ANTHROPOMETRIC STATUS OF PRETORIA CHILDREN OF FOUR POPULATIONS: INCREASES IN CROSS-SECTIONAL SAMPLES*

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SUMMARY

Total percentage increases per 10 years of growth and average triennial percentage increases were calculated for 11 anthropometric variables in males and females aged 6 - 15 years from four South African populations studied cross-sectionally. The increase of various measurements for each population was discussed and compared with that for the other populations; also, values for males and females were compared.

Growth—the rate of which has been expressed by different mathematical equations—can be observed most successfully by means of a longitudinal study. Tanner[1] has demonstrated why a cross-sectional study fails to show, for example, when the adolescent growth spurt occurs. Although one may not expect to find in cross-sectional data conclusive indications of any spurt, and although none of the growth equations can be applied because subjects are observed only once, cross-sectional surveys such as those undertaken by the National Nutrition Research Institute of the South African Council for Scientific and Industrial Research can provide a rough indication of the growth of the 4 populations studied. This report is aimed at investigating percentage increases in the four populations, White, Bantu, Indian and Coloured, and is a sequel to previous reports[2,3] dealing with the anthropometric investigations undertaken during the surveys.

The observing of absolute increments of various measurements from year to year in a cross-sectional study may be satisfactory where large numbers of subjects are investigated.[4,5] In samples which are relatively small, such as those representing individual ages in the present study, considerable fluctuations of the means may occur from age-group to age-group. These, in the statistical sense, are sample fluctuations and do not necessarily reflect any change in the growth rate. Polynomials offer a more stable basis for comparison.

It was therefore decided to study percentage increases (reported in Tables I - IV) as derived from the polynomials (reported previously.[2,3])

METHOD

Percentages were calculated on the basis $\frac{y - x}{x} \times 100$

where x = measure at lower age limit; and y = measure at upper age limit.

In Tables II - IV attention is drawn to the number of times males and females from the non-White groups have greater percentage increases than Whites. One limitation was that not all of the polynomials reported were straight lines. All 4 populations were considered in age classes of 3 years (6 - 9, 9 - 12 and 12 - 15).† This division was arbitrary and had no connection with the onset of any development stage. To obtain an indication of growth velocity by an admittedly crude method, the percentage increases for each year were calculated, but the fluctuations were so great that no meaningful interpretations were possible. The average annual increases for 3 triennial periods were consequently used as the basis for comparing the 2 sexes and the 4 populations. It was reasonable to expect such triennia to give a rough indication of any period during which a population developed faster than it did in another period, and when one population developed faster than another.

Further questions that arose were whether, after the age of 6 years and up to the age of 15 years, males grow faster in relation to their anthropometric status at 6 years than females do, and also whether one population grows faster than another over this total time span. In the absence

TABLE I. PERCENTAGE INCREASES IN BODY MEASUREMENTS OF THE WHITE POPULATION, SHOWING MEAN ANNUAL INCREASES FOR EACH OF 3 TRIENNIAL PERIODS, AND TOTAL INCREASES FROM 6 TO 15 YEARS

	Mean increase per annum						*Total increase over 9 years (6 - 15)*	
	6 - 9		*9 - 12*		*12 - 15*			
Body measurement	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*
Weight	8·7	10·0	11·5	12·9	*11·9*	9·6	148·9	152·2
Stature	4·4	5·1	*3·9*	3·7	*3·5*	2·7	*41·7*	40·3
Cristal height	5·3	6·0	*4·6*	4·0	*4·0*	2·7	*48·4*	45·5
Ulnar length	5·1	5·9	*4·4*	4·1	*4·0*	2·7	*50·6*	45·1
Biacromial width	4·2	4·4	3·6	4·0	3·4	3·5	39·1	41·6
Intercristal width	4·1	4·8	3·6	4·3	3·4	3·7	38·6	45·5
Arm circumference	2·9	3·4	*5·0*	4·6	*6·2*	5·4	*50·8*	48·3
Leg circumference	2·9	4·4	3·8	3·8	*4·4*	3·5	38·6	41·2
Skinfold:								
Triceps	*2·1*	−0·9	2·0	6·8	1·9	8·2	19·2	50·0
Subscapular	*7·7*	1·7	5·7	10·1	5·4	13·3	72·7	103·3
Para-umbilical	*9·1*	5·8	6·7	14·3	5·5	16·1	85·1	176·7

Cases (17) where male percentage increases were greater than female are printed in italics. In the 3 successive triennia, these cases occurred 3, 4 and 6 times respectively. Thus, a few more measurements show male predominance in successive triennia.

TABLE II. PERCENTAGE INCREASES IN BODY MEASUREMENTS OF THE BANTU POPULATION, SHOWING MEAN ANNUAL INCREASES FOR EACH OF 3 TRIENNIAL PERIODS, AND TOTAL INCREASE FROM 6 TO 15 YEARS

	Mean increase per annum							
	6 - 9		*9 - 12*		*12 - 15*		*Total*	
Body measurement	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*
Weight	4·9	10·4*	8·5	11·2	9·9	10·7	95·8	150·2
Stature	3·8	4·2	3·4	3·7	3·1	3·4*	35·7	39·5
Cristal height	4·7	4·8	4·1	4·2*	3·7	3·7*	44·9	45·1
Ulnar length	4·7	5·1	4·1	4·4*	3·5	3·8*	43·8	47·9*
Biacromial width	3·4	4·1	3·2	3·8	2·8	3·3	32·5	38·7
Intercristal width	3·8	5·1*	3·3	4·2	3·0	3·8*	34·5	46·6*
Arm circ mference	0·7	3·8*	2·8	4·1	4·0	4·1	24·7	42·0
Leg circumference	3·9	5·0*	3·5	4·3*	3·1	3·8*	36·3	47·0*
Skinfold:								
Triceps	−2·7	6·9*	0·0	5·7	3·3	4·9	1·5	66·1*
Subscapular	−1·5	2·1*	2·3	8·2	5·5*	11·5	20·0	86·9
Para-umbilical	−1·7	3·8	2·6	11·8	5·4	14·3	20·0	132·6

There were no cases where male percentage increases were greater than those of females, indicating that Bantu males' growth rate is slower than that of Bantu females over the age range surveyed.

*In only one case, viz. subscapular skinfold at 12 - 15 years, was the percentage increase of Bantu males greater than that of White males—and then only slightly—whereas percentage increases of Bantu females were not infrequently greater than those of White females (18 out of 44 cases, which occurred 6, 3 and 5 times in the 3 successive triennia respectively). Judged by these crude standards the growth rate of Bantu females is therefore not expected to differ considerably from that of White females. The 18 cases referred to are denoted by an asterisk.

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†The figures for 6-year-old Bantu children were obtained by extrapolation.[3]

TABLE III. PERCENTAGE INCREASES IN BODY MEASUREMENTS OF THE INDIAN POPULATION, SHOWING MEAN ANNUAL INCREASES FOR EACH OF 3 TRIENNIAL PERIODS, AND TOTAL INCREASE FROM 6 TO 15 YEARS

	Mean increase per annum							
	6 - 9		*9 - 12*		*12 - 15*		*Total*	
Body measurement	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*
Weight	8·9*	16·5*	11·1	11·8	_11·2_	9·3	143·0	188·6
Stature	4·4	4·4	3·9	3·9*	3·5	3·5*	41·3	41·5*
Cristal height	5·3	6·5*	_4·5_	4·2*	_4·0_	2·5	_49·9_	47·2*
Ulnar length	5·1	6·1*	4·4	4·4*	_3·9_	3·1*	48·0	49·1*
Biacromial width	3·8	4·7*	_3·9*_	3·7	_3·9*_	3·1	_40·7*_	40·5
Intercristal width	3·8	5·3*	3·6	4·7*	3·1	4·0*	36·4	51·2*
Arm circumference	4·1*	4·3*	3·8	4·0	3·4	3·7	39·4	42·1
Leg circumference	_4·5*_	3·3	3·9*	5·4*	_3·5_	2·4	_41·8*_	38·4
Skinfold:								
Triceps	2·4*	8·1*	2·2*	6·2	2·1*	5·0	22·1*	75·0*
Subscapular	5·1	10·6*	4·4	11·2*	3·9	11·0	47·7	154·9*
Para-umbilical	5·6	16·0*	4·8	12·7	4·6	10·7	54·9	196·9*

Cases (11) where male percentage increases were greater than female are printed in italics. During the 3 triennia, these cases occurred 1, 2 and 5 times respectively. Male growth therefore tends to become faster in relation to female growth as subjects become older.

*In 12 out of 44 cases, Indian male percentage increases were greater than those of White males. In the 3 triennia these cases occurred 4, 3 and 2 times respectively. There were 26 out of 44 cases where Indian female percentage increases were greater than those of White females. In the three triennia, these cases occurred 9, 6 and 3 times respectively. The growth rate of Indian males therefore probably becomes slower in relation to that of White males as subjects grow older, but in the case of females there is probably not much difference between the two races.

TABLE IV. PERCENTAGE INCREASES IN BODY MEASUREMENTS OF THE COLOURED POPULATION, SHOWING MEAN ANNUAL INCREASES FOR EACH OF 3 TRIENNIAL PERIODS, AND TOTAL INCREASE FROM 6 TO 15 YEARS

	Mean increases per annum							
	6 - 9		*9 - 12*		*12 - 15*		*Total*	
Body measurement	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*
Weight	9·8*	11·4	10·5	12·1	10·1	11·3	138·1	168·3*
Stature	4·5*	5·1	3·9	4·0*	_3·5_	3·2*	31·9*	43·8*
Cristal height	5·3	6·3*	_4·6_	4·4*	_4·0_	3·2*	_50·3_	49·8*
Ulnar length	5·2*	5·4	4·3	4·6*	4·0	4·1*	48·3	51·2*
Biacromial width	4·2	4·2	3·7*	3·7	3·4	3·4	_39·5*_	39·3
Intercristal width	4·1	4·9*	3·7*	4·1	3·3	3·8*	38·6	45·3
Arm circumference	1·9	3·0	_4·3_	4·1	3·2	4·5	32·0	40·5
Leg circumference	3·6	3·7	3·7	4·3	3·8	4·6*	38·7	44·5*
Skinfold:					3·8	4·6*	38·7	44·5*
Triceps	0·5	5·8*	0·5	5·0	0·0	4·3	3·1	55·7
Subscapular	4·0	4·8*	3·6	9·0	2·6	10·7	35·0	102·1
Para-umbilical	4·9	6·1*	3·6	12·8	3·8	14·6	43·5	157·7

Cases (6) where male percentage increases were greater than female are printed in italics. In the 3 triennia, these cases occurred 0, 2 and 2 times. The growth of Coloured males is probably somewhat retarded in relation to that of Coloured females.

*In 8 out of 44 cases, Coloured male percentage increases were greater than those of White males. In the 3 triennia these cases occurred 3, 2 and 0 times respectively. The growth of Coloured males therefore tends to become slower in relation to that of White males as they become older. There were 19 out of 44 cases where Coloured females' percentage increases were greater than those of White females. In the 3 triennia these cases occurred 5, 3 and 5 times respectively. The growth rate of Coloured females therefore tends to become neither slower nor faster in relation to that of White females as they become older.

of longitudinal data, this could roughly be calculated by simply taking the total increase in mean metrical characters in each population between 6 and 15 years, and expressing this increase as a percentage of the means at 6 years. Although 6 years happened to be the first age covered in this study, Tobias[6] has stated this to be more or less the age at which differential growth in the occipital bone of the skull of Bantu and Bushman sets in; it is not altogether illogical to think that other manifestations of differential growth may also be observed at or after this stage. I have previously[7] drawn attention to one of these possible manifestations, namely the earlier onset of greater variability in cristal height of Bantu males, which occurred earlier than in the other groups. It was thought likely that a varying rate of growth, as understood from the percentage increases, would shed further light on genetic aspects of development, but this expectation was not fulfilled when the scope of the fluctuations in annual percentage increases became known.

To have taken the age of 15 years, the arbitrary end-point of the present study, as the basis of calculations of percentage increases would have been patently unsatisfactory, for it would have ignored the fact that there are more late-maturers in some populations than in others, with a positive skewness of their maturity distribution curve.

Had the end-results of growth in the populations, i.e. the mean adult dimensions, been known, progress along the path to the adult means could have been noted for every cell (defined as a group of children belonging to one population, sex and age, e.g. 11-year-old Coloured males). Thus one could have eliminated at least one additional source of variance in comparisons of these populations. However, even the end-result is not independent of environmental influences, so that the nutritional implications would not have been too clear by following such a procedure in any case.

In the absence of applicable adult data, the best available figures had to be used for expressing progress in terms of adult dimensions (Fig. 1) as explained below under the sub-heading 'Percentage of Expected Adult Sizes Attained'.

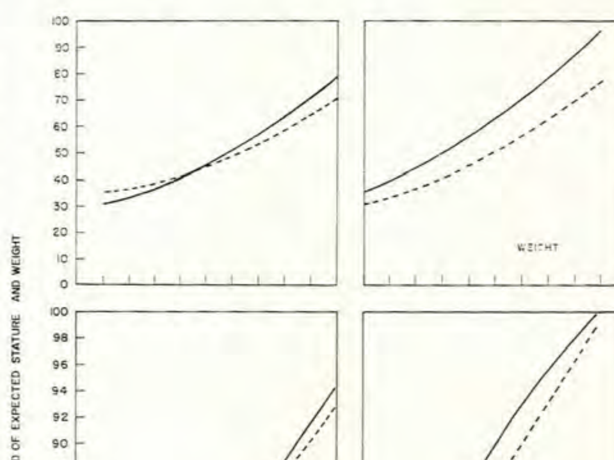

Fig. 1. Percentages of expected adult weight and stature attained by Pretoria White and Bantu children of successive ages. ——— = White
- - - - - - = Bantu

RESULTS

The total percentage increases and mean percentage increases per year, for 3 triennia (ages 6 - 9, 9 - 12 and 12 - 15 years), of the 4 populations, as calculated from the polynomials, are shown in Tables I - IV. In order to take into account any artificial influence included by using population means (polynomials) for calculating total percentage increases, such increases were also calculated on the sample means reported previously.[3] Results were closely similar to those derived from the polynomials. In particular the findings for Bantu males, whose percentage increases differed considerably from those of males and females of the other groups and also from those of Bantu females, were confirmed in every respect.

Weight

The total percentage increase in weight from 6 to 15 years is higher in females than in males in every one of the groups studied. The most spectacular sex difference in total percentage increase in weight was observed in Bantu (males 95·8; females 150·2) and the least marked in Whites (males 148·9; females 152·2). With one exception (Coloured 12 - 15 years), average annual increases in weight of males are accelerated in each successive triennium. This means that the rate of weight gain generally increases in males as they grow older. In females, average annual increases in the first triennium (6 - 9 years) and in the third triennium (12 - 15 years) are lower than in the second (9 - 12 years). Indian females, among whom percentage increases diminish as children grow older, are an exception. Of the other females, the Whites have the highest peak. This means that the rate of weight gain in females generally increases after the age of 9 and then decreases after the age of 12 years.

Vertical Growth

The rate of vertical growth may be understood by considering the measurements of stature, cristal height and ulnar length. In Whites, the total percentage increases for all 3 measurements are greater in males than in females, but in Bantu the opposite holds. In the Indian and Coloured populations no generalization is possible, for the total percentage of stature and ulnar length increases are greater in females of both populations, but the cristal height of males increases more than that of females.

In all 3 measurements, percentage increases of the 4 population groups become smaller during succeeding triennia.

Lateral Growth

Two measures of lateral growth are biacromial width and intercristal width. With the exception of Bantu males, total percentage increases in these measures are similar in males of different groups; total percentage increases per 10 years in Bantu males are conspicuously lower in these measurements. As seen from the total percentage increases, lateral growth, most notably intercristal width, is greater in females than in males. With two exceptions, namely the biacromial width increases of Coloured and Indian children, the rate of growth (judged from the total increase) differs so slightly between the sexes as to be negligible.

The total percentage increase in mean intercristal width of females is greater than that of males. In Whites, the difference in percentage increase between males and females is 6·9, in Coloureds 6·7, in Bantu 12·1 and in Indians 14·8. In succeeding triennia, percentage increases in the measures of lateral growth become smaller; an exception was found in Indian males whose biacromial width showed a very small acceleration during the 9 - 12-years age period. During the 12 - 15-years age period, the increase in biacromial width of males of the White, Indian and Coloured populations are similar to, or have surpassed, those of females, but the increase in Bantu males is much slower than that in Bantu females.

Osteo-muscularity and Adiposity

The state of muscular development of children is appreciably obscured by the absence of data on transverse bone development, the humerus being naturally included in circumference measurements of the arm and the tibia and fibula in those of the leg. I have attempted to differentiate between the bone and muscle components of the arm of these populations by using the known ratios of Philadelphia children.[7] In order to gauge muscularity, it is wise to consider the circumference measurements in conjunction with the skinfolds[8] and transverse bone measurements. In the absence of measurements on the latter, the discussion will mainly centre on circumference and skinfold measurements.

The most obvious result is that all 3 skinfolds develop markedly more slowly in males than in females; this holds for all 4 population groups. The total percentage increases in skinfold measurements give the impression that White males generally accumulate adipose tissue at a faster rate than Indian, Coloured and Bantu males, whose total percentage increases follow in that order. Indian females have the fastest addition of adipose tissue, followed by White and Coloured and, slowest of all, Bantu females. Judged by the mean percentage increases for each triennial period, the thickening of skinfolds generally decreases with age in males, except for very small increases in Bantu.

In White females, percentage addition in all 3 skinfold measurements increases with age; in Indian females, with the exception of the subscapular skinfold, which shows a very slight acceleration, percentage addition of skinfolds decreases with age; in both Coloured and Bantu females, the thickening of the triceps skinfold decreases, whereas those of the subscapular and para-umbilical skinfolds increase with age.

In males, the total percentage increases in arm circumference are greatest in Whites, followed consecutively by Indians, Coloureds and Bantu. In females, the order is: White, Indian, Bantu, Coloured. Differences among the 3 non-White groups are comparatively small.

In males, the total percentage increase in leg circumference is greatest in Indians, followed closely by Coloureds, Whites and Bantu. In females, the order is: Bantu, Coloured, White, Indian.

Arm circumference grows more from 6 to 15 years in White males than in White females, but in all 3 non-White populations the females' arm circumferences grow more than those of males. The leg circumference of Indian males grows more from 6 to 15 years than that of Indian females, but, in the other 3 populations, the females' leg circumferences grow more. Because the arm was measured at the same level as the triceps skinfold, these two measurements are dealt with in detail.

In White males, though the arm circumference tends to show greater increase over the triennial periods, the triceps skinfold shows a smaller increase.

In White females, the greater increase of arm circumference, reflected in the averages of the 3 triennia, was matched by a greater increase in the triceps skinfold measurement.

Indian males as well as females show a deceleration in arm circumference growth over the 3 triennia; this is matched by a deceleration in the growth of subcutaneous fat at the triceps.

Percentage increases of arm circumference and triceps skinfold over the 3 triennia are more or less 'parallel' in Bantu males, but in Bantu females the percentage for arm circumference goes up slightly, whereas the skinfold percentages imply a smaller fat accumulation in the area as they get older.

Percentage increases in the arm circumference of Coloured males show a relative acceleration until the second triennium (9 - 12 years), after which there is a slower rate of increase. The triceps skinfold increases very slowly until the second period and during the third period no increase takes place whatsoever. In Coloured females the percentage increases for arm circumference go up with age, but those for the triceps skinfold come down with age.

DISCUSSION

Weight

From a comparison of the total percentage increases of males and females, it appears that over-all Bantu male growth is slower than that of Bantu females, whereas the growth of White males and females is similar in most measurements, except for differences in the period of greatest acceleration. Growth rate differences in weight of Indian and Coloured males and females lie somewhere in between those of White and Bantu; in relation to their female counterparts, Coloured males put on weight faster than Indian males.

It is known that the rate of weight increase accelerates at the onset of puberty. The present data seem to confirm that females in general reach their period of accelerated weight addition earlier than males.

It is possible that, although Coloured males put on weight faster than Indian males, subjects aged 12 - 15 years expend more energy in relation to their calorie intake than any of the other groups and that weight addition in the older Coloured males is impaired because of this. In tests of motor performance,[7] Coloured males performed better than Indian males, suggesting that Coloureds were more accustomed to large-muscle physical activity. At their level of calorie and protein intake, weight gain may well have been affected.

Similarly, the early acceleration in the weight gain of Indian females may be ascribed in part to their lack of activity. One wonders whether, by the time the average Indian female has reached the age of 12 years, the body has not adapted itself to an inactive way of life, having learnt to dispose (via the excreta, for example) of at least some of the excess calories. This theory is partially supported by the fact that increases of the triceps and paraumbilical skinfolds all follow the same incremental pattern as that of weight, becoming lower as subjects get older; mean subscapular values for the 3 periods lie too near each other to allow for any conclusion as regards this measurement.

Vertical Growth

The slower over-all growth of Bantu males is reflected in all 3 measurements representing vertical height (stature, cristal height and ulnar length). There is a spurt in the growth of the lower limbs (gauged from increases in cristal height) of growing children before that of other regions. In the present series there is no reason to believe that an acceleration of growth of the lower limbs in Coloured and Indian males precedes that of the upper limbs (presumed to be reflected by ulnar length), before these males catch up with their female counterparts in physical dimensions.[3] In Whites, the over-all percentage increase not only in the trunk but also in its segments is greater in males than in females, indicating that the male rate of growth was the faster at some stage between 6 and 15 years. Vertical growth tends to slow down as children get older.

Lateral Growth

Percentage increases of parameters of lateral growth in Bantu males are decidedly lower than those in the other groups, and higher in females than in males. Faster growth in females probably starts at an early stage. Male increases eventually catch up with those of females in biacromial width, but one reason for believing that Bantu males lag behind in maturity[3] is their slow rate of increase in biacromial width (taken to be a secondary sexual characteristic) during the 12 - 15-year age period; this is seen to be much slower than that of Bantu females.

Osteo-muscularity and Adiposity

It is true that the (faster) development of subcutaneous fat in females contributes towards the development of the female form. One can hardly deny that the high rate noted in the White and Indian females is the result of an adequate diet. In spite of a well-organized physical education programme at school, White males also tend to accumulate subcutaneous fat rather rapidly.

As White, Indian and Coloured males grow older, they generally manifest a slower rate of acquiring adipose tissue. In Bantu males, the reverse is true, but the increases are very small, even negligible or zero.

No clear-cut picture emerges from the rate of addition of adiposity in females, as judged from mean percentage increases appearing at each of the 3 triennia. What stands out is that female skinfold increases are generally greater than those of males.

Of the total percentage increases in the mean arm circumferences of the 4 population groups, that of Whites is greatest, while that of the mean leg circumference of Indian males is greater than those of the other 3 male groups. Leg circumference of Bantu females grows faster than that of the other 3 female groups. The contribution made by accelerated osteo-muscular development in White males towards their ascendancy in the rate of arm circumference development over that of White females is likely to be an important one. Unfortunately, no skinfold measurement was taken on the leg. The composition of the leg is not necessarily comparable with that of the arm,* so that at present no similar conclusion may be drawn regarding the observation that increases in the leg circumference of Indian males are greater from 6 to 15 years than those of Indian females.

It is reasonable also to conclude, from the rate at which arm circumference and triceps skinfold in White males increase, that the non-fatty components making up the arm circumference contribute more towards an accelerated growth in circumference during the later years.

It is likely that in White females, subcutaneous fat makes a substantial, if not predominant, contribution towards the accelerated increase of arm circumference. (In males, arm circumference may well be correlated with total muscularity of the arm.) This leads to a rejection of circumference measurements *per se* as parameters of muscularity.

In Indian males, deceleration in the increase of arm circumference, accompanied by a deceleration in the growth of subcutaneous fat over the triceps, superficially suggests that their musculature increases in proportion to their subcutaneous adiposity. However, because this group's increases in the two skinfolds measured on the trunk are far greater than that measured on the arm, arm composition alone cannot be taken summarily as an indicator of total body composition in this group.

Because their total percentage increase of arm circumference is far greater than that of the triceps skinfold, it would seem that muscular development in Coloured males contributes more towards the percentage increases in arm circumference than does subcutaneous fat.

It may seem that, in Coloured females, subcutaneous fat contributes relatively less towards increases in arm circumference than it does in White females, but, as in other female groups, the issue of muscularity is obscured by the large total percentage increases in the 3 skinfolds (55·7, 102·1 and 157·7% respectively).

Bantu Male Retardation

From analyses described previously, it has been shown that Bantu children, on the whole, have smaller body measurements than White children:[3] that these differences tend to become greater with age;[2] and that, in the Bantu group, males probably mature later in relation to females, than in any of the other groups studied.[3] From a consideration of the percentage increases in various measurements, it appears that the over-all growth rate of Bantu males aged between 6 and 15 years is slower than that of Bantu females and all other groups studied here; this applies to the ages covered by the present study.

The general growth rate and development of Bantu females, gauged from percentage increase per 10 years, keep pace with those of other population groups. There is no reason to believe that sexual dimorphism in the Bantu is any greater than in the other populations. In fact, Tobias[6] cites various authors who reported feminine features in Bantu males (manifested, *inter alia*, by gynaecomastia and higher urinary oestrogen secretion than in Whites, possibly as a result of an inadequate diet or even a greater incidence of hepatic dysfunction in Bantu). On this basis, one might expect sexual dimorphism to be even less in Bantu than in some of the other populations. The slower growth of Bantu males† may therefore not be ascribed simply to hereditary (genetic) factors.

The most likely reason for the Bantu male retardation observed is that nutrition in the Bantu population is inadequate. Females are not expected to show such marked retardation as males, when food intake in a population is inadequate.

Le Riche[9] had concluded, on the basis of the ACH Index, based on arm and chest girths, and stature, that there was more malnutrition among boys than among girls, and that the incidence among the boys increased at a greater rate with age, than was the case with the girls. He thought the greater sensitivity of boys to environmental conditions was a result of 'the fact that the propagation of the species is more dependent on the female' who 'would be more resistant to, for instance, lack of food or lack of enough rest, than the male', and also of a possibly more 'economical' utilization of foodstuffs by the female. McCance[10] has confirmed, with studies on animals, that, under conditions of malnutrition, males are more vulnerable than females in some and possibly all species and rehabilitate less completely. Hiernaux[11] reported that retardation was present in males, but absent in females, some 14 years after a severe famine had occurred in Central Africa. The Ministry of Health and Welfare of Japan[12] reported faster recovery from nutritional diseases in females than in males. Latsky,[13] referring to hospital cases observed during his travels in Africa, stated that males were more often affected by nutritional diseases than females.

As far as we are aware, the mechanism responsible for this greater male susceptibility to undernutrition has never been fully determined. It is known that, during exercise, the oxygen consumption per unit of body-weight of males is higher than that of females; this implies that females operate with greater efficiency than males,[14,15] but whether this applies at high levels of energy expenditure is another matter. Also the BMR of males is higher than that of females.[16] Le Riche[9] pointed out that females are possibly more 'economical' in their utilization of food and that boys are more active than girls.

The storage mechanism of females is undoubtedly better than that of males. This is shown by the high subcutaneous fat deposits of females in the present study. The influence of the female sex hormone oestrogen, which is known to facilitate fat addition, and the greater availability‡ of material for storage (fewer calories are converted into energy during activity and there is probably less activity), might well be important factors, although perhaps not the only ones, which favour greater female resistance to stress, and faster growth in females under conditions of malnutrition.

When the data of Theron[17] whose subjects ranged only

*Muscularity does not always increase at the same rate throughout the trunk and its segments. Apart from constitutional factors, the nature of an exercise programme could contribute towards a greater muscular development in one area than another—for example, the powerful development of the muscles of the lower limb induced by cycling.

†It may be argued that low percentages were attained for the Bantu males because the polynomials had been affected by slower maturation (implied previously).[3] Such an argument would merely introduce one of the possible causes for the retardation in Bantu male maturation.

‡Dietary intake of females is generally not expected to be less than that of males (NNRI unpublished data).

from 4 to 12 years, were re-examined by me to determine the percentage increases in those populations, the present trend could not be demonstrated. However, it is probably only when they are about 12 years old that growth in Bantu males becomes relatively so retarded that percentage increases drop noticeably. It is hoped that the age factor may be further investigated in future, by means of a statistical technique at present being developed at the National Research Institute for Mathematical Sciences of the Council for Scientific and Industrial Research (Pretoria).

Dreyer *et al.*,[18] among others, have shown that maize meal (mealie meal), the staple food of the South African Bantu population, has intrinsic shortcomings in nutritive value. For a 2-year-old child, the recommended daily calorie intake is 1 300; if the staple food were the sole source of calories, about 317 g of meal would be needed for this purpose. The assimilable protein derived from 317 g of meal, surprisingly, amounts to 85% of the recommended daily requirements prescribed by the National Research Council, USA. The problem lies in the fact that in South Africa maize meal is usually eaten as maize porridge, and it is seldom realized that maize porridge contains at least 70% water. This means that, for the 2-year-old child to consume 317 g maize meal, the capacity of the stomach must be such as to accommodate a weight of about 2¼ lb of stiff porridge each day.[18] The efforts of workers to develop a suitable supplement for the predominantly maize diet are to be strongly applauded.*

Landauer and Whiting[20] have pointed out that the relation between diet and growth is not as simple as it has sometimes been presumed; physical stress was stated to be a factor which contributed to added bodily growth. Shimazono *et al.*[21] have stated that extra vitamin B_{12} has no growth-promoting effect; however, it may not be excluded as a factor where the intake of daily vitamin B_{12} is smaller than 1 μg. These remarks show that further studies, even of apparently remote factors, e.g. physical stress, are necessary and that such factors have to be included in one's thinking about the assessment of nutritional status.

Laird[22] and Laird *et al.*[23] have shown that the 'specific' growth rate decays exponentially with age; this has been demonstrated in longitudinal studies of growth, and is probably also true of bone age. The present method of calculating percentage increases in a cross-sectional population has its weaknesses. Thus, even when these percentages are plotted on a logarithmic scale, certain of the present measurements do not show an exponential decay. The principle of exponential decay with age is, however, as will be shown, not violated by the method of calculating percentage increases: for a given increase in two populations the percentage increases calculated with age 6 years as basis would be greater in the one (say Bantu) if the first point that was measured (e.g. in the 6-year-old group) were lower than the first-measured point in the other (say White). This point is elucidated on p. 337.

*Supplementation has long been urged and has even been instituted on a national scale before. The reasons for abandoning the national scale supplementation scheme have been shown at length,[19] but efforts at finding suitable supplementation formulae are continuing. Supplementations are often unsuitable because they spoil too soon or otherwise cannot be combined with accepted staple foods. Persuading the Bantu to eat such a supplement is yet another matter, for superstition and scepticism of new foods are often met with among South African Bantu, especially those from the rural areas, where poverty is common, the standard of education is low and communication is poor.

Comment on Coloured Male Growth

A slower over-all or average growth in Coloured males from 6 to 15 years can be noted from a comparison of their total percentage increases with those of Coloured females. Whereas the reason for the lower percentage increases of Coloured males may be similar to those of Bantu males, their relatively high level of activity (inferred from their performances in motor tests[7]) probably has an adverse effect on the positive caloric balance in this group, complicating any clear-cut inference. The point to be noted is that the percentage increases observed in Coloured males do not differ greatly from those of males of other populations. Growth rate, on the average, is probably similar to those of males of the other groups, although differences will occur as children grow older.

In contrast, the over-all development of Bantu males is slower, not only than that of their own female counterparts, but also than that of other males and females. When comparing percentage increases derived from sample means (as distinguished from population means), it was found that the trends were identical with those thus far reported. Reservations about the influence the shapes of the curves (1st, 2nd or 3rd order polynomials)[3] may have had on the percentages reported in this study were deferred when the results of such a comparison became known. The presentation of 4 further tables based on the sample means was considered, but abandoned when it was found that no additional information emerged from such a comparison of percentages based on sample means. Whereas logs provide a true instantaneous difference between measurements in cases where their use results in a straightening of polynomials, logs, in the present case, did not prove more informative than percentages. The latter were preferred for their simplicity.

Percentage of Expected Adult Sizes Attained

There are no random figures of stature and weight available for adults of all 4 populations studied. Although weight and stature have been reported for certain White and Bantu communities in South Africa, there are none for Pretoria. Had the body measurements of the parents of children studied in the present series been available, calculations of percentages of expected adult statures could have been undertaken with a greater measure of confidence. Some correction could have been made for the 'secular change' which was expected to take place in those populations by the time the children were to reach adult size.

The reports on White South Africans[4,5] are the most representative of this population's adult measurements in stature and weight. The best available information on weight and stature of South African Bantu adults is that compiled by Fleming *et al.*[24] (among others, they quoted Slome *et al.*[25] whose male and female subjects were all Zulu).

By using the data given in these reports as a basis for calculating percentage of adult stature and weight attained at successive ages, Fig. 1 was compiled. These calculations may, in some measure, indicate the percentages attained by children of the putative sizes of White and Bantu adults from Pretoria.

It is seen that percentages of putative adult stature and weight of White females were greater than those of Bantu females at all age levels. In weight, these differences are considerable and they become greater with increasing age up to 15 years.

In males, the Bantu had attained greater percentages of expected adult stature and weight by the age of 6 years, whereas, by the age of 15 years, the picture became reversed. Differences between percentages of weight attained by Whites and Bantu were more marked than those in stature. Although the differences between percentages attained by White and Bantu boys are not as great as those attained by girls generally, it appears that Bantu boys increase more slowly in relation to putative adult size than White males.

A comparison of the curves of White males with those of White females, and of Bantu males with those of Bantu females, indicates that the dimorphism in percentages attained of putative adult weight is greater in White than in Bantu children, but in stature the dimorphism is slightly greater in Bantu than in Whites. I believe that the percentage of adult weight attained by Bantu females at the age of 15 years would have been higher (and the dimorphism between Bantu males and females greater) if the adult weight could have been taken in a Bantu female community where fatness was not regarded as a virtue. Rural Zulu female figures for weight, reported by Slome *et al.*,[25] averaged 59·3 kg whereas those of urban females, also Zulu, averaged 65·9 kg. It was on the latter sample that the percentages reported in Fig. 1 were compiled.*

Stature and weight of urban Zulu males averaged 1 656 mm and 61·4 kg respectively, and those of rural Zulu males 1 658 mm and 59·0 kg respectively. Slome's urban Zulu women, although heavier than Fleming's[24] White women (the two groups weighed 65·9 and 59·6 kg respectively), were far shorter (stature was found to be 1 565 and 1 646 mm respectively). Fleming's data show the mean triceps skinfold of White women to be 18·6 mm, whereas that of urban Bantu women is 21·4 mm, and that of rural Zulu women 20·6 mm. The Pretoria White girls, at the age of 15 years, have reached 84·4% of adult triceps skinfold, whereas the Pretoria Bantu girls have attained 70·0% of the adult skinfold. Mean triceps skinfold (9·3 mm) of Pretoria White males, at this age, is over 100% of the mean (7·3 mm) for several skinfolds of adults reported by Fleming, the mean (8·1 mm) of the triceps skinfold of a group of physical education recruits,[7] and the mean (4·6 mm) of a group of national-grade adult gymnasts.[7] Obviously, the last-mentioned sample is biased and provides no fair basis for calculating percentage increases attained; but neither do the subjects of Grobbelaar,[4] Fleming *et al.*[24] and Slome *et al.*[25]

These data serve to illustrate how complicated the picture really is, and provide renewed reason for a cautious approach in simplifying anthropometric criteria for nutritional status assessment. The most reliable parameter of the 3 (stature, weight and skinfold), is stature and it seems to confirm the conclusions drawn from calculating percentage increases with the age of 6 years as a basis. The dimorphism in Bantu is greater than that in Whites, and the graph of Bantu males, who have attained greater percentages of the putative adult size at the lower ages, crosses that of White males, and, at the age of 15 years, they have a lower percentage attainment than Whites. Bantu females, however, stay more or less parallel with White females, and, by the age of 15 years, have attained a high percentage (98·5) of putative adult stature.

Whereas the role of the genes is not clear in regard to the children themselves and the adults upon whose dimensions percentages of adult sizes attained were calculated, the slower advance of Bantu male children to their full-grown adult stature is probably heavily dependent on nutritional inadequacies.

*Urban Zulu women, in fact, were 5 mm shorter than their rural counterparts.

'Retarded Male Growth' Hypothesis

The following hypothesis emerges: if, in a Pretoria population (e.g. Bantu) the general growth of males is slower than that of females, whose rate of growth is similar to that of a population where nutritional disorders are rare (e.g. Whites), such retarded male growth is an expression of a state of inadequate nutrition in the Bantu population. The principle it implies may also apply to a wider range of populations than the 4 groups studied here.

This hypothesis must be assessed further in the light of all the other data to be analysed during the multi-disciplinary investigation envisaged by the National Institute for Nutritional Diseases.

Du Plessis[26] has reported a significant difference ($P<0.1\%$) in the serum albumin of the two sexes (all races and the ages 7 - 11 years combined), but has failed to undertake any breakdown of figures. No comparison with his data was therefore possible.

CONCLUSIONS

Do these data point unambiguously to inadequate nutrition in the Bantu population? If they do, then anthropometry alone is a more powerful tool in nutritional status assessment of populations than it has been taken for up till now.

However, two basic objections have to be considered before any conclusion will be possible. These are:

(*a*) If all children aged 6 years did not reach similar proportions of their prepubertal growth as a result, for instance, of genetic influences, would a conclusion from a comparison of their percentage increases with those of other South African groups, that Bantu children are undernourished, be invalidated?

(*b*) If the age of 15 years did not denote similar stages of average progress towards maturity in children of the 4 populations, would variable effects of growth accelerations in these populations contribute so considerably towards differences in percentage increases that the expectations about the informative value of the present comparison of percentage increases are disappointed?

In answer to the first question, it is re-stated that growth (in this case from 6 to 15 years) is affected by nutritional, genetic and many other factors. If there were dissimilarities in growth before the age of 6 years, as a result of one or more of these factors, then, according to the principle of 'exponential decay' of the growth rate,[22,23] those who had progressed furthest by 6 would thenceforth develop more slowly than those who had not progressed so far.

This principle will undoubtedly be seen more clearly in populations where slight individual departures from the rule are 'cancelled out' by averaging. From nutritional causes, Whites might be expected to have reached greater proportions of their prepubertal development by the age of 6 years. Other factors being equal, one would expect the White population to grow more slowly than the Bantu from an arbitrary age, such as 6 years. But irrespective of the cause, the percentage increases, and, *inter alia,* the growth rate from now on is expected to be slower than that of Bantu. In body measurements, however, the increases in Bantu males were so much lower than those of the other groups that the logical implications of the abovementioned principle of 'exponential decay' of the growth rate seem not to have applied.

It is true that the psychomotor development of Bantu children, up to the age of about 3 years, is in advance of that of White children (psychomotor data summarized by Tobias[6]). However, there is no record available to show what the position is at the age of 6 years.

Beresowski and Lundie,[27] quoting various reports, have shown Johannesburg Bantu children to be ahead of North American White children in their carpal ossification at birth and up to the age of 2½ years. Between the ages of 2½ years and 6 years, both Bantu males and females from Johannesburg became retarded as compared with North American White children.[28] Bantu males were retarded by about one year and Bantu females by about 6 months. If one assumes that Whites in South Africa who were children at the time of the Johannesburg study, show stages of ossification that are comparable to those of children in America before 1936, then ossification was retarded in the South African Bantu also as compared with his local White counterpart.

To my knowledge, there are no representative figures on the body dimensions of South African Bantu between birth and the age of 6 years. It still has to be shown in future studies whether Bantu male retardation, apparent from the present study, links up with any metric retardation during the earlier ages. It also has to be shown whether the dimorphism seen from ossification times has either been maintained into later stages of development, or been matched by dimorphism in metric dimensions before the age of 6 years. However, although one cannot say for certain whether the retardation and comparative dimorphism witnessed in carpal ossification had applied in other ways, such as body dimensions, this possibility should not be ruled out. If Bantu children had been retarded in physical growth before the age of 6 years, one would expect them to grow faster from then on than any other group that had not been retarded; but they do not.

The most likely reason for retardation in South African Bantu males is inadequate nutrition. Although parasitism and other environmental causes may not be ruled out, the 'handicap'* parasitism would impose has been tentatively said to have been 'less than expected' in several Bantu populations.[29]

Of course, the hypothesis of retarded male growth, proposed in this chapter, should definitely be followed up by means of a longitudinal study, and, if possible, experimentally.

*It is not clear whether 'handicap' refers to physical growth or to physical performance; presumably it refers to both.

As to the second question, the following considerations appear to be justified. That the 4 populations did not reach similar stages of progress towards maturity by the age of 15 years was suggested by the comparisons of polynomials.[3] The sexual dimorphism in absolute physical measurements of the 4 populations was greatest in the Bantu population. It was postulated that this population, on the whole, was probably less mature than the others by the age of 15 years. It is not known whether the principal contributory cause was environmental or genetic. If the cause was principally genetic the Bantu population will probably have a greater percentage of individuals, and also families, of late maturers than the White, but this has not been confirmed experimentally. Such evidence is likely to be supplied only by means of an experiment where nutrient intake can be regulated or otherwise studied, together with chromosomal and other observations, in families selected at random. Such a study will have to be longitudinal. It is conceivable in a genetic context that there are 'early maturing families' and 'late maturing families' as well as early and late maturing individuals in any population. Such families and individuals may not appear in similar proportions in different populations.

Whereas one cannot preclude a difference in genetical make-up as a possible cause of difference in maturity at the age of 15 years, we do know that inadequate nutrition generally results in the postponement of the initiation of puberty in children, and that this is accompanied by smaller physical dimensions.[30] Inadequate nutrition may then confidently be singled out as at least one of the causes resulting in the greater sexual dimorphism in maturity and percentage increase in physical dimensions of the Bantu population from 6 to 15 years.

Coloureds

In the Coloured population, the increase in most of the measurements was less in males than in females, but did not differ greatly from that of males of the other populations. It was not certain whether the lesser increases had been caused by inadequate nutrition, although the possibility is not ruled out.

Indians

The Indian population showed signs of an adequate diet, especially in females. The mean increases in circumferences of arm and calf indicated a substantial development in these regions over the ages surveyed. The contribution of bone and muscle development towards increases in these circumstances was smaller in females than in males. Female skinfolds increased phenomenally over the 10 years.

General

It has been my aim to find an uncomplicated way of pointing to inadequate nutrition in populations. The present approach holds promise of being an effective method, and is to be followed up in future studies.

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