Variability in the Anthropometric Status of Four South African Populations*

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SUMMARY

Coefficients of variation (V) of 4 populations were compared for each of 11 parameters. Males differed significantly in cristal height and 3 skinfolds. It has been suggested that negroids vary more in relation to their means in cristal height because of the onset of differential growth of the lower limbs. Relatively large Vs in skinfold measurements of White and Indian boys, notably those of the trunk, arose because there were more obese individuals with extreme values in the White and Indian populations than in the Cape Coloured and negroid populations.

In females, leg circumferences and subscapular skinfolds differed significantly. Leg circumference Vs of Indian females were probably enhanced as a result of variably high adiposity in the calf region. The presence of extreme values in obese girls of this group had been the cause of raised Vs in subscapular skinfold measurements. There appear to be three periods during which the Vs of males and females differed: males varied more than females at the ages of 6 and 7 years; then females varied more until between 13 and 15 years, when males again became more variable. White males, however, varied more than White females in skinfolds. This may be caused by the presence of extreme values at either end of the distribution graph of both 'over-optimal' nutrition and undernutrition.

It is shown that confidence limits based on a central value of the standard deviation (σ) do not take into account the increasing variability with age noted in most parameters in populations of growing individuals. In future studies, variability changes should be shown by placing polynomials into one of the categories described in this article.

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The purpose of this article is to examine the anthropometric variability of 4 South African populations, as represented by samples of White, negroid, Coloured and Indian children from Pretoria who were measured during a nutritional status survey from 1962 to 1965. Variability may be understood from the standard deviation (σ) or the coefficients of variation (*V*). These parameters for each of 11 measurements have been reported previously. By examining variability, it is hoped to shed light on certain aspects which may be of importance in the nutritional and growth contexts.

Smit *et al.*[1] calculated 70% and 95% confidence limits and constructed polynomials for the age groups from 6 to 15 years. The form presenting the confidence limits was decided on after visual inspection of scatter diagrams which served as the basis for determining the order of polynomials (first, second or third). Figs 1 - 4 are examples of such scatter diagrams.

Confidence limits based on 1 σ would include about 68% of all subjects in a population, whereas those based on 2 σ about 95%. The previous report, then, showed confidence limits which were slightly different from those based on the standard deviations, and which were placed at regular distances from the means of all age groups. Whether this was advisable, in the case of populations of growing juveniles may be assessed from the results obtained when the coefficients of variation (*V*)*, are considered.

The influence of population and age on the coefficient of variation was tested by means of Friedman's two-way analysis of variance (Table I). Where significant differences were found, figures in the first two columns were underlined. The means of *V* of all ages combined are shown in the right-hand columns in Table I.

Figs 5 - 8 are graphic representations of the coefficients of variation of various body measurements in children from the 4 population groups. Comparisons were made by inspecting the graphs visually. The probable changes of *V* with age are noted for each anthropometric parameter.

RESULTS

Population Differences (Table I)

Significant differences were found among the 4 population groups in cristal height and the 3 skinfolds in males, and in leg circumference and the subscapular skinfold in females. In cristal height, negroid males have the greatest *V*, followed by Whites. In Coloured and Indian males, *V*s for cristal height are similar and lower than those of negroid and White males, respectively. In all 3 skinfolds, *V*s of White males are highest, those of Indian males second highest, followed by those of Coloured and negroid males, in that order. The greatest differences are found in the 2 skinfold thicknesses taken on the trunk (subscapular and para-umbilical). In relation to the means, leg circumferences of Indian females vary greatly (9,55%) compared with those of females from the other groups,

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*The utility of σ for comparative purposes is rather restricted, as σ shows the degree of variation in concrete units. On the other hand, *V* makes it possible to compare variation in height with that of skinfolds, these in turn with those of girths; intercristal width with that of biacromial width, etc.

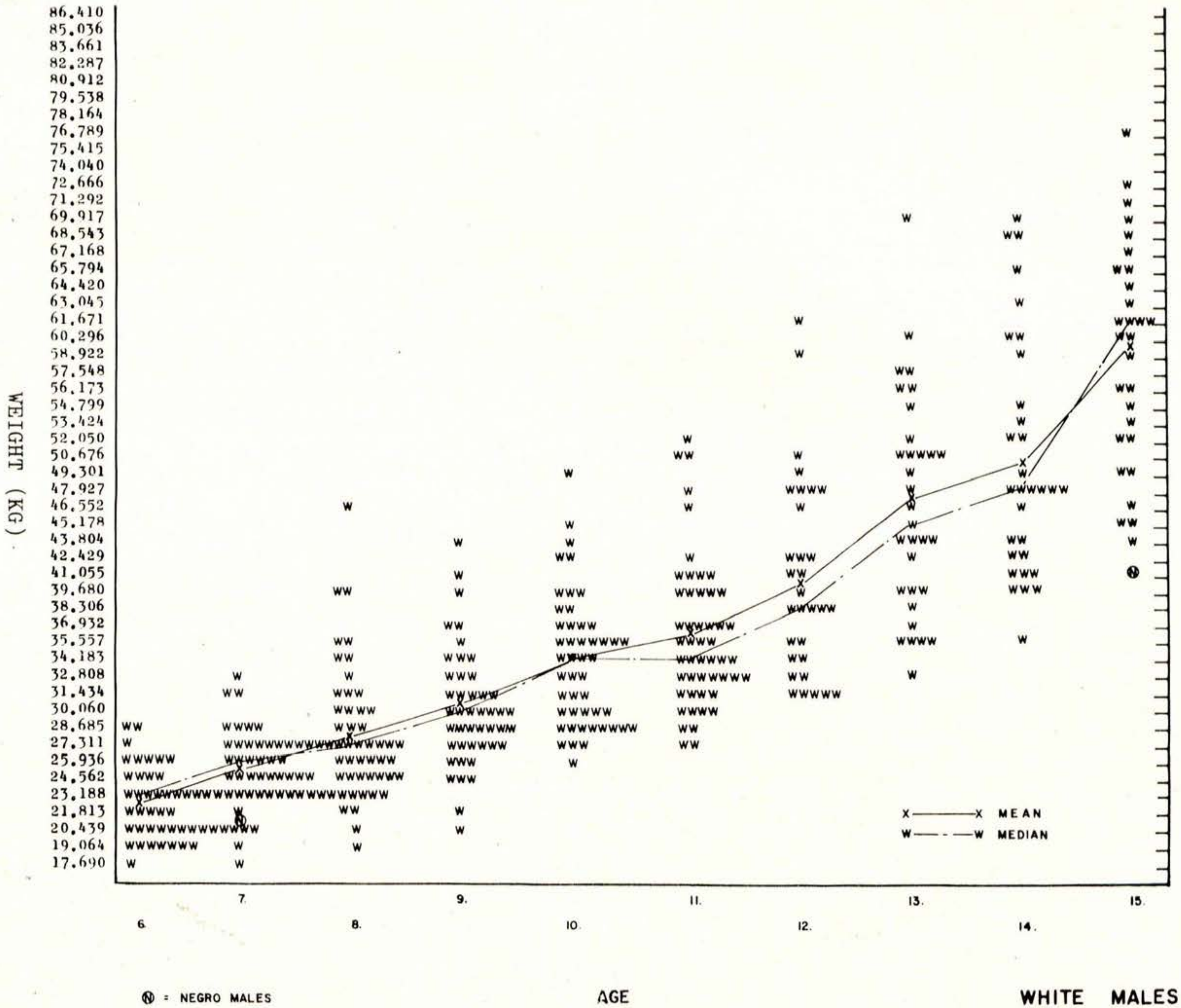

Fig. 1. Example of scatter diagram: mass of White males aged 6 - 15 years.

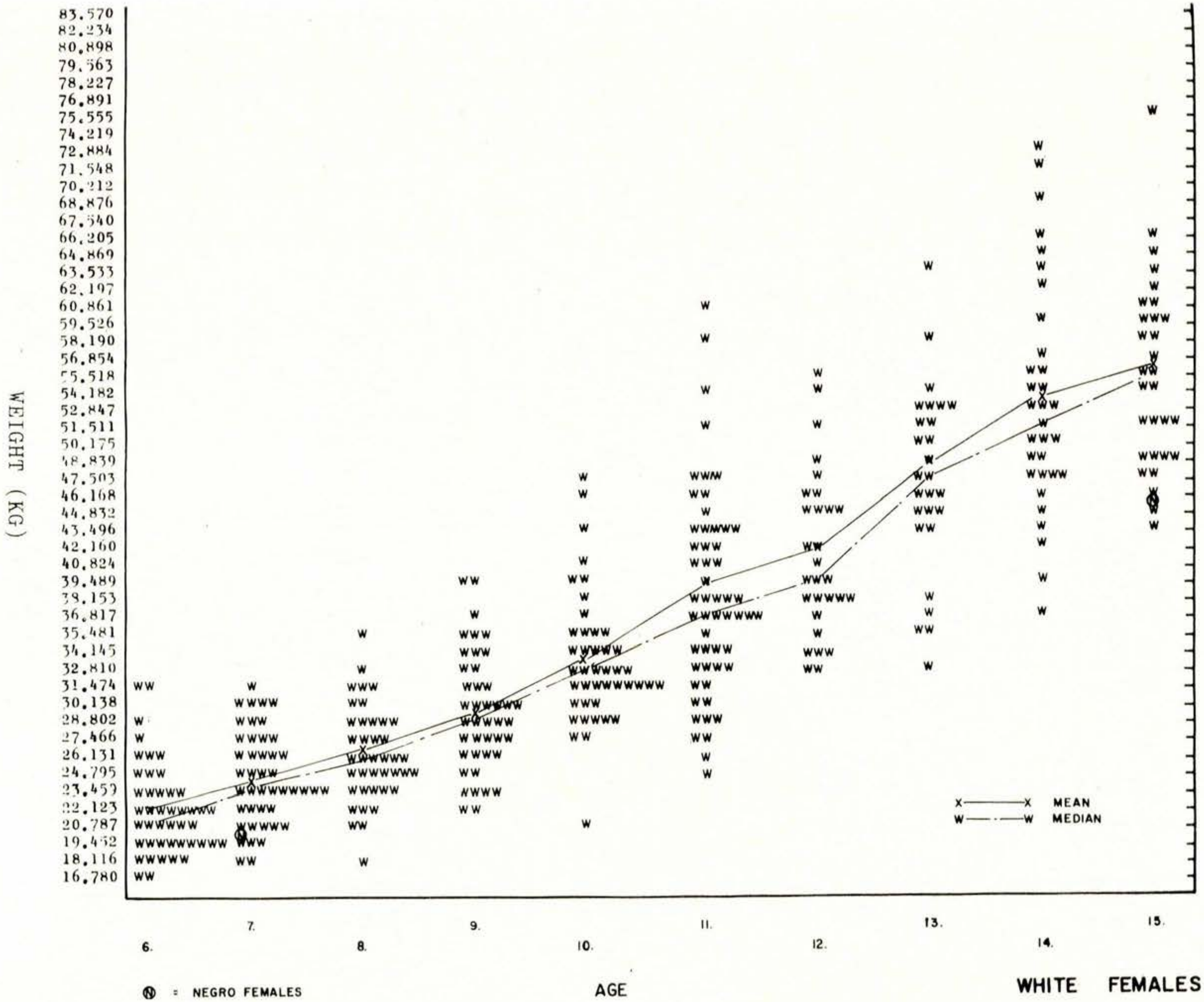

Fig. 2. Example of scatter diagram: mass of White females aged 6 - 15 years.

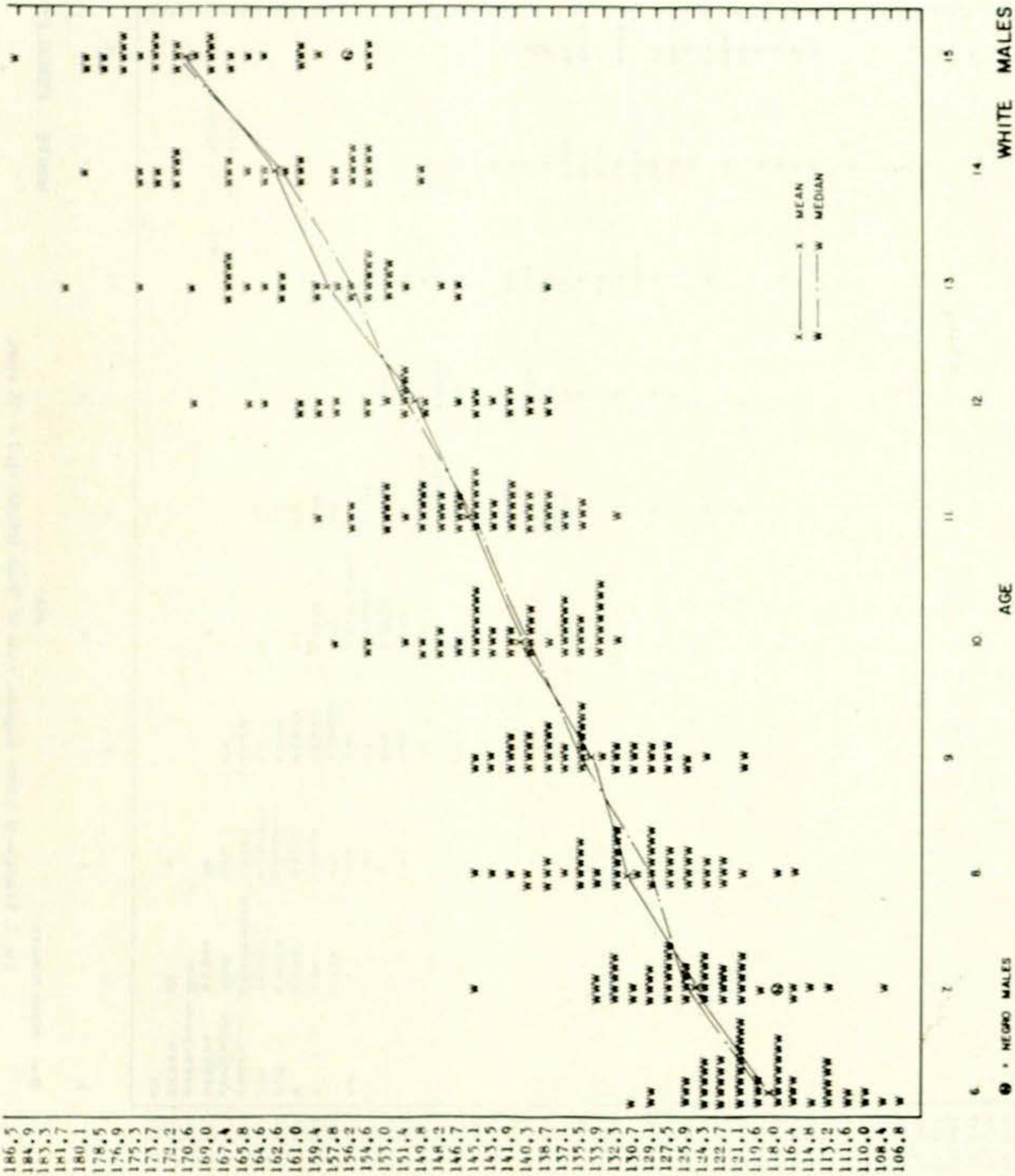

Fig. 3. Example of scatter diagram: stature of White males aged 6 - 15 years.

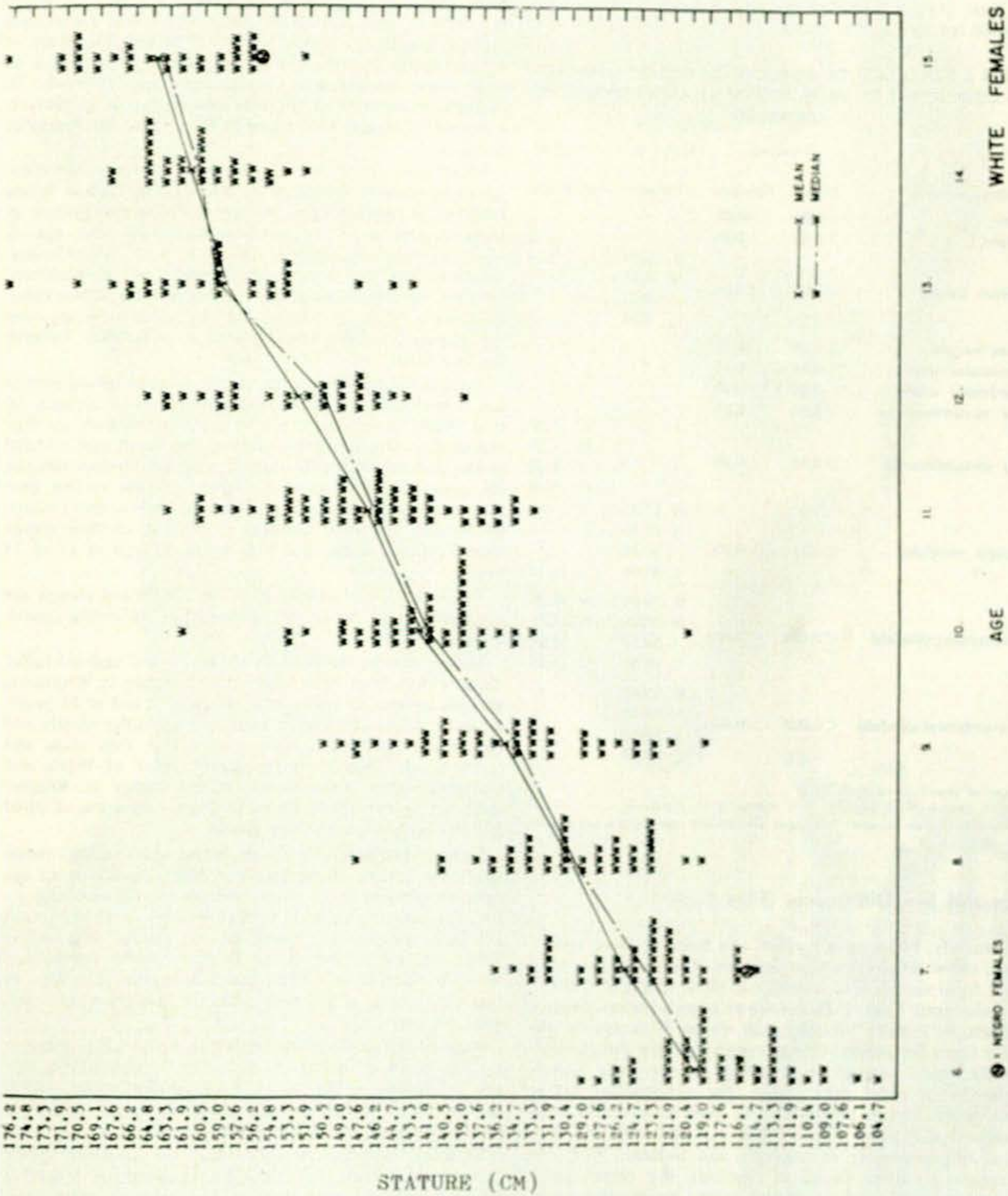

Fig. 4. Example of scatter diagram: stature of White females aged 6 - 15 years.

whose *V*s fall between 7,23% and 7,55%. In subscapular skinfolds, Indian females also vary the most in relation to their means, followed by the Coloured, White and negroid females, in that order.

TABLE I. INFLUENCE OF POPULATION GROUP* AND AGE ON COEFFICIENT OF VARIATION OF 11 ANTHROPOMETRIC VARIABLES

	P values		Means of *V* (all ages)	
Measurement	Males	Females	Males†	Females†
Mass	>0,05	>0,05		
Height	>0,05	>0,05		
Cristal height	<0,05	>0,05	W 6,30 N 6,51 I 5,63 C 5,69	
Ulnar length	>0,05	>0,05		
Biacromial width	>0,05	>0,05		
Intercristal width	>0,05	>0,05		
Arm circumference	>0,05	>0,05		
Leg circumference	>0,05	<0,05		W 7,39 N 7,75 I 9,55 C 7,23
Triceps skinfold	<0,01	>0,05	W 31,98 N 22,86 I 30,46 C 25,86	
Subscapular skinfold	<0,001	<0,001	W 39,00 N 17,71 I 30,17 C 21,51	W 38,76 N 27,71 I 44,94 C 29,33
Para-umbilical skinfold	<0,001	>0,05	W 53,97 N 24,13 I 39,15 C 36,28	

(Level of significance $P<0,05$).

* W = White; N = negroid; I = Indian; C = Coloured.

† The differences between the sexes and among age groups are shown in Figs. 5 - 8.

Age and Sex Differences (Figs 5 - 8)

Generally, males aged 6 years, and more so those aged 7 years, show greater *V*s than females. The exceptions may result from sample fluctuations, e.g. ulnar length of Coloured males aged 7 years. Then follows a period when females are relatively more variable than males. It occurs at different times for different measures in different populations. Thirdly, male variability is again greater than female variability at older ages; again, the dimorphism differs from population to population. In both stature and mass it appears earliest in Whites, then in Coloureds, and then about simultaneously in negroids and Indians. With the exception of ulnar length in negroids, the remaining 2 measurements of vertical growth (ulnar length and cristal height) of males begin surpassing those of females in relative variability in all the groups, at about the same time as those noted in stature and mass. Biacromial and intercristal widths, indicative of lateral growth, show greater *V*s in males than in females in the non-White populations, from about the point where the stature and mass *V* graphs cross over; the *V*s of intercristal width of White females, however, differ only slightly from those of their male counterparts at successive age intervals. In biacromial width, after the first female rise in *V*, there is a period of greater variability in relation to the means in females.

Coefficients of variation in leg and arm circumferences generally seem to be higher in White males than in White females; in negroids, the arm circumference is greater in females, and so is leg circumference from the age of about 12 years. In Indians, the *V*s of both circumference measurements are greater in females; in the Coloured subjects the arm is more variable in relation to the mean in females than in males, but leg circumference does not appear to differ considerably in variability between the two sexes.

Annual fluctuations in the *V*s of skinfold measurements are considerable in all 4 populations, but it appears (*a*) that White males are more variable in relation to their means than White females—this applies to all ages covered in the present study; (*b*) that negroid and Indian females are generally more variable relative to the means than their male counterparts in this respect; and (*c*) that Coloured females are more variable in relation to their means than Coloured males, but only up to the age of 13 or 14 years.

When the *V*'s of skinfolds of the non-White groups are compared with those of Whites, the following points emerge:

Males: Triceps skinfold *V*s of White and negroid males differ widely from each other (being higher in Whites) at all ages covered in this study, except at 7 and at 14 years; those of White and Indian males do not differ widely and the graphs fluctuate in such a way that they cross and recross each other fairly frequently; those of White and Coloured males differ widely (being higher in Whites) until the age of about 13 to 14 years, when the skinfold *V*s of Coloured males are greater.

Subscapular skinfold *V*s of White and negroid males also differ widely (being higher in White males) at all age intervals, except at 7 years; differences between the *V*s for subscapular skinfolds in the White and Indian males are high, mainly as a result of the greater *V* noted in White males after the age of 12 years; the *V* of the subscapular skinfold of White males is higher than that of Coloured males at all ages, with the exception of males aged 14 years.

Para-umbilical skinfolds of White males have a higher *V* than those of males of the other 3 populations, with two exceptions: at the age of 9 years Indian males, and at the age of 14 years Coloured males are more variable in relation to their means than White males.

Females: Subscapular skinfolds are relatively more variable in White than in either negroid or Coloured females, with an exception at 13 years in either case; Indian females, however, vary relatively more in this measurement than do White females.

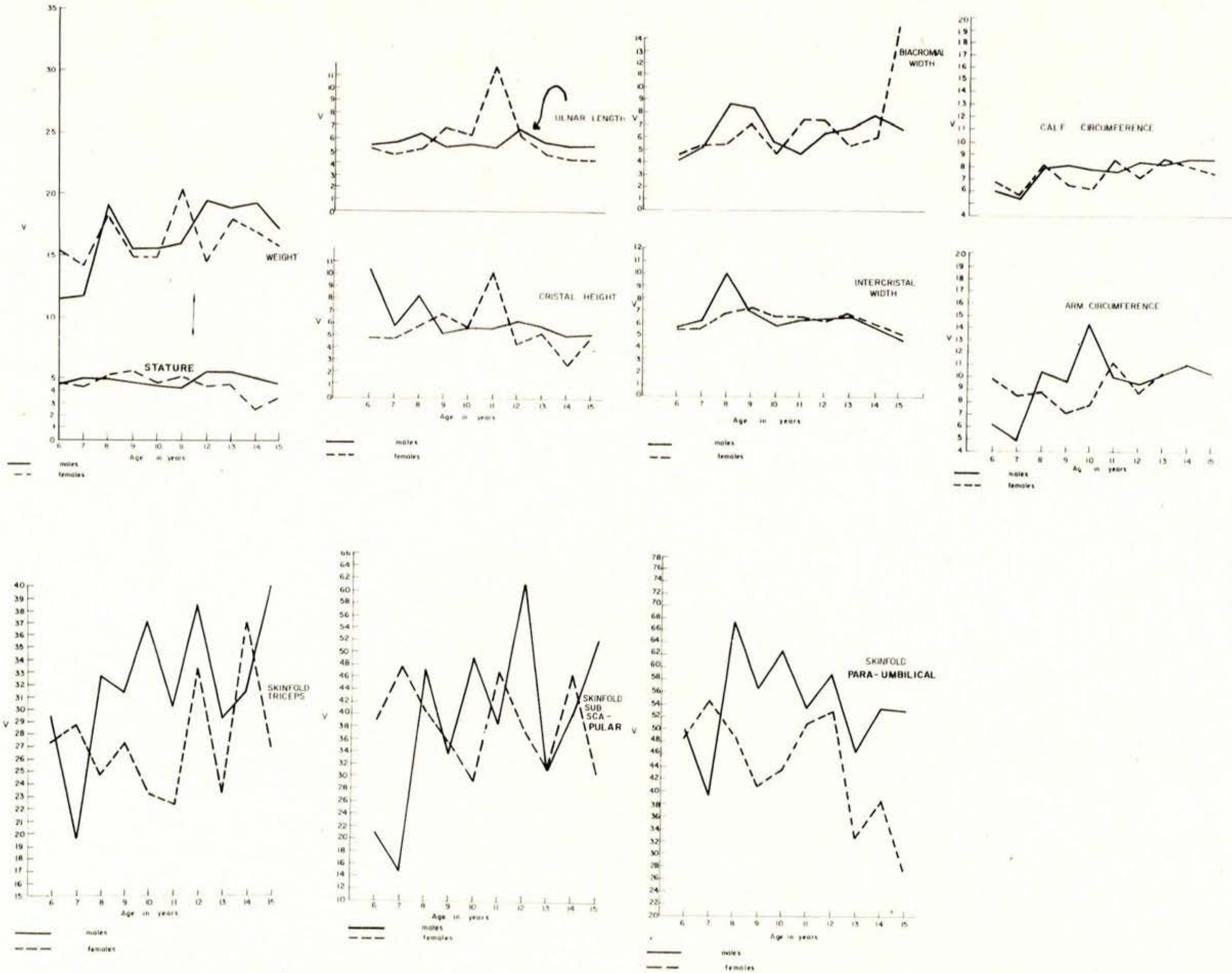

Fig. 5. Coefficient of variation (*V*) in White children aged 6 - 15 years.

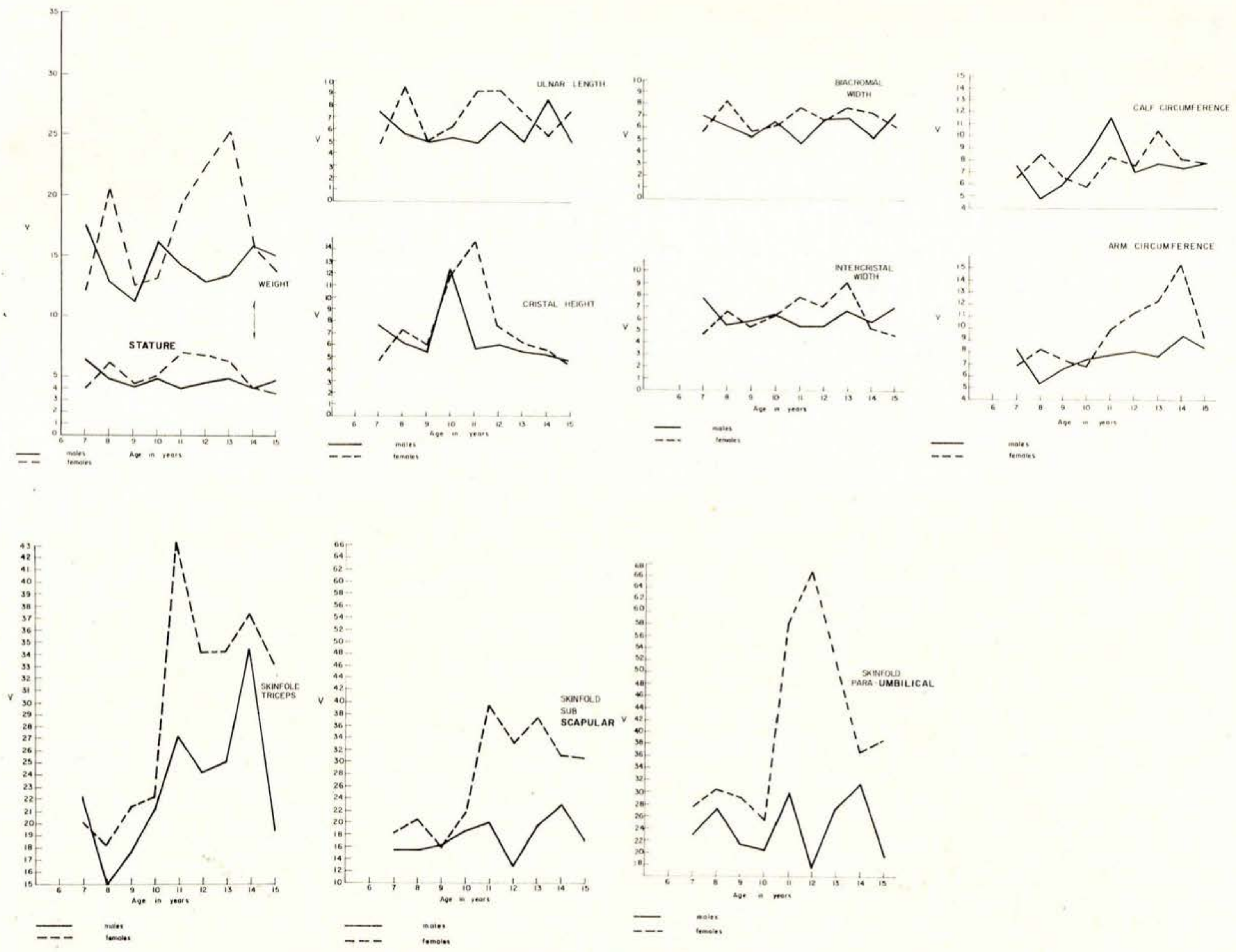

Fig. 6. Coefficient of variation (V) in Negro children aged 7 - 15 years.

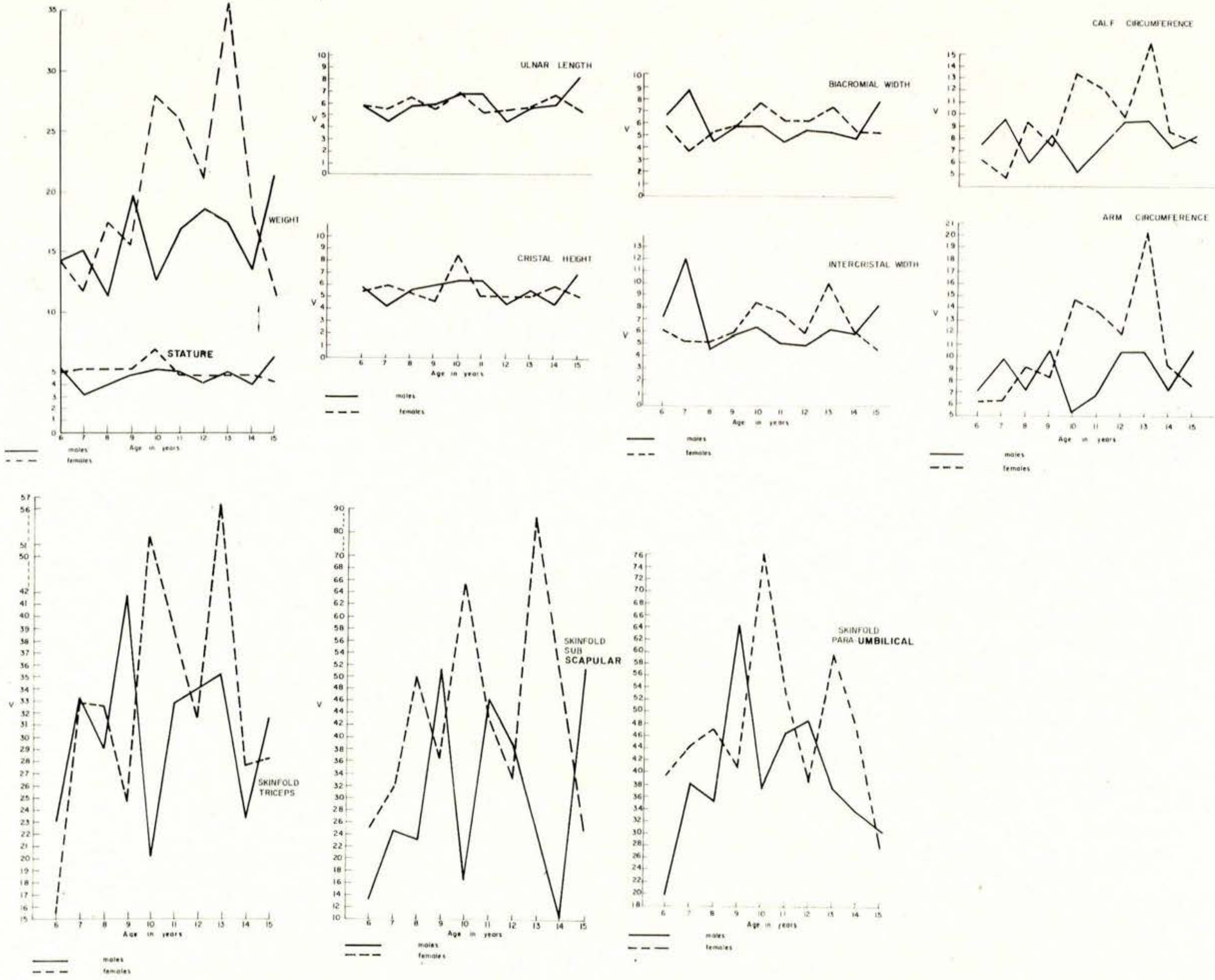

Fig. 7. Coefficient of variation (V) in Indian children aged 6 - 15 years.

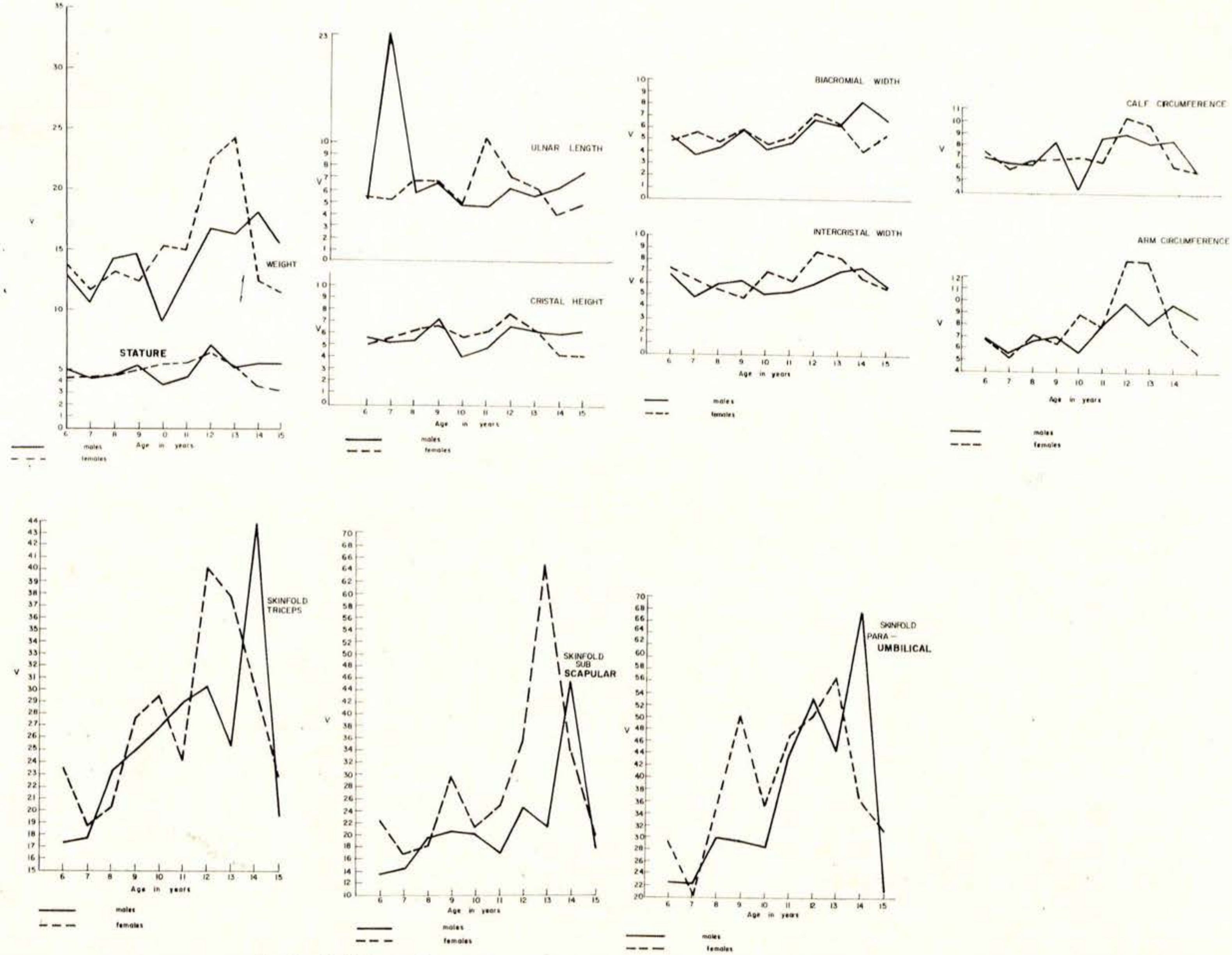

Fig. 8. Coefficient of variation (*V*) of Coloured children aged 6 - 15 years.

TABLE II. DISTRIBUTION CHARACTERISTICS OF 11 ANTHROPOMETRIC VARIABLES OF MALES AND FEMALES OF 4 POPULATIONS

	White		Negroid		Indian		Coloured	
	M	F	M	F	M	F	M	F
Mass	S (P>11-14)	P	S	P	S (N>11, 15)	P-1 (14)	P-2 (6,7)†	P-1 (7)
Stature	S	P-1 (13)	S	P-3 (11, 13 15)*	S (N>15)	S	P-2 (12, 15)	S
Cristal height	S	S	S (P11-15)	S	S	S	S	S
Ulnar length	S (N>6, 7)	S	S	S	S (N>15)	S (6-10); P (11-15)	S	P-3 (9, 12, 15)*
Biacromial width	S (P>14)	S	S (P7-11)	S (P>13)	S (N>7, 15)	S	S (6-11); P (12-15)	S (P>7)
Intercristal width	P-3 (9, 14, 15)	P-2 (6, 15)	S (P7-9)	S (P>12 and 13)	S	S	P-3 (6, 8, 12)	P-1 (7)
Arm circumference	P-1 (10)	S (6-11); P (12-15)	P	P	S (P>13)	P-3 (6, 7, 14)	S (P>13)	S (P>12-14)
Leg circumference	P-3 (10, 12, 15)	S	S (P>15)	S (P>13)	S (P>13, N>15)	P-3 (6, 7, 12)	S	S (P>8)
Skinfold: Triceps	P-1 (7)	P	P-3 (7 ,8, 15)	P-1 (9)	P-1 (10)	P-2 (6, 15)	P-2 (7, 9)	P
Subscapular	P	P	P-2 (11, 13)	P	P-3 (6, 10, 14)	P	P-4 (6, 7, 12, 15)	P-1 (15)
Para-umbilical	P	P-1 (14)	P	P	P	P	P-1 (15)	P

S = symmetry, inferred from similarity (nearness) or frequent crossing of mean and median lines in the age groups 6 - 15 years.
P = positively skewed at all age groups; general positive skewness inferred.
p-*i* (e.g. P-2) = positively skewed at all but *i* (e.g. two) age groups; *i* (e.g. two) ages where the distribution has been found to be negative are shown next to or below p-*i* (P-2). If such figures are underlined, the mean and median values are the same.
N = negative skewness at the ages indicated.
P>15 or N>15 indicates that P or N is pronounced at the age (15) indicated, such skewness providing a noteworthy exception in a distribution that is otherwise generally symmetrical.
* S considered possible.
† 6 - 11 likely.

Categories of *V* Graphs

Theoretically, the 4 main categories into which the *V** graphs may fall, are where the coefficients of variation (*a*) rise as subjects grow older; (*b*) remain more or less constant with age; (*c*) drop moderately as children grow older; and (*d*) there is a severe drop. These imply the following, as regards the scatter:

A: If *V* rises as subjects grow older, then the variation (scatter) around the mean becomes progressively greater with age (Fig. 9). The increase in variation becomes proportionately greater than the increase of mean measurements at successive ages.

B: If *V* remains constant in the age groups, then the variation also becomes progressively greater with age, but now it increases in proportion to the means at successive ages, probably as shown in Fig. 10.

C: If *V* drops moderately as children grow older, the variation (scatter) remains more or less constant with age, and a regular distance from the polynomial to the confidence limits is implied at successive ages (Fig. 11).

D: A very severe drop in *V* as subjects grow older would indicate a narrowing down of confidence limits (Fig. 12), but such an occurrence has not been observed.

*Fluctuations on the *V* graphs have been disregarded and only the general trend of the lines were considered (visual inspection).

There were altogether 44 *V* graphs in the A category, 22 in B, 22 in C and none in D (Fig. 13).

DISCUSSION

Population Differences from Table I

Males: The greater *V* of negroid and White males in cristal height suggests that at similar ages in these 2 groups, as compared with the Coloured and Indian groups, there are more subjects, proportionately, whose development has either progressed more slowly or otherwise faster, or both, than that of the others. The greater *V*s of negroid and White males may not arise from the same cause. It is known that the limbs of negroids are longer in relation to stature than those of Whites. The juvenile negroid males studied here varied more in relation to their means than other males during the period 8 - 10 years (Fig. 6). This is unlikely to be attributable to a pre-adolescent growth spurt, for such a growth spurt would then have been reflected in the sample means for cristal height.[1] There must, then, be another reason for the ascendancy in *V* of the cristal height of negroid males aged 8 - 10 years. Although sample fluctuations are not ruled out, negroid females show a similar increase in *V* only a year or so later, although no

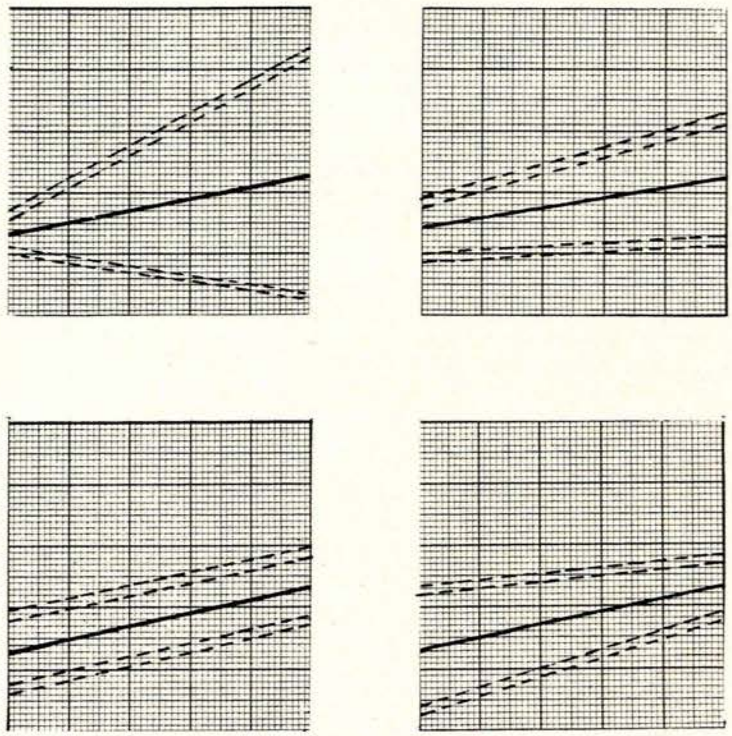

Fig. 9 - 12. The 4 main theoretical categories into which *V* graphs (Fig. 5 - 8) may fall.

significant differences from other populations were apparent from the two-way analysis of variance. One is tempted to speculate whether this phenomenon does not have its origin in one of those racially distinct morphogenetic processes referred to by Tobias[2] which manifest themselves during growth; if, during this period, increased differential (or allometric) growth of the lower limbs had begun in some negroid males, it may well have resulted in an increased variation such as is implied by Fig. 6. Within a year or 18 months of its onset differential growth of the lower limbs in negroids may have progressed to a point where differences in relative cristal height (cristal height/stature × 100) would become apparent. Thenceforth, the lower limbs would continue to grow more rapidly in relation to stature, or to the trunk or sitting height, than those of Whites (or other populations not thus affected), until after adolescence or maturity. However, because of a later or slower maturation in negroids[3] the absolute measurements would neither increase faster nor vary more than those of other populations from the point where differences in relative cristal height occur, onwards, despite the faster growth in relation to other measurements of vertical development.

The raised mean coefficients of variation in cristal height of White males may be the result of sampling fluctuations, or of an earlier general vertical upsurge of some boys which started at 6 - 8 years, observed not only in cristal height but also in stature and ulnar length measurements.

The greater *V*s in skinfold measurements of White and Indian boys, notably those on the trunk, arise because there are more obese individuals with extreme values in the White and Indian populations than in the Coloureds and negroids.

Females: The leg circumference of Indian females differs widely in *V* from that of the other groups. It is likely that *V* in this measurement is enhanced in Indian females as a result of variably high adiposity in the calf region. An inspection of the fat deposits in the leg and the arm, as pictured in *Gray's Anatomy* for instance, might lead one to surmise that leg circumference provides an adequate measure of muscularity, but then a textbook of this kind depicts only one limb and not a series drawn from subjects of different populations, somatotypes, ages and sexes. The present findings destroy any hope of employing a single circumference measurement as an indicator of muscularity in females, unless it is adjusted by at least one skinfold, and preferably by a bone measurement as well. Brozek[4] has suggested that this procedure be followed when assessing muscularity in the arm, and Neser[5] recognised the principle in her nomogram for the assessment of nutritional status in labourers from various populations. It is suggested that the means of the triceps and the biceps skinfolds be taken when implementing the skinfold correction. However, the possibility of a parallel development in adiposity, muscularity and bone thickness over a period in other groups or populations is not ruled out, so that a single circumference measurement may still, if properly evaluated, be useful as an indicator of muscularity when such groups are studied. Future surveys should, in addition to taking the measurements reported in this study, include the gastrocnemius skinfold measurement, as well as the measurement of epicondylar width of humerus and

	White		Negro		Indian		Coloured	
	M	F	M	F	M	F	M	F
Weight	A	B	B	A	A	A	A	A
Height	A	C	C	C	A	C	A	C
Ulnar length	B	C	B	B	A	B	B	C
Cristal height	C	C	C	C	B	B	B	C
Biacromial width	B	A	A	A	C	A	A	A
Intercristal width	C	C	B	B	B	B	B	A
Calf circumference	A	A	A	A	B	A	B	C
Arm circumference	A	A	A	A	B	A	C	C
Skinfold triceps	A	A	A	A	B	A	A	A
Subscapular	A	C	A	A	B	A	A	A
Para-umbilical	A	C	C	A	B	C	A	A

Fig. 13. The relation between age and variability: probable category of graphs allocated by visual inspection of Figs 5 - 8. A: *V* rises with age (44 cases); B: *V* remains ± constant with age (22 cases); C: *V* drops as children grow older (22 cases).

›icondylar width of femur. By so doing, a clearer picture ›f the components of the body may be gained from anthro›ometric techniques.

Because of a large incidence of obesity, it is not sur›rising that the *V* in the subscapular skinfold of Indian emales is higher than those of other groups. Again the ıfluence of extreme values would enhance variability. ılthough, in females, significant differences among all populations are noted only in subscapular skinfolds, it ; expected that a pattern similar to that of males would btain for the *V*s of triceps and para-umbilical skinfolds. ndian girls, having more subcutaneous fat than Whites at everal ages, occasionally show a greater *V* in these skin›lds too.

›ifferences in *V* of Measurements Other than kinfolds

From those tables giving the polynomials or expected ıeans of various measurements,[1] it is seen that the skeletal ıd girth measurements of males mostly surpass those of females at 6 and 7 years. The greater *V* in males of the younger ages covered by this study indicates that more males than females had passed (or had not yet reached) the average state of development denoted by the polynomials (Figs 5 - 8).

Age: The age when females become more variable in relation to their means than males is thought to be connected with the onset of puberty. Support for this view is probably afforded by the following: (*a*) *V* for intercristal width in White and negroid females surpasses that in males at an age earlier than that at which biacromial width *V* surpasses those of males; (*b*) *V* for intercristal width in Coloured and Indian females starts to increase before it does so in males. This suggests that differential hormonal secretion has begun in some females, resulting in an increase in variability.

Sex: By comparing the male with the female graphs and from noting when they cross over and cross back (or fail to cross back), Smit *et al.*[1] suggested that the cross-over was an indication that the female growth spurt had started, while the 'crossing back' marked the stage when the male growth spurt had begun. The later onset in negroids of the stage where male *V*s again become greater than female *V*s is likely to result from a later puberty and concomitant development. Negroid males, as is well known, reach puberty later than White males. Furthermore, the observations by Smit *et al.*[1] suggest that the onset of female puberty and of male puberty in the negroid population are likely to be further apart than in the White. The present graphs of stature and mass (Figs 5 and 6) appear to confirm this conclusion. Similar considerations may apply to Indian and Coloured children.

The onset of the stage when male *V*s for stature and mass become greater than the corresponding female *V*s, is denoted by arrows on the graphs. These stages appear to be synchronised for the 2 parameters of stature and mass. The graphs for other parameters frequently show the same or a similar trend. Higher female *V*s in the measurements of leg and arm circumference probably result from the fact that more females than males showed extreme values in these 2 measurements. The reason may be sought in the greater adiposity of females.

Differences in *V* of Skinfolds (Figs 5 - 8)

The main differences in skinfolds may be described as follows:

Sex differences: White males are more variable (in relation to their means) in measurements of subcutaneous fat than White females, in contrast with the non-White groups, where females are found to be generally more variable than males. This may result from the fact that whereas an adequate state of nutrition prevailed among most White children in the survey, there were also homes where food was scarce and below 'threshold-value'. About 2 out of 30 White males aged 12 years in Pretoria are thought to suffer from inadequate nutrition; this ratio may well obtain in other age groups as well. Males from such households, and from those communities living below the breadline, are expected to show signs of undernutrition, including anthropometric retardation, more than females do, which accounts for one possible source of greater male variation. Thus, the series seems to have included boys from homes where food was scarce, who suffered from undernutrition and consequent depletion of subcutaneous stores, and also boys who were receiving optimal nutrition, or even excess, accompanied by too little exercise. This may have contributed towards a greatly variegated sample. In contrast, the females from poorer homes are expected not to have shown such marked depletion in their subcutaneous fat stores.[5]

Similar conditions may apply in the Indian population, but here the females have the greatest *V*s. Even though some Indian males may have been malnourished, this did not produce much greater *V*s for skinfold measurements of males than those of females. There were several individual Indian females at every age level who were obese, so that one would have expected a greater relative variability.

Males in the Coloured, and more especially the negroid population, vary relatively less in skinfold measurements than their female counterparts, not because the latter have a high incidence of obesity, but simply because skinfolds were similarly low in practically all negroid and Coloured boys.

Differences in skinfold variability of the 4 populations: White males were found to have higher *V*s in the 3 skinfold measurements than males of the non-White groups. This strengthens the view that there could have been several cases of 'over-optimal' nutrition, accompanied by too little exercise among White males of certain families, and of inadequate nutrition.

Besides, there may be a genetic tendency towards low skinfolds in negroids, judged from reports on other negroids;[6-9] this probably applies also, to a lesser degree, to Coloureds.

Among the female subsamples the highest coefficients of variation in skinfolds are found in Indians. This is likely to be the result of a greater percentage of obese Indian females. The influence of adiposity upon girth measurements of arm and leg in Indian females has been noted.

Reassessment of the 70% and 95% Confidence Limits (Fig. 13)

The fact that three-quarters of the *V* graphs fell into categories A or B, where the variation (scatter) became progressively greater with age, indicates that many of the confidence limits shown on the published population graphs might have been more accurate had they been fitted to take account of increasing variation. It is recommended that in populations of growing individuals, confidence limits for all anthropometric variables should be calculated on the basis of an increasing scatter with age. Stated differently, relative variability in these populations of growing children becomes greater as the means increase.

To explain this phenomenon, it is suggested that children in any population may attain varying stages of development at each age level, particularly those stages when adolescence occurs; and/or attain states of growth that differ in relation to the end results of their growth, which will also be affected by the stages when adolescence occurs. A further point is that the end results would almost certainly differ *inter se*. Increasing variability may be attributed to each point or any combination of these.

Physicians comparing measurements in children with the norms suggested by the graphs containing the 70% and 95% confidence limits, are reminded that limitations are implied by the procedure followed in fitting those confidence limits. In practice, the population graphs in their present form may nevertheless be useful in the assessment of growth in most children and for determining the status of divergent groups, such as the trained or the malnourished.

SUMMARY OF THE DISTRIBUTION CHARACTERISTICS OF ANTHROPOMETRIC VARIABLES

Eighty-eight scatter diagrams, not all of which could be reproduced in print but which have been illustrated by Figs 1 - 4, were originally used for deciding on the shape of the polynomials.[5] On these scatter diagrams, the median values were connected by pencil. The lines thus drawn were suitable for comparison with the sample means, to obtain an indication of which anthropometric variables had symmetrical distributions. Where the mean is the same as the median, a symmetrical distribution is indicated; where it is higher than the median the distribution is positively skewed and where lower, negatively skewed. Instead of showing the distribution for each cell, which may, after all, have contained sampling errors, the author made an effort to summarise the distribution characteristics of 11 anthropometric variables by means of Table II. Thus the possible types of distribution are shown separately for males and females of 4 population groups, though all ages were combined within each sex group.

The legends at the foot of Table II explain the symbols used.

I wish to thank the Council for Scientific and Industrial Research of South Africa for having placed the data at my disposal, and for administrative and other facilities.

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