types of trends observed here. In this paper, I have shown that weight for height -as measured by the BMI and MEB- and the SA:V ratio are measuring very similar things.

The BMI and MEB are essentially inverse expressions of the SA:V ratio. Figure 4a-b shows the SA:V ratio plotted against the BMI and the MEB, respectively. Both plots show an inverse relationship. The MEB more closely approximates the SA:V ratio's inverse than does the BMI. The great deal of scatter in the BMI plot is likely due to the "extra information" it contains as shown in the geometric model. The BMI also has a higher coefficient of variation (CV) than does the MEB (10.6 versus 6.2 in the worldwide sample, respectively. The MEB's CV is consistently around half of the BMI's CV in each subsample).

On this basis, it is reasonable and tempting to locate explanation for the clines in the BMI and MEB with the SA:V ratio. However, it is best not to interpret the correlations of ratios containing similar information with each other (cf. Tanner, 1949). More importantly, each ratio was correlated with other anthropometrics that alter the biological SA:V ratio. The BMI, MEB, and the SA:V (negatively) were all correlated with sitting height and bi-acromial and bi-iliac breadths. The MEB was more highly correlated with the former two variables than was the BMI. Sitting height and bi-acromial and bi-iliac breadths all literally or effectively increase body breadth or decrease the SA:V ratio as they increase. The BMI and MEB's geometrically-predicted relationships to the SA:V ratio can thus be verified outside of the inter-related statistical properties of the ratios themselves.

The MEB's correlations with these variables reinforce the concept of *mean effective breadth*: there is more than one way to reach the same biological outcome regarding the SA:V ratio (cf. Schreider, 1964:3). Weight-for-height expressed as the MEB better captures these relationships -statistically and heuristically- than does the BMI. Further, the BMI's correlations with these structural aspects of body build confirm and expand previous findings that the BMI reflects body proportions or build (Garn et al., 1986; Ross et al., 1988;

Norgan, 1994a,b), in line with Quetelet's (1835) intent when he first expressed the W/H^2 ratio.

The BMI and MEB's geometric and statistical associations with the SA:V ratio and SA:V-altering body dimensions provide proximate, physiological explanations for their clines with latitude. As Mayr (1956) has discussed, whether this physiological explanation has ultimate grounding via natural selection depends on genetic heritability of the trait(s). There are of course no heritability (h^2) estimates of the MEB, and I am unaware of any such estimates for the SA:V ratio. However, there are a number of (widely variable) h^2 estimates for the BMI.

Narrow h^2 estimates for the BMI range from .05 (Bouchard et al., 1988, in Canadians) to .70 - .90 (e.g. Stunkard et al., 1990; reviewed in Bouchard, 1993:426). Twin-study estimates fall in the .40 -.70 range; adoption studies tend to produce estimates of .30 or less (Bouchard, 1996:310,311). Bouchard et al. (1988) conclude that 30% of the variance in the BMI is culturally transmissible. Similarly, Tambs et al. (1991) estimate broad h^2 at about .40 in a group of Norwegians.

In contrast, some family pedigree studies claim higher estimates of narrow h^2. Ness et al. (1991) estimate polygenic h^2 at .34 in white Americans and .50 in African Americans. Their h^2 estimate is truly broad, though, as it includes "(n)ongenetic within-family influences on trait transmission, if they exist" (Ness et al., 1991:44). Comuzzie et al. (1993) find a narrow h^2 of .408 in

Mexican Americans, and estimate weight and height h^2 at .517 and .728, respectively, in the same pedigree. Overall, while results are variable, they implicate a significant genetic contribution to the BMI (and its components) in some populations. A potential ultimate or adaptive aspect to the BMI cannot be ruled out.

On the other hand, several environmental factors vary with latitude which could alter growth, weight-for-height, and body proportions and hence affect the SA:V ratio independent of its physiological role in thermoregulation. For example, Newman (1960) cited nutritional differences in certain groups, especially nutritional deficiencies and parasite loads in tropical and sub-tropical Mesoamericans and South American Quechuas. At the other extreme, "environmental cold has been found to retard postnatal growth, as available energy is channeled from storage to growth and heat production ... (and) can influence the size and shape of the skeleton" (reviewed in So, 1980:77-78). Thus, factors associated with latitude or temperature can affect weight, height, and proportions in the direction predicted by the SA:V ratio's thermoregulatory function.

In spite of such environmental influences on morphology, Roberts (1978) argues rather forcefully that they are minor when examined on a between-population scale. For example, differential nutrition during growth and adulthood hardly alters canalized interpopulational differences in physique (Roberts, 1978:62-65). Roberts (1978) cites dietary variation amongst several Nilotic groups, and describes how such factors differentially influence their weights and heights relative to each other. When compared to Europeans, though, they are all very similarly "ectomorphic" (Roberts, 1978:64). Whichever interpretation one chooses, all of these ideas reinforce the concept of the SA:V ratio as one of "gross energetics" or of physical and physiological proportions which extend beyond and subsume its thermoregulatory role and advantages.

It should be noted that SA and the SA:V ratio as measured here likely deviate systematically from their actual values in certain groups. DuBois and DuBois (1916:866) anticipated this when they noted the importance of variations in leg length (alternatively, relative sitting height) in determining body surface area, and how height as a unitary measure fails to reflect this influence. Their linear formula will tend to underestimate surface area in the long-legged (e.g. tropical African groups), and overestimate it in the very short-legged (e.g. Arctic Eskimo groups) (cf. Nwoye, 1989; Takai and Shimaguchi, 1986). "Real" surface area measurements are rare; they are usually obtained by the very laborious method of "coating" the entire body with some flexible, inelastic substance, and taking the surface area of that substance after it is peeled from the body (reviewed in Boyd, 1935; Brozek et al., 1987). Hence, linear formulas using weight and height (Boyd, 1935; Haycock et al., 1978; Nwoye 1989) or perhaps an additional measurement (Takai and Shimaguchi, 1986) are the most practical and widely-used surface area estimators.

This, plus the fact that weight must be taken for volume when calculating the SA:V ratio in this and other (Schreider, 1950,1964; Ruff, 1994) studies, means that estimated SA:V ratios reflect an unquantified error component. The "real" SA:V ratios of the groups studied here may cline with latitude more strongly. However -inasmuch as we measure the SA:V ratio with linear formulas- the SA:V ratio and the BMI and MEB represent similar things, as argued above. This makes the SA:V ratio perhaps as much a measure of "nutritional status" as the BMI is of "proportions".

There is a great deal of variation in the BMI, MEB, and SA:V ratio that was not associated with latitude. Their respective correlation coefficients produce r^2 of 13%, 25%, and 23%. The unexplained variation could be partially due to several uncontrolled factors in this study relating to ontogenetic and secular influences on weight and height. As these factors were not controlled, it could alternatively be argued that they biased the results in the predicted direction. Since ontogenetic and secular changes are or have been quite variable in different populations, though, it is doubtful that they converged to systematically vary by latitude. I thus consider them more as sources of error variance.

For example, ontogenetically, weight declines with age in some groups (e.g. Iban men, Strickland and Ulijaszek, 1993), shows peaks and subsequent drops in others (e.g. Yolungu and Indian women, Jones and White, 1994; Sidhu and Sidhu, 1987), or remains stable (e.g. Zoro Indians, Fleming-Moran et al., 1991). Further, weight fluctuates with seasonal dietary or subsistence cycles (reviewed in Ulijaszek, 1995:26; Beall et al., 1996); parity in women ("maternal depletion", Little et al., 1992), and altitude (Khalid, 1995).

Secular changes in weight and height can also obviously affect weight-for-height. Such changes have not been uniform, though. While some groups have shown increases in height, others' heights have decreased; in some groups there has been a concomitant increase in weight, in others not; some have shown no changes in BMI or weight-for-height, while others have seen decreases or increases (e.g. Papua New Guinea groups in Ulijaszek, 1993; European groups reviewed in Van Wieringen, 1986).

The fact that Europeans showed no within-group latitudinal clines may be partially related to secular changes there. More likely, the non-significant results are due to sampling procedures and sample availability. Many of the European samples were national in scope, so less-precise midpoint latitudes had to be estimated. Others came from cities or urban locales characterized by mobility and migration. Thus, Europeans were procedurally and culturally more decoupled from their adaptive environments than were perhaps other groups.

Chapter 6: Conclusion

Geometric modeling showed that the BMI measures size and shape and is inversely related to the SA:V ratio. The model also suggested that the BMI is very shape-dependent and differentially height-dependent, with height having a greater impact on the BMI quotient in absolutely narrow individuals. The BMI quotient itself is not helpful in understanding what it measures, or "how much" it measures size versus shape. A new height-weight based variable was derived - the mean effective breadth (MEB)- which more clearly relates to the SA:V ratio and represents what weight-for-height does: it alters body breadth.

Previous findings of a geographical cline in the BMI in Native Americans (Johnston and Schell, 1979) were expanded to a worldwide sample of 328 adult populations. These results appear robust as they were replicated in subsamples by sex, by pole, by several population groupings, and in an independent sample collected by another researcher (Ruff, 1994). The BMI and MEB increased with increasing latitude, while the SA:V ratio decreased. All three ratios were also correlated with variables that alter the biological SA:V ratio: sitting height, relative sitting height, and bi-acromial and bi-iliac breadths. The MEB showed higher correlations with latitude, weight, height, sitting height, relative sitting height, and bi-acromial breadth than did the BMI, though coefficients were similar to those of the SA:V ratio.

The BMI's geometric and statistical associations with the SA:V ratio and measures of proportion or shape such as sitting height and bi-iliac and bi-acromial breadths accord with and expand prior researchers' claims that the BMI is not a shape-independent index of body size or nutritional status (Garn et al., 1986; Ross et al., 1988; Norgan, 1994a,b). These findings are not surprising since the W/H^2 ratio was originally conceived by Quetelet (1835) as a "proof" of body proportionality. As Norgan (1994a,b) has warned, nutritional epidemiologists should beware these associations when using BMI thresholds to diagnose chronic energy deficiency or obesity.

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Appendices

Appendix A: Tables and Figures

Table 1.
Summary Statistics for Worldwide Sample

Sample	Latitude in degrees*			BMI in kg/m			MEB in cm			Height in cm			Weight in kg		
	N	Range	Mean	N	Range	Mean	N	Range	Mean	N	Range	Mean	N	Range	Mean
overall:	330	1 - 70	23.6	331	17.6-31.2	22.1	331	18.4-25.6	21.3	333	135.8-181.6	160.6	331	37.0-88.1	57.4
by sex:															
males	185	1 - 70	23.8	185	17.6-30	22.1	185	18.7-25.6	21.6	187	145.0-181.6	165.6	185	40.0-88.1	60.8
females	145	1 - 70	23.4	146	17.8-31.2	22.2	146	18.4-25.2	20.9	146	135.8-166.5	154.2	146	37.0-80.0	53.1
by group:**															
Africans	53	1 - 30	8.4	53	17.6-29.1	20.6	53	18.4-24.0	20.5	53	135.8-181.6	160.7	53	37.0-70.8	53.3
Asians	36	2 - 48	24.8	34	18.5-26.2	20.9	34	19.1-23.3	20.6	36	142.4-170.1	160.2	34	40.8-69.7	53.7
Europeans	54	39 - 65	49.3	54	20.7-26.8	23.3	54	20.5-24.1	22.3	54	155.4-178.1	167.2	54	51.4-79.3	65.4
Indo-Mediterranean s	48	13 - 44	28.1	48	18.0-27.2	21.4	48	18.9-24.0	20.9	48	151.0-172.5	161.3	48	42.7-78.12	55.8
Native Americans	61	1 - 70	27.8	64	19.8-27.9	23.4	64	19.9-24.0	21.7	64	142.8-177.4	158.9	64	44.4-76.6	59.3
Pac. Isl./ Aust.Ab.	78	2 - 25	9.6	78	18.4-31.2	22.3	78	18.7-25.6	21.1	78	137.0-173.4	157.1	78	38.9-88.1	55.5
by pole:															
north	205	1 - 70	31.8	204	17.6-31.2	22.3	204	18.5-25.6	21.5	206	138.0-181.6	162.7	204	37.0-88.1	59.3
south	120	1 - 30	10.5	120	17.6-30.5	21.9	120	18.4-25.1	20.9	120	135.8-176.5	156.8	120	38.5-84.8	54.2

*Latitude in absolute degrees

**Groupings were made according to the classifications of Eveleth and Tanner (1976, 1990), except New World "Asiatics" were separated from Old World Asians

Table 2.
Correlations with Latitude: Overall and by Sex, Group, and Pole

Variable	Overall	Males	Females	Africans	Asians	Europeans	Indo-Med	Native Americans	Pac. Isl./ Aust. Abor.	North Latitudes	South Latitudes
BMI	0.3664	0.38328	0.3440	**0.0123**	0.5666	**-0.2508**	0.4257	0.3255	**0.1518**	0.4911	**0.1779**
	0.0001	0.0001	0.0001	0.9302	0.0005	0.0673	0.0026	0.0105	0.1845	0.0001	0.0518
	328	183	145	53	34	54	48	61	78	203	120
MEB	0.5029	0.5354	0.5113	**0.2390**	0.6954	**-0.0468**	0.3843	0.4923	0.3406	0.5732	0.3119
	0.0001	0.0001	0.0004	0.0848	0.0001	0.7371	0.0070	0.0001	0.0023	0.0001	0.0005
	328	183	145	53	34	54	48	61	78	203	120
weight	0.5270	0.6017	0.5762	**0.3032**	0.6830	**0.0649**	**0.3097**	0.5113	0.4171	0.5524	0.3367
	0.0001	0.0001	0.0001	0.0273	0.0001	0.6409	0.0322	0.0001	0.0001	0.0001	0.0002
	328	183	145	53	34	54	48	61	78	203	120
height	0.4306	0.5754	0.5888	**0.2689**	0.4763	0.3641	**0.0191**	0.4293	0.4972	0.3358	0.2913
	0.0001	0.0001	0.0001	0.0516	0.0033	0.0068	0.8978	0.0006	0.0001	0.0001	0.0012
	330	185	145	53	36	54	48	61	78	205	120
SA	0.5131	0.6300	0.6161	**0.3011**	0.6203	**0.2084**	**0.1946**	0.5269	0.4898	0.4947	0.3411
	0.0001	0.0001	0.0001	0.0284	0.0001	0.1305	0.1851	0.0001	0.0001	0.0001	0.0001
	328	183	145	53	34	54	48	61	78	203	120
SA:V	-0.4823	-0.5052	-0.4808	**-0.1881**	-0.6863	**0.1169**	-0.4121	-0.4692	-0.2918	-0.5676	-0.2810
	0.0001	0.0001	0.0001	0.1774	0.0001	0.3998	0.0036	0.0001	0.0095	0.0001	0.0019
	328	183	145	53	34	54	48	61	78	203	120

The three values listed for each group-by-variable intersection are (from top to bottom): r_s, two-tailed *p* value, and N
Since most correlations are significant at $p < .01$, **non-significant** correlations are in **boldface**

Table 3.
Correlations with Latitude: Excluding Europeans or Pacific Islanders, and with Ruff's (1994) Sample

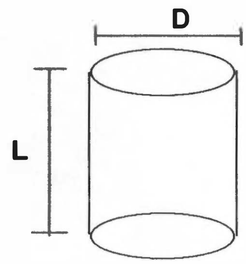
Variable	Excluding Europeans	Excluding Pacific Isl.	Ruff's (1994) data
BMI	0.2408	0.4855	0.5820
	0.0001	0.0001	0.0001
	274	258	56
MEB	0.3643	0.5869	0.6538
	0.0001	0.0001	0.0001
	274	258	56
weight	0.3942	0.5808	0.6467
	0.0001	0.0001	0.0001
	274	258	56
height	0.3351	0.3562	**0.2729**
	0.0001	0.0001	0.0419
	276	260	56
SA	0.3939	0.5225	0.5603
	0.0001	0.0001	0.0001
	274	258	56
SA:V	-0.3420	-0.5757	-0.6528
	0.0001	0.0001	0.0001
	274	258	56

The three values listed for each group-by-variable intersection are (from top to bottom): r_s, two-tailed *p* value, and N
Since most correlations are significant at $p < .01$, **non-significant** correlations are in **boldface**

Table 4.
Correlations with other Anthropometric Variables

variable	latitude	BMI	MEB	weight	height	SA	SA:V
weight	(see Table 2)	0.7464	0.9564	-	-	0.9626	-0.9213
		0.0001	0.0001			0.0001	0.0001
		331	331			331	331
height	(see Table 2)	0.1656	0.5504	0.7542	-	0.8947	-0.4653
		0.0025	0.0001	0.0001		0.0001	0.0001
		331	331	331		331	331
sitting height	0.4150	0.3069	0.5832	0.7209	0.7316	0.7842	-0.5195
	0.0001	0.0008	0.0001	0.0001	0.0001	0.0001	0.0001
	113	116	116	116	116	116	116
relative sitting height	0.2920	0.5131	0.3169	**0.1469**	-0.3062	**-0.0300**	-0.3739
	0.0017	0.0001	0.0005	0.1155	0.0008	0.7496	0.0001
	113	116	116	116	116	116	116
bi-acromial breadth	**0.2207**	**0.2542**	0.5656	0.7073	0.7006	0.7523	-0.4968
	0.0705	0.0351	0.0001	0.0001	0.0001	0.0001	0.0001
	68	69	69	69	69	69	69
bi-iliac breadth	0.6270	0.5199	0.5193	0.4927	**0.1277**	0.3940	-0.5147
	0.0001	0.0001	0.0001	0.0001	0.3108	0.0012	0.0001
	64	65	65	65	65	65	65

The three values listed for each group-by-variable intersection are (from top to bottom): r_s, two-tailed p value, and N
Since most correlations are significant at $p < .01$, **non-significant correlations** are in **boldface**



D = diameter
L = length or height
SA = surface area
V = volume or weight, mass

Partial rendering of Ruff's (1991:83) cylindrical model of the lateral surface area:volume (SA:V) ratio:

lateral SA = πDL

V = $^{\pi}/_{4}\, D^2L$

lateral SA:V = $4/D$

Total SA:V ratio:

total SA = $\pi DL + 2\pi\ ^{1}/_{4}D^2$

total SA:V = $4/D + 2/L$

Cylindrical model of the body mass index (BMI):

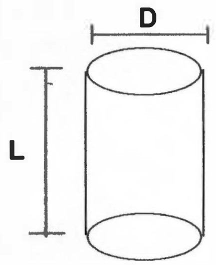
BMI = weight/height^2

= V/L^2

= $(^{\pi}/_{4}\, D^2L)/L^2$

= $\pi D^2/(4L)$

Figure 1.
Cylindrical Model of the Body Mass Index vs. the Surface Area:Volume Ratio



D = diameter
L = length or height
V = volume or weight

$$V = {}^{\pi}/_{4}\, D^2 L$$

- substitute weight in kg for V
- substitute height in cm for L
- to solve for D, the equation reduces to:

D = square root (weight/(.785 height))

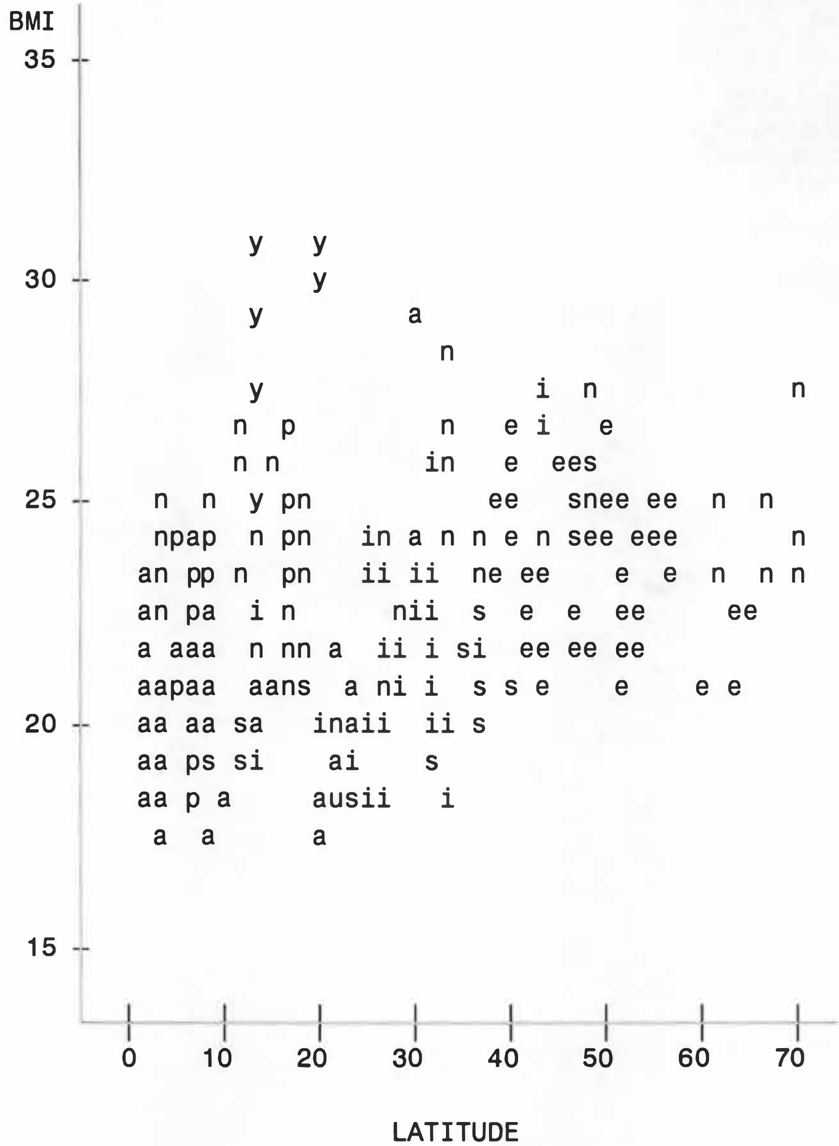
- here, D is called the "mean effective breadth" (MEB)
- to express the MEB in cm, weight in kg is multiplied by 1,000 (in other words, weight is expressed in grams) to convert it to cm^3
- the resulting formula is:

MEB in cm = square root ((1,000 weight in kg)/(.785 height in cm))
= 35.69 $(W^{.5}/H^{.5})$

- the first formula would be easier to solve if one were using a hand-held calculator

Figure 2.
Derivation of the Mean Effective Breadth

Plot of BMI*LATITUDE. Symbol is value of ETCLASS.

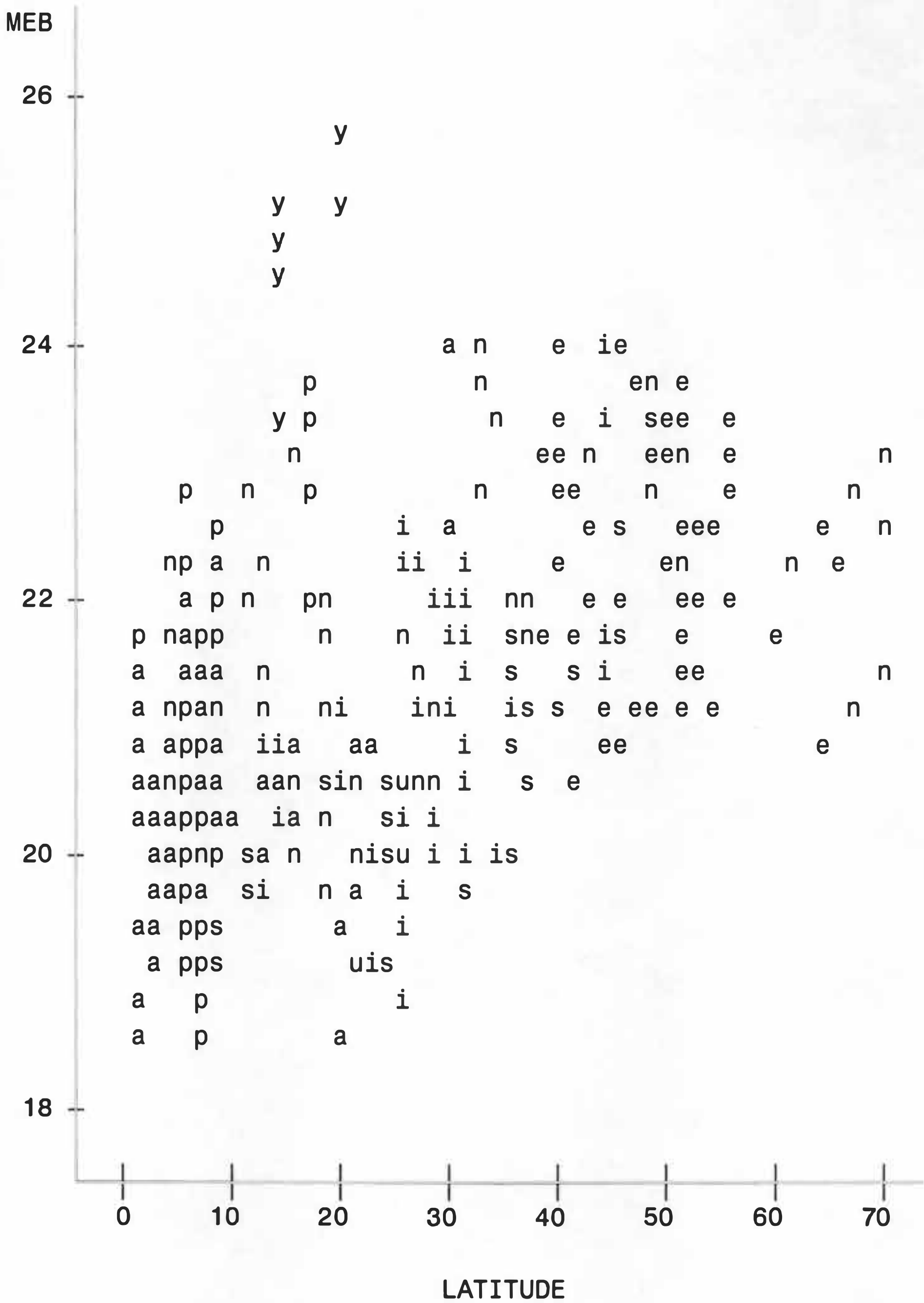


NOTE: 5 obs had missing values. 158 obs hidden.

Key: a=Africans, s=Asians, i=Indo-Mediterraneans, e=Europeans, n=Native Americans, u=Australian Aborigines, y=Polynesians, p=Pacific Islanders (non-Australian, non-Polynesian)

Figure 3. Plots of Variables vs. Latitude
a. BMI

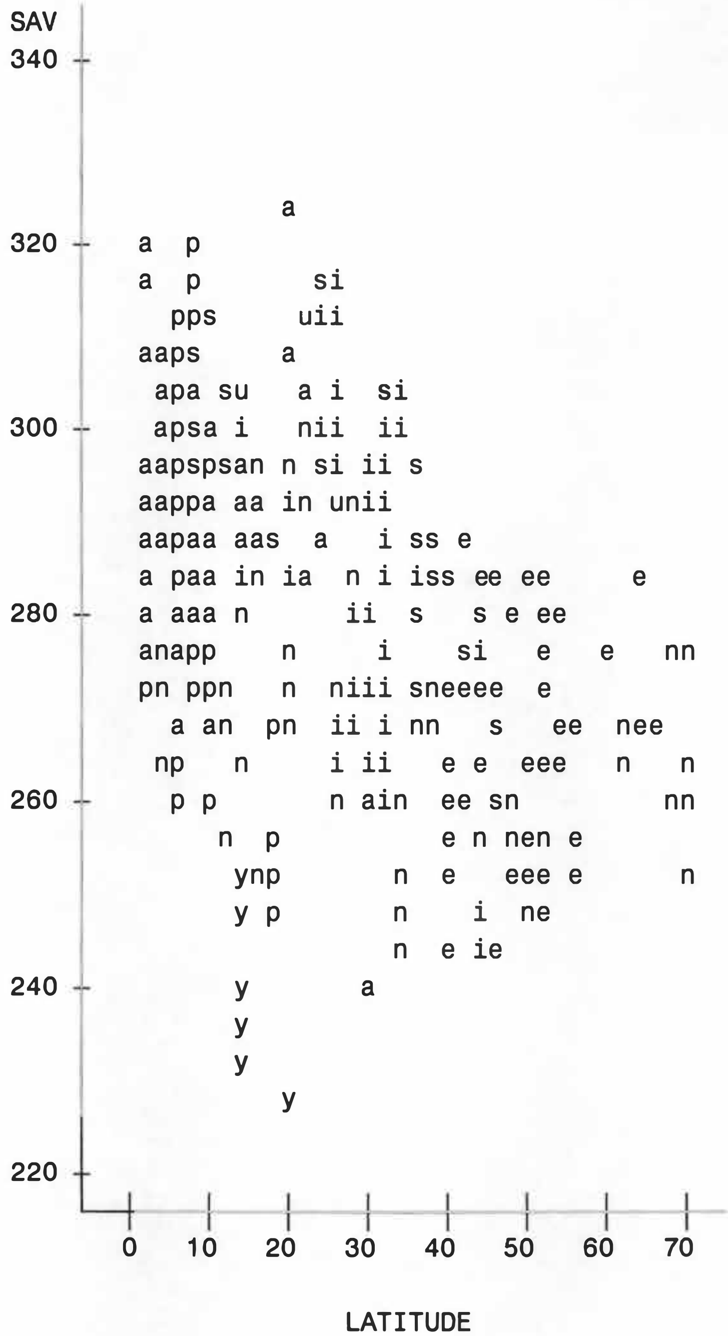
Plot of MEB*LATITUDE. Symbol is value of ETCLASS.



NOTE: 5 obs had missing values. 106 obs hidden.

b. MEB

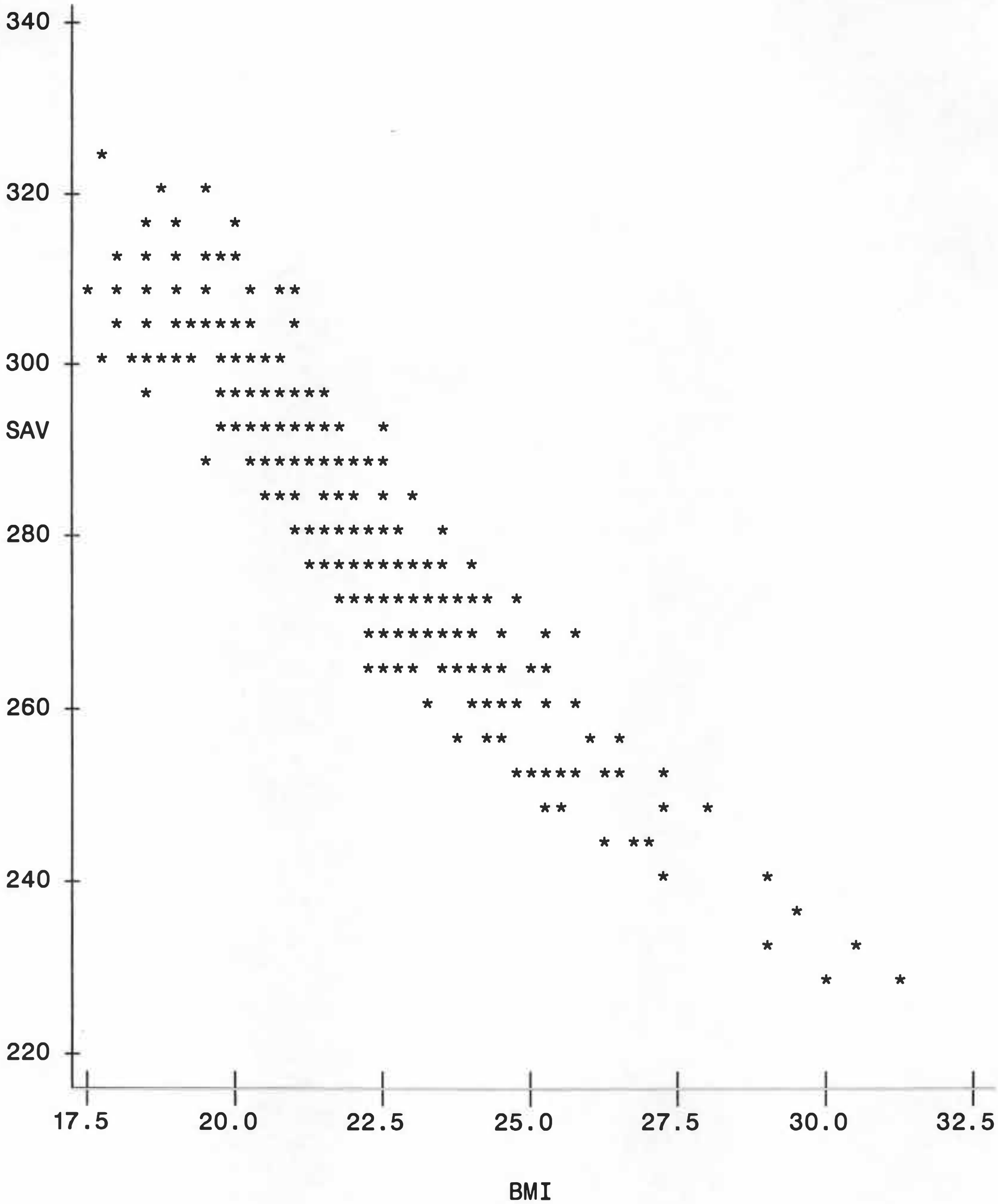
Plot of SAV*LATITUDE. Symbol is value of ETCLASS.



NOTE: 5 obs had missing values. 117 obs hidden.

c. SA:V ratio

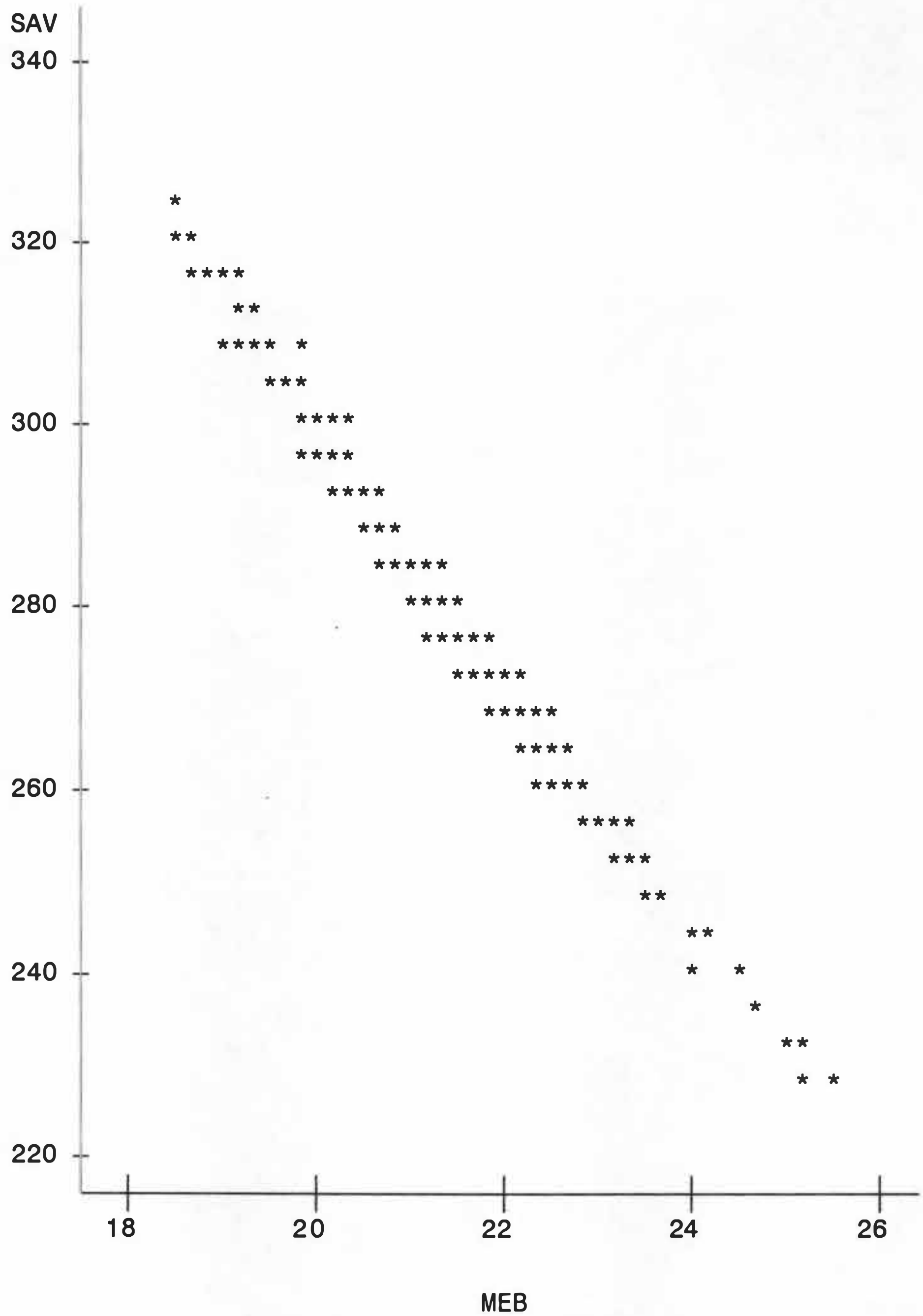
Plot of SAV*BMI. Symbol used is '*'.



NOTE: 2 obs had missing values. 165 obs hidden.

Figure 4. Plots of SA:V Ratio vs. Variables
a. BMI

Plot of SAV*MEB. Symbol used is '*'.



NOTE: 2 obs had missing values. 249 obs hidden.

b. MEB

Appendix B: Worldwide Sample

	A	B	C	D	E	F	G	H	I	J	K	L
1	ID #	latitude degrees	pole n or s	group/location/number* see Notes on page 76	sex** see Notes	age*** see Notes	height cm	weight kg	BMI kg/m^2	MEB cm	sitting height cm	bi-acromial breadth cm
2	1	39	n	Greek Students	1	students	172.2	73	24.62	23.24	.	.
3	2	39	n		0	students	159.1	58.7	23.19	21.68	.	.
4	3	40	n	W Armenians	1	adults	169.19	76.95	26.88	24.07	89.45	.
5	4	40	n	45f 61m	0	adults	156.07	60.9	25	22.3	83.94	.
6	5	40	n	E Armenians	1	adults	171.54	71.93	24.44	23.11	90.52	.
7	6	40	n	30f 34m	0	adults	155.93	63.48	26.11	22.77	83.43	.
8	7	40	n	Madrid, Spain	1		168.25	72.9	25.75	23.49	.	.
9	8	40	n	125f 119m	0		156.83	61.88	25.16	22.42	.	.
10	9	44	n	Bucharest, Rumania	1	students	171.2	60.7	20.71	21.25	.	38.1
11	10	44	n		0	students	157.1	53.9	21.84	20.91	.	35.4
12	11	49	n	Paris, France	1	students	174.3	73.9	24.32	23.24	.	.
13	12	49	n		0	students	161.4	56.2	21.57	21.06	.	.
14	13	50	n	Czechs, Czechoslovakia	1	25-39	173.5	75.3	25.01	23.51	.	.
15	14	50	n		0	25-39	161.0	63.5	24.5	22.42	.	.
16	15	51	n	Cracow, Poland	1	21-25	173.2	69	23	22.53	90	.
17	16	51	n		0	21-25	160.2	59	22.99	21.66	84	.
18	17	51	n	Brussels, Belgium	1	21-25	174.5	66.9	21.97	22.1	.	39.9
19	18	51	n		0	21-25	162.0	56.2	21.41	21.02	.	35.8
20	19	51	n	Leipzig, Germany	1	students	175.0	69.6	22.73	22.51	.	.
21	20	51	n		0	students	163.4	59.3	22.21	21.5	.	.
22	21	52	n	London, England	1	18-25	178.1	70.7	22.29	22.49	.	.
23	22	52	n	25f 21m	0	18-25	166.5	58.2	20.99	21.1	.	.
24	23	52	n	Oxfordshire Villagers, UK	1	adults	173.9	76.4	25.26	23.66	.	40
25	24	52	n	434f 439m	0	adults	161.1	63.9	24.62	22.48	.	36.4
26	25	53	n	Netherlands	1	25	177.7	71.4	22.61	22.62	.	.
27	26	53	n		0	25	166.3	60	21.7	21.44	.	.
28	27	55	n	Northern England	1	16-64	173.3	73.95	24.62	23.31	.	.
29	28	55	n	large N not split by group	0	16-64	160.0	61.4	23.98	22.11	.	.

	A	B	C	D	E	F	G	H	I	J	K	L
30	29	56	n	Scotland	1	16-64	173.0	72.6	24.26	23.12	.	.
31	30	56	n		0	16-64	160.0	60.3	23.55	21.91	.	.
32	31	43	n	sofia bulgaria	1	24	171.3	68.8	23.45	22.62	89.6	37.7
33	32	43	n		0	24	160.2	60.2	23.46	21.88	84.6	34.4
34	33	56	n	national denmark	m	20-49	172.0	74.7	25.25	23.52	90.4	39.3
35	34	60	n	helsinki finland constripts	m		176.2	65.9	21.23	21.83	.	.
36	35	46	n	national france conscripts	m		169.2	64.3	22.46	22	.	.
37	36	47	n	railway wrkr hungary	m		170.9	74.6	25.54	23.58	89	39.2
38	37	41	n	naples italy	1	21	174.4	71	23.34	22.77	.	.
39	38	41	n		0	21	162.5	60.5	22.91	21.78	.	.
40	39	64	n	national norway conscripts	m		177.5	70.1	22.25	22.43	91.2	.
41	40	52	n	warsaw poland	1	18-20	173.0	64	21.38	21.71	.	39.6
42	41	52	n		0	18-20	158.9	56	22.18	21.19	.	35.2
43	42	52	n	port talbot uk steel wrkrs	m	20-29	174.2	75.4	24.85	23.48	.	.
44	43	54	n	national uk BP staff	1	20-24	176.5	70.1	22.5	22.49	.	.
45	44	54	n		0		163.6	58.1	21.71	21.27	.	.
46	45	56	n	moscow russia	m		171.8	71.3	24.16	22.99	.	.
47	46	50	n	national czech	f	20-49	159.5	67.3	26.45	23.18	84.8	36.2
48	47	64	n	finland students	f		165.0	56.8	20.86	20.94	.	.
49	48	46	n	national france	f	20-34	160.4	55.5	21.57	20.99	85.1	35.8
50	49	47	n	hungary students	f	18-25	159.8	56.2	22.01	21.17	84.5	36.6
51	50	53	n	ireland	f	mean 28	159.8	61.5	24.08	22.14	86	.
52	51	41	n	sassari prov italy	f		155.4	51.4	21.28	20.53	.	35.4
53	52	48	n	basel switzerland students	f		165.0	58	21.3	21.16	.	.
54	53	45	n	Italy padova northern 197	m	20-59/36.68	174.02	79.3	26.19	24.09	.	.
55	54	22	s	botswana bushmen n=15	m		157.8	47.7	19.16	19.62	.	.
56	55	9	n	chad rural sara m=238	1	young ad	173.5	66.8	22.19	22.15	89	38.4
57	56	9	n	f=269	0	young ad	163.9	58.3	21.7	21.29	84.6	34.5
58	57	3	.	congo fulero n=100	m		159.1	47.8	18.88	19.56	81.3	34.8
59	58	3	.	congo tutsi n=100	m		173.5	55.7	18.5	20.22	85.9	35.7
60	59	7	.	congo congolese n=32	1		167.8	59.1	20.99	21.18	86.8	.
61	60	7	.	f=26	0	18.5	156.7	48.2	19.63	19.79	81.4	.
62	61	1	s	congo twa pygmies n=23	m		160.0	51.2	20	20.19	.	.

	A	B	C	D	E	F	G	H	I	J	K	L
63	62	3	s	congo mbaiki pygms n=15	m		151.8	46.1	20.01	19.67	.	.
64	63	2	n	congo bunia pygms m=14	1		145.0	40	19.02	18.75	.	.
65	64	2	n	f=21	0		138.0	37	19.43	18.48	.	.
66	65	5	n	congo kasai n=214	m	23.4 mean	166.9	60	21.54	21.4	71.8	37.5
67	66	9	s	congo katanga n=112	m	29.8 mean	164.3	56.6	20.97	20.95	70.6	36.8
68	67	14	n	gambia	1		166.6	54.9	19.78	20.49	.	.
69	68	14	n		0		158.0	52.2	20.91	20.52	.	.
70	69	4	s	kenya samburu n=153	m		175.3	54	17.57	19.81	.	.
71	70	13	s	malawi bantu m=23	1	20-29	165.7	55.7	20.29	20.69	.	.
72	71	13	s	f=119	0	20-29	154.1	48.6	20.47	20.04	.	.
73	72	9	n	nigeria akufo(yoruba)n=340	1		167.5	56.2	20.03	20.67	.	.
74	73	9	n	f=205	0		155.0	51.8	21.56	20.63	.	.
75	74	7	n	nigeria ibadan slum m101	1		168.7	60.1	21.12	21.3	.	.
76	75	7	n	f=239	0		158.3	52.9	21.11	20.63	.	.
77	76	6	n	nigeria lagos m=89	1	30-39	168.9	62.7	21.98	21.75	.	.
78	77	6	n	f=131	0	30-39	158.5	60.5	24.08	22.05	.	.
79	78	2	s	rwanda tutsi n=177	m		176.5	57.4	18.43	20.35	87.7	36.8
80	79	2	s	rwanda hutu n=184	m		167.1	57.5	20.59	20.94	.	.
81	80	23	s	so africa venda(rural)n199	m	41.5 mean	166.5	56.8	20.49	20.85	84.7	37.3
82	81	23	s	so africa venda(rural)n134	m	20-29	167.6	56.8	20.22	20.78	.	36.6
83	82	30	s	so af durban zulus m=106	1	20+	166.1	66.9	24.25	22.65	.	.
84	83	30	s	f=219	0	20+	156.0	70.8	29.09	24.04	.	.
85	84	9	n	sudan dinka n=279	m		181.6	58.2	17.65	20.21	.	.
86	85	10	n	sudan shilluk n=48	m		178.6	58.1	18.21	20.36	.	.
87	86	3	s	tanzania hadza m=36	1	25-34	160.5	53.6	20.81	20.63	.	.
88	87	3	s	f=31	0	25-34	150.0	47.7	21.2	20.13	.	.
89	88	2	n	uganda baganda rural m61	1	25-34	163.6	59	22.04	21.43	.	.
90	89	2	n	f=66	0	25-34	156.2	56.3	23.08	21.43	.	.
91	90	3	s	congo bayenga pygm n42	f		135.8	38.5	20.88	19	.	.
92	91	2	.	congo bayenga bantu	f		154.0	54.2	22.85	21.17	.	.
93	92	2	s	rwanda tutsi n=28	f	19.5-20.5	161.8	52.8	20.17	20.39	.	33.9
94	93	2	s	rwanda hutu n=25	f	18.5-19.5	155.9	52.1	21.44	20.63	.	34
95	94	21	n	sudan nubians n=282	f	18-45	157.4	53.6	21.63	20.83	.	.

	A	B	C	D	E	F	G	H	I	J	K	L
96	95	4	n	CAR bagandu&issongo 50	1		161.2	54.6	21.01	20.77	81.6	.
97	96	4	n	f=62	0		154.4	50.4	21.14	20.39	78	.
98	97	15	n	sudan fur m=359	1		167.9	57.6	20.43	20.91	.	.
99	98	15	n	f=202	0		159.2	51.8	20.44	20.36	.	.
100	99	4	n	Turkana, Kenya	1	20-29	172.4	53.5	18	19.88	.	.
101	100	4	n	28each	0	20-29	166.1	50	18.12	19.58	.	.
102	101	2	n	Lese, Ituri Forest, Zaire	1	21-65	159.3	53.8	21.2	20.74	.	.
103	102	2	n	41f 35m	0	32-70	149.5	48.6	21.74	20.35	.	.
104	103	2	n	Efe Pygmies, Ituri Forest	1	20-60	146.4	43.2	20.16	19.39	.	.
105	104	2	n	26f 23m	0	20-60	138.63	38.27	19.91	18.75	.	.
106	105	20	s	Dobe !Kung	1	15-83	160.92	47.91	18.5	19.47	.	.
107	106	20	s	74f 79m	0	15-75	150.14	40.08	17.78	18.44	.	.
108	107	44	n	North Pag Island, Croatia 97	1	19-84	172.49	78.12	26.26	24.02	90.48	40.56
109	108	44	n	(indo=yugo/eur=locatn)139f	0	19-84	158.84	68.72	27.24	23.48	84.8	36.72
110	109	44	n	Yugoslavia (Gypsies)	1	21-30	167.4	61.6	21.98	21.65	.	33.1
111	110	44	n	43f 29m	0	21-30	154.8	55.1	22.99	21.29	.	30.1
112	111	29	n	Salme Village, Nepal	1		159.0	51.65	20.43	20.34	.	.
113	112	29	n	39f 35m	0		151.0	47.9	21.01	20.1	.	.
114	113	26	n	Kolis of Rajasthan	1		163.8	48.2	17.96	19.36	81.3	35.8
115	114	26	n	100each m and f	0		151.7	42.7	18.55	18.94	74.5	30.6
116	115	30	n	Shiraz, Iran	1	25-69	169.8	68	23.58	22.59	.	.
117	116	30	n	926f 882m	0	20-59	158.9	58.6	23.21	21.67	.	.
118	117	30	n	Multan, Pakistan	1	14-65	169.3	63.92	22.3	21.93	.	.
119	118	30	n	245f 1334m	0	14-65	156.92	55.35	22.48	21.2	.	.
120	119	25	n	Santal of Bihar, India	1	21-45	159.42	46.7	18.38	19.32	80.31	35.82
121	120	25	n	100each m and f	0	21-45	151.74	45.5	19.76	19.54	76.82	34.38
122	121	14	n	india madras	m	35 mean	165.2	56.8	20.81	20.93	.	.
123	122	20	n	india ooty	m	34 mean	164.4	54	19.98	20.46	.	.
124	123	23	n	india gujarat m99	1	adults	164.1	51.2	19.01	19.94	.	.
125	124	23	n	f83	0	adults	151.4	43.6	19.02	19.15	.	.
126	125	20	n	india students 86	m	22	171.6	60.1	20.41	21.12	.	.
127	126	31	n	egypt alexandria	1	young ad	171.6	67	22.75	22.3	.	.
128	127	31	n		0	young ad	159.2	58.3	23	21.6	.	.

	A	B	C	D	E	F	G	H	I	J	K	L
129	128	25	n	saudia arabia 250	m	young ad	165.5	65.8	24.02	22.51	.	.
130	129	13	n	yemen democ rural	f	mothers	151.4	51.5	22.47	20.82	.	.
131	130	28	n	algeria students 96	1	19-37	172.5	64.8	21.78	21.88	.	.
132	131	36	n	f29	0	19.2mean	160.8	56.1	21.7	21.08	.	.
133	132	27	n	egypt farmers 28	m	19-68	166.1	59	21.39	21.27	.	.
134	133	27	n	egypt professionals 33	m	19-68	169.2	65.7	22.95	22.24	.	.
135	134	14	n	ethiopia debarech 81	1		167.3	56.8	20.29	20.8	84.5	37.9
136	135	14	n	f37	0		156.6	50	20.39	20.17	.	.
137	136	13	n	ethiopia adi-arkai 68	1		168.8	53.6	18.81	20.11	85.6	38.1
138	137	13	n	f35	0		152.6	47	20.18	19.81	.	.
139	138	31	n	india punjab	1	17-21	168.3	55.6	19.63	20.51	87.8	.
140	139	31	n		0	17-21	155.8	48.4	19.94	19.89	82.6	.
141	140	34	n	india jammu & kashmir	1	17-21	167.5	52.1	18.57	19.91	88.2	.
142	141	34	n		0	17-21	156.1	48.6	19.94	19.92	83.4	.
143	142	26	n	india lahaulis 131/lalauli	m		161.8	52.3	19.98	20.29	84.7	.
144	143	26	n	india assam 51	1	20-21	163.0	52.4	19.72	20.24	84.5	.
145	144	26	n	f 51	0	20-21	155.2	47.8	19.84	19.81	80.1	.
146	145	32	n	iran village	1	20-30	164.4	59.4	21.98	21.45	.	.
147	146	32	n	f	0	26-31	152.3	51.9	22.38	20.84	.	.
148	147	32	n	israel kurdish jews 56	1	20-30	167.6	66.0	23.5	22.4	89.6	39.5
149	148	32	n	f41	0	20-30	152.6	59.7	25.64	22.32	82.3	34.5
150	149	32	n	israel yemenite jews 33	1	20-30	162.2	61.7	23.45	22.01	87	37.8
151	150	32	n	f34	0	20-30	152.0	51.1	22.12	20.69	80.2	33.5
152	151	32	n	pakistan lahore 192	1	22-35	166.8	55.6	19.98	20.61	.	.
153	152	32	n	f=221	0	22-35	152.8	48.6	20.82	20.13	.	.
154	153	25	n	saudi arab/bedouin arabs19	m	27.4 mean	167.2	64.7	23.14	22.2	.	.
155	154	32	n	iran urban n=120	f	>19	152.3	50.8	21.9	20.61	.	.
156	155	25	s	aust abor m=22	1	25-29	168.6	56.2	19.77	20.61	79.9	.
157	156	25	s	22f	0	25-29	156.8	48.9	19.89	19.93	75.3	.
158	157	17	s	fiji 130	1	25-29	172.0	71.4	24.13	23	.	.
159	158	17	s	142f	0	25-29	161.8	62	23.68	22.09	.	.
160	159	6	s	ng(=newguinea)bundi 214	1		156.5	53.7	21.93	20.91	82.2	.
161	160	6	s	214f	0		147.9	45.6	20.85	19.82	77	.

	A	B	C	D	E	F	G	H	I	J	K	L
162	161	6	s	ng kaiapit 102	1		166.1	59.6	21.6	21.38	.	.
163	162	6	s	102f	0		156.8	52.8	21.48	20.71	.	.
164	163	6	s	ng chimbu 74	1		157.4	55.6	22.44	21.21	.	.
165	164	6	s	74f	0		149.3	49.3	22.12	20.51	.	.
166	165	2	s	ng manus 20	1	21-25	162.9	60.2	22.69	21.7	.	.
167	166	2	s	20f	0	21-25	151.0	48.2	21.14	20.17	.	.
168	167	6	s	ng asai valley 125	1	20-29	150.4	45.3	20.03	19.59	79.1	.
169	168	6	s	125f	0	20-29	142.7	41.4	20.33	19.22	75.8	.
170	169	6	s	ng lumi 20	1	22	157.9	51.7	20.74	20.42	.	.
171	170	6	s	20f	0	22	148.9	45.8	20.66	19.79	.	.
172	171	5	s	ng karkar isl 115	1	21-35	161.0	56.4	21.76	21.12	84	36.2
173	172	5	s	115f	0	21-35	151.7	47	20.42	19.87	79.3	32.1
174	173	7	s	ng lufa 107	1	21-35	160.3	58.5	22.77	21.56	84.4	37.3
175	174	7	s	107f	0	21-35	151.6	49.2	21.41	20.33	79.6	33.7
176	175	6	s	ng kukukuku 59	1		151.2	49.2	21.52	20.36	.	.
177	176	6	s	59f	0		142.7	42.8	21.02	19.55	.	.
178	177	6	s	ng megiar 30	1		161.9	52.9	20.18	20.4	.	.
179	178	6	s	30f	0		151.5	47.3	20.61	19.94	.	.
180	179	6	s	ng okapa 78	1		155.1	52.6	21.87	20.79	.	.
181	180	6	s	78f	0		147.8	47.7	21.84	20.28	.	.
182	181	6	s	ng wosera 39	1		155.9	51.6	21.23	20.53	.	.
183	182	6	s	39f	0		146.6	42.3	19.68	19.17	.	.
184	183	6	s	ng kalabu 69	1		156.2	54.5	22.34	21.08	.	.
185	184	6	s	69f	0		147.2	45.9	21.18	19.93	.	.
186	185	6	s	ng baiger vs baiyer 68	1		158.6	56.8	22.58	21.36	.	.
187	186	6	s	68f	0		147.1	46.5	21.49	20.07	.	.
188	187	6	s	ng simbai 139	1		148.8	45.1	20.37	19.65	.	.
189	188	6	s	139f	0		137.0	38.9	20.73	19.02	.	.
190	189	6	s	ng wabag 98	1		158.3	61.6	24.58	22.26	.	.
191	190	6	s	98f	0		149.0	52	23.42	21.09	.	.
192	191	14	s	wstrn samoa salamumu101	1	<45	170.4	73.4	25.28	23.42	.	.
193	192	14	s	f144	0	<45	158.3	68.4	27.3	23.46	.	.
194	193	14	s	am sam manu'a islands 43	1	<45	172.8	81.2	27.19	24.47	.	.

	A	B	C	D	E	F	G	H	I	J	K	L
195	194	14	s	f88	0	<45	162.7	77.9	29.43	24.7	.	.
196	195	14	s	am sam tutuilia 425	1	<45	170.8	84.8	29.07	25.15	.	.
197	196	14	s	f610	0	<45	160.3	78.3	30.47	24.94	.	.
198	197	20	n	hawaii samoans 182	1	<45	171.5	88.1	29.95	25.58	.	.
199	198	20	n	f280	0	<45	160.1	80	31.21	25.23	.	.
200	199	7	s	png wopkaimin 47	1	20-25	159.6	58.8	23.08	21.66	82.5	.
201	200	7	s	f58	0	20-25	149.5	49.1	21.97	20.45	77.7	.
202	201	7	s	png ningerum 55	1		157.5	51.7	20.84	20.45	.	.
203	202	7	s	f59	0		146.9	40.8	18.91	18.81	.	.
204	203	7	s	png awin 56	1		158.4	52.5	20.92	20.55	.	.
205	204	7	s	f77	0		147.1	42.3	19.55	19.14	.	.
206	205	7	s	png yonggom 23	1		155.6	52.1	21.52	20.65	.	.
207	206	7	s	f26	0		146.0	39.9	18.72	18.66	.	.
208	207	7	s	png gidra 332	1		165.2	55.7	20.41	20.72	.	.
209	208	7	s	f419	0		154.6	45.2	18.91	19.3	.	.
210	209	9	s	solomon isl aita 39	1	20-34	159.6	60.9	23.91	22.05	84.6	.
211	210	9	s	f49	0	20-34	149.9	54.1	24.08	21.44	79.1	.
212	211	9	s	sol isl nagovisi 29	1	20-34	160.5	58.6	22.75	21.57	84.1	.
213	212	9	s	f37	0	20-34	151.3	49.1	21.45	20.33	79.1	.
214	213	9	s	sol isl nasioi 28	1	20-34	163.2	58.2	21.85	21.31	84.3	.
215	214	9	s	f24	0	20-34	152.3	48.2	20.78	20.08	79.2	.
216	215	9	s	sol isl baegu 39	1	20-34	162.0	58.6	22.33	21.47	85.2	.
217	216	9	s	f42	0	20-34	150.8	49.1	21.59	20.37	79.1	.
218	217	9	s	sol isl kwaio 46	1	20-34	161.0	57.7	22.26	21.37	86.2	.
219	218	9	s	f49	0	20-34	149.7	48.6	21.69	20.34	80.1	.
220	219	9	s	sol isl lau 20	1	20-34	164.0	65.4	24.32	22.54	86.7	.
221	220	9	s	f38	0	20-34	153.4	55.9	23.76	21.55	81	.
222	221	9	s	sol isl ulawa 37	1	20-34	162.9	60.9	22.95	21.82	84	.
223	222	9	s	f51	0	20-34	151.0	50	21.93	20.54	78.2	.
224	223	5	s	sol isl ontong java 75	1	20-34	166.2	67.7	24.51	22.78	88.7	.
225	224	5	s	f119	0	20-34	156.0	59.5	24.45	22.04	83.1	.
226	225	13	s	Aust Abor. Arnhem Land	1	20-29	173.4	58.9	19.59	20.8	83.2	.
227	226	13	s	71f 67m	0	20-29	161.5	49.3	18.9	19.72	77.5	.

	A	B	C	D	E	F	G	H	I	J	K	L
228	227	17	s	Rural Qamea, Fiji	1		173.0	76	25.39	23.66	.	.
229	228	17	s	34f 37m	0		162.0	69	26.29	23.29	.	.
230	229	23	s	Aust. Aborigines Central	1		168.7	57.4	20.17	20.82	81.3	.
231	230	23	s	43f 44m	0		157.3	49.5	20.01	20.02	75.1	.
232	231	4	n	Trio, Surinam So America	1		157.7	58.2	23.4	21.68	79.8	36.7
233	232	4	n	142f 115m	0		147.5	48.7	22.38	20.51	75.5	33.5
234	233	9	s	Tanu, W Java	1	20-50+	155.3	48.6	20.15	19.97	.	.
235	234	9	s	37f 39m	0	20-50+	142.4	40.8	20.12	19.1	.	.
236	235	8	s	Jogjakarta, W Java	1		161.5	50.5	19.36	19.96	.	.
237	236	8	s		0		150.0	44	19.56	19.33	.	.
238	237	2	n	Iban of Sarawak, Malaysia	1	18-42	159.7	53.9	21.13	20.74	.	.
239	238	2	n	41f 43m	0		148.7	49	22.16	20.49	.	.
240	239	9	s	Quechua, Peru So Amer	1		160.0	55.9	21.84	21.1	84.5	.
241	240	9	s	50each m and f	0		148.0	54	24.65	21.56	80	.
242	241	46	n	Khalkha Mongols,Mongolia	1		164.8	66.5	24.49	22.67	87.6	.
243	242	46	n	49f 59m	0		151.3	56.3	24.59	21.77	82.2	.
244	243	16	n	Guatemalan Highlanders	1		160.7	53.9	20.87	20.67	.	.
245	244	16	n	49each m and f	0		147.7	45.8	20.99	19.88	.	.
246	245	19	s	Arica, Chile So America	1		161.5	62	23.77	22.11	.	.
247	246	19	s	63f 70m	0		149.1	56.3	25.33	21.93	.	.
248	247	35	n	Japanese-Ibaraki Area	1	18-23	169.6	61.2	21.28	21.44	90.6	39.6
249	248	35	n	93f 121m	0	18-23	158.9	53.8	21.31	20.77	85.2	35.7
250	249	36	n	Tokyo, Japan	1	18-29	167.2	58.9	21.07	21.18	.	38.5
251	250	36	n	112f 96m	0	18-23	155.3	48.9	20.28	20.03	.	34.6
252	251	21	n	Burma	1		167.9	55.8	19.79	20.58	.	.
253	252	21	n	m 221 f ?	0	19-24	153.2	47.7	20.32	19.92	.	.
254	253	24	n	Taiwan	1	17-29	167.6	52.6	18.73	19.99	90.4	.
255	254	24	n	29f 31m	0	19-38	154.3	49.3	20.71	20.17	85.1	.
256	255	26	s	Chaco, Argentina So Amer	1	20+	164.3	65.7	24.34	22.57	.	.
257	256	26	s	37f 29 m	0	20+	152.9	56.7	24.25	21.73	.	.
258	257	27	n	Bhutan	1	19+	169.2	60.6	21.17	21.36	87.1	.
259	258	27	n	28f 44m	0		161.1	52.8	20.34	20.43	84.3	.
260	259	67	n	Eskimos-Canadian Arctic	1	18-39	164.14	66.6	24.72	22.74	87.37	.

	A	B	C	D	E	F	G	H	I	J	K	L
261	260	67	n	m 396 f 321	0	18-39	153.16	54.21	23.11	21.23	82.33	.
262	261	70	n	Inuit of Igloolik, Cnda NWT	1	20-29	164.0	65	24.17	22.47	.	.
263	262	70	n	m70 f46	0	20-29	153.0	54.6	23.32	21.32	.	.
264	263	15	n	nic=nicaragua miskito 30	m		164.0	69.4	25.8	23.22	89.4	39.7
265	264	13	n	nic sumo n=20	m		158.6	61.4	24.41	22.21	.	40.2
266	265	12	n	nic rama n=27	m		163.3	61.6	23.1	21.92	86.9	38.9
267	266	13	n	nic subtiava n=25	m		163.3	57.3	21.49	21.14	84.8	39.8
268	267	2	s	ecuador chachi 25	1	25-29	156.1	56.6	23.23	21.49	85.3	.
269	268	2	s	f=25	0	25-39	145.0	48.3	22.97	20.6	78.8	.
270	269	19	s	chile aymara altiplana m70	1	44	163.0	61.1	23	21.85	85.8	32.8
271	270	19	s	f=90	0	44	150.0	52.8	23.47	21.18	80	29.5
272	271	13	s	peru quechua lowlnd n=57	1	20-40	163.1	58.5	21.99	21.38	.	.
273	272	13	s	n=60	0	20-40	149.8	47	20.94	19.99	.	.
274	273	.	.	brazil xavante m=42	1		170.2	69.8	24.1	22.86	87.8	.
275	274	.	.	39	0	>18	156.3	57.9	23.7	21.72	81.3	.
276	275	1	n	brazil cayapo 110	1	>15	165.4	61.4	22.44	21.75	84.9	.
277	276	1	n	156	0	>15	153.9	51.6	21.79	20.67	79.9	.
278	277	28	s	brazil caingang 354	1	18-45	161.0	56.3	21.72	21.11	82.4	.
279	278	28	s	219	0		149.1	50	22.49	20.67	.	.
280	279	13	n	cambodia	m		165.0	56.8	20.86	20.94	.	.
281	280	24	n	formosa 54	1	21	166.8	56	20.13	20.68	.	.
282	281	24	n	19	0	21	155.3	44.5	18.45	19.11	.	.
283	282	16	n	guatemala maya 42	m		156.8	54.2	22.04	20.98	85.1	31.6
284	283	16	n	guatemala maya 20	f	17+	142.8	45.7	22.41	20.19	78.4	33.2
285	284	8	s	indonesia west java	1		158.0	50.5	20.23	20.18	.	.
286	285	8	s		0		150.0	44	19.56	19.33	.	.
287	286	44	n	japan ainu 21	m	18-27	161.7	57.1	21.84	21.21	.	.
288	287	36	n	japan military urban 160	m	18-29	167.7	62.5	22.22	21.79	.	.
289	288	36	n	japan military rural 350	m	25 mean	166.1	61.7	22.36	21.75	.	.
290	289	18	n	laos 136	m		163.2	54.7	20.54	20.66	.	.
291	290	.	n	mexico trigue m=101	m		156.4	50.8	20.77	20.34	83.2	36.5
292	291	12	s	peru cashinahua 12	1	30-39	155.0	63.5	26.43	22.84	.	.
293	292	12	s	26	0	30-39	145.3	54.5	25.81	21.86	.	.

	A	B	C	D	E	F	G	H	I	J	K	L
294	293	13	n	philippines national 36	1	20	164.6	52.2	19.27	20.1	.	.
295	294	13	n	45	0	20	151.1	48	21.02	20.12	.	.
296	295	37	n	south korea 280	1	23	170.1	59.7	20.63	21.14	.	.
297	296	37	n	49	0	23	156.2	51.9	21.27	20.57	.	.
298	297	11	n	south vietnam military2129	m	26.8 mean	160.5	51.1	19.84	20.14	.	.
299	298	11	n	south vietnam military n=78	m	30 mean	162.5	50	18.93	19.8	.	.
300	299	4	n	surinam wajana 75	1		156.6	61.3	25	22.33	79.9	37.4
301	300	4	n	91	0		146.2	51.4	24.05	21.16	75	33.3
302	301	15	n	thailand military 2950	m	24 mean	163.4	56	20.97	20.89	86.4	.
303	302	70	n	usa wainwright eskimo 43	1	>25	166.3	67.2	24.3	22.69	87.8	38.5
304	303	70	n	36	0	>25	155.8	66.3	27.31	23.28	83.7	35.6
305	304	33	n	usa apache 31	m	>20	168.4	69	24.33	22.85	.	.
306	305	34	n	usa western apache 31	m	20-27	170.2	74	25.55	23.53	.	40.3
307	306	51	n	usa blackfeet 38	1	20-39	177.4	74.7	23.74	23.16	.	.
308	307	51	n	46	0	20-39	164.8	64.2	23.64	22.28	.	.
309	308	48	n	usa fort belknap 27	1	20-39	173.7	73.9	24.49	23.28	.	.
310	309	48	n	42	0	20-39	160.4	65	25.26	22.72	.	.
311	310	33	n	usa seminole 44	1	42.5 mean	169.4	76.6	26.69	24	.	.
312	311	33	n	143	0	39.8 mean	157.2	69	27.92	23.65	.	.
313	312	23	n	south china guangdong 232	m	adult	160.7	.	.	.	.	.
314	313	39	n	north china soldiers 942	m	adult	167.6	.	.	.	.	.
315	314	42	n	Kirghiz, Kurgyzstan n=40	m	adult	165.3	59.7	21.85	21.45	.	.
316	315	48	n	Kazak, Kazakhstan n=30	m	adult	163.1	69.7	26.2	23.33	.	.
317	316	65	n	Iceland n=652	m	adult	173.6	68.1	22.6	22.35	.	.
318	317	40	n	Beijing, China n=49	m	adult	169.3	59.2	20.65	21.11	.	.
319	318	32	n	Miaozhan, China n=24	m	adult	154.0	46.4	19.56	19.59	.	.
320	319	7	s	Zoro, Aripuana Pk Brazil	1	35.9mean	160.0	55.9	21.84	21.1	.	.
321	320	7	s	44 each m and f	0	39.3mean	149.7	46.6	20.79	19.91	.	.
322	321	43	n	Seneca Iroquois NY n=507	m	30.7	173.3	72.8	24.24	23.13	.	.
323	322	36	n	Hopi n=276	m		161.1	60.8	23.43	21.93	.	.
324	323	35	n	Zuni n=348	m		161.4	56.3	21.61	21.08	.	.
325	324	49	n	Assiniboine Gros Ventres	1		171.8	75.4	25.55	23.64	.	.
326	325	49	n	m=77 f=100	0		159.4	69	27.16	23.48	.	.

	A	B	C	D	E	F	G	H	I	J	K	L
327	326	37	n	Navaho	1		169.5	65	22.62	22.1	.	.
328	327	37	n	m=272 f=245	0		156.0	58.1	23.87	21.78	.	.
329	328	62	n	Alaskan Athabascan	1		167.2	65	23.25	22.25	.	.
330	329	62	n	m=24 f=25	0		154.3	60.4	25.37	22.33	.	.
331	330	19	n	Nahua	1		154.8	49.5	20.66	20.18	83.1	37
332	331	19	n	100 each m and f	0		143.5	44.4	21.56	19.85	76.6	33.2
333	332	22	s	Aust Ab Yuendumu m=22	1	adult	169.791	56.71	19.67	20.63	79.245	34.45
334	333	22	s	f=20	0	adult	157.1	45.43	18.41	19.19	73.225	31.09
335												
336	**Notes:**											
337	*	Numbers in the group/location column = the sample size for that row (and is sometimes preceded by "n"). If the										
338		number is adjacent to "m" or "f", then it = the sample size for males or females, respectively, of that group.										
339	**	Females are denoted by "0" or "f", and males are denoted by "1" or "m". When sex is coded numerically, the data are										
340		on "matched pairs" of males and females sampled at the same time. Alpha sex codes are for data from sources										
341		reporting males only, or females only.										
342	***	Age is given as mean or range, whichever was reported. Blank age means age was reported as only "adult".										
343	[1]	Eveleth and Tanner (1976, 1990) classify populations into five broad categories: African, Asiatic (or Asian), Indo-										
344		Mediterranean (abbreviated "indomed" above), European, and Australian Aborigine/Pacific Island (abbreviated										
345		"austpaci" above). I added a sixth category, Native Americans ("native am" above), to separate New World Asiatics										
346		from Old World Asiatics.										
347	General: Blank boxes (e.g. in "group..." and "reference" columns) or "ibid" mean same entry as above applies.											

	M	N	O
1	bi-iliac breadth cm	Eveleth & Tanner classific.[1] see Notes	reference
2	.	european	Eveleth & Tanner 1976
3	.	european	p284 5a,b
4	.	european	RL Jantz printout 1980 (1979)
5	.	european	personal communication
6	.	european	RL Jantz printout 1980 (1979)
7	.	european	personal communication
8	.	european	Sanchez-Andres 1995
9	.	european	
10	27.9	european	Eveleth & Tanner 1976
11	27.9	european	p284 5a,b
12	.	european	Eveleth & Tanner 1976
13	.	european	p284 5a,b
14	.	european	Eveleth & Tanner 1976
15	.	european	p284 5a,b
16	.	european	Eveleth & Tanner 1976
17	.	european	
18	28.6	european	Eveleth & Tanner 1976
19	27.4	european	p284 5a,b
20	.	european	Eveleth & Tanner 1976
21	.	european	p284 5a,b
22	.	european	Davies et al. 1986
23	.	european	
24	.	european	Hiorns & Harrison 1985
25	.	european	
26	.	european	Eveleth & Tanner 1976
27	.	european	p284 5a,b
28	.	european	Rosenbaum et al. 1985
29	.	european	

	M	N	O
30	.	european	Rosenbaum et al. 1985
31	.	european	
32	28.1	european	Eveleth & Tanner 1976 t5ab
33	27.5	european	males table 5a 284-5
34	28.5	european	females table 5b286-7
35	.	european	ibid
36	.	european	ibid
37	.	european	ibid
38	.	european	ibid
39	.	european	ibid
40	.	european	ibid
41	24.8	european	ibid
42	23.8	european	ibid
43	.	european	ibid
44	.	european	ibid
45	.	european	ibid
46	.	european	ibid
47	28.3	european	ibid
48	.	european	ibid
49	29.8	european	ibid
50	.	european	Eveleth&Tanner1976t5ap287
51	29.2	european	ibid
52	27.5	european	ibid
53	.	european	ibid
54	.	european	Folin & Contiero 1994
55	.	african	Eveleth & Tanner 1976:338-0
56	26.3	african	males table 44 p 338
57	25.7	african	females table 45 p 340
58	23.8	african	sitting ht(sh)estimated from ht and rel. sh
59	25.6	african	sitting ht(sh)estimated from ht and rel. sh
60	.	african	ibid
61	.	african	ibid
62	.	african	ibid

	M	N	O
63	.	african	ibid
64	.	african	ibid
65	.	african	ibid
66	25.2	african	sitting ht(sh)estimated from ht and rel. sh
67	24.7	african	sitting ht(sh)estimated from ht and rel. sh
68	.	african	ibid
69	.	african	ibid
70	.	african	ibid
71	.	african	ibid
72	.	african	ibid
73	.	african	ibid
74	.	african	ibid
75	.	african	ibid
76	.	african	ibid
77	.	african	ibid
78	.	african	ibid
79	26.5	african	sitting ht(sh)estimated from ht and rel. sh
80	.	african	ibid
81	25.6	african	ibid
82	25.3	african	ibid
83	.	african	ibid
84	.	african	ibid
85	.	african	ibid
86	.	african	ibid
87	.	african	ibid
88	.	african	ibid
89	.	african	ibid
90	.	african	ibid
91	.	african	ibid
92	25.2	african	ibid
93	23.9	african	ibid
94	23.5	african	ibid
95	.	african	ibid

	M	N	O
96	24.7	african	Eveleth & Tanner 1990 p274
97	.	african	table 37a
98	.	african	ibid
99	.	african	ibid
100	.	african	Little & Johnson 1986
101	.	african	small N, but no oth sample
102	.	african	Jenike 1996
103	.	african	
104	22.93	african	Shea & Bailey 1996
105	22.82	african	
106	.	african	Truswell & Hansen 1976
107	.	african	
108	28.3	indomed	Smolej-Narancic et al. 1994
109	29.08	indomed	
110	.	indomed	Eveleth & Tanner 1976
111	.	indomed	p 396 tables 77,78
112	.	indomed	Panter-Brick et al. 1992
113	.	indomed	
114	23.1	indomed	Mittal et al. 1992
115	27.2	indomed	
116	.	indomed	Ayatollahi & Carpenter 1993
117	.	indomed	
118	.	indomed	Khan et al. 1996
119	.	indomed	
120	.	indomed	Buzarbaruah 1992
121	.	indomed	
122	.	indomed	Eveleth & Tanner 1990 p309
123	.	indomed	table 60 p 309 for all
124	.	indomed	ibid
125	.	indomed	ibid
126	.	indomed	ibid
127	.	indomed	ibid
128	.	indomed	ibid

	M	N	O
129	.	indomed	ibid
130	.	indomed	ibid
131	27.6	indomed	Eveleth & Tanner 1976 396-7
132	.	indomed	table 77 p 396 for males
133	.	indomed	table 78 p 397 for females
134	.	indomed	ibid
135	26.9	indomed	ibid
136	.	indomed	ibid
137	25.2	indomed	ibid
138	.	indomed	ibid
139	25.9	indomed	ibid
140	28.4	indomed	ibid
141	27.6	indomed	ibid
142	28.5	indomed	ibid
143	.	indomed	ibid
144	.	indomed	ibid
145	.	indomed	ibid
146	.	indomed	ibid
147	.	indomed	ibid
148	27.6	indomed	ibid
149	27.7	indomed	ibid
150	25.4	indomed	ibid
151	25.8	indomed	ibid
152	.	indomed	ibid
153	.	indomed	ibid
154	.	indomed	ibid
155	.	indomed	ibid
156	.	austpaci	Eveleth & Tanner 1976:410-1
157	.	austpaci	males t 93 p 410
158	.	austpaci	females t 94 p 411
159	.	austpaci	ibid
160	.	austpaci	ibid
161	.	austpaci	ibid

	M	N	O
162	.	austpaci	ibid
163	.	austpaci	ibid
164	.	austpaci	ibid
165	.	austpaci	ibid
166	.	austpaci	ibid
167	.	austpaci	ibid
168	.	austpaci	ibid
169	.	austpaci	ibid
170	.	austpaci	ibid
171	.	austpaci	ibid
172	26.3	austpaci	ibid
173	25.7	austpaci	ibid
174	26.7	austpaci	ibid
175	25.6	austpaci	ibid
176	.	austpaci	ibid
177	.	austpaci	ibid
178	.	austpaci	ibid
179	.	austpaci	ibid
180	.	austpaci	ibid
181	.	austpaci	ibid
182	.	austpaci	ibid
183	.	austpaci	ibid
184	.	austpaci	ibid
185	.	austpaci	ibid
186	.	austpaci	ibid
187	.	austpaci	ibid
188	.	austpaci	ibid
189	.	austpaci	ibid
190	.	austpaci	ibid
191	.	austpaci	ibid
192	.	austpaci	Eveleth & Tanner 1990:320-1
193	.	austpaci	males t 67 p 320
194	.	austpaci	fem t 68 p 321

	M	N	O
195	.	austpaci	ibid
196	.	austpaci	ibid
197	.	austpaci	ibid
198	.	austpaci	ibid
199	.	austpaci	ibid
200	.	austpaci	ibid
201	.	austpaci	ibid
202	.	austpaci	ibid
203	.	austpaci	ibid
204	.	austpaci	ibid
205	.	austpaci	ibid
206	.	austpaci	ibid
207	.	austpaci	ibid
208	.	austpaci	ibid
209	.	austpaci	ibid
210	.	austpaci	ibid
211	.	austpaci	ibid
212	.	austpaci	ibid
213	.	austpaci	ibid
214	.	austpaci	ibid
215	.	austpaci	ibid
216	.	austpaci	ibid
217	.	austpaci	ibid
218	.	austpaci	ibid
219	.	austpaci	ibid
220	.	austpaci	ibid
221	.	austpaci	ibid
222	.	austpaci	ibid
223	.	austpaci	ibid
224	.	austpaci	ibid
225	.	austpaci	ibid
226	.	austpaci	Jones & White 1994
227	.	austpaci	sitting ht(sh)estimated from ht and rel. sh for m and f

	M	N	O
228	.	austpaci	Sutherland et al. 1995
229	.	austpaci	
230	.	austpaci	Norgan 1994b
231	.	austpaci	
232	.	native am	Eveleth & Tanner 1976
233	.	native am	p366 tables 61,62
234	.	asiatic	Koyama et al.1988
235	.	asiatic	
236	.	asiatic	Eveleth & Tanner 1976
237	.	asiatic	p366 tables 61,62
238	.	asiatic	Strickland & Ulijaszek 1993
239	.	asiatic	
240	.	native am	Eveleth & Tanner 1976
241	.	native am	p366 tables 61,62
242	.	asiatic	ibid
243	.	asiatic	ibid
244	.	native am	Diaz et al. 1991
245	.	native am	
246	.	native am	Eveleth & Tanner 1976
247	.	native am	p366 tables 61,62
248	26.6	asiatic	Hattori et al. 1991
249	25.4	asiatic	
250	27.5	asiatic	Eveleth & Tanner 1976
251	27.4	asiatic	p366 tables 61,62
252	.	native am	ibid
253	.	native am	ibid
254	.	asiatic	ibid
255	.	asiatic	ibid
256	.	native am	ibid
257	.	native am	ibid
258	.	native am	ibid
259	.	native am	ibid
260	.	native am	Schaefer 1977

	M	N	O
261	.	native am	
262	.	native am	Rode & Shepard 1995
263	.	native am	
264	27.8	native am	Eveleth & Tanner 1990:292-3
265	27.6	native am	apdx table 48 pp292-3 for all
266	27.2	native am	ibid
267	28.9	native am	ibid
268	.	native am	ibid
269	.	native am	ibid
270	.	native am	ibid
271	.	native am	ibid
272	.	native am	ibid
273	.	native am	ibid
274	.	native am	Eveleth & Tanner 1976 t61-2
275	.	native am	males table 61 p366-369
276	.	native am	females t 62 p370-371
277	.	native am	ibid
278	.	native am	ibid
279	.	native am	ibid
280	.	asiatic	ibid
281	.	asiatic	ibid
282	.	asiatic	ibid
283	25.2	native am	ibid
284	27.8	native am	ibid
285	.	asiatic	ibid
286	.	asiatic	ibid
287	.	asiatic	ibid
288	.	asiatic	ibid
289	.	asiatic	ibid
290	.	asiatic	ibid
291	27.1	native am	ibid
292	.	native am	ibid
293	.	native am	ibid

	M	N	O
294	.	asiatic	ibid
295	.	asiatic	ibid
296	.	asiatic	ibid
297	.	asiatic	ibid
298	.	asiatic	ibid
299	.	asiatic	ibid
300	.	native am	ibid
301	.	native am	ibid
302	.	asiatic	ibid
303	29.7	native am	ibid
304	29.5	native am	ibid
305	.	native am	ibid
306	29.6	native am	ibid
307	.	native am	ibid
308	.	native am	ibid
309	.	native am	ibid
310	.	native am	ibid
311	.	native am	ibid
312	.	native am	ibid
313	.	asiatic	Murray 1994
314	.	asiatic	Murray 1994
315	.	asiatic	Roberts 1953 apdx A p557
316	.	asiatic	Roberts 1953 apdx A p557
317	.	european	Roberts 1953 apdx A p557
318	.	asiatic	Roberts 1953 apdx A p558
319	.	asiatic	Roberts 1953 apdx A p558
320	.	native am	Fleming-Moran et al., 1991
321	.	native am	Fleming-Moran et al., 1991
322	.	native am	Newman 1960 Table 1 p289
323	.	native am	ibid
324	.	native am	Newman 1960 Table 1 p290
325	.	native am	Johnston&Schell 1979:280-1
326	.	native am	males table 12.2 p280

	M	N	O
327	.	native am	females table 12.3 p281
328	.	native am	ibid
329	.	native am	ibid
330	.	native am	ibid
331	27.1	native am	ibid
332	26.9	native am	ibid
333	25.864	austpaci	Abbie 1956-7 p236m p238f
334	24.615	austpaci	Abbie 1956-7 p236m p238f
335			
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347			

Appendix C: Ruff's (1994) Sample

latitude	sex o=f	height	weight	latitude	sex o=f	height	weight
9	0	163.9	58.3	54	1	164.2	67.7
2	0	161.8	52.8	36	1	167.2	58.9
2	0	155.9	52.1	36	1	172.5	64.8
2	0	137.3	38.2	13	1	167.3	56.8
2	0	154.0	54.2	13	1	168.8	53.6
15	0	159.0	52.5	23	1	164.1	49.2
15	0	159.8	51.4	32	1	167.6	66.0
3	0	145.0	42.7	32	1	162.6	61.7
4	0	154.4	50.4	18	1	172.9	76.1
51	0	162.0	56.2	5	1	161.0	56.4
42	0	160.2	60.2	7	1	160.3	58.5
42	0	157.7	58.7	22	1	169.8	56.7
49	0	159.5	67.3				
48	0	160.4	55.5				
40	0	155.4	51.4				
53	0	159.8	61.5				
46	0	157.1	53.9				
70	0	155.8	66.3				
54	0	152.8	80.5				
36	0	155.3	48.9				
32	0	152.6	59.7				
32	0	152.0	51.1				
5	0	151.7	47.0				
7	0	151.6	49.2				
22	0	157.1	45.4				
9	1	173.5	66.8				
3	1	159.1	47.8				
3	1	175.0	56.6				
23	1	166.7	60.4				
15	1	170.1	59.3				
15	1	169.8	58.4				
2	1	153.8	45.8				
2	1	144.6	43.4				
2	1	163.9	56.6				
8	1	164.3	56.6				
6	1	166.9	60.0				
3	1	152.7	48.3				
4	1	161.2	54.6				
51	1	174.5	66.9				
42	1	171.3	68.8				
42	1	169.8	67.0				
56	1	172.0	74.7				
46	1	171.2	60.7				
70	1	166.3	67.2				

weight is in kg
height is in cm
latitude is in absolute degrees

Data from Ruff (1994:75) Table 2

Vita

A native of the Adirondack Region of upstate New York, Brandy Lea O'Neil was born in 1971. She was graduated from New York's South Glens Falls Central Schools in June 1989. She received her Bachelor of Arts degree in Anthropology and Psychology from Skidmore College, Saratoga Springs, NY, in May 1992.

Before coming to the University of Tennessee in August 1995 to pursue her Master of Arts degree in Anthropology, Ms. O'Neil worked as a medical social worker and volunteered as a mentor to young children in the South Glens Falls Schools. She received her M.A. in August 1998.

Ms. O'Neil left Knoxville in August 1998 to work on her Ph.D. in Anthropology at the University of Pennsylvania, where she planned to combine her research interests in human biology with community service.