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An anthropometric survey of growth and physique of the populations of Karkar Island and Lufa subdistrict, New Guinea

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Child growth, adult physique and somatic changes in old age are compared in the two populations by means of a cross-sectional survey.

The results indicate that the physique of the Lufa Highlanders has features in common with high-altitude populations. Throughout the growth period the Lufa people are heavier, more muscular and skeletally more robust than the Karkar Islanders. Maturity is reached earlier in the coastal population and the close relation between adult height, child growth rate and maturity observed in some parts of New Guinea, including Lufa, does not apply to the island community. The two populations are similar in adult height but differ significantly in body proportions and in dimensions of the head and face.

Ageing proceeds rapidly after the third decade and the effects appear with greater uniformity than in Western populations. Decrease in body mass is particularly striking. Physiological and pathological ageing together with secular trends contribute to the variation in anthropometric characteristics with age, although the relative contributions of these phenomena appear to differ in the two populations.

Introduction

The people of Papua and New Guinea represent two major ethnic elements, the 'Papuans' of the mainland interior and the South and the 'Melanesians' of the coast and islands (Seligman 1909; Howells 1943). These people are linguistically distinct, the Papuans speaking the numerous and diverse non-Austronesian languages while the coastal and island dwellers speak the Austronesian (or Melanesian) languages (Capell 1962; Wurm 1964).

Since the early expeditions to New Guinea and the surrounding islands at the beginning of this century and the studies in physical anthropology, for example those of Chinnery (1925), a substantial amount of anthropometric data has been accumulated. Recently, growth and development of children has received special attention, largely as a result of the work carried out by Dr L. A. Malcolm and his colleagues (Malcolm 1969*a*, *b*, 1970*a–e*; Wark & Malcolm 1969). Growth rates that are remarkably slow in comparison with populations outside New Guinea have been reported, particularly among the highlanders.

Some research workers have been attracted to New Guinea by the unique opportunities presented for studying the forces of micro-evolution (Littlewood 1972). Others have found the investigation of nutritional status challenging, especially in areas where dietary protein intake is extremely low by world population standards (Sinnett 1972; Sinnett, Keig & Craig 1973).

The present study is an attempt to define and to compare the physical characteristics of the populations of Karkar and Lufa, cross-sectionally, over the whole of their life-span. It includes a survey of growth and development of children, using a somewhat larger battery of measurements than in previous investigations, and an assessment of physique and age changes in body build of the adults.

2. Methodology

(a) *The samples*

The Karkar Island sample of 1164 children and 612 adults was drawn mainly from the village complex of Kaul. In order to include larger numbers of children and young adults of known age the survey was extended to cover five other Karkar villages and two primary schools. Both Waskia and Takia language speakers were represented.

The Lufa sample of 652 children and 576 adults represented 83.2 % of seven village populations located within a few kilometres radius of the subdistrict administration centre.

Ages of the subjects were obtained from Maternal and Child Health and mission records and from the I.B.P. Karkar and Lufa census forms, which included age estimates made by field investigators. Very few of the adults knew their ages and estimates had to be based on physical appearance and reference to past notable events.

Only 29 % of Lufa subjects aged between 0.5 and 20 years had ages known to within 1 month. This was in contrast to the 71 % of Karkar Islanders in the same age range.

(b) *Methods of measurement and analysis*

The measurements were the I.B.P. 'basic list', plus bicondylar humerus, chest circumference and supra-iliac skinfold. They were taken using the instruments and techniques described by Tanner, Hiernaux & Jarman (1969). In addition to the actual measurements the following indices were calculated:

$$\text{ponderal index} \quad \frac{\text{stature}}{\sqrt[3]{\text{body mass}}},$$

$$\text{cormic index} \quad \frac{\text{sitting height} \times 100}{\text{stature}},$$

$$\text{acromion/iliac index} \quad \frac{\text{biiliocristal} \times 100}{\text{biacromial}},$$

$$\text{cephalic index} \quad \frac{\text{head breadth} \times 100}{\text{head length}},$$

$$\text{morphological face index} \quad \frac{\text{morphological face height} \times 100}{\text{bizygomatic}},$$

$$\text{nasal index} \quad \frac{\text{nose breadth} \times 100}{\text{nose height}}.$$

Stages of breast and axillary hair development were assessed according to the criteria described by Weiner & Lourie (1969).

Comparison of growth and development of the two populations is based on the calculation and graphical plotting of arithmetic means of measurements for subjects grouped by 2-year age cohorts. The method is aimed at providing broad comparisons of growth trends and its choice was influenced by the paucity of age records at Lufa and the uncertain reliability of age estimates. The interpretation of growth data from measures of central tendency and dispersion based on broad age intervals necessitates caution (Healy 1952).

Growth measurements of the Karkar Island sample, which had substantially greater numbers of children of known age than Lufa, have been subjected to a more rigorous analysis. This has enabled direct comparisons to be made with published data for populations both within and outside the Territory of Papua and New Guinea.

In the adults the variation in anthropometric measurements with age has been analysed by the computation of linear regression and correlation for measurements on age. The anthropometric data were processed on an I.B.M. 360/50 computer at the Australian National University.

The complete anthropometric data summarized in this paper have been deposited in the National Library of Australia, Canberra, A.C.T.

3. Results

(*a*) *Growth and development*

The two populations differ little in stature during growth. In view of the uncertain age reliability of the Lufa sample detailed comparisons are clearly not justified. However, in females, the consistently higher Karkar mean values from the age of about 8–22 years provides evidence of earlier maturation in the coastal group.

Adult stature of 160 cm in males and 152 cm in females is reached by about 21 and 19 years respectively in the two sexes. There is a well-defined period of growth during which the girls overtake the boys in stature as a result of their earlier pubertal development. For the Karkar Islanders this lies between the ages of 9 and 16 years.

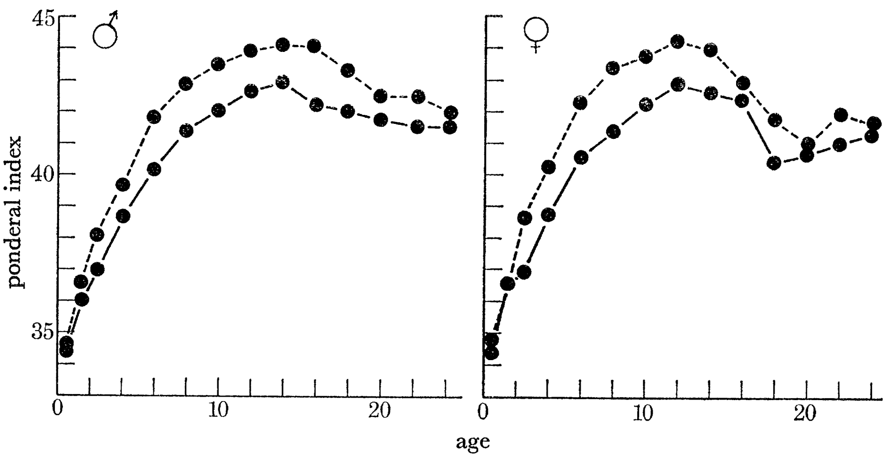

Figure 1. Growth in ponderal index (stature/∛mass) for males and females of Karkar Island (– –) and Lufa sub-district (——).

At all ages and in both sexes the Lufa children are heavier than the Karkar Islanders. The magnitude of the difference appears to be greater in the males. As a result the difference in ponderal index of the coastal and highland populations during growth is well marked (figure 1). Maximum mean values of the index are attained at about 12 years in females and 14 years in males. Inter-sex comparisons indicate that females have higher values of the index until about 13 years of age.

Measurements of sitting height and height of anterior superior iliac spine reveal that the highland children are longer in trunk and shorter in leg than their coastal counterparts.

The bicondylar humeral and femoral measurements of the highland children exceed those of the coast throughout growth. The mean differences are small but apply to both sexes. Similar results have been obtained for the biacromial diameter.

As far as revealing significant variations between coastal and highland populations in chest dimensions, the results of measuring antero-posterior and transverse chest diameters are inconclusive. There appears to be no consistent trend towards larger chest diameters in the Lufa children. There is, however, some evidence that chest circumference is greater at certain ages among the highlanders. Between 6 and 16 years in males the Lufa means are greater than those of Karkar, as are the means for females between 4 and 12 years (the upper age limit in the girls to which the parameter was measured).

Upper-arm muscle diameter, calculated from upper arm circumference and triceps skinfold thickness (Brozek 1961), is larger in the Lufa children until the age of about 16 years in both sexes. This indicates a tendency towards greater muscularity in the pre-pubertal highlanders. Calculation of this muscle index in adults shows that it is highly correlated with body mass.

Variation in triceps, subscapular and supra-iliac skinfolds with age during growth show similar trends in the two populations. At all ages the females have greater skinfold thicknesses than the males, the differences becoming more marked after puberty. Plotted on percentile charts for British children (Tanner & Whitehouse 1962) the more reliably aged Karkar children have triceps values that in both sexes lie between the corresponding British 3rd and 10th percentiles. The subscapular values are, however, closer to the 25th percentile, exceeding it during the first ten years of life.

Some important distinctions between the two populations are found in the cranial dimensions. The highland children are longer-headed than those of the coast and in males there is a tendency for them to have broader bizygomatic diameter and morphological face height than the islanders. Noses are shorter and broader throughout growth in the highland children.

(*b*) *Pubertal development*

Because of the uncertainty concerning Lufa ages, probit analysis to determine median age of menarche has been confined to the Karkar sample. Using the method of Burrell, Healy & Tanner (1961) a value of 15.56 ± 1.11 years was obtained. A tentative estimate for Lufa females is 16.5 years.

The mean age of entering stage 2 of breast development has been estimated as 13.3 years for Karkar. The number of girls examined at Lufa was too small for a reliable estimate to be made. Mean ages for entering stage 2 of axillary hair development for the Karkar Islanders are 16.3 years for males and 14.0 years for females.

(*c*) *The physique of young adults*

It was noted early in the analysis that in the adults a number of anthropometric measurements were correlated significantly with age. In order to eliminate as far as possible the effects of age changes in physique, samples of adults of both sexes aged between 21 and 35 years were selected for comparison of coastal and highland groups. The upper limit of this age range was chosen because inspection of the anthropometric data indicated that the onset of the age changes did not occur much before the middle of the third decade.

The means and standard deviations of the measurements and indices together with the coefficients of variation are given in table 1. It is noteworthy that in the majority of measure-

TABLE 1. ANTHROPOMETRIC MEASUREMENTS AND INDICES FOR MALES AND FEMALES OF KARKAR ISLAND AND LUFA SUBDISTRICT, AGED 21–35 YEARS

	males								females							
	Karkar				Lufa				Karkar				Lufa			
measurements/cm	no.	mean	s.d.	v.	no.	mean	s.d.	v.	no.	mean	s.d.	v.	no.	mean	s.d.	v.
stature	115	160.98	5.73	3.56	107	160.34	4.39	2.74	128	151.66	5.71	3.74	136	151.65	5.23	3.45
ht. ant. sup. il. spine	115	90.27*	4.17	4.62	107	88.91	3.32	3.73	158	84.35	4.84	5.74	146	84.03	3.69	4.39
sitting height	115	84.05	2.89	3.44	107	84.38	2.34	2.77	159	79.27	2.89	3.65	149	79.56	2.72	3.42
total arm length	79	73.02	3.25	4.45	107	72.84	2.48	3.40	113	66.94	3.23	4.83	148	67.12	3.20	4.77
chest circumference	114	83.54*	3.33	3.99	107	82.61	2.76	3.34	—	—	—	—	—	—	—	—
a-p chest	79	18.51	1.12	6.05	107	18.93*	1.00	5.28	158	16.66	0.95	5.70	147	16.72	1.00	5.98
transv. chest	79	24.45	1.17	4.79	107	24.76	1.14	4.60	113	22.64	1.24	5.48	147	22.91	1.10	4.78
upper arm circum.	115	25.45	1.30	5.11	107	25.08	1.48	5.90	158	22.33	2.09	9.36	147	22.19	1.44	6.49
calf circum.	115	33.82	1.73	5.11	106	34.00	1.94	5.71	158	31.17	2.39	7.67	148	31.26	1.68	5.37
biacromial	79	36.18	1.41	3.89	106	37.31*	1.51	4.05	113	32.10	1.42	4.42	148	33.68*	1.37	4.07
biiliocristal	79	26.34	1.46	5.54	107	26.68	1.24	4.65	113	25.73	1.43	5.56	146	25.60	1.28	5.00
bicond. humerus	79	6.52	0.36	5.52	107	6.62*	0.25	3.77	113	5.66	0.27	4.77	147	5.76*	0.28	4.86
bicond. femur	79	8.93	0.40	4.48	107	8.96	0.38	4.24	113	8.04	0.38	4.73	146	8.12	0.33	4.06
triceps skinfold (mm)	115	5.11	0.87	17.03	107	5.07	0.89	17.55	158	7.52*	2.34	31.12	146	6.62	1.71	25.83
subscap. skinfold (mm)	115	8.88	1.68	18.92	107	8.87	1.49	16.80	157	11.62*	4.28	36.83	146	10.08	3.18	31.55
supra-iliac skinfold (mm)	115	4.00	0.59	14.75	107	3.83	0.43	11.23	152	5.19*	2.25	43.35	137	4.48	1.34	29.91
head length	79	18.60	0.58	3.12	107	19.15*	0.58	3.03	113	17.64	0.53	3.00	147	18.23*	0.62	3.40
head breadth	79	14.46	0.44	3.04	107	14.36	0.48	3.34	113	13.69*	0.44	3.21	147	13.56	0.39	2.88
bizygomatic breadth	79	14.10	0.45	3.19	107	14.37*	0.50	3.47	113	13.05	0.44	3.37	147	13.38*	0.40	2.99
morph. face height	79	11.48	0.55	4.79	107	11.96*	0.52	4.35	113	10.59	0.57	5.38	147	10.68	0.54	5.06
nose height	79	5.04	0.36	7.14	107	4.96	0.33	6.65	113	4.66*	0.30	6.44	147	4.52	0.32	7.08
nose breadth	79	4.19	0.33	7.88	107	4.54*	0.32	7.04	113	3.67	0.23	6.27	147	3.99*	0.27	6.77
mass (kg)	115	56.43	5.13	9.09	107	58.46*	5.11	8.74	128	47.04	5.92	12.59	133	49.21*	5.06	10.28
indices																
ponderal index	115	42.01*	1.04		107	41.36	0.98		128	42.12*	1.37		133	41.44	1.07	
cephalic index	79	77.81*	3.30		107	75.05	3.17		113	77.62*	2.93		147	74.49	3.04	
morph. face index	79	81.68	4.24		107	83.29*	3.96		113	81.18*	4.57		147	79.84	4.30	
nasal index	79	83.44	7.86		106	91.45*	8.35		113	79.13	6.78		147	88.61*	7.80	
cormic index	115	52.23	1.18		107	52.63*	0.93		128	52.32	1.28		136	52.52	1.01	
relative arm length	79	45.15	0.91		107	45.43*	0.93		89	43.88	1.35		136	44.26*	1.13	
acromion iliac index	79	72.83*	3.37		106	71.50	3.26		113	80.31*	3.68		146	76.00	3.10	
rel. ht. ant. sup. il. spine	115	56.06*	1.12		107	55.44	1.00		127	55.59	1.39		135	55.41	1.03	

* Indicates a significant difference ($P < 0.05$) between Karkar and Lufa means and marks the larger of the two values.
† Non-pregnant.

ments the coefficients of variation are larger for the Karkar samples than they are for the Lufa highlanders. This strongly suggests that in their physical characteristics the coastal people are a more heterogeneous group, a result confirmed by the anthroposcopic observations made in the field and on standard photographs of the subjects.

Much of the anthropometric variation between young adults of the two populations is foreshadowed during growth. In males, body mass, antero-posterior chest, biacromial diameter and bicondylar humerus are among the postcranial measurements significantly larger in the highlanders. It is of interest that chest circumference is greater in Karkar males; however, this measurement is less reliable than the two thoracic diameters for assessing the size of the rib cage as its magnitude depends not only on skeletal dimensions but on such factors as thoracic adiposity and pectoral musculature.

Notable among the variations in cranial measurements are bizygomatic diameter, morphological face height and nasal index, all of which are larger in the Lufa males.

Similar results are observed in the females although the inter-population differences are not as marked as in males. The Karkar women have substantially thicker triceps, subscapular and supra-iliac skinfolds than their Lufa counterparts.

TABLE 2. ANTHROPOMETRIC MEASUREMENTS CORRELATED WITH AGE IN KARKAR AND LUFA ADULTS (24–69 YEARS)

Karkar	Lufa
positive and significant correlations	
bicondylar humerus (m & f)	—
bicondylar femur (f)	—
antero-posterior chest (m)	antero-posterior chest (f)
morphological face height (m)	supra-iliac skinfold (m)
nose height (m & f)	—
triceps skinfold (m)	—
negative and significant correlations	
—	stature (m & f)
sitting height (m & f)	sitting height (m & f)
—	iliospinal height (m & f)
—	total arm length (m & f)
—	bicondylar femur (f)
biacromial diameter (m & f)	biacromial diameter (m & f)
transverse chest (f)	transverse chest (m & f)
—	chest circumference (males)
upper arm circumference (m & f)	upper arm circumference (m & f)
calf circumference (m & f)	calf circumference (m & f)

m, significant correlation in males only.
f, significant correlation in females only.
m & f, significant correlation in both sexes.

(*d*) *Age changes in physique*

A summary of the findings of the linear regression and correlation analysis is given in table 2. The results show that in the list of measurements negatively correlated with age the contribution of the Lufa samples is much greater than that of Karkar. The reverse is found among the positive correlations. Only one skeletal measurement, antero-posterior chest in females, is positively correlated in the Lufa adults compared with five among the Karkar Islanders. It is of particular interest that bicondylar humerus and femur, the principal indicators of skeletal robustness, appear among the negative correlations in the Lufa adults and among the positive correlations in the Karkars.

Table 3 gives the results of correlation analysis for various anthropometric measurements and indices. The sample numbers are well balanced between the sexes and between population groups and are representative of the whole of the adult age-span. The measurements and indices were selected for analysis because of their importance as anthropometric indicators of body composition.

Table 3. Correlation coefficients of various anthropometric measurements on age for males and females of Karkar and Lufa (> 24 years)

	males		females	
measurement	Karkar (n = 252)	Lufa (n = 237)	Karkar (n = 240)	Lufa (n = 238)
stature	−0.035	−0.308***	−0.073	−0.352***
mass	−0.230***	−0.496***	−0.396***	−0.552***
chest circum.	−0.086	−0.390***	—	—
upper arm circum.	−0.311***	−0.585***	−0.376***	−0.451***
calf circum.	−0.166***	−0.488***	−0.333***	−0.527***
triceps skinfold	0.173***	−0.209**	−0.224***	−0.197**
subscapular skinfold	−0.054	−0.174**	−0.146*	−0.258***
supra-iliac skinfold	0.077	0.285***	−0.166*	0.060
sum of 3 skinfolds	0.039	−0.126*	−0.194**	−0.210**
upper arm muscle diam.	−0.351***	−0.587***	−0.358***	−0.447***
ponderal index	0.269***	0.316***	0.427***	0.315***

* Significant at $P < 0.05$.
** Significant at $P < 0.005$.
*** Significant at $P < 0.0005$.

Stature is negatively and significantly correlated with age in both sexes at Lufa; however, as in the case of many of the skeletal measurements, no significant correlation is found for the Karkar Islanders.

The decrease in body mass is striking, especially among the highlanders (figure 2). Regression coefficients of 0.3048 ± 0.0081 and 0.3472 ± 0.0077 for men and women of Lufa compare with 0.1195 ± 0.0084 and 0.1783 ± 0.0073 for Karkar.

The high negative correlations for limb circumferences and age are noteworthy. These again are greater for the highland population group. Upper arm muscle diameter shows a similar and highly significant regression on age.

The majority of skinfold thicknesses are negatively correlated with age, the most notable exceptions being triceps in Karkar males and supra-iliac in the males of Lufa.

The ponderal index shows a marked increase with age in men and women of both areas, the regression coefficients being greater for females than for males.

4. Discussion

(a) *Growth and development*

It has been established by a number of recent surveys (Malcolm 1966, 1969*a*, *b*, 1970*b*, *c*) that the growth of New Guinea children is delayed in comparison with Western populations and that maturity is reached later. It is clear that there is considerable variation in child growth rates

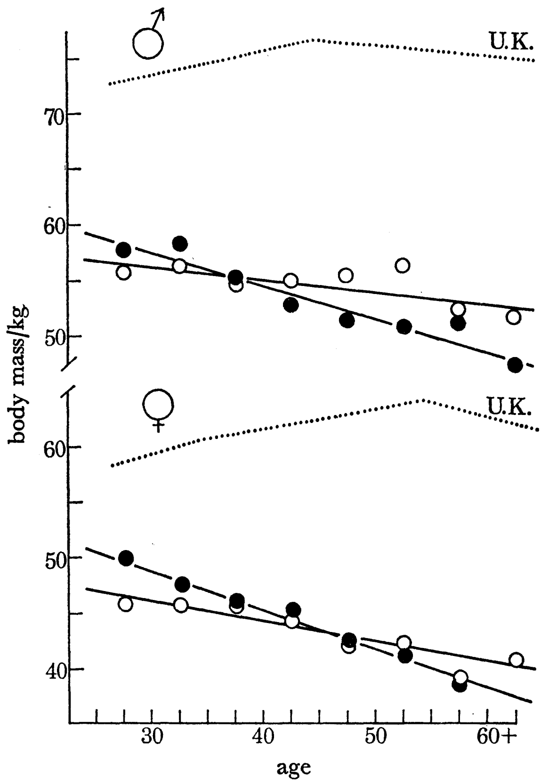

FIGURE 2. Cross-sectional variation in body mass with age among samples of adults of Karkar Island (○) and Lufa subdistrict (●). Regression lines of mass on age, shown in the diagram, have been computed from individual values. Data for a United Kingdom population are from Montegriffo (1968).

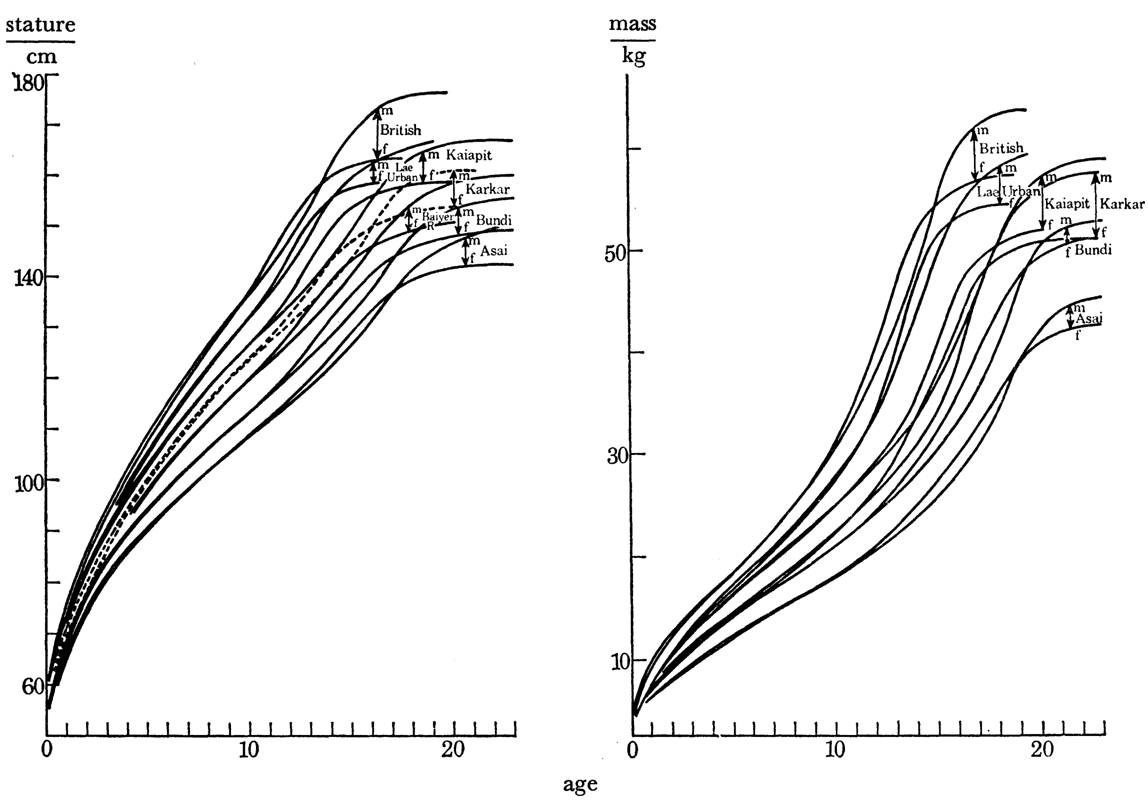

FIGURE 3. Growth in stature and body mass of Karkar Islanders compared with other New Guinea populations (Malcolm 1970c, and unpublished) and the 50th percentile for British children (Tanner, Whitehouse & Takaishi 1966).

among the different populations of the Territory, some of which appear to be related to improvements in nutrition and health, particularly in urban communities. It has been suggested (Malcolm 1970*c*) that the slow rate of growth in traditional New Guinea societies may be an adaptive response to conditions of sub-optimal nutrition and that in populations whose culture is as yet unchanged by Western influences there is a close relation between the age of attainment of secondary sex characters, menarche and the adult stature of the population group.

Compared with other New Guinea populations the characteristics of growth in the Karkar Islanders and Lufa villagers are unexceptional. Figure 3 shows the position of the distance curves for stature and body mass of the more reliably aged Karkar sample among other New Guinea populations and British children (Tanner, Whitehouse & Takaishi 1966). Adult stature in the Karkar Islanders is attained about three years later than in children of the United Kingdom.

Perhaps the most appropriate comparison to make among data at present available is with the lowland, rural population of Kaiapit in the Markham Valley. Stature curves for Karkar are approximately parallel to but below those of Kaiapit. In body mass the form of the Karkar curve is somewhat different, being closer to the highland population of Bundi (Malcom 1970*a*) for about the first eight years of life. Body masses attain a level close to those of Kaiapit after puberty. Possibly the nutritional status of the younger age-groups of Karkar children is poor in relation to those of the Markham Valley.

The differences between body mass of the Karkar and Lufa populations is of interest in that similar results have been reported for inter-altitude comparisons of Ethiopian children (Clegg, Pawson, Ashton & Flinn 1972), the higher-altitude children having the greater body mass. The anthropometric evidence of the present study indicates a less linear physique for the highland population and this may, in part, be responsible for the difference in body mass. It almost certainly accounts for the lower mean values of the ponderal index observed in the Lufans.

The distinction between coastal and highland populations in cormic index indicates that there are genetic differences between the two populations. Greulich (1957), among others, has demonstrated that body proportions are under strong genetic influence and are maintained irrespective of improvements in nutritional status. Because significant differences occur between the adults, it is unlikely that the result is due simply to a steeper fall in the index of the Karkar Islanders due to earlier maturation. Similarly, the greater bicondylar measurements of the Lufa children reflect differences that can be observed in adulthood and indicate a more robust skeletal structure.

Considerable interest must be attached to the variations in chest dimensions between the two populations in view of the differences in altitude between them. Frisancho (1969, 1970) reports enlarged chest size and increased lung volumes among high-altitude Peruvian children compared with those of low altitude. Clegg *et al.* (1972) found increased mean chest circumference and transverse chest diameter during growth of high altitude Ethiopian males compared with lowlanders. The latter results were somewhat different to those found by Harrison *et al.* (1969) for the Ethiopian adults. A similar situation exists in the present study. There is some indication of greater thoracic circumference in the highland children during growth but antero-posterior chest diameter only is found to be greater in the highland adults. By world population standards Lufa can hardly be described as a high-altitude population as most of the villages sampled were situated at about 1900 m. Although hypoxia may have some influence on chest morphology among the Lufans, it is difficult to apportion the effects of genetic and environmental influences when comparing the two population groups.

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The studies of Osborne & de George (1959) and the investigations of Hiernaux (1963) have shown that a number of cranio-facial measurements are less 'ecosensitive' than many somatic dimensions. It is therefore of interest that in head length, morphological face height, bizygomatic diameter and nasal index there are marked differences between the Karkars and the Lufans. This provides further evidence that the populations are genetically distinct.

New Guinea has produced some spectacular results for the late age at which menarche is reached (Malcolm 1970*c*). It cannot be claimed that the results of the present study add much to the already impressive list. However, in comparison with Western populations menarche is considerably delayed. The tentative estimate for Lufa suggests that the coastal population is in advance of the highland, a result which is similar to that obtained by Cruz-Coke (1968) for the inter-altitude studies of Chilean populations.

The close relation between adult stature, child growth rate and attainment of sexual maturity observed in some parts of New Guinea (Malcolm 1970*c*) does not seem to hold for the Karkar Islanders. The regression equation published as a result of a number of growth studies by Malcolm for predicting age of menarche from female adult height (62.71–0.303 × adult female height in cm) yields a result of 16.76 years for Lufa, which is close to the estimate made in this study, and an almost identical result for Karkar. Clearly, for the coastal population the prediction is not a good one. The result indicates that in some coastal areas of New Guinea, especially those in which traditional dietary patterns are changing, the rate of maturation may be faster than in the highlands in spite of similarities in adult height. Convincing evidence of this phenomenon has been published by Heath & Carter (1971) in a survey of growth on Manus Island.

(*b*) *The physique of young adults*

Observations of adult physique given in table 1 reinforce conclusions already made concerning the distinctions between the Karkar and Lufa populations. The less linear physique, greater trunk length relative to leg length, greater bicondylar dimension, body mass and larger facial skeleton and head length have already been discussed. The investigations of McHenry & Giles (1971) in the New Guinea highlands have illustrated the importance of shape differences as measures of genetic 'distance' between groups.

The Lufa men and women are, on average, taller and heavier than those of Goroka studied by Kariks *et al.* (1960) and the averages for males are about 5 cm taller and about 1 kg heavier than those given for four major language groups in another area of the Eastern Highlands district (Littlewood 1972). However, the validity of making such broad comparisons is questionable; first, because of the significant heterogeneity found among physical characteristics in populations of the Eastern Highlands, and secondly, because of the changes that occur in certain body dimensions with advancing age.

(*c*) *Age changes in physique*

The interpretation of cross-sectional data in adults is complicated by the difficulties of partitioning the effects of secular changes, degenerative age changes and changes due to continuing growth in certain parts of the body, notably in the facial skeleton (Goldstein 1943; Lasker 1953; Baer 1956).

The decrease in mean values of skeletal measurements with increasing age in groups of adults studied cross-sectionally has frequently been ascribed to the effects of secular trend (Tanner 1962; Damon 1965; Vlastovsky 1966; Tanner 1966; Kimura 1967; Miller 1970). The almost universal trend towards larger body size in younger generations seems to be principally due to health and socio-economic improvements. There is, however, some evidence that heterosis and the dispersion of breeding isolates are involved (Hulse 1958; Froelich 1970; Strouhal 1971). This could well be a significant factor in hitherto geographically isolated populations in New Guinea, particularly those of the highlands.

Secular changes almost certainly account for part of the negative regression on age observed for measurements in the Lufa sample. Iliospinal height, total arm length and bicondylar femur are perhaps the most revealing of secular trends as these measurements are not expected to be greatly influenced by degenerative age changes. It is interesting that they are absent from the list of negative correlations for the Karkar sample (table 2); moreover, bicondylar humerus and femur are among the positive correlations. It appears that age changes among the Karkar adults are operating in a different manner to those of Lufa. Selective survival of the more robust physical types would be a possible explanation, such as that proposed by Hooton & Dupertuis (1951) in their study of Irish males; however, it is not possible at present to elucidate the factors that may be responsible.

Longitudinal studies such as those of Büchi (1950) and Miall & Ashcroft (1967) have demonstrated that a number of factors, including physical stress during the lifetime of the individual, are implicated in the age changes in physique. Studies of the musculo-skeletal system have shown that compression of the intervertebral disks (Walmsley 1953), osteoporosis (Nordin 1966) and postural changes (Freeman 1957) contribute to the decline in stature and sitting height. As a result of dorsal kyphosis thoracic diameters are altered (Agostini & Margaria 1962; Pařízková & Eiselt 1968) and there is a decrease in biacromial diameter (Bourlière, Parot, Pineau & Cendron 1962). In measurements of stature and sitting height the effects have been noted to be greater among women than men, especially after the menopause. This may account for the greater negative regressions observed in these two measurements with age in the New Guinean women. Age-related changes in longitudinal and transverse skeletal dimensions similar to those of the Lufa population have recently been reported by Sinnett, Keig & Craig (1973) for New Guineans of the Western Highlands.

Among the changes in anthropometric indicators of body composition, the decrease in body mass is particularly striking (figure 3). The negative regression coefficient is greater for the Lufans than for the Karkars and the inter-population differences are significant.

The negative regression of body mass on age for cross-sectional samples of adults appears to be a well-established feature of New Guinea anthropometry (Whyte 1958; Wolstenholme & Walsh 1967; Sinnett 1972). It has been suggested that this may, in part, be due to the unsatisfactory nutritional status of the older age-groups of adults, at least as far as protein intake is concerned. The decrease in body mass with age appears to be strongly associated with a reduction in lean body mass (Sinnett *et al.* 1973), evidence of this coming from negative regressions of limb circumferences, calculated muscle indices and urinary creatinine excretion on age. The results of the present study, especially of the Lufa population, are closely similar to those reported for the Western Highlanders. Body mass, limb circumferences and upper-arm muscle diameter show marked negative regression on age, whereas, at least in males, there appears to be little reduction in subcutaneous fat thickness.

Among the longitudinal studies of Western populations, that of Pařízková & Eiselt (1966) is relevant to the New Guinea investigations. These authors report a decrease in upper-arm and calf circumference and in absolute amount of lean body mass among men over 65 years who practised phyiscal training. Fryer (1962) found a decrease in mean urinary creatinine excretion with increasing age in groups of Americans over 60 years of age. In the New Guineans there appear to be similar changes in the tissue compartments of the body, although the onset of these changes is earlier than in Western populations and there is considerable uniformity in their expression among members of the community.

Clearly, there is a need for further investigation of ageing among New Guinea populations to determine to what extent the age-related changes are associated with nutritional factors and to what extent they are accelerated by the sort of physical stress to which individuals are subject through the demands and traditions of their society.

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