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Advances in Somatotype Methodology and Analysis

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ABSTRACT During the past four decades, different approaches to somatotyping have resulted in changes in methods and analyses. The shift from a static or typological to a dynamic or phenotypical viewpoint is reviewed and different methods are summarized. Somatotype terminology and new concepts and techniques of analysis are presented as are details of two- and three-dimensional analyses. Descriptive and comparative statistical procedures are demonstrated through use of distances between somatotypes as a whole. Somatopoints, somatoplots, somatotype dispersion and attitudinal distances, t and F ratios between somatotype samples, correlation, intensity, and migratory distance are described. Suggestions are also made for approaches to somatotype analysis.

There are several methods for describing the characteristics of the human body as a whole. One is through the classification of body type according to its appearance or metric characteristics. Somatotyping is one such method. A somatotype is a rating of body form, and is a general descriptor of what the body as a whole looks like. The word "somatotype" was coined by Sheldon et al. (1940) and had a very specific meaning until modifications in methodology resulted in a more general meaning for the term. The process of somatotyping now refers to a group of method-specific techniques, but all are derived from the original Sheldonian concepts and use a three-component rating system.

The methodological modifications have resulted in some confusion regarding the utility of somatotyping as a tool in human biology, physical anthropology, and the exercise and sport sciences. Examination of the literature, including textbooks, reveals two problems: (1) Authors in general seem to be largely unaware of developments and modifications in somatotype methodology since 1940; and (2) inappropriate analyses have been used for examining relationships between somatotype and other variables. This report reviews developments in somatotype methodology and presents several new concepts in analysis of somatotype data.

WHY CLASSIFY PHYSIQUE?

Interest in classifying human physique dates from at least the time of Hippocrates (c. 460–c. 370 B.C.), and the various systems developed since then have been well documented in summaries reported in Tucker and Lessa (1940) and Sheldon et al. (1940). Essentially, these classifications were categorical in nature, usually two to five categories, and were generally regarded as unsatisfactory by later investigators because all persons could not be fitted easily into the specified categories.

A problem in the classification of body shape is that it is difficult to measure and quantify, although it is relatively simple to observe (Tanner, 1953). Part of the

problem relates to measurement versus observation, i.e., anthropometric versus anthroposcopic (or photoscopic) procedures. Anthropometric quantification of body types has been described by many investigators and is exemplified by the methods of Viola (1932), Lindegard (1953), Behnke (1961), and Conrad (1963). Somatotyping has utilized photoscopy (Sheldon et al., 1940), photogrammetric anthropometry (Sheldon et al., 1940, 1969), anthropometry (Damon et al., 1962; Parnell, 1958), and anthropometry plus photoscopy (Heath and Carter, 1967).

The notion of classifying physique into some meaningful system has considerable appeal and has been the stimulus for repeated efforts in this direction. If, for example, behavioral, disease, and functional characteristics of humans can be associated with certain physiques, then knowledge and understanding of those characteristics and their manipulation can be enhanced. In addition, if a large number of observational or metric characteristics of the physique can be reduced to relatively simple categories, or to a single rating as in the somatotype, analysis of the data can then be simplified. Body type classifications, however, do result in a loss of precise data about single metric characteristics. Body types are by nature "summaries" of many characteristics and as such cannot be expected to answer specific questions about single measurements. Too much is often expected of such systems, including somatotyping. On the other hand, a classification is only useful if it can shed light on problems and can relate one set of facts to another (Tanner, 1953).

In a review of constitutional medicine, Damon (1970) defined "constitution" as the sum of a person's innate and relatively fixed biological development. Damon goes on to state that the term constitution means different things to different investigators; however, "To physical anthropologists, psychologists, and behavioral scientists generally, constitution means physique in relation to environmental adaptation, disease, or behavior. As such, constitution is one application to man of the structure-function relationship, the central concern of physical anthropologists" (Damon, 1970, p. 180). Morphology is viewed as one of several constitutional approaches, but it is probably less important than age, sex, race, biochemical and genetic makeup, and disease diathesis. In addition, physique can be correlated with other characteristics of the individual partly because it is "obvious and easily described." Damon (1970) also gives several reasons for studying body form (physique) in relation to constitutional medicine. Body form is studied to predict in advance susceptibility and response to disease and therapy, to obtain clues to mechanisms underlying a detected association, to elucidate causes, and to identify several places in the web of causation at which intervention can help prevent disease. These reasons, with some modification, are valid for studies in areas such as behavior and physical performance.

At this point, it is important to note that the strong constitutional bias of physique typologies that lasted until the mid-1950s is no longer common. Hunt (1981, p. 344,345) states that the "older physical anthropologists . . . became frozen into a typological paradigm well along into the twentieth century," and that the use of somatotype components (using Sheldon's methods) and "morphological types have been virtually abandoned in the new physical anthropology because neither paradigm could be effectively defended." The shift in thinking has been from fixed classifications to plasticity of humans and is supported by Pollitzer (1981) and Hulse (1981), who along with Hunt (1981) see more emphasis on process and cause than on classification, i.e., a shift from the static (typological) to the dynamic (phenotypical, plastic) viewpoint.

METHODS OF SOMATOTYPING

Sheldon et al. (1940) were not the first to recognize the limitation of typologies, but they were the first to devise a workable system that utilized continua rather than categories. The somatotype was defined as "a quantification of the three primary components determining the morphological structure of an individual expressed as a series of three numerals, the first referring to endomorphy, the second to mesomorphy, and the third to ectomorphy" (Sheldon et al., 1954, p. 337). Somato-

type ratings were made from descriptions of somatotypes and height-weight ratios (height/cube root of weight) in conjunction with criterion-rated photographs (Sheldon et al., 1940, 1954). Subsequently, Sheldon changed the method of rating to a "trunk index" method. In this method, a trunk index is derived from planimetric measurements of the thoracic and abdominal trunk regions as marked on a somatotype photograph. The somatotype is then obtained from tables of the trunk index, height-weight ratios, and maximal stature (Sheldon et al., 1969). The components were redefined operationally: Endomorphy refers to the predominance of the abdominal trunk area over the thoracic trunk area as determined from the trunk index; mesomorphy refers to the predominance of the thoracic trunk area over the abdominal trunk area; and ectomorphy is equated to adult stature. Sheldon and colleagues always maintained that the somatotype is fixed and the rating remains the same throughout life even though appearance may change. This assertion firmly attached Sheldon's method of somatotyping to constitutional typology. Other books by Sheldon and colleagues are concerned with constitutional psychology (Sheldon et al., 1942) and constitutional psychiatry (Sheldon et al., 1949). However, Sheldon's method of somatotyping was the last major system proposed for constitutional classification (Hunt, 1981).

After the introduction of somatotyping in 1940, the genetic and constitutional bases of Sheldon's system were questioned (Meredith, 1940; Hunt, 1952). However, many investigators found the concept of somatotyping potentially useful, and several developed modifications of Sheldon's system.

Hooton (1951, 1959) developed a modification of Sheldon's technique by making estimates of "fatty development," "muscular development and strength of body framework," and by deriving "attenuation" from scaled height-weight ratios. He stated that these corresponded to endomorphy, mesomorphy, and ectomorphy, respectively. The ratings were essentially phenotypic and were not age-adjusted. When compared to the method of Sheldon et al. (1940), Hooton's first component ratings were more liberal, and the second component was rated more strictly. Further, Hooton did not limit the sum of the three components to nine through 12 (Dupertuis and Emanuel, 1956).

An elaborate checklist of 105 specific points based on observable criteria for the three components was derived from Sheldon's criteria by Bullen and Hardy (1946) for a study on college women. The authors proposed that this list could be used as a universal scale for comparison between all ages and the sexes. This method was applied in studies by Bullen (1952), Danby (1953), Kraus (1951), and Roberts and Bainbridge (1963).

Cureton (1947, 1951) developed a system that combined inspectional photoscopy, palpation of musculature, skinfold measurements using a Franzen caliper, height-weight ratios, and assessments of strength and vital capacity. Although Cureton claimed that this somatotype estimate was sufficiently similar to Sheldonian ratings for practical purposes, the ratings clearly differed on ectomorphy (Carter and Heath, 1971).

Parnell (1954, 1958) was the first to use anthropometry to derive somatotype ratings that would correspond with the photoscopic ratings of Sheldon. Skinfolds, bone diameters, and girths, in addition to age, height, and weight, were measured and entered on an No. M. 4 deviation chart that included the necessary tables. M. 4 charts were developed for children aged 7 and 11 years and for adults. Parnell substituted the terms fat, muscularity, and linearity (with their respective abbreviations F, M, L) for the three components, and indicated that the M. 4 ratings were phenotypes. Note, however, that age-adjusted scales were used so that different measurements would give the same somatotype at later ages.

Anthropometry was also used by others to estimate somatotypes. Damon et al. (1962) derived multiple regression equations to predict the somatotype of black and white soldiers from up to ten anthropometric dimensions. Multiple correlations ranged from 0.66 to 0.90. Regression equations derived from anthropometry and physical performance were derived to predict somatotypes of boys 9 through 17 years

of age in the Medford Growth Study (Munroe et al., 1969; Clarke, 1971). The criterion ratings were the photoscopic ratings of Heath, who used her modification of Sheldon's criteria for the ratings (Heath, 1963). The authors found good predictions for endomorphy and ectomorphy but lower predictions for mesomorphy. In addition, the equations were specific to the age at which the measurements were taken.

Peterson (1967) presented an atlas of somatotypes of Dutch school children 6–15 years of age. The ratings appear to be phenotypes, based upon the photoscopic criteria of the young adult males studied by Sheldon et al. (1954). However, no criteria for rating the children nor metric data other than age were given.

Swalus et al. (1970) designed a modified somatotype method for use in the Leuven Growth Study after comparisons of the techniques of Sheldon et al. (1954), Parnell (1957), and Heath and Carter (1967). This modified "Leuven" method consisted of (1) obtaining a first estimate of endomorphy from the sum of three skinfolds according to Parnell (1957); (2) obtaining a first estimate of ectomorphy from the height-weight ratios of Heath and Carter (1967); and (3) using these first estimates to match the somatotype photograph with the standard photos of Sheldon et al. (1954) for 16–24-year-old males. Good interobserver reliabilities were obtained using the method (Ostyn et al., 1980).

The first clear departure from the constitutional approach of Sheldon was that of Heath (1963), who was a research associate with Sheldon from 1948 to 1952. She criticized certain limitations of Sheldon's method and described modifications designed to overcome the limitations. The criticisms were basically concerned with the "permanence" of the somatotype, limitations of the seven-point scale (a closed upper limit for each component and the sum of three components was limited to 9 through 12), lack of a logical relationship between some height-weight ratios and somatotypes in the tables used by Sheldon, and the age-adjusted nature of the tables. Heath's modifications consisted of rating the present somatotype, reconstructing the table of somatotypes and height-weight ratios to preserve a logical incremental relationship throughout, and eliminating extrapolations for predictions of future somatotypes with increasing age.

After comparing the methods of Heath and Parnell (M. 4 method), Heath and Carter (1966, 1967) further objectified Heath's method by incorporating the anthropometric aspects of the M. 4 system. They redefined the somatotype as a rating of the present morphological conformation, which is the observable, external view of bodily structure. It may be thought of as a size-dissociated descriptor of shape and relative composition of the body. It is expressed in a three-numeral rating, representing three components: (1) Endomorphy (the first component) refers to relative fatness; (2) mesomorphy (the second component) refers to musculoskeletal development relative to height; and (3) ectomorphy (the third component) refers to relative linearity. The criterion somatotype is determined from both anthropometric and photoscopic procedures. The somatotype can be estimated from anthropometric procedures alone, or from photoscopic ratings (by a criterion rater) alone. When photoscopic ratings are made, they are recorded as half-unit ratings (usually written, for example, as 2-4½-4). Ratings from anthropometric dimensions alone may be calculated to tenths of a unit (e.g., 3.2-4.8-2.3), or rounded to whole or half-units (e.g., 3-5-2½). The decimal ratings may give a sense of spurious accuracy to the estimated somatotype; therefore, rounding to the half-unit may be preferable. However, the decimal rating may assist analysis in longitudinal studies where changes or trends in the components over time are followed and perhaps predicted, or where curve fitting might be appropriate (Carter, 1980a).

It is possible to rate and compare somatotypes at all ages and for both sexes with the Heath-Carter method because a single set of criteria is used (Carter, 1980a). In addition to accepting the possibility of change in somatotype, the method adds concepts of body composition (and anthropometry) to the rating of components. This latter aspect was advocated long ago by both Hunt (1959) and Brozek (1959), who felt that such an addition would improve the biological utility of somatotyping.

Some of the above-mentioned modifications in somatotype methodology reflect adherence to the concept of the genotype or fixed somatotype, while others reflect the concept of the phenotype or present somatotype. Sheldon's methods (Sheldon et al., 1940, 1954, 1969), Parnell's M. 4 method (1954, 1958), and Peterson's (1967) method for children are all based upon rating scales and concepts that assume that the somatotype is fixed. These authors concede that the physique may change its appearance, but the rating is the same when allowance is made for age and "nutritional" discrepancies. The rating of present physique (phenotype) and subsequently relating it to the variable(s) in question is in contrast to the above. Such ratings have been calculated by regression equations (Damon et al., 1962; Munroe et al., 1969), and by the modifications of Bullen and Hardy (1946), Cureton (1947), Hooton (1951, 1959), Roberts and Bainbridge (1963), Heath (1963), and Heath and Carter (1967). Differences between somatotype methods have been examined in various studies (Dupertuis and Emanuel, 1956; Zuk, 1958; Livson and McNeill, 1962; Haronian and Sugarman, 1965; Heath and Carter, 1966; Carter and Heath, 1971; Clarke, 1971; Villanueva, 1976; Walker and Tanner, 1980) but will not be elaborated in this review.

Carter (unpublished observations) surveyed the somatotype literature from 1970–1979 and found that 74% (167/225) of the reports utilized the somatotype methods of Heath and Carter (1967). Most of the remaining reports used the methods of Sheldon or of Parnell. This trend thus indicates a shift from the genotypic to the phenotypic somatotype methodology. Part of this shift may be because the Heath-Carter anthropometric method is relatively easy to use. A variety of studies undertaken during the past decade have used the Heath-Carter somatotype method as a tool in studies of diverse areas of human biology, physical anthropology, and the exercise and sports sciences (e.g., Clarke, 1971; De Garay et al., 1974; Broekhoff, 1976; Fleischmann et al., 1977; Heath, 1977; Kovar, 1977; Slaughter et al., 1977; Štěpnička et al., 1977; Szmodis, 1977; Hebbelinck and Borms, 1978; Smit, 1979; Villanueva Sagrado, 1979; Carter, 1980b; Perez, 1981; Jensen, 1981; Bailey et al., 1982). In addition, Malina and Rarick (1973) and Malina (1975) have reviewed the relationships of somatotypes rated by a variety of methods with growth, strength, and motor performance.

In summary, there are different somatotype methods and these may be based on a genotypic or phenotypic approach. Thus, the word somatotype is a generic term embracing a number of different methods. The methods, however, are not strictly comparable.

ANALYSIS OF SOMATOTYPE DATA

Since the somatotype is a three-number rating, it presents several unique problems for analysis using traditional statistics. Each of the numbers represents a rating of separate components and it is the relationship of the ratings to each other that provides the meaning for the somatotype rating. Taken separately, the component ratings lose some of their meaning, although some such analysis may be useful (Carter, 1980b). Recently, new approaches to analysis have been developed as a result of attempts to treat the somatotype as a single entity, rather than using the separate components in analysis. Special emphasis will be given in the following sections to analysis of the somatotype in two- and three-dimensional space. Although differences in somatotype methods have been indicated above, the analyses that follow are in general applicable to any of the somatotype methods.

Choice of analysis

The choice of analysis depends on the purpose of the study and the hypothesis to be tested. A summary of typical methods of analysis of a set of somatotype data is presented in Figure 1. Descriptive statistics such as means and standard deviations can be applied to separate components of the somatotype, i.e., endomorphy, mesomorphy, and ectomorphy, or to characteristics of the somatotype, i.e., somatotype (S), somatotype attitudinal distance (SAD), and somatotype dispersion distance (SDD).

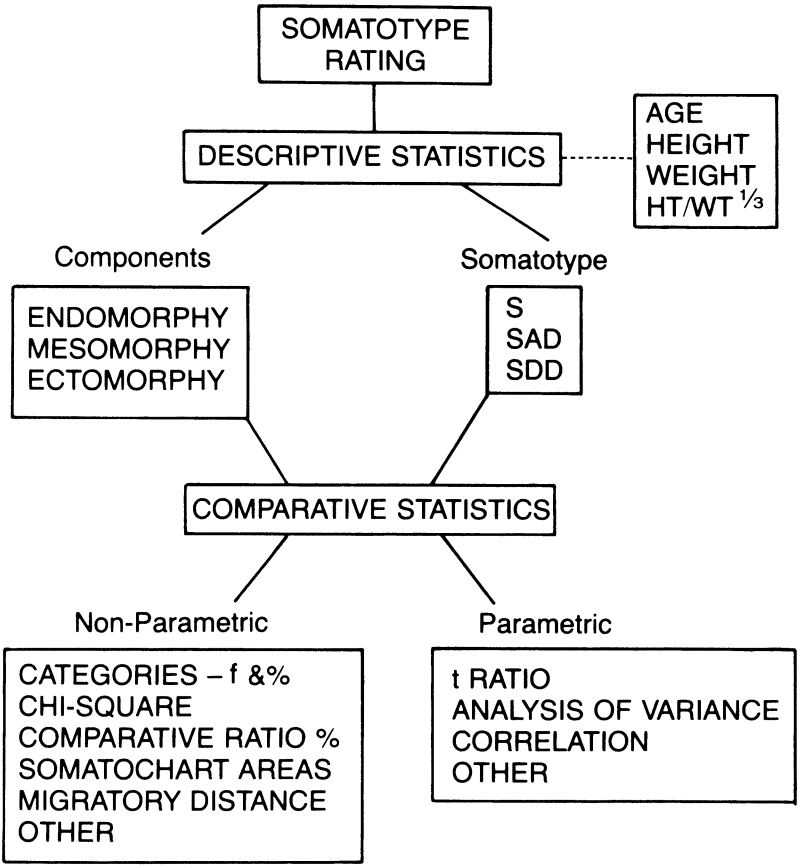

Fig. 1. A summary of typical methods of analysis of somatotype data (see text for explanation). S, somatotype; SAD, somatotype attitudinal distance; SDD, somatotype dispersion distance.

The latter are defined later in the report. In addition, frequency and percentages of component ratings or of somatotypes can be calculated for the sample.[1] When comparisons are made among samples, both parametric and nonparametric statistics can be applied. The nonparametric statistics most commonly applied are frequencies and percentages by somatotype category or somatochart area, chi-square, and comparative ratios for differences between distributions of somatoplots (Parnell, 1958), and migratory distance of somatotypes in growth studies (Parízková and Carter, 1976). These and other techniques have been applied to the somatotype as a single entity. Parametric statistics can be applied to components as well as to somatotypes. However, their application to the somatotype presents several conceptual and computational difficulties. The following sections describe and present examples of recent developments in the application of comparative statistics to somatotype analysis.

Somatopoints and somatoplots

In a given sample of somatotypes, the means and standard deviations for each somatotype component can be calculated separately. However, using separate com-

[1]Descriptive statistics are calculated routinely for age, height, weight, and the height/cube root of weight ratio.

ponents of the somatotype largely ignores essential information about component dominance. In somatotype terminology, dominance refers to the rank of component ratings. Thus, a somatotype in which the mesomorphic rating is highest has dominance in mesomorphy. Furthermore, somatotypes with the same dominant component may have different secondary dominances as in somatotypes 4-5-1 and 1-5-4. Clearly these somatotypes are quite different. Recent developments in somatotype analysis are based on using whole ratings and plotting the projected positions of the somatotypes on a two-dimensional (planar) grid system, or plotting the positions in a three-dimensional system (Ross and Wilson, 1973; Duquet and Hebbelinck, 1977).

The somatotype, having three components, is best represented conceptually by a point in three-dimensional space called a somatopoint. It can thus be represented as a triad of x, y, and z coordinates. The x,y,z coordinates are respectively the first, second, and third components of the somatotype (endomorphy, mesomorphy, and ectomorphy). The scales on the coordinate axes are component units with the hypothetical somatotype of 0-0-0 at the origin of the three axes. While this three-dimensional representation is precise, it does not lend itself to simple graphic display of sample distributions. Furthermore, the three-dimensional model is a theoretical representation in which the component scales are at right angles to each other. This model facilitates comparisons of different sample plots. There are, however, moderate intercorrelations between components, but these differ from sample to sample. At present, the only practical alternative is to plot relative to a model so that comparisons can be made between samples.

Despite the completeness of the three-dimensional representation, investigators have generally used a two-dimensional projection for displaying somatotypes. A somatoplot is the projection of a somatotype location in three-dimensional space onto a two-dimensional grid or somatochart. Figure 2 shows a somatochart for plotting individual or mean somatotypes from the component ratings using two-dimensional x,y coordinates. An example of a two-dimensional distribution of somatoplots of a sample of female athletes is shown in Figure 3. Figure 4 illustrates the three- and two-dimensional representations of the somatotype 3-6-2. When the somatotypes of a sample are projected onto a somatochart (i.e., from somatopoints to somatoplots), there is some reduction in the original information about the distribution. The "real" distance between somatoplots of two somatotypes will most often be less than the "real" distance between somatopoints of the same two somatotypes. The limitations of the two-dimensional approach are more fully discussed in Duquet and Hebbelinck (1977).

Figure 5 shows the abbreviations used for somatotype analysis. The means, variances, and standard deviations for components, and x,y coordinates of the two-dimensional somatochart are calculated using conventional methods. However, to calculate the same statistics for the whole somatotype, the distances between somatotypes are used. Although the mean x,y coordinates are used for plotting the mean somatotype, variances and standard deviations are seldom needed for analysis. However, they were used for comparative purposes by Szmodis (1977).

Somatotype dispersion and attitudinal distances (SDD and SAD)

Two parameters characterize a somatotype distribution in either two or three dimensions. One is the location of its measure of central tendency or mean somatotype ($\bar{S}$), and the other is the dispersion of somatotypes about the mean somatotype. Relationships between mean somatotypes or between sample dispersions can be analyzed by parametric statistics using distances calculated in either two or three dimensions. However, there are conceptual and practical difficulties in using conventional statistical methods to analyze somatotypes as a whole. Because of these difficulties, it is helpful to operationally define equivalent terms which are more appropriate to the somatotype distribution characteristics being analyzed.

In two dimensions, the distance between any two somatoplots on the somatochart is termed the somatotype dispersion distance (SDD) and is calculated in the y-units of the two-dimensional coordinate system (Ross and Wilson, 1973). The average of

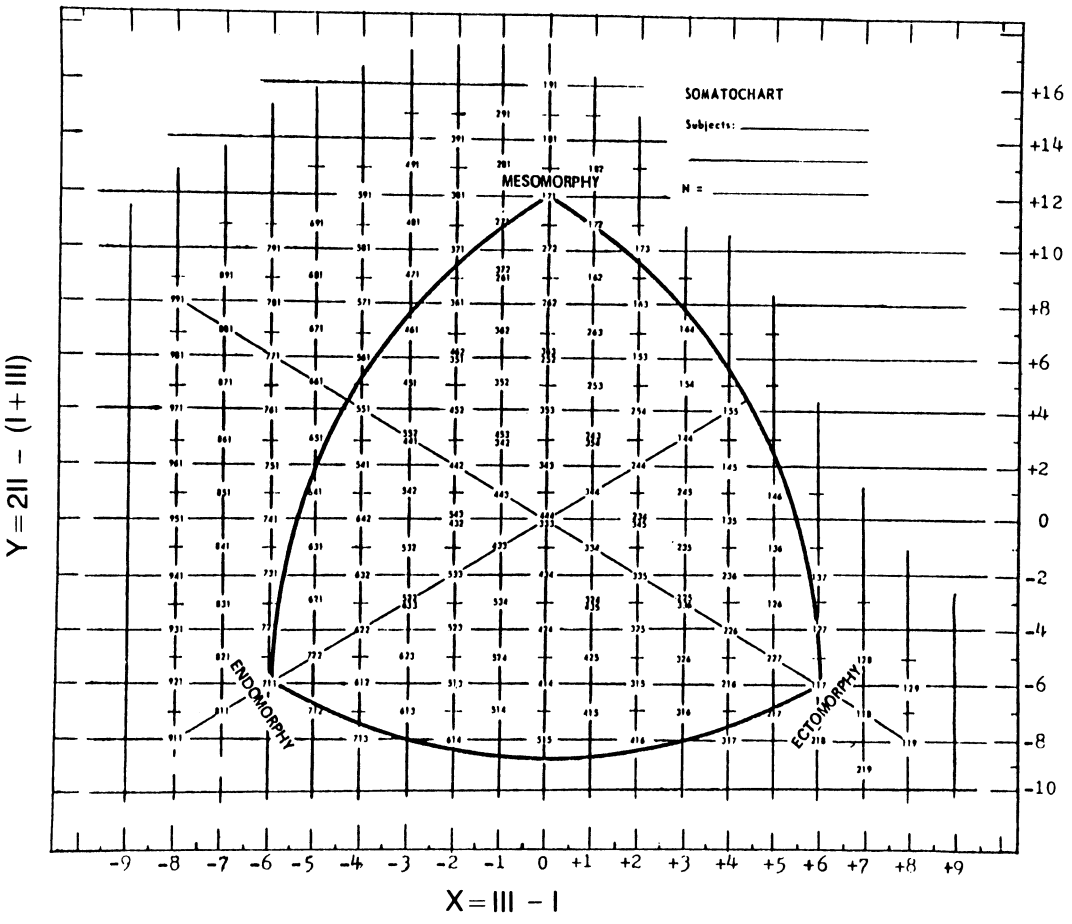

Fig. 2. A two-dimensional somatochart on which somatotypes can be plotted in terms of their x,y coordinates. I, endomorphy; II, mesomorphy; III, ectomorphy.

the SDDs of each somatoplot form the mean somatoplot; ($\bar{S}$) of a given sample is termed the somatotype dispersion index (SDI) by Ross and Wilson (1973). The SDI is thus the average distance of somatoplots from the mean somatoplot. In order to be consistent with other terms in this paper, the SDI is renamed the somatotype dispersion mean (SDM). The formulae for calculating SDD and SDM are

$$SDD_{1,2} = \sqrt{3\,(x_1 - x_2)^2 + (y_1 - y_2)^2} \quad (1)$$

where (x_1,y_1) and (x_2,y_2) are the coordinates of somatotypes 1 and 2, and the square root of 3 is a constant that converts the x units to y units; and

$$SDM = \sum_{i=1}^{n} SDD_i/n \quad (2)$$

where SDD_i is the distance from a somatoplot (S_i) to the mean somatoplot ($\bar{S}$).

In three dimensions, the distance between any two somatopoints is called the somatotype attitudinal distance (SAD) and is calculated in units of the original

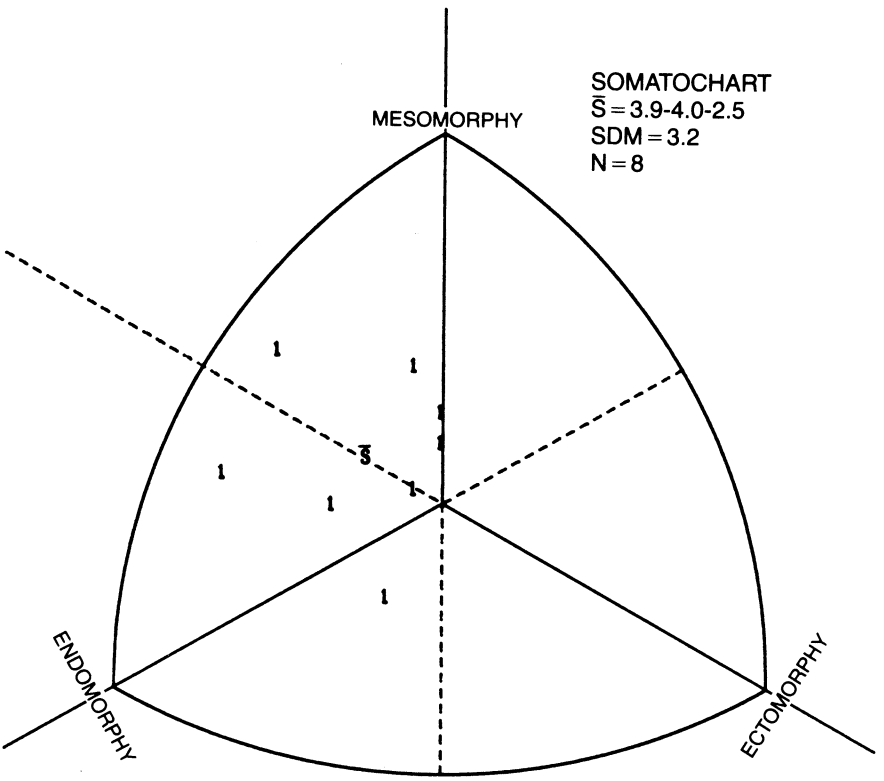

Fig. 3. A two-dimensional somatochart showing the mean somatoplot ($\bar{S}$), individual somatoplots, and the somatotype dispersion mean (SDM) of a sample of female athletes.

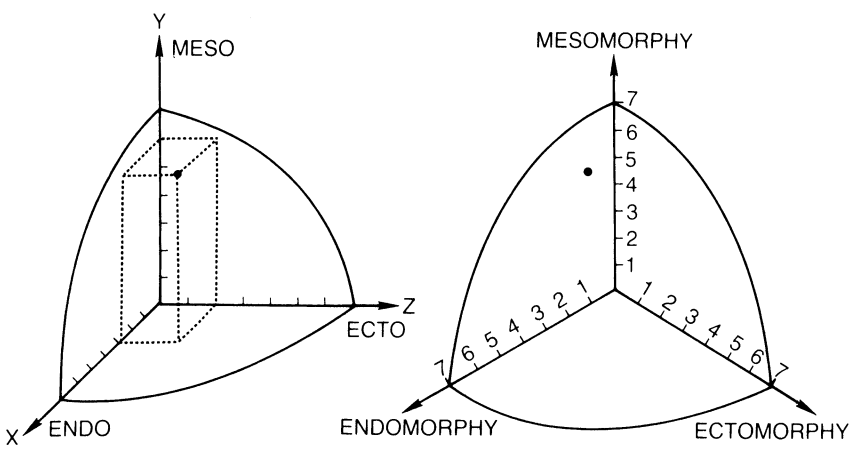

Fig. 4 The three- and two-dimensional representation of the somatotype 3-6-2 (redrawn after Duquet and Hebbelinck, 1977).

SOMATOTYPE COMPONENTS

	Endomorphy	Mesomorphy	Ectomorphy
Mean	$\bar{X}_{EN}$	$\bar{X}_{ME}$	$\bar{X}_{EC}$
Variance	s^2_{EN}	s^2_{ME}	s^2_{EC}
Standard Deviation	s_{EN}	s_{ME}	s_{EC}

PLANAR COORDINATES FOR SOMATOPLOTS

	x coordinate	y coordinate
Mean	$\bar{X}$	$\bar{Y}$
Variance	s^2_x	s^2_y
Standard Deviation	s_x	s_y

SOMATOTYPE AS A WHOLE

SOMATOTYPE

	Two dimensions	Three dimensions
Mean	$\bar{S}$	$\bar{S}$
Variance	s^2_D	s^2_A
Standard Deviation	s_D	s_A

SCATTER ABOUT $\bar{S}$

	Two dimensions	Three dimensions
Mean	SDM	SAM
Variance	s^2_D	s^2_A
Standard Deviation	s_D	s_A

Fig. 5. Abbreviations used for somatotype analysis (see text for explanation).

components. The average of the SADs of each somatopoint from the mean somatopoint ($\bar{S}$) of a sample is known as the somatotype attitudinal mean (SAM) (Duquet and Hebbelinck, 1977). Thus, the somatotype attitudinal mean is the three-dimensional counterpart of the somatotype dispersion mean. The formulae for calculating the SAD and SAM are

$$SAD_{1,2} = \sqrt{(I_1 - I_2)^2 + (II_1 - II_2)^2 + (III_1 - III_2)^2} \quad (3)$$

where I, II, and III represent the endomorphy, mesomorphy, and ectomorphy components of a somatotype, and 1 and 2 are any two somatotypes; and

$$SAM = \sum_{i=1}^{n} SAD_i/n \quad (4)$$

where SAD_i is the distance from a somatopoint (S_i) to the mean somatopoint ($\bar{S}$).

In order to describe the somatoplots on a somatochart, i.e., to make comparisons in two dimensions, the SDD and its derived measures are used. To describe or compare somatopoints and interpoint distances in three dimensions, the SAD and its derived measures are used. Three-dimensional descriptions and analyses are preferable in most instances.

It should be noted that a SAD is a measure of the absolute difference between two somatotypes using component ratings, and an SDD is a projection of this difference (expressed in y-units) onto a plane. Neither distance gives information about the pattern of dominance of the component ratings or dominance changes. The SAD expresses how similar two somatotypes are; the smaller the SAD, the closer they are to each other. The size of the SAM (or SDM) expresses the degree of homogeneity of the sample somatopoints (or somatoplots) about the mean. A small SAM indicates a tight cluster of somatopoints (or somatoplots) about $\bar{S}$, while a large SAM indicates a wide scatter about $\bar{S}$.

Sample variances

The distances of scores from a central point are called deviations, and their absolute values divided by the number of scores is an index of variability known as the mean deviation (Blommers and Forsyth, 1977). Thus, the SAM and the SDM are mean deviations from $\bar{S}$. Because they are means, the variances and standard deviations of the SADs or SDDs about SAM or SDM, respectively, can be calculated. Examples of these calculations are shown in Table 1 (the somatotypes in this table are those plotted in Fig. 3).

An index of variability of somatotypes about $\bar{S}$ is important if statistical comparisons using $\bar{S}$ are to be considered. As noted earlier, the distance (in either two or

TABLE 1. Descriptive statistics for eight somatotypes

	Somatotype			Two dimensions: Plot coordinates			Three dimensions: SAD
Subject	Endomorphy	Mesomorphy	Ectomorphy	X	Y	SDD	
24	2.5	4.5	2.0	−0.50	4.50	3.25	1.55
30	3.0	4.0	3.0	0.00	2.00	2.42	1.01
84	4.0	5.0	1.0	−3.00	5.00	4.39	1.81
86	4.5	2.5	3.5	−1.00	−3.00	4.67	1.91
15	3.5	3.5	3.0	−0.50	0.50	1.89	0.80
61	6.0	4.5	2.0	−4.00	1.00	4.58	2.23
75	4.5	3.5	2.5	−2.00	0.00	1.94	0.80
87	3.0	4.5	3.0	0.00	3.00	2.76	1.13
Statistic							
Mean	3.88	4.00	2.50	−1.38	1.63	SDM = 3.24	SAM = 1.41
Variance	1.27	0.64	0.64	2.20	6.77	S_D^2 = 1.37	S_A^2 = 0.30
Standard deviation	1.13	0.80	0.80	1.48	2.60	S_D = 1.17	S_A = 0.55

	Two dimensions	Three dimensions
Mean of somatotype as a whole	$\bar{S}$ = 3.88-4.00-2.50	$\bar{S}$ = 3.88-4.00-2.50
Variance of distribution about $\bar{S}$	S_D^2 = 13.35	S_A^2 = 2.55
Standard deviation about $\bar{S}$	S_D = 3.65	S_A = 1.61

three dimensions) of each somatotype from $\bar{S}$ is a deviation from the mean. The squares of these deviations can be summed (ΣSAD_i^2), and then divided by $n-1$ to give an unbiased estimate of the population variance (s_A^2). The square root of the variance gives the standard deviation (s_A) of the somatotypes about their mean $\bar{S}$, i.e., $s_A^2 = (\Sigma SAD_i^2)/(n-1)$, and $s_A = \sqrt{s_A^2}$. The subscript A indicates that the calculations are based on SADs; the subscript D is used if the calculation is based on SDDs. The results of such calculations are shown in Table 1.

When there are two or more somatotype distributions, the significance of the differences between variances and between means can be tested, but care must be taken to use the correct formulae for calculating the variance from the above (see Table 2). Before proceeding with tests of significance between means, a test should be made to insure that the homogeneity of the variances (either about dispersion or attitudinal means [SDM or SAM], or about $\bar{S}$) is tenable. Conventional statistics such as Hartley's F_{max} test (Winer, 1971) may be calculated. In order to test differences between somatotype means, the sum of the squared deviations (ΣSAD_i^2) must be used for each group to calculate either the standard error of the difference between means for the t ratio or the sum of squares within groups (SS error) for the F ratio. For the t ratio, the numerator is the SAD between the two somatotype means. For the F ratio, the sum of squares between groups is calculated by summing the squares of the distances between each group somatotype mean and the overall somatotype mean ($\bar{M}$) multiplied by the number of subjects in each group; i.e., SS treatment $= \Sigma n_j (\bar{S}_j - \bar{M})2$, where n_j refers to the number in each group.

These statistical tests appear to be valid when the scatter of the somatotypes about their mean is approximately uniform in all directions, but are less likely to be valid when at least one sample of somatoplots is asymmetrical, e.g., elliptical rather than circular. There is at present no statistical test for assessing the shape of somatotype dispersions. Therefore, an empirical evaluation must be made based on the two-dimensional somatoplots on the somatochart. Procedures for calculating t and F ratios are shown in Table 2. The somatotypes and SADs for group 1 are from Table 1 and are compared to an independent sample, group 2, with their values calculated in a similar manner. The hypothesis tested is that $\bar{S}_1 = \bar{S}_2$. Calculations for t and F ratios produce the same results. There is no difference between $\bar{S}_1$ and $\bar{S}_2$. Furthermore, the square root of F equals t, $\sqrt{2.17} = 1.47$, which is similar to the obtained t of 1.46.

When one wishes to test for significant differences in a repeated measures experiment, a two-way analysis of variance (ANOVA) is appropriate. Care must be taken to use only SAD values in these calculations, and the two-way ANOVA allows for this. There is no analogous somatotype t-test for correlated data.[2] An example of the two-way ANOVA is given in Table 3. For computational convenience, the data from groups 1 and 2 in the previous examples are used, but it is now assumed that the data are from two somatotype measurement occasions on a single sample, rather than from two different samples. Note the two-way somatotype ANOVA can be extended to accommodate more than one replication. The hypothesis tested is that there is no difference between somatotypes on occasions 1 and 2.

Means are calculated for each occasion, for each individual (Table 3), and for the first-plus-second occasions ($N = 16$) to get the overall mean ($\bar{M}$). The total variation

[2]In the traditional paired t-test, the intention is to measure if the positive or negative deviation of the mean difference of pairs of scores ($\bar{D}$) is attributable to chance. In the case of somatotypes, a change can only result in a positive SAD value, and $\bar{D}$ can never be zero (unless there are no somatotype changes) or a negative value. A typical equation for a paired t-test based on differences is $t = \bar{D}\sqrt{(N-1)}/s_D$, where $\bar{D}$ = the mean of the sample of D-values, and s_D = the standard deviation of the sample of D-values. For the t-test to be applicable the difference between the mean somatotypes ($\bar{S}_1 - \bar{S}_2$), should equal the average difference between somatotypes on occasions 1 and 2 ($\Sigma SAD_{1-2}/n$). In our example in Table 2, the first difference is $\bar{S}_1 - \bar{S}_2 = 1.08$, and the second difference is $\bar{D} = 1.37$ (calculated from Table 3). Thus $\bar{D}$ is always larger than $\bar{S}_1 - \bar{S}_2$, giving rise to t-ratios that are too large for somatotype applications. Although D in the numerator could be replaced by $\bar{S}_1 - \bar{S}_2$, there is no correct alternative for the standard deviation of the D-values in the denominator.

TABLE 2. Calculations for comparisons between two independent groups, using somatotypes as a whole, by t and F ratios[1]

Group 1, n = 8					Group 2, n = 8				
Subject	Somatotype			SAD_1	Subject	Somatotype			SAD_2
24	2.5	4.5	2.0	1.55	23	2.0	4.0	3.0	0.88
30	3.0	4.0	3.0	1.01	06	2.5	3.0	3.5	1.16
84	4.0	5.0	1.0	1.81	05	3.0	4.5	2.5	0.72
86	4.5	2.5	3.5	1.91	65	3.0	3.0	4.0	1.42
15	3.5	3.5	3.0	0.80	01	2.0	4.0	3.0	0.88
61	6.0	4.5	2.0	2.23	86	5.0	5.0	2.0	2.55
75	4.5	3.5	2.5	0.80	00	3.0	3.5	3.0	0.46
87	3.0	4.5	3.0	1.13	02	2.5	4.5	2.5	0.81
	$\bar{S}_1 = 3.9$	4.0	2.5	$SAM_1 = 1.41$		$\bar{S}_2 = 2.9$	3.9	2.9	$SAM_2 = 1.11$

[1]Overall somatotype mean $\bar{M}$ = 3.38-3.97-2.72 (rounded to 3.4-4.0-2.7).
Test for equality of variances about $\bar{S}$:

$$F_{max} = \frac{S_1^2}{S_2^2} = \frac{17.88/7}{12.80/7} = \frac{2.55}{1.83} = 1.39 \quad (P > 0.05, \text{ df} = 1,7).$$

A. Calculation of t ratio—independent samples

$$t = \frac{\bar{S}_1 - \bar{S}_2}{\sqrt{\frac{\Sigma(SAD_1^2) + \Sigma(SAD_2^2)}{n_1 + n_2 - 2}\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

$$\Sigma(SAD_1^2) = 1.55^2 + 1.01^2 + 1.81^2 + 1.91^2 + 0.80^2 + 2.23^2 + 0.80^2 + 1.13^2 = 17.88$$

$$\Sigma(SAD_2^2) = 0.88^2 + 1.16^2 + 0.72^2 + 1.42^2 + 0.88^2 + 2.55^2 + 0.46^2 + 0.81^2 = 12.80$$

$$t = \frac{1.08}{\sqrt{\frac{17.88 + 12.80}{8 + 8 - 2}\left(\frac{1}{8} + \frac{1}{8}\right)}} = \frac{1.08}{\sqrt{(2.19)(0.25)}} = \frac{1.08}{0.74}$$

t = 1.46 (not significant, $P > 0.05$. $\bar{S}_1$ and $\bar{S}_2$ do not differ).

B. Calculation of F ratio—independent samples

$$F = \frac{SS_{treatment}/df_t}{SS_{error}/df_e} = \frac{MS_t}{MS_e}$$

$SS_t = \Sigma\, n_j (\bar{S}_j - \bar{M})^2$; and $SS_e = \Sigma\, \Sigma(SAD_j^2)$.

$SS_t = SS_{t1} + SS_{t2}$

$SS_{t1} = n_1 (\bar{S}_1 - \bar{M})^2 = 8\,(0.54)^2 = 2.33$

$SS_{t2} = n_2 (\bar{S}_2 - \bar{M})^2 = 8\,(0.55)^2 = 2.42$

$SS_t = 2.33 + 2.42 = 4.75$

$SS_e = 17.88 + 12.80 = 30.68$

$$F = \frac{4.75/1}{30.60/14} = \frac{4.75}{2.19} = 2.17^*$$

*Not significant, $P > 0.05$. $\bar{S}_1$ and $\bar{S}_2$ do not differ.

TABLE 3. Calculations for comparisons between two paired groups, using somatotypes as a whole, by a two-way ANOVA

First occasion (treatment) $n_1 = 8$				Second occasion (treatment) $n_2 = 8$						
Subject	Somatotype			Subject	Somatotype			Subject somatotype means		
24	2.5	4.5	2.0	24	2.0	4.0	3.0	2.25	4.25	2.50
30	3.0	4.0	3.0	30	2.5	3.0	3.5	2.75	3.50	3.25
84	4.0	5.0	1.0	84	3.0	4.5	2.5	3.50	4.75	1.75
86	4.5	2.5	3.5	86	3.0	3.0	4.0	3.75	2.75	3.75
15	3.5	3.5	3.0	15	2.0	4.0	3.0	2.75	3.75	3.00
61	6.0	4.5	2.0	61	5.0	5.0	2.0	5.50	4.75	2.00
75	4.5	3.5	2.5	75	3.0	3.5	3.0	3.75	3.50	2.75
87	3.0	4.5	3.0	87	2.5	4.5	2.5	2.75	4.50	2.75
	$\bar{S}_1 = 3.88$	4.00	2.50		$\bar{S}_2 = 2.88$	3.94	2.94	$\bar{M} = 3.38$	3.97	2.72

ANOVA calculations

$$SS_{treat} = \Sigma n_j (\bar{S}_j - \bar{M})^2 = SS_{treat_1} + SS_{treat_2} \quad \text{(see Table 2)}$$

$$SS_{treat_1} = n_1 (\bar{S}_1 - \bar{M})^2 = 8(0.54)^2 = 2.33$$

$$SS_{treat_2} = n_2 (\bar{S}_2 - \bar{M})^2 = 8(0.55)^2 = 2.42$$

$$SS_{treat} = 2.33 + 2.42 = 4.75$$

$$SS_{bet\ people} = k\Sigma (\bar{S}_i - \bar{M})^2$$

$$= 2\Sigma (\bar{S}_{24} - \bar{M})^2 + (\bar{S}_{30} - \bar{M})^2 + \ldots + (\bar{S}_{87} - \bar{M})^2$$

$$= 2\Sigma [(2.25 - 3.38)^2 + (4.25 - 3.97)^2 + (2.50 - 2.72)^2] \ldots + [(\ldots + (2.75 - 2.72)^2]$$

$$= 27.47$$

$$SS_{total} = \Sigma\Sigma(S_{ij} - \bar{M})^2$$

$$= \Sigma[(2.5 - 3.38)^2 + (4.5 - 3.97)^2 + (2.0 - 2.72)^2] + \ldots + [(\ldots + (2.5 - 2.72)^2]$$

$$= 35.47$$

$$SS_{wp} = SS_{treat} + SS_{res}, \text{ and } SS_{total} - SS_{bp} = 35.47 - 27.47 = 8.00$$

$$SS_{res} = SS_{wp} - SS_{treat} = 8.00 - 4.78 = 3.22$$

ANOVA summary

Source		SS	df	MS	F
Between people	(SS_{bp})	27.47	7		
Within people	(SS_{wp})	8.00	8		
Treatment	(SS_{treat})	4.78	1	4.78	10.39[1]
Residual	(SS_{res})	3.22	7	0.46	
Total	(SS_{total})	35.47	15		

[1] $F_{.01}(1,7) = 5.59$.

is the sum of squared distances for each individual somatotype (N = 16) from $\bar{M}$, [SStotal = $\Sigma\Sigma(S_{ij} - \bar{M})^2$]. The variation between treatments or occasions is the weighted sum of the squared deviations of the treatment means about $\bar{M}$, [SStreat = $\Sigma n_j (\bar{S}_j - \bar{M})^2$]. This is the same calculation as for the independent F as shown in Table 2. The between individual variation is the sum of the squared distances of the somatotype means for the individuals about $\bar{M}$, [SSbp = $k\Sigma(S_i - \bar{M})^2$], where k = number of treatments. The obtained F ratio for the differences between treatments

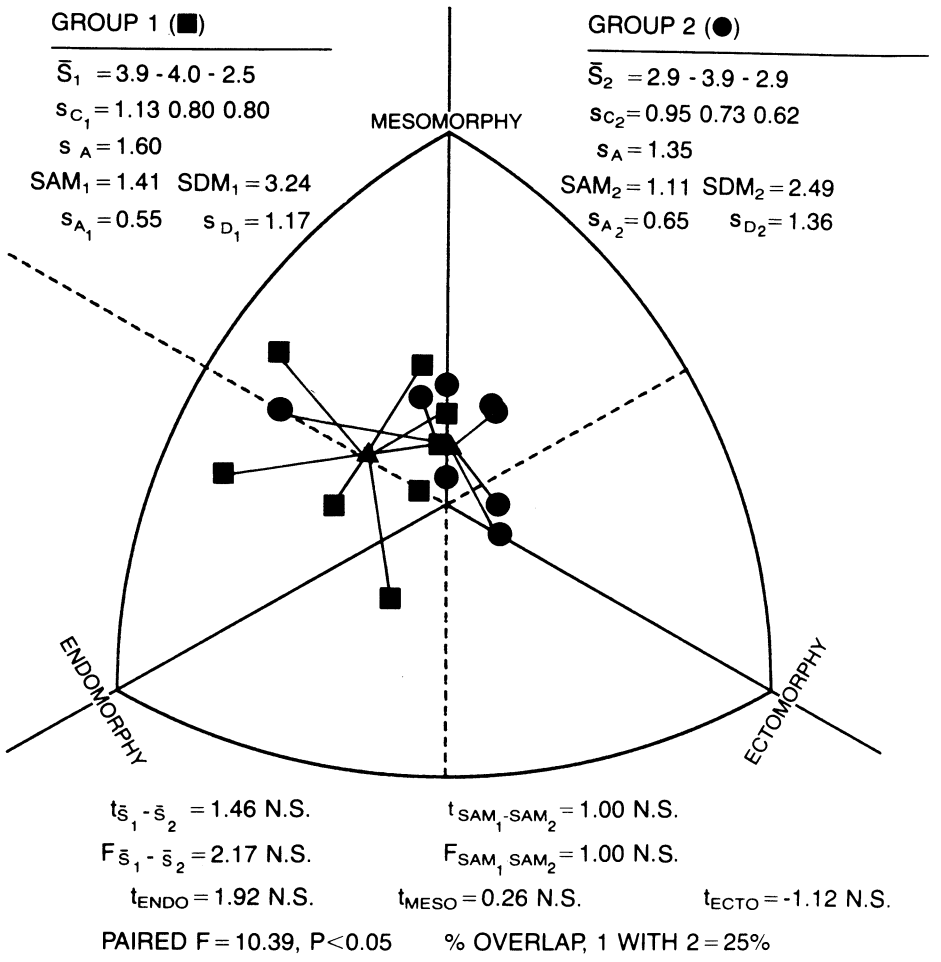

Fig. 6. Somatochart showing two somatotype samples (groups 1 and 2), with a summary of descriptive and comparative statistics. Sc_1 and Sc_2 represent the standard deviations for each of the components of their respective groups. S_A = standard deviation of somatotypes about S_1 and S_2 using SADs. In each sample, the lines connecting each somatoplot to its respective mean (triangles) represent the SDDs.

is 10.39, which is significant with df = 1,7 ($P < 0.05$). A summary of the descriptive and comparative statistics discussed above and the somatoplots for groups 1 and 2 are presented in Figure 6.

In addition to testing differences among mean somatotypes, it may be of interest to determine if the scatters of the somatotypes in different groups are similar, regardless of where the distributions are relative to each other. Standard computational procedures for t and F ratios can be applied to differences between or among SAMs or SDMs when the appropriate standard errors associated with these means are used. For example, calculations of t and F ratios for differences between SAM_1 and SAM_2 (groups 1 and 2 in Table 2) are shown in Table 4. Because t = 1.00 and F = 1.00, it is concluded that there is no difference in the scatter of somatopoints for group 1 or group 2. Alternatively, a test of equality of variances about their respective $\bar{S}$ (mentioned above) may be used to assess the scatter of the somatotypes. The variances about $\bar{S}_1$ and $\bar{S}_2$ are 2.55 and 1.83, respectively. Thus, $F_{max} = s_1^2/s_2^2 = 2.55/1.83 = 1.39$ ($P > 0.05$, df = 1,7). Therefore, the variances are not significantly

different. It should be noted that the tests in Table 4 use the average scatter, whereas the variance ratio tests the variance about the $\bar{S}$'s. Either procedure appears valid provided the meaning of each is kept clearly in mind.

Several nonparametric approaches to describing somatoplot dispersions have been recommended. Ross et al. (1977) used the SDM as a radius to draw a circle representing the scatter of somatoplots about $\bar{S}$. Although the I-index which they proposed is not ordinarily calculated, graphic comparisons using 1.0, 1.5, or 2.0 times SDM as the radii for somatotype samples can be made to illustrate variation and overlap between samples (Fig. 7). Such comparisons may be appropriate only if the circles approximate the shape of the scatter of the somatoplots about their respective means. Another method is to circumscribe the limits of each of a pair of somatotype distributions on the somatochart and count the number and percentage of somatotypes that overlap in each distribution (Hebbelinck et al., 1980).

Correlation

Relationships between separate components and selected structural and functional variables have been examined using product-moment, partial, and multiple correlations (e.g., Clarke, 1971; Sills, 1950; Slaughter et al., 1977; Štěpnička et al., 1977).

TABLE 4. Calculation of t and F ratios for differences between independent somatotype attitudinal means (SAM): Data from Table 2

Test for equality of variances about SAMs

$$F_{max} = \frac{S_1^2}{S_2^2} = \frac{0.42}{0.30} = 1.40 \quad (P > 0.05, \text{ df} = 1,7)$$

A. Calculation of t ratio

$$t = \frac{SAM_1 - SAM_2}{\sqrt{\frac{\Sigma d_1^2 + \Sigma d_2^2}{n_1 + n_2 - 2}\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

where $\Sigma d_j^2 = \Sigma(SAD_j^2) - [(\Sigma SAD_j)^2/n_j]$,
and the SADs for each group are from Table 2,

$$t = \frac{1.41 - 1.11}{\sqrt{\frac{2.09 + 2.94}{14}(0.25)}} = \frac{0.30}{\sqrt{0.09}} = 1.00 \text{ (not significant)}$$

B. Calculation of F ratio

$$F = \frac{SS_{treat}/df_t}{SS_{error}/df_e}, \text{ where } SS_{treat} = \Sigma n_j (SAM_j - \bar{G})^2,$$

and $\bar{G}$ = overall mean; and $SS_{error} = \Sigma(\Sigma d_j^2)$, from t ratio calculations above.

$$SS_{treat} = 8(1.41 - 1.26)^2 + 8(1.11 - 1.26)^2 = 0.36$$

$$SS_{error} = 2.09 + 2.94 = 5.03$$

$$F = \frac{0.36/1}{5.03/14} = \frac{0.36}{0.36} = 1.00 \text{ (not significant)}$$

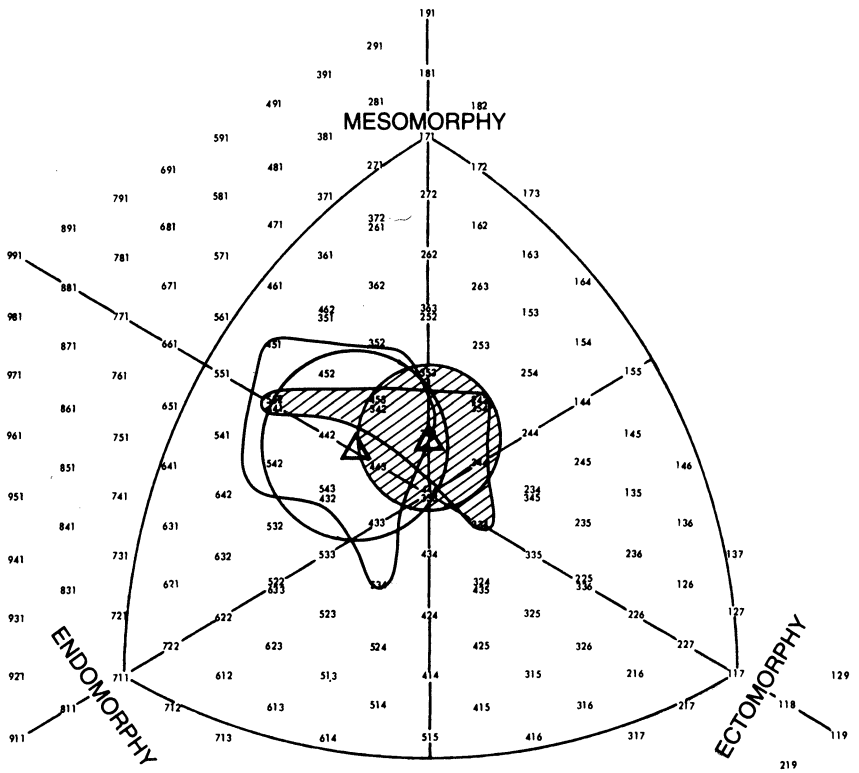

Fig. 7. Somatochart showing the mean somatoplots (triangles) and circles with radii equal to 1.0 × SDM for groups 1 and 2; also shown are the areas encompassing all somatoplots in each group.

These methods have provided useful results regarding the components, but sometimes interpretation is misleading or difficult because the selected component is treated independently and is taken out of the context of the somatotype. Methods for obtaining correlations between the somatotype rating and other variables using a tetrachoric correlation and subsequent test of significance by chi-square have been described by Parnell (1958) and Walker (1962).

A recent correlational approach using distances between somatotypes and variables such as motor performance scores has been proposed by Araujo (1979). In this approach, the distances (either SADs or SDDs) of each somatotype from a mean or reference somatotype are correlated with performance. For example, in order to examine the relationship between somatotype and swimming performance, the SADs between the Olympic winner (the reference) and each of the other swimmers in the same event are calculated and correlated with swimming place or time. Assuming that the subjects in Table 1 are swimmers listed in order of finish (second through ninth place), and the mean somatotype ($\bar{S}$) is the somatotype of the first-place swimmer, the product-moment correlation between the place of the swimmers and the somatotype distance of each swimmer from that of the winner is 0.24. This low correlation indicates an absence of any meaningful relationship between somatotype and place in this event. (The rank difference correlation, rho, using the same data is 0.19.)

Intensity and migratory distance

Stability, or lack of it, in the somatotype of a subject followed longitudinally is a measure of the change of the somatotype. Stability can be measured in terms of

distance moved by the somatotype, direction of its path, change in dominance (e.g., endomorphic mesomorph to ectomorphic mesomorph, a 3-5-2 to 2-5-3), or change in intensity. The intensity (INT) of a somatotype is the magnitude of the vector from the origin (the hypothetical 0-0-0 somatotype) to the somatopoint in three dimensions as follows:

$$INT_P = SAD_{O,P} \tag{5}$$

where the intensity of somatotype P is equal to the magnitude of the SAD from the origin O to P. Thus for the somatotype 3-5-2

$$INT_{352} = SAD_{O,352} \tag{6}$$

$$INT_{352} = \sqrt{(3 - 0)^2 + (5 - 0)^2 + (2 - 0)^2} = \sqrt{38} = 6.16.$$

The intensity of a somatotype is an expression of the distance of the somatotype from the origin of the x,y,z coordinates. In growth studies, intensity indicates if the somatotypes are moving toward or away from the origin. Every change in somatotype will have an associated intensity change, providing the change is not a switch of component values (e.g., 3-4-1 to 4-3-1 has no change in intensity, but 3-4-1 to 2-4-2 does change in intensity). The intensity is expressed in component units (because it is derived from the SAD), and the difference in intensity between two somatotypes cannot exceed their SAD.

The sum of the SADs between a sequence of several somatotypes obtained at different times is called the migratory distance (MD) and is determined as follows:

$$MD_{P_1,P_4} = SAD_{P_1,P_2} + SAD_{P_2,P_3} + SAD_{P_3,P_4} \tag{7}$$

where P_1 to P_4 are four somatopoints. The MD, like the SAD, is expressed in component units. Whereas the SAD between the first and last of a sequence of somatotypes measures only the difference between these two, the MD takes into account the magnitude of the complete pathway through all the intermediate somatotypes. The MD is a useful measure of individual or mean somatotype changes in longitudinal studies (Parízková and Carter, 1976). The smaller the MD, the greater the stability of the somatotype.

It can thus be noted that the somatotype may change in intensity (e.g., 2-4-1 to 3-5-2), in dominance (e.g., 3-5-2 to 2-5-3), in both dominance and intensity (e.g., 2-5-3 to 2-4-1), or in stability (e.g., 2-4-1 to 3-5-2 to 2-5-3). Changes in direction may also occur. Calculations for these examples follow:

$$\text{2-4-1 to 3-5-2: SAD} = 1.73;\ \text{SDD} = 0.0;\ \text{INT} = 1.58. \tag{8}$$

$$\text{3-5-2 to 2-5-3: SAD} = 1.41;\ \text{SDD} = 3.46;\ \text{INT} = 0.0. \tag{9}$$

$$\text{2-5-3 to 2-4-1: SAD} = 2.24;\ \text{SDD} = 3.46;\ \text{INT} = -1.58. \tag{10}$$

$$MD_{P_1,P_2,P_3} = 1.73 + 1.41 = 3.14. \tag{11}$$

A schematic illustration of the relationships between these measures is shown in Figure 8.

Summary of approaches to analysis

The choice of analysis obviously depends on the purpose of the study and the hypotheses to be tested. The following approaches are suggested.

(1) For sample descriptions: (a) means and standard deviations for each component, SAM, and SDM; (b) somatocharts showing individual values and mean somatoplots as these are the best way to display somatotype data; (c) somatoplots by category or area on the somatochart.

(2) For average differences between samples: (a) between somatotype means ($\bar{S}_1 - \bar{S}_2$); (b) between component means (endomorphy, mesomorphy, or ectomorphy); (c)

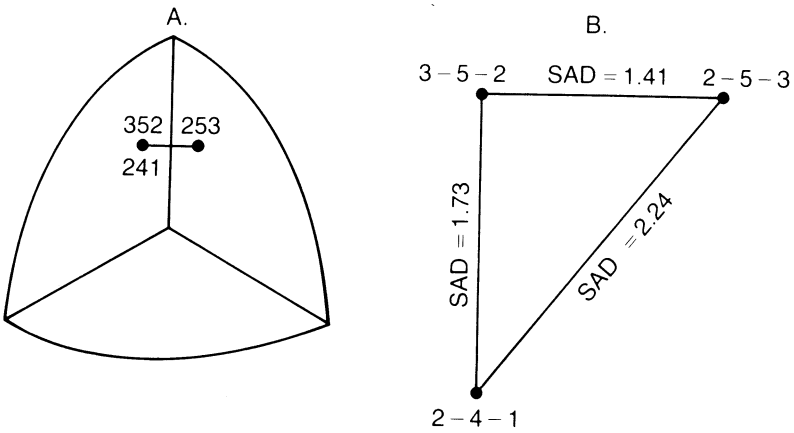

Fig. 8. A schematic representation of the relationships among three somatotypes. A is a two-dimensional representation showing both the 3-5-2 and 2-4-1 somatotypes plotted at the same point; and B is a three-dimensional representation showing the somatotype attitudinal distances (SAD) among somatotypes (enlarged but drawn to scale).

between the scatter of somatotypes about $\bar{S}$ ($SAM_1 - SAM_2$; variances about $\bar{S}_1$ and $\bar{S}_2$); (d) between categories or areas; (e) differences in intensity ($INT_{\bar{P}_1,\bar{P}_2}$).

(3) For differences between two somatotypes: (a) $S_1 - S_2$; (b) ($INT_{\bar{P}_1,\bar{P}_2}$); (c) differences between a particular somatotype (S_i) and a group somatotype ($\bar{S}_j$).

(4) For change in somatotype: (a) SAD (total change); (b) INT (change in magnitude); (c) MD (consecutive change).

It should be noted that some of the calculations could be made by using SDDs, but some distortion of the true values in three dimensions may result. SDDs should only be used when describing or comparing the somatoplots on the somatochart. It should be emphasized that there are certain assumptions made when using the SAD (and thus MD and INT). The basic model uses perpendicular coordinate axes and equal units on all axes. This means that the model has "equal appearing intervals," not only within each component but also between the components.

The choice of approach depends upon the problem being investigated and is not limited to those presented here. All the techniques can be calculated by hand (or small electronic calculator), but their application to group data can be tedious. To relieve this tedium and to encourage consistency among investigators a software package of programs called "PROSOMAN—Computer Programs for Somatotype Analysis" has been developed for several of the methods described above.[3] Other techniques, such as those described by Carter (1980a) and Parnell (1958), but not presented here, are useful, but the intent of this article has been to present possibilities for somatotype analyses. In so doing, it is hoped that they can be utilized in examining old and new questions involving somatotype in resolution of problems in human biology, physical anthropology, growth, constitutional medicine, and the exercise and sport sciences.

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[3]For information on PROSOMAN, write to J.E.L. Carter, Department of Physical Education, San Diego State University, San Diego, CA 92182.

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