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Phil. Trans. R. Soc. Lond. B 1974 **268**, 293-308
doi: 10.1098/rstb.1974.0032

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Karkar and Lufa: an epidemiological and health background to the human adaptability studies of the International Biological Programme

BY R. W. HORNABROOK, G. G. CRANE AND J. M. STANHOPE*

Papua New Guinea Institute of Human Biology, Goroka, Papua New Guinea

Assessments of the health standards of the population of two village complexes, selected for investigation in the I.B.P. Human Adaptability Studies in New Guinea, have been made. These investigations have been extended on Karkar to permit a study of epidemiological patterns on the whole island. The observations at Lufa have been made in conjunction with investigations of health in the general area of the Eastern Highlands of New Guinea.

Chronic degenerative diseases were uncommon in both locations and particularly noteworthy was the absence of the diseases commonly associated with Western society, such as hypertension, arteriosclerosis, diabetes mellitus and gout. The incidence of chronic infectious diseases in both localities has been influenced by the available health services and the duration of Western contact. The warm, moist climate on Karkar creates an environment which is suitable for the existence of mosquitoes and the presence of endemic malaria contrasts with the infrequent sporadic cases of this disease at Lufa. Differences in the prevalence of certain other infections may also be the result of climatic variations, e.g. the prevalence of certain alimentary parasites, of yaws and of some skin diseases. Tuberculosis is quite prevalent on Karkar and absent at Lufa. Clinical evidence of malnutrition was not prominent in either location although occasionally encountered at Lufa. Anaemia was an almost universal finding on Karkar and, although neither as severe nor as common, was also seen at Lufa. Various investigations have been undertaken to account for the basis of the anaemia, which appears to be principally due to iron deficiency aggravated by chronic malaria and alimentary parasitaemia. The only other evidence of a deficiency disease was the presence of goitre in significant numbers of young women on Karkar.

The normal range of a number of biochemical fractions in the serum has been established for both populations and these can be compared with those in other societies.

INTRODUCTION

The Human Adaptability Studies of the International Biological Programme were conducted among the inhabitants of two very different village complexes – one sited on the Western extremity of Karkar Island, and the other in the vicinity of Lufa station in the Eastern Highlands. The ecological and historical background of these two populations has been described in detail elsewhere. Suffice it to state here that Karkar Island belongs environmentally to the hot, humid and wet New Guinean coastal region, where rain falls throughout the year, the average annual rainfall being 355 cm. The population has been in contact with European settlers continuously throughout this century. Lufa station is situated at an altitude of 1600 m above sea level: the population was first contacted by administration officials in 1951.

Medical investigations in these locations were designed to serve two rather different purposes. On the one hand the I.B.P. scientists engaged in investigations such as nutrition and normal physiology required background health data on the subjects they studied. On the other hand an investigation of human adaptability in New Guinea requires that consideration should be given to the deleterious effects of the environment on health, survival and reproduction. Medical investigations were therefore centred on the inhabitants of the studied villages while steps were taken to integrate these observations into an investigation of the pattern of health of the surrounding region.

* Present address: Epidemiology Unit, Wellington Hospital, New Zealand.

The medical examination was performed on each subject once only, and in consequence this study suffers from the limitations of all such surveys. Chronic degenerative diseases, metabolic abnormalities and current infections will be detected, and previous exposure to some infectious agents may be detected by immunological techniques; but in general the significance of acute infections such as meningitis, pneumonia and gastro-enteritis, which may well form the bulk of all illnesses, is underestimated.

This paper reports the results of the medical assessments of approximately 1700 subjects from Karkar and 2000 from Lufa. Some aspects of the disease spectrum, such as chronic respiratory disease and degenerative arterial disease, have been the subject of more intensive and specialized investigations, which will not be alluded to here. On the other hand, both laboratory investigations which were performed on all subjects and which amplify the general clinical findings, and studies which have included adjacent villages and have given a broader picture of the disease pattern in the two environments, will be referred to when they assist the interpretation of the findings of the initial survey which was restricted to the I.B.P. study villages.

METHODS

All the inhabitants of the Kaul village complex and 2000 subjects living in villages within one hour's walk of Lufa Station, were examined by a medical team. The people were seen in family groups and a number of key enquiries of a general nature were made. These included questions designed to reveal the stage of economic development such as the educational attainment, the participation in cash cropping or paid employment and the number of pigs or other forms of wealth. Enquiries were also pursued in respect to certain common or important symptoms of ill health such as the presence of angina, joint pain and cough. A general clinical examination of all subjects lying on a couch was then carried out. Blood pressure was recorded at the end of the examination. Each family then reported to another member of the team who withdrew two vacutainers of venous blood from adults and many of the children, one being into EDTA. Simple laboratory procedures such as blood counts and urine examinations were measured in a small field laboratory at the time of collection. The serum was separated in the field and divided into several aliquots which were dispatched frozen to various laboratories for the estimation of biochemical fractions, various antibodies and other components.

The subjects have not been re-examined unless some finding of the initial survey suggested further medical investigation was warranted. Where indicated, investigations have been extended to include other villages and communities within the general geographical region of the two study villages, using the same techniques.

RESULTS

In general, as befitting the historical distinctions between the two regions, the Karkar people were more sophisticated, judged by almost all criteria. There were a greater number of English speakers, greater economic development, and the community used money as a means of exchange to a much greater extent than the inhabitants of Lufa. Thus on Karkar 56.6% of adult males and 87.6% of adult females described themselves as subsistence farmers, the corresponding values for Lufa being 95.9% and 99.1% respectively; 62.0% of Karkar men, but only 9.6% of Lufa men, had a bank account. Of the Karkar men, 7.6% had more

KARKAR AND LUFU: HUMAN ADAPTABILITY STUDIES 295

sophisticated housing than the traditional variety; no Lufa men did (table 1). The Karkar people were also more prone to utilize alcohol on social occasions.

In all New Guinean communities historical confirmation of previous illness or of the symptoms of current illness is difficult to elicit; and this difficulty is often compounded by the barriers of communication in Pidgin, or through an interpreter. One might therefore have expected the questionnaire to be more informative on Karkar. There was a striking absence of symptoms of angina or claudication in both locations, though joint pains were more commonly complained of on Karkar. Almost the commonest complaint at both Karkar and Lufa was cough and shortness of breath, becoming increasingly frequent with advancing age.

TABLE 1. ECONOMIC STATUS OF KARKAR AND LUFU ADULTS

Figures represent percentage of the population

occupation	Karkar		Lufa	
	men	women	men	women
subistence farmer	56.6	87.6	95.9	99.1
labourer/domestic	18.9	3.7	1.4	0.2
cash cropper	7.7	1.3	0.5	—
tradesman	4.1	—	0.5	—
other	12.7	7.4	1.7	0.7
own bank account	62.0	36.2	9.6	2.1
type of housing				
native	92.3	—	100.0	—
resthouse design	3.5	—	0	—
permanent materials	3.5	—	0	—
European style	0.6	—	0	—

TABLE 2. PREVALENCE OF ABNORMAL PHYSICAL FINDINGS (%)

condition	Karkar			Lufa		
	males	females	total	males	females	total
splenomegaly	49.39	43.19	46.20	1.56	1.43	1.49
hepatomegaly	28.01	36.59	32.55	7.09	7.53	7.32
skin disease	16.29	11.30	13.74	4.37	3.33	3.82
goitre	0.83	7.99	4.49	1.36	2.29	1.84
dental caries	1.08	0.92	0.99	28.36	30.81	29.64
periodontal disease	1.79	1.14	1.46	6.30	4.49	5.35
parotid enlargement	1.65	1.82	1.74	12.41	6.77	9.46
respiratory disease	5.60	4.01	4.79	5.47	4.01	5.18
proteinuria	5.60	7.82	6.75	13.40	19.76	16.67
lymphadenopathy	2.43	1.51	1.96	2.61	1.62	2.09
c.n.s. disease	2.50	2.18	2.34	0.21	0.38	0.30
obesity	0.24	0.47	0.35	0.00	0.00	0.00
subnutrition	0.83	1.30	1.06	2.92	3.62	3.29
leprosy	0.24	0.00	0.12	0.10	0.38	0.25
cardiac decompensation	0.72	0.80	0.76	0.00	0.20	0.11
glycosuria	0.35	0.00	0.17	0.00	0.00	0.00
angina	0.00	0.37	0.19	0.00	0.00	0.00
claudication	0.00	0.12	0.06	0.00	0.00	0.00
arthralgia	1.14	2.07	1.61	0.10	0.28	0.20
deafness	0.13	0.25	0.19	0.00	0.00	0.00
otitis externa	0.79	0.63	0.71	7.47	7.18	7.32
otitis media	1.05	1.13	1.09	2.33	1.55	1.92

The overall prevalence of diseases detectable by the clinical examination alone in the two populations is shown in table 2. From an inspection of this table one can make general statements about the frequency of the more common abnormalities. Thus splenomegaly, hepatomegaly and skin disease were much more common on the hot humid coast. Goitre was commonly seen only in Karkar females. Conversely, dental caries, periodontal disease and parotid swelling were much more common in the highland group. Respiratory disease was equally common in both groups. With the exception of eye disease, other abnormal physical findings were uncommon in either place, and particularly noteworthy was the absence of degenerative arterial disease, of gout, diabetes and the other degenerative processes, and of clinically evident malnutrition.

Further analysis of the distribution of the diseases which were found with significant frequency, extension of the observations to adjacent village groups, and examination of the relevant laboratory investigations performed at the time or subsequently, has allowed us to elaborate on the important disease problems in these communities.

Malaria

In the absence of any other common disease tending to produce splenic enlargement, one can take the high incidence of splenomegaly in both children (45.1%) and adults (43.1%) to reflect the prevalence of malaria; and, as befits the warm and humid coastal climate of Karkar, one would expect malaria to be one of the greatest of chronic health problems. In such situations, hepatomegaly tends to parallel the prevalence of splenomegaly and provides a further measure of cumulative exposure to malarial infection (Black 1954). Thick blood films, made at the time of the medical examination and examined subsequently for the presence of malaria parasites, confirmed this clinical impression (table 3). Thus the overall parasite rate was 27%.

P. vivax was present in 47.8% of positive films, *P. falciparum* in 31.3%, and *P. malariae* in 10.0%; and this preponderance of *P. vivax* is typical of coastal New Guinea as a whole. Parasite rates were significantly higher in children (39.4% in age-group 2–9 years) than in adults (13.0%); the decrease in parasite rate with increasing age reflecting the development of active immunity in the population as a whole, as a result of recurrent infections. The spleen rate of 45.1% in children aged 2–9 years establishes that the island is mesoendemic for malaria, by the W.H.O. criteria for degrees of endemicity (W.H.O. 1963). Comparison of Waskia and Takia groups indicates significantly higher parasite rates amongst the Takia in both children and adults, and a correspondingly higher childhood spleen rate (table 4). These may be related to higher rainfall and humidity, more conducive to the transmission of malaria in the southeastern (Takia) portion of the island. The persistence of splenomegaly into adult life, despite the demonstrable development of effective immunity, well illustrated by the Waskia but not the Takia in this study, is a phenomenon characteristic of the response of many New Guinean populations living in malarious areas. Since its first description by Peters & Standfast in 1957 it has been the subject of much investigation which still continues; his hypothesis that it reflects the preponderance of chronic *vivax* infections in such populations remains unconfirmed, but is perhaps supported by our own data on the species distribution of malaria parasites among the Karkar islanders, in that there was a greater persistence of *P. vivax* infections in the adult Waskia population.

The low incidence of malaria parasites in the blood of individuals at Lufa (1.30%) is to be expected in a population living above the altitude range at which transmission of malaria takes

KARKAR AND LUFU: HUMAN ADAPTABILITY STUDIES 297

place (approximately 1500 m), and closely matches the low prevalence of splenomegaly (1.49%). The positive films could usually be accounted for by recent travel to lowland situations or to the warmer regions in the valley floor.

TABLE 3. MALARIA PARASITE RATES AND SPLEEN RATES ON KARKAR (WASKIA) AND LUFU

	Karkar			Lufa		
	male	female	total	male	female	total
malaria parasite rate (%)	28.32	26.34	27.28	1.26	1.32	1.30
<i>P. falciparum</i>	8.07	8.99	8.55	0.38	0.44	0.41
<i>P. vivax</i>	13.27	12.86	13.05	0.75	0.55	0.65
<i>P. malariae</i>	3.42	2.12	2.74	0.00	0.00	0.00
<i>P. sp.</i>	3.56	2.37	2.94	0.13	0.33	0.24
spleen rate (%)	49.39	43.19	46.20	1.56	1.43	1.49

TABLE 4. MALARIA PARASITE AND SPLEEN RATES ON KARKAR FOR WASKIA AND TAKIA LINGUISTIC GROUPS

	Waskia		Takia	
	2-9 years	15+ years	2-9 years	15+ years
population				
no. examined	353	631	245	308
overall parasite rate (%)	39.4	13.0	48.6	18.8
ratio				
<i>P. falciparum</i>	1	1	1	1
<i>P. vivax</i>	1.5	2.3	1.9	1.6
<i>P. malariae</i>	0.3	0.1	0.4	0.4
mixed	0.2	0.2	0.3	0.1
indefinite	0.2	0.6	0.2	1.4
spleen examination				
no. examined	406	733	245	308
averaged enlarged spleen	1.74	1.80	2.00	1.67
spleen rate (%)	45.1	43.1	63.4	33.1

Anaemia

A clinical assessment of the presence of anaemia was not recorded at the time of the medical examination, since blood counts were performed on all subjects at that time. In fact, the subsequent laboratory investigations showed anaemia to be almost universal among the Karkar population, only 3% of adult males, 7% of adult females and 9% of children having haemoglobin values within the generally accepted normal range (14.0-18.0 g/100 ml for men, 12.0-16.0 g/100 ml for women, 11.5-15.5 g/100 ml for children). Figure 1 illustrates the distribution of individual values, and indicates both the infrequency of normal values (shown by the horizontal shading on the graph) and the high frequency of severely depressed levels. Thus 31% of men, 48% of women and 55% of children had haemoglobin values below 10 g/100 ml. This is reflected in the low mean values shown in table 5 for all subject groups.

Mean corpuscular haemoglobin concentrations (m.c.h.c.) were also generally depressed, only 30% of subjects having values within the normal range. In general, the degree of depression of m.c.h.c. matched that of the haemoglobin level, the correlation coefficients between the two measurements being highly significant in all three subject groups. A low m.c.h.c. indicates a hypochromic anaemia; and thus on Karkar the majority of anaemias are hypochromic in

type. Furthermore, in the absence of haemoglobinopathies such as Hb C, D, E and S, and the infrequency of thalassaemia, there is presumptive evidence that iron deficiency is responsible for these hypochromic anaemias. Further work, to be reported elsewhere, has confirmed the dominant roles of iron deficiency and malaria in the production of anaemia on Karkar, and suggests that inadequate dietary intake of iron plays a greater part than does pathological loss through intestinal helminthiasis.

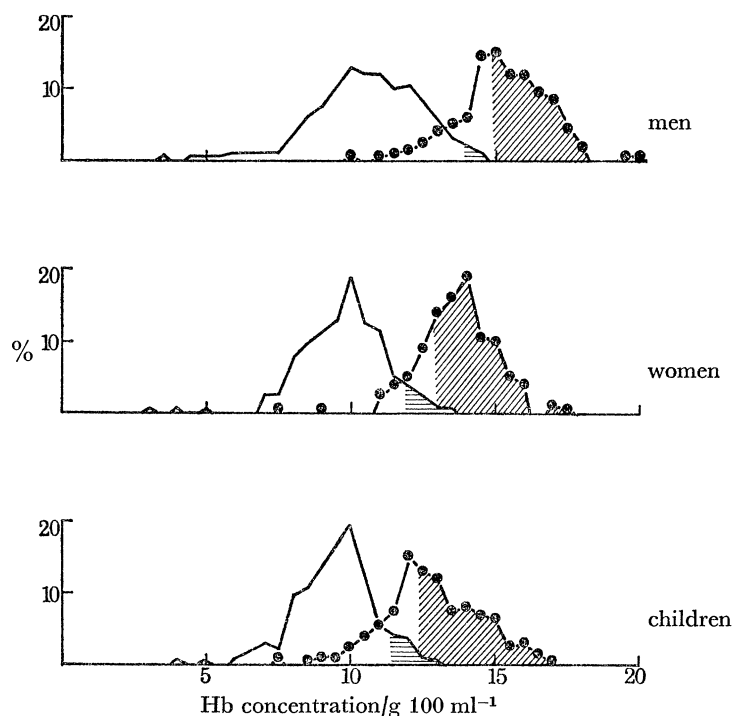


FIGURE 1. Haemoglobin concentration g/100 ml (from Crane, Hornabrook & Kelly 1972).

TABLE 5. MEAN VALUES AND RANGES FOR HAEMOGLOBIN CONCENTRATION, HAEMATOCRIT (P.C.V.) AND MEAN CORPUSCULAR HAEMOGLOBIN CONCENTRATION (M.C.H.C.) IN MEN, WOMEN AND CHILDREN FROM KARKAR AND LUFU

Results are expressed as mean \pm standard deviation \pm standard error

	men	women	children
Karkar			
Hb (g/100 ml)	10.68 \pm 1.85 \pm 0.13	9.84 \pm 1.65 \pm 0.11	9.73 \pm 1.40 \pm 0.10
p.c.v. (%)	38.24 \pm 4.43 \pm 0.33	35.42 \pm 4.23 \pm 0.29	34.91 \pm 3.94 \pm 0.27
m.c.h.c. (%)	27.8 \pm 3.45 \pm 0.24	27.7 \pm 3.15 \pm 0.22	27.7 \pm 2.66 \pm 0.18
Lufa			
Hb (g/100 ml)	15.40 \pm 1.57 \pm 0.11	13.90 \pm 1.38 \pm 0.10	13.10 \pm 1.77 \pm 0.125
p.c.v. (%)	47.79 \pm 3.58 \pm 0.25	42.25 \pm 3.62 \pm 0.25	40.67 \pm 4.38 \pm 0.31
m.c.h.c. (%)	32.15 \pm 2.50 \pm 0.18	32.7 \pm 2.74 \pm 0.19	32.0 \pm 2.92 \pm 0.21

At Lufa, anaemia is much less widespread, and severe anaemia is quite uncommon. The normal ranges of haemoglobin shown in figure 1 have been increased by 1 g/100 ml to allow for the erythropoietic effect of increased altitude; but even so, 63% of men, 79% of women and 62% of children had haemoglobin values which fell within the altitude-adjusted normal range (figure 1). Only 6% of subjects had values below 10 g/100 ml. Thus the mean haemoglobin

values (table 5) were 4.7 g/100 ml higher for men than on Karkar, 4.05 g/100 ml higher for women and 3.4 g/100 ml higher for children – whereas, if altitude were the only factor tending to increase haemoglobin values, one would anticipate a mean increase of approximately 1 g/100 ml. As on Karkar, most anaemias were hypochromic and presumably due to iron deficiency; but the severity and prevalence at a community level of iron deficiency, as reflected by that of the consequent anaemia, is considerably less at Lufa.

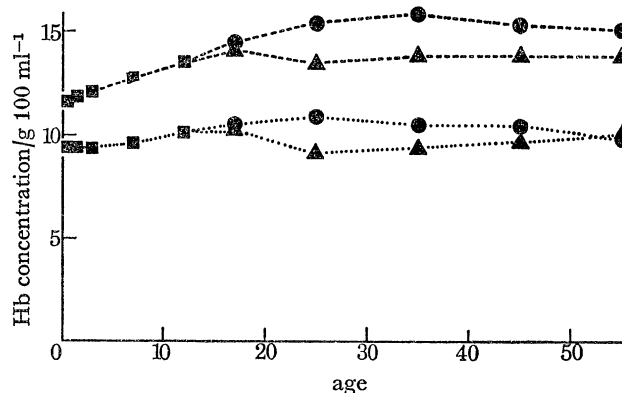


FIGURE 2. Variation in mean haemoglobin level with age and sex at Karkar Island and Lufa. Values for children (■) of both sexes have been combined, as there were no significant sex differences before puberty. ●, adult males; ▲, adult females; ---, Lufa;, Karkar.

These differences between the populations are also illustrated in figure 2, which shows the change in mean haemoglobin level with age in the two populations. Although at Lufa mean levels are all somewhat lower than optimal values at the same altitude, the changes with age and sex are quantitatively and qualitatively normal; thus throughout childhood the mean level rises by 2 g/100 ml; following puberty levels in females do not alter significantly, but there is a further increase of 2 g/100 ml in mean values in males. This signifies that the population can respond in the normal manner to androgenic and other physiological stimuli to erythropoiesis. In the Karkar population, on the other hand, haemoglobin values are depressed in the first year of life, show a rise of less than 1 g/100 ml to puberty, and a further rise of 0.65 g/100 ml in males, which is not sustained. In females of child-bearing age a fall to the lowest mean value of any age-group is recorded (9.2 g/100 ml). This fall represents predominantly the effect of pregnancy, since the mean values for pregnant and non-pregnant women are 8.3 and 9.9 g/100 ml respectively. The overall Karkar pattern can best be explained on the basis of iron-deficient mothers bearing children whose iron stores are inadequate at birth, and in whom a combination of inadequate iron intake and increased losses throughout childhood result in a grossly iron-deficient adult population. Malaria contributes to the overall depression of haemoglobin levels at all ages, but particularly during infancy and childhood and in pregnancy; other dietary deficiencies, notably of folate, play only a secondary role.

Intestinal parasites

Only the studies from Karkar are reported here, but they include those from a number of Takia as well as Waskia villages (table 6). There are in fact significant differences between the levels of infestation in the two groups, which may be attributable to climatic differences, or to greater ease of access of the Takia people to hospital facilities. Thus in the Waskia villages the

severity of hookworm infestation was lower, but the prevalence of *Ascaris* infestation was appreciably higher than on the Takia side of the island. There was, furthermore, a significantly greater frequency of alimentary protozoal infestation among the Waskia.

TABLE 6. HELMINTHS AND PROTOZOA ON KARKAR

	Waskia			Takia		
	0-14 years	15+ years	all ages	0-14 years	15+ years	all ages
number examined	124	103	227	261	217	478
helminths						
hookworm (%)	54.0	54.3	54.1	72.4	84.3	77.8
ascaris (%)	58.0	29.1	44.9	29.9	9.6	20.7
trichuris (%)	43.5	40.8	42.3	21.5	11.1	16.7
protozoa						
<i>E. histolytica</i> (%)	4.0	4.8	4.4	0.4	2.7	1.4
<i>E. coli</i> (%)	9.7	14.5	11.8	6.5	10.1	8.1
<i>E. nana</i> (%)	4.8	5.8	5.2	1.9	3.2	2.5
<i>G. lamblia</i> (%)	0.8	0.9	0.8	2.7	0.9	1.8
<i>I. butschlii</i> (%)	0.0	0.0	0.0	0.8	0.5	0.6
negative (%)	80.6	73.7	77.5	88.9	84.7	87.0

TABLE 7. INCIDENCE AND DENSITY OF MICROFILARIAE BY AGE-GROUP AND LINGUISTIC GROUP ON KARKAR

age-group (years)	Waskia			Takia		
	no. examined	microfilaria prevalence rate (%)	average no. microfilariae per 20 cm per infected person	no. examined	microfilaria prevalence rate (%)	average no. microfilariae per 20 cm per infected person
0-5	10	0.0	—	84	1.1	14
6-10	36	5.5	7	113	3.5	25
11-15	31	6.4	7	72	4.1	41
16-20	48	4.1	41	50	14.0	18
21-40	49	16.3	28	127	33.0	32
40+	31	12.9	36	107	43.9	33
all ages	205	8.7	22	553	18.8	29

Filariasis

The results of the survey of the presence of microfilariae are described in table 7, where the data are broken down by age and linguistic group. It is clear that there is a greater prevalence of microfilaraemia among the adult Takia population than on the Waskia side of the island ($\chi^2 = 10.53$). Exposure to infestation with microfilariae apparently occurs earlier in this part of the island. Clinical manifestations of filariasis were uncommon, but were also more frequently seen among the Takia population. Thus hydrocoele and elephantiasis rates of 0.7% were observed in the 21-40 year age-group and of 7.4% and 3.7% respectively in the 40 year and over age-group among the Takia villages, whilst elephantiasis alone was observed in the Waskia villages, occurring in 2.0% in the 20-40 year age-group and 3.2% in those aged over 40.

Treponematosi

Before the Second World War, Karkar was described as the island of crooked men because of the severe deformities produced by infection with yaws. After the war, yaws campaigns, first with arsenicals and later with penicillin, were carried out. In the present study (table 8) sera were collected from Kaul and four other Waskia villages, and from three Takia villages. A number of Waskia adults had clinical evidence of old yaws, and ten children had clinically active secondary yaws (over all 5.6%). No active yaws was seen among the Takia subjects. Similarly, the proportion of serologically positive subjects was significantly lower on the Takia side of the island (31.7%, cf. 72.5% t.p.i.-reactive), and both findings may reflect a higher exposure to penicillin, not only for yaws, in the Takia who have easier access to the island's mission hospital. The high proportion of reactors among Waskia children (65.9%) and the presence of active yaws amongst them indicate that there are active reservoirs of infection among the children on the island.

TABLE 8. FREQUENCY OF T.P.I.-REACTIVE SERA IN CHILDREN AND ADULTS OF WASKIA AND TAKIA LANGUAGE GROUPS

	Waskia	Takia
total no. of sera tested	866	120
t.p.i.-reactive		
no.	628	38
%	72.5	31.7
no. of adult sera tested	652	97
t.p.i.-reactive		
no.	487	34
%	74.7	35.1
no. of sera tested from children	214	23
t.p.i.-reactive		
no.	141	4
%	65.9	17.4

TABLE 9. PREVALENCE OF EYE CONDITIONS AT KARKAR AND LUFU (%)

condition	Karkar			Lufa		
	male	female	total	male	female	total
eye disease	0.96	0.91	0.93	7.08	5.08	6.04
arcus	3.62	2.76	3.18	11.93	7.90	9.22
conjunctivitis	0.24	0.23	0.24	0.45	0.21	0.33
trachoma	0.24	0.11	0.18	0.23	0.10	0.16
pterygium	0.97	0.80	0.88	4.44	4.99	4.73
cataract	3.05	2.04	2.53	1.59	0.94	1.25
corneal opacity	0.51	0.73	0.62	2.62	1.25	1.90
iridocyclitis	0.13	0.12	0.13	0.00	0.00	0.00
choroiditis	0.39	0.16	0.27	0.00	0.00	0.00
retinopathy	3.10	2.79	2.93	4.16	4.06	4.11

Eye disease

All subjects were examined for the prevalence of eye disease but it is important to appreciate that these examinations were not undertaken by a skilled ophthalmologist. However, certain distinct differences in the prevalence of eye disease were observed in the two locations (table 9).

The prevalence of corneal opacity was significantly higher in males at Lufa than in females, and eye disease in general was commoner at Lufa than in the Karkar population in all age-groups over 19 years. The incidence of cataract was particularly prominent. Arcus senilis was also significantly higher in Lufa in the 40–49 and 50 and over cohort. The incidence of pterygium at Lufa was higher in the 30–39 and over age-groups. In both populations the incidence of conjunctivitis, trachoma, iridocyclitis and choroiditis was less than 0.5%, and even allowing for misdiagnosis there would appear to be little evidence of the presence of these diseases as important problems in either location. The eye disorders which we have alluded to all showed an increasing prevalence with increasing age.

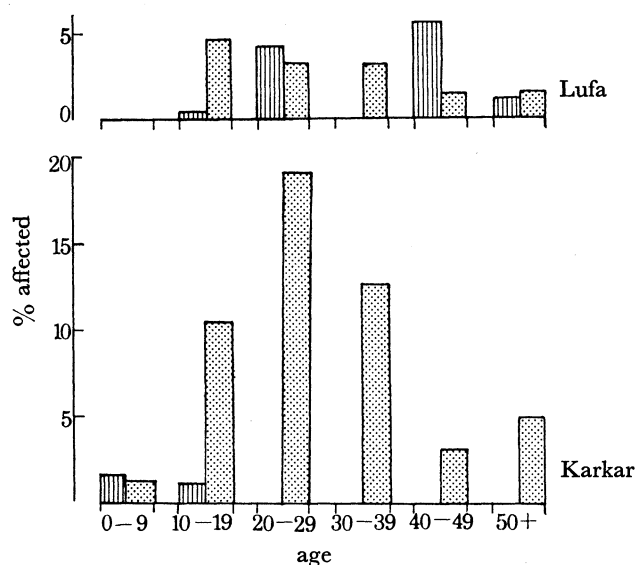


FIGURE 3. Prevalence of goitre in each sex, in 10-year-age-groups, in the two populations. □, males; ▨, females.

Goitre

The prevalence of goitre in Kaul village was 0.83% in males and 7.99% in females. These figures for Kaul village are low compared with other inland villages on Karkar where examinations have been undertaken. Most of the cases of goitre in the Kaul complex were in females in the 10–39 year age-group (figure 3). Of the females aged 20–29 years, 19% had detectable goitres compared with nil in males in the corresponding age-group. However, whilst the prevalence of enlarged goitre is not inconsiderable, there were relatively few individuals with Perez grade II or III goitres. At Kaul only 23 out of 806 females showed goitres of this severity. At Lufa goitre was even less common – 1.36% in males and 2.29% in females – but here also goitres were found most frequently in women aged 10–39 years. There was no evidence in either survey of other endocrine disorders. Endemic cretinism was absent in Kaul although present in other Karkar villages. It was not seen in the Lufa survey.

Skin disease

There was a significantly greater prevalence of skin disease in the Karkar population (13.74%) than at Lufa (3.82%) (figure 4). Skin disease was not a function of age in either population and no sex differences were observed at Lufa. On Karkar, on the other hand, males

KARKAR AND LUFA: HUMAN ADAPTABILITY STUDIES 303

were significantly more affected than females ($P < 0.01$) with the greatest difference in the 10–14 year age-cohort, where 23% of males had skin disease compared with 11% of females. Scabies was the commonest and most important skin disease at Lufa while on Karkar both scabies and tinea imbricata and related fungus diseases were of equal significance. The increased prevalence of skin disease on Karkar is attributable to the greater prevalence of the fungal skin conditions.

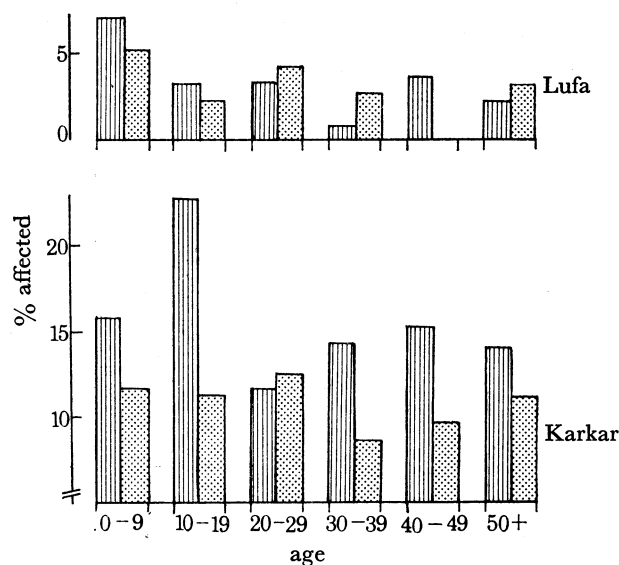


FIGURE 4. Prevalence of skin disease in each sex, in 10-year age-groups, in the two populations. □, males; ▤, females.

TABLE 10. NUTRITIONAL STATUS AND PREVALENCE OF PAROTID ENLARGEMENT AT KARKAR AND LUFA

	subnutrition		parotid enlargement	
	no. examined	% positive	no. examined	% positive
Karkar				
males	847	0.83	846	1.65
females	847	1.30	879	1.82
both sexes	1694	1.06	1725	1.74
Lufa				
males	959	2.92	959	12.41
females	1049	3.62	1049	6.77
both sexes	2008	3.29	2008	9.46

Nutrition

Assessment of malnutrition was made in both locations (table 10). It is significant that the incidence of individuals regarded as being poorly nourished was very low on Karkar (1.06%), and was not much greater at Lufa (3.29%). Kwashiorkor and signs of vitamin undernutrition were not seen at either location. Reddish tinting of the hair, particularly at the temples, is commonly regarded as a sign of malnutrition. However, it is a ubiquitous finding in New Guinean populations, and we do not feel that its presence alone constitutes sufficient grounds

for making a diagnosis of malnutrition. Similarly, parotid enlargement is often regarded as a sign of malnutrition. On Karkar there were few individuals of either sex with parotid enlargement and the overall incidence was only 1.74 %, which corresponds quite closely to the incidence of malnutrition. At Lufa the incidence of enlarged parotid was significantly greater (9.46 %), and significant differences were observed between the two sexes. Thus the incidence of males was 12.41 %, being twice as high as that in females (6.77 %). This sex difference was apparent in all age-groups above 19 years. The disparity between these figures and the prevalence of malnutrition is such that one suspects parotid enlargement must have some other explanation in this population.

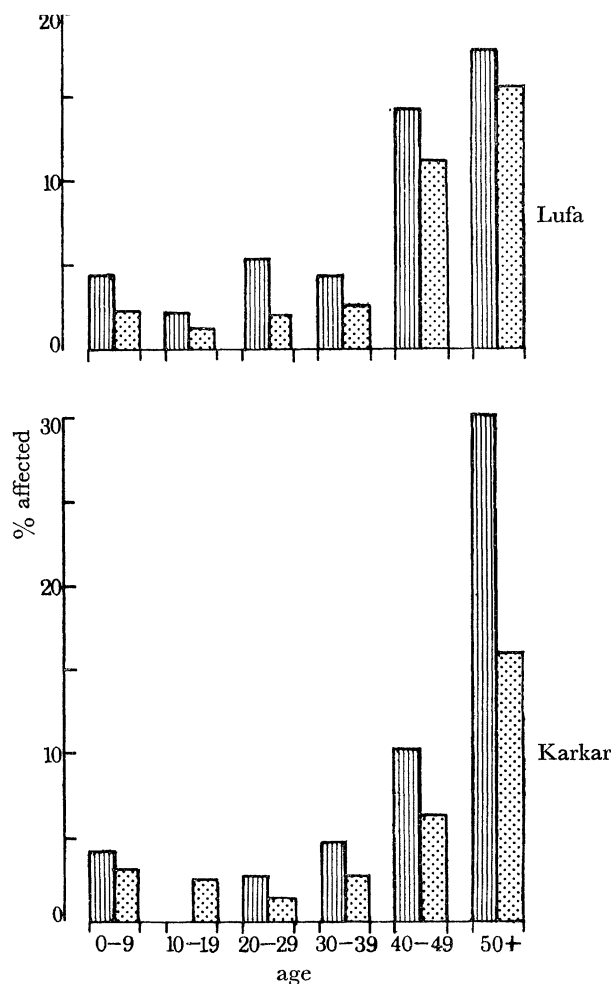


FIGURE 5. Prevalence of clinically detectable respiratory disease in males and females, by 10-year age-groups, in the two populations. ■, males; ▨, females.

Degenerative diseases

The lack of symptoms suggesting angina pectoris or claudication has already been pointed out, and this was supported by the absence of signs of degenerative arterial disease or of cardiac failure. Clinical manifestations of gout, diabetes (as determined by glycosuria) and their sequelae were equally rare. It has, however, been pointed out that symptoms of chronic cough and shortness of breath were relatively common in both populations, and signs of chronic

respiratory disease were also elicited in some 5% of each population. The incidence of respiratory disease increased with age at a comparable rate in both populations (figure 5). No significant differences were found in any age-group between the two areas or between the sexes, with the exception of the 50+ cohort on Karkar (males 30%, females 16%, $0.01 < P < 0.05$). It should be mentioned that in this context 'chronic' respiratory disease means disease detectable by physical examination alone, and that no attempt was made to establish the aetiology. In subsequent studies, employing respiratory function tests, both the nature of the impairment to lung function and the prevalence of clinically inapparent respiratory disease have been established in these populations. This work, however, does not fall within the scope of this paper.

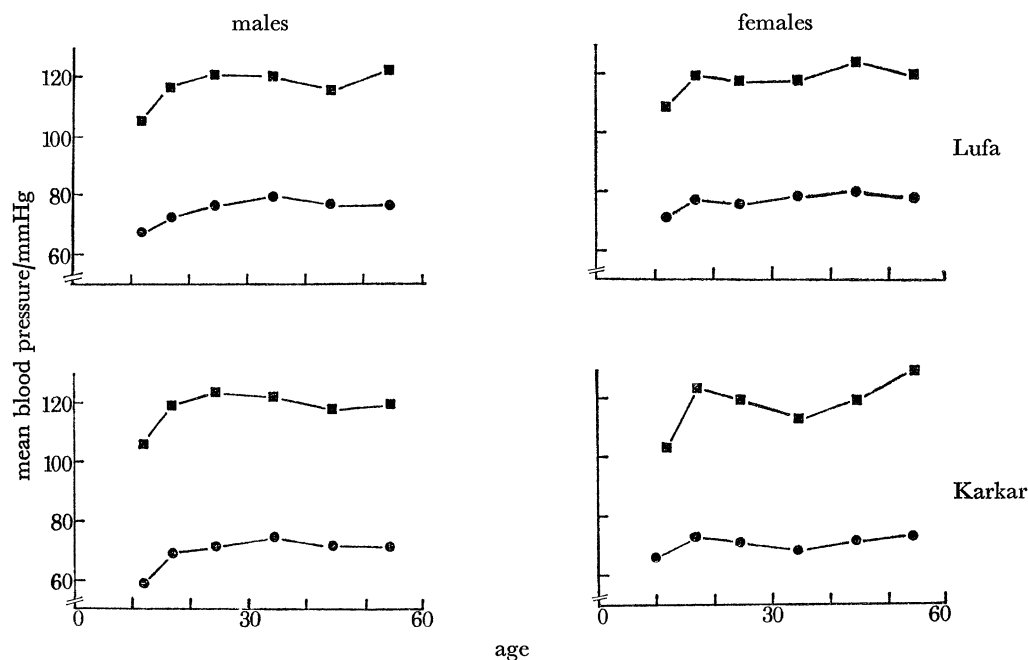


FIGURE 6. Variation in mean systolic (■) and diastolic (●) blood pressure with age, in males and females from Karkar and Lufa.

Blood pressure

Figure 6 shows the variations in mean systolic and diastolic blood pressure with age in males and females from the two areas. The mean diastolic pressures were significantly lower in Karkar men and women than in corresponding Lufa subjects, but no such differences occurred in systolic pressures.

Biochemical parameters

Mean values for adults of both sexes from the two populations are shown in table 11. The most marked differences in values between the two populations occurred in serum globulin levels, the higher values on Karkar representing predominantly antibody produced in response to recurrent malarial infection.

DISCUSSION

Attempts to evaluate the significance of different pathological processes in the health and well-being of New Guinean populations have been assayed in the past. As long ago as 1934 an expedition from Australia concentrated its attention on a number of different ecological

environments, studying intensively the inhabitants of villages in the Markham Valley, Trobriand Islands and other coastal areas. This expedition followed in general similar principles to those adopted in the survey of Kaul village. They reported their results in the Proceedings of the New Guinea Research Expedition in 1934. After the war individual doctors in different regions undertook surveys, which culminated in the elaborate study undertaken by Vines for the Department of Public Health, in which randomly selected villages in the New Guinea highlands, mainland and islands were surveyed and a number of supporting laboratory investigations were undertaken. In presenting his findings Vines pooled his data according to administrative region, with a gain in statistical impact and in the demonstration of general trends, though inevitably with some loss of detail. All these studies utilized a single physical examination as the major means of assessing the health status of a community, and so have the inherent defects which can only be partly overcome by the addition of laboratory investigations. An accurate picture will be obtained by such methods of the prevalence of chronic degenerative and metabolic diseases,

TABLE 11. MEANS AND STANDARD DEVIATIONS (S.D.) FOR BIOCHEMICAL PARAMETERS IN ADULTS

	Lufa				Karkar			
	men		women		men		women	
	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.
serum								
albumin (g/100 ml)	4.33	0.44	4.26	0.59	3.72	0.30	3.67	0.31
globulin (g/100 ml)	3.67	0.45	3.92	0.49	4.35	0.75	4.31	0.64
total protein (g/100 ml)	7.99	0.48	8.17	0.68	8.07	0.72	7.98	0.68
cholesterol (mg/100 ml)	124.80	36.84	140.39	34.81	113.19	26.28	129.84	29.97
creatinine (mg/100 ml)	0.966	0.162	0.765	0.163	1.100	0.226	0.822	0.165
urea (mg/100 ml)	12.46	3.43	12.40	4.79	—	—	—	—
uric acid (mg/100 ml)	5.67	0.81	5.38	0.91	5.70	1.35	4.94	1.10
sodium (mmol/l)	144.06	5.58	140.33	7.46	137.42	3.00	137.56	2.68
potassium (mmol/l)	3.97	0.42	3.73	0.30	4.26	0.49	4.25	0.32
urine								
pH	7.97	0.69	7.93	0.74	7.43	1.49	7.75	1.38

chronic infections, and previous infections which leave serological abnormalities in their wake. But of the acute infections, only in the case of malaria can a reasonable estimate of incidence be obtained. Likewise other illnesses of short duration, e.g. those associated with neoplasia, will also be underestimated – although it is unlikely that their total impact is great. Only a continuing day-to-day assessment of health in the community over a lengthy period of time, including all seasons of the year, would reveal the relative importance of acute infections such as meningitis, pneumonia and gastro-enteritis in the overall pattern of morbidity and mortality. A study of this sort is being undertaken by Maddocks in Pari village, and preliminary reports indicate that acute illnesses are of far greater importance than are the chronic diseases, readily detected in a survey of this nature, which *appear* to be the major causes of ill health as a whole, although only affecting a minority of the total population.

With this reservation, one can state that, from the data presented here, it appears that at Lufa we are dealing with an essentially healthy population, suffering only from dental caries and, in older age-groups, chronic respiratory disease. A wider spectrum of disease is present on Karkar, and this is largely explicable by the environment – fungal disease, treponematoses, and

above all malaria, flourish in a hot humid environment, and Karkar unquestionably provides suitable conditions for the perpetuation of these diseases. Comparison of our data with those of Vines indicates that in most respects related to health Karkar and Lufa populations are typical of those occupying similar environmental niches in New Guinea. Thus haematological indices on Karkar were comparable with those of his coastal villages less than 300 m above sea level and, apart from higher m.c.h.c., those at Lufa corresponded to his overall highland values. This suggests that iron-deficiency anaemia is probably widespread throughout coastal New Guinea, and may be rather more prevalent in the highlands than our Lufa data would indicate. Spleen and malaria parasite rates at Lufa, the prevalence of hepatomegaly in both Karkar and Lufa, the predominance of goitre among adult females on the coast, and the high incidence of *Tinea versicolor* skin infections on the coast, all correspond closely with his pooled village samples of coastal and highland populations. The major differences from his data lie in the lower spleen and parasite rates on Karkar (reflecting a lower level of transmission than in his mainland villages), a lower rate of hookworm and *E. histolytica* infestation (particularly among the Waskia) and in comparable prevalence of chronic respiratory disease in our coastal and highland populations.

However, this does not imply that one can safely extrapolate findings derived from one circumscribed area to large areas of the country, however similar they may be ecologically. The significant differences demonstrated between Waskia and Takia people in terms of malaria, intestinal parasites and sero-positivity to treponematoses illustrate the effects that micro-environmental differences may have on disease patterns. Thus on an island such as Karkar we have in fact a mosaic of separate entities. Each village possesses its own separate standards, and there is very considerable variation resulting from environmental, biological and other factors. It is surprising that in such a small environment where climatic factors are remarkably uniform, as they are in most tropical coastal locations, there are such statistically significant variations in disease pattern. Although the major disorders which have been revealed at Karkar and Lufa appear to be due to environmental and geographical factors rather than the result of inherent predisposition of the population, European contact or the impact of health services, this is not entirely the case. For example, although not revealed in our study, which did not explore the respiratory diseases in detail, tuberculosis is common on Karkar, having been introduced by European and other travellers. The treponematoses which were widespread and universal in the highlands as well as on the coast have been eliminated from Lufa as the result of a mass penicillin campaign of the 1950s. This campaign was less effective on Karkar, and residual clinical disease is still prevalent, particularly on the Waskia side of the island. The fact that the organism has survived on Karkar at all may well be related to the fact that conditions on Karkar are more congenial to the organism in a biological sense than at Lufa. The organism succumbs at Lufa because it is at the limits of its biological environment and under biological competition while on Karkar, under more favourable conditions, it resists the effects of a campaign. Furthermore, we are here seeing the impact of health services in more ways than one, in that the treponematoses apparently are less common on the Takia side, where hospital services, particularly penicillin, are more readily available to the population for all diseases, and the organism more frequently exposed to effective therapy.

Finally, one must consider the influence of pathological states on human adaptability. It is, for example, difficult to discern any benefit to the population of Karkar in the widespread presence of malaria and anaemia, at least when of severe degree. On the other hand, although

the deleterious effects of these diseases are difficult to quantitate, it would be impossible to deny that these chronic states are physiologically significant in retarding the development and productivity of the Karkar people, and in reducing population growth. Profound changes would be expected to follow the eradication of malaria, for example; and to some extent the consequences of an increase in population, with pressure on the existing resources of the island, are difficult to envisage. The Lufa population, on the other hand, does not appear to be limited in its growth and size to the same extent by any of the specific diseases we have described; and profound changes of the same magnitude are less likely to follow foreseeable improvement in the economic and public health services to the area. It seems that the Lufa population is functioning much more closely to its optimal level, in a biological sense, than is that of Karkar.

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