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The energy and nutrient intake and the energy expenditure of 204 New Guinean adults

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Two village populations, Kaul in a coastal region and Lufa in a highland region, were studied each for 9–10 months. Measurements of food intake and total daily energy expenditure were made on individual subjects, 51 men and 69 women in Kaul and 43 men and 41 women in Lufa. Each individual was investigated during a period of 5–7 consecutive days.

The way of life for all the people was moderately active – more so in the highlands – since they were subsistence farmers cultivating their own gardens for food.

The mean daily energy intakes were 8.12 MJ (1940 kcal) for the Kaul men, 10.55 MJ (2520 kcal) for the Lufa men, 5.95 MJ (1420 kcal) for the Kaul women and 8.81 MJ (2105 kcal) for the Lufa women. There were almost no differences in the energy intakes of the non-pregnant non-lactating, the pregnant, and the lactating women in each village. The intakes of protein were low, providing 6.7, 6.0, 6.5 and 7.2% of the energy value of the diets of the Kaul men and women and the Lufa men and women respectively. Fat provided only about 10% of the energy in the highland diet and 17% in the coastal diet.

Age and body mass showed surprising relationships with energy intake.

Although most of the energy and protein in the diets came from the staple vegetable (taro in Kaul and sweet potato in Lufa), this was less so than in previous studies.

A total of 1160 measurements of energy expenditure were made on various activities of the individual people and mean values are given for these activities. The pattern of daily energy expenditure is also shown. Lying, sitting and standing accounted for about 70% of the total day and 60% of the total energy expenditure. Walking occupied about 10% of the 24 h and between 20 and 27% of the energy output.

Some of the results of food intake, particularly on the women in the coastal region, are very difficult to explain on currently accepted grounds.

There has been considerable interest among nutritionists in New Guinean populations since the original report of Hipsley & Clements (1950) which showed low intakes of energy, protein and other nutrients in adults who appeared physically well developed. These findings have been essentially duplicated by later studies (Oomen 1961; Hipsley & Kirk 1965). While *all* the nutritional studies on New Guineans have not shown uniformly low intakes of energy – moderate to moderately high daily intakes in adult men were found by Hamilton (1956) (13.4 MJ; 3200 kcal), Venkatachalam (1962) (12.1 MJ; 2900 kcal) and Bailey & Whiteman (1963) (11.3 MJ; 2700 kcal) – the intake of protein has always seemed low (often less than 30 g daily for male adults). Indeed, the small amounts of protein in the diet coupled with apparently negative nitrogen balances in people of good muscular development has led to the suggestion that a nitrogen-fixing intestinal flora might fulfil the function, in these people, of supplementing food nitrogen (Oomen 1970; Oomen & Corden 1970).

The lack of correlation between the apparently inadequate nature of the nutrient intake – not only in quantity but also in quality – and the relatively minor and infrequent signs of malnutrition, has sufficient importance to warrant a further study of the nutritional state of New

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Guinean populations. This is particularly pertinent now because doubts are being expressed about the validity of some of the international standards of energy and protein requirements. These may in the past have been set at too high a level, and the intakes found in previous studies in New Guinea may simply be an illustration of the inapplicability of these standards to certain populations.

The present paper describes a study on individual adult men and women living in a coastal village (Kaul) and in a highland village (Lufa) in New Guinea. During a period of several consecutive days, the total food intake and total energy expenditure of each individual was measured. Various anthropometric dimensions (including body density by underwater weighing) were also measured. These studies were done on 51 men and 69 women in Kaul and 43 men and 41 women in Lufa. A report is published elsewhere (Ferro-Luzzi, Norgan & Durnin 1974) on the energy and nutrient intake in the diets of 264 children in Kaul and 222 in Lufa.

General background

Kaul

The way of life and general environment of these two groups of people were somewhat dissimilar. *Kaul* was a conglomeration of four villages containing about 1200 people. It is situated on Karkar Island, which is about 80 km north of Madang on the northern coast of New Guinea and about 16 km off-shore. Karkar is a fertile volcanic island which has many coconut plantations around its coast, although Kaul itself was a few kilometres inland and was positioned between the edge of one set of plantations and the edge of moderately open jungle. The climate was fairly typical equatorial in having a wet season lasting from October till April and a so-called dry season which also included a fairly high quantity of rain, the total annual rainfall being about 380 cm (150 in). The temperature was hot and humid throughout the year. The people were mainly subsistence farmers with their own gardens which were on average 3 km or so from the village. These gardens provided food for the villagers' own needs. Although the type of farming on Karkar required moderate physical activity, the yield of the staple foods (taro and bananas) was fairly high and the work was not too demanding, so that there was a reasonable amount of extra time for such activities as house-building, canoe-making, pig husbandry and hunting with, as well, many hours spent on general discussion of local affairs and informal chatting.

The people of Kaul were smaller in stature and lighter in weight, with less variability in body build, than most European populations. There were virtually no endomorphs among these people. The age, height, mass, skinfold thicknesses and body fat of the adult population are given in table 1.

Malaria is endemic in the region, and although there is a high prevalence of anaemia, obvious malnutrition is uncommon and the general health of the people is moderately good by European standards. A detailed account of the health status and of the prevalence of various diseases in the population is given elsewhere (Hornabrook, Crane & Stanhope 1974).

Single houses in the village were usually occupied by only one family. These houses are built on stilts normally about 0.75 m above the ground and are open, with woven bamboo walls and roofs of morota. They provide very good shade and the maximum of circulation of air and are ideally suited to hot, humid conditions.

There is no indigenous alcoholic drink. However, most of the population, including even fairly young children, chew betel nut, and its effect is potentiated with lime obtained from crushed coral together with the fruit of the betel pepper plant. Betel nuts are chewed at any time of the day but especially when the individuals are sitting around during meetings and in the evening. Its effect seems to be to produce a mild euphoria.

Food production

Gardens are usually in secondary forest which, although often a thick tangle of undergrowth, is easily cleared with the assistance of burning. The gardens are mostly on flat ground. They are usually planted twice before being abandoned and allowed to revert to bush. The root crops are planted mainly by the women. The main crop is taro, of which there are many varieties, but bananas are also planted. Occasionally yams or sweet potato are grown but in small quantities. At some times of the year breadfruit becomes the staple food. Galip nuts, which are very tasty and are preserved over much of the year, are another source of food. Animal protein was restricted to flying foxes which were shot by arrow or occasionally by the use of shotguns, and kapuls or opossum, but the total amount consumed by most of the population was small.

Table 1. Physical characteristics of the subjects

Mean values and standard deviations.

	n	age	height/cm	mass/kg	skinfolds†/mm	fat‡ (%)
men						
Kaul						
all	51	34 ± 10	160 ± 6	56.0 ± 4.9	23	10
18–29 years	19	24 ± 3	162 ± 6	57.4 ± 4.4	24	10
30 and over	32	40 ± 8	159 ± 6	55.1 ± 5.1	23	10
Lufa						
all	43	28 ± 6	159 ± 5	57.5 ± 5.8	23	10
18–29 years	28	24 ± 4	161 ± 5	58.3 ± 5.4	24	10
30 and over	15	34 ± 5	157 ± 4	56.0 ± 6.3	22	10
women						
Kaul						
all	69	31 ± 10	151 ± 5	47.3 ± 5.9	33	22
18–29 n.p.§	29	23 ± 4	152 ± 5	49.0 ± 5.1	38	24
30 and over n.p.	31	40 ± 7	150 ± 4	44.4 ± 4.7	30	21
pregnant	9	27 ± 5	153 ± 6	51.7 ± 7.0	27	21
Lufa						
all	41	25 ± 6	152 ± 5	50.9 ± 6.1	31	22
18–29 n.p.	28	23 ± 4	152 ± 5	51.3 ± 6.1	35	23
30 and over n.p.	6	36 ± 4	150 ± 4	45.8 ± 5.2	23	18
pregnant	7	25 ± 6	153 ± 4	53.5 ± 4.9	31	22

† Sum of skinfolds at biceps, triceps, subscapular and suprailiac areas.
‡ From Durnin & Rahaman (1967). § Non-pregnant.

None the less the nutritional importance was probably greater than that of pig-meat and of sea-food since these formed only occasional items in the diet. Pigs played an important role in the life of the village. Some of the pigs were very large in size and these were fed regularly and lived mostly under the houses, although a considerable number of smaller pigs ranged freely round the village and in the secondary forest in the vicinity. They were usually killed only on ceremonial occasions and therefore rarely contributed significantly to the total food intake of the village. Little fishing was done, although the village was situated fairly near to the sea and the villagers had canoes and had access to the beach, and the contribution of sea-food to the diet was therefore limited. The fishing by the villagers in general seldom seemed related to the availability of food or to the desire for change in the diet. Normally it appeared to be looked on as a leisure-time activity.

Various types of leaves were commonly included with boiled taro and presumably were used for their flavouring.

Foods such as 'mons' and pawpaw (papaya) were eaten frequently when in season, and mango, sour sop, Malay apples and oranges appeared less frequently in the diet.

Coconut is important nutritionally and economically. Coconut was eaten by most people on most days of the year and moderate quantities of the immature flesh and water of the coconut were eaten by individuals working in the gardens or in the plantations of coconuts and cocoa.

Insects and lizards were eaten by children but they were not important nutritionally because of the small quantities. In Kaul village there are now shops where stored foods, particularly tinned foods, are available, and because of the high energy and protein content of these foods they play a significant role in the diet even although the number of occasions when they were eaten was not frequent and the amounts were not large.

Meal patterns

The main meal of the day was in the evening and consisted of a large bowl of cooked taro together with some of the other items mentioned. Food was sometimes eaten at frequent intervals throughout the day. Breakfast usually consisted of the remains of the previous evening's meal or perhaps a roast taro. Snacks were taken during the day unless the people were working in a new garden and away from food crops.

Lufa

The population studied in the highlands in the villages around Lufa were of a different type to those in the coastal area of Kaul. Physically they were of approximately the same height and mass but were much more muscular and, in general, had grosser facial features. Again, there were no endomorphs. Malaria was not endemic and overt malnutrition was very uncommon. A detailed description of the health status and epidemiology of these people is given elsewhere (Hornabrook *et al.* 1974).

The total population of the Lufa subdistrict is about 20000 people, although some of them live in very remote areas. The subjects studied here all lived in seven villages situated near a government station.

The wet and dry seasons were more sharply defined than on Karkar and the annual rainfall was about 250 cm. Temperature ranged from quite cool in the evening (the altitude of the area where these people lived was about 1850 m) to daytime temperatures which were sometimes quite high (33–35 °C); humidity, in general, was only moderate. Vegetation was mixed mountain forest, and the country was rugged with the gardens being often on steep slopes which necessitated much climbing up and down. The Lufan people were subsistence farmers. Coffee has been introduced in the recent past as a cash crop.

The villages themselves differed in pattern from the coastal area. The dwellings were close to each other and were much smaller than those on the coast. Most of the houses were rectangular in shape with a grass roof. They are built on the ground with no stilts and they had a fireplace which was usually central and near the door. Most families also had a house in their garden, perhaps a considerable distance from the village, where frequently pigs were kept. The people often lived in these 'pig houses' so that the village did not contain all of the population at any given time.

Even more than in the coastal region, pigs represented much more than just a supply of food. They epitomized wealth, and a considerable amount of effort and of the supply of root crops were devoted to feeding these pigs.

Gardens were sited in secondary forest and were occasionally up to 4 km from the villages and perhaps from 300 m in higher to 1000 m in lower. All gardens were surrounded by strong fences to keep out marauding pigs.

Food production

Sweet potato is the staple crop. Yams and bananas are relatively plentiful. Pandanus-bearing trees are found in the gardens but are usually planted and cultivated in the bush.

All tubers (sweet potato, yams or taro) may be roasted or cooked in a 'mumu' or, less usually, boiled. 'Mumu' is a common form of cooking akin to steaming, the tuber being placed in a small pit surrounded by hot stones and covered in leaves. Corn was very popular and contributed appreciably to the dietary intake, although it is partly seasonal. Some legumes, including peanuts, are eaten but do not form a large part of the diet. Sugar-cane is also eaten extensively. Large quantities of leaves are an article of diet. Bananas are not as important as on the coast although they are consumed in moderately large quantities. The principal animal food is pig, although chickens, duck, turkeys and goats occasionally appeared in the diet.

Store foods

Although these were consumed in approximately the same variety as those in Kaul they contributed a less significant portion of the total diet.

The age, height, mass, skinfold thickness and total body fat of the adult population of Lufa are also shown in table 1. Both the men and the women were smaller and lighter than a comparable European population, although the total body fat was relatively less for all groups and the lean body or fat-free mass (f.f.m.) was therefore relatively larger than for European-type populations.

For example, the body mass of the young men of Lufa was 58.3 kg and the percentage body fat was 10 %. Thus their f.f.m. was 58.3 – 5.8 kg; that is, 52.5 kg. An average young man in many European countries might weigh 65 kg with a body fat of 15 %. His f.f.m. would therefore by 65 – 9.8 kg; that is, about 55 kg. The difference between the f.f.m. of these New Guinean men and that of a typical European man is therefore comparatively small. Similar situations apply to the Kaul young men and to both Kaul and Lufa young women.

The age-range was divided, for both men and women, into a younger group – 18–29 years – and an older group of 30 years or more. This division was partly arbitrary although also based on certain social and physiological changes which seemed to occur at about that age. The '30 and over' group of both men and women in Kaul is older than in Lufa and the numbers in this group are larger in Kaul than in Lufa. This limits somewhat the reliability of comparisons between these two older populations. The subdivision of age was somewhat rough since definite information about the age of any individual was often a matter of some guesswork. The way of life altered to some extent with ageing and, as can be seen, there is a reduction in both heights and masses of all the older groups compared to the younger. This may well represent the proper physiological process whereby older people are lighter in mass than young adults, since their skeletal and muscular masses may be reduced, although it differs from the situation in European cultures where ageing usually goes hand-in-hand with an increase in total body mass (and fat). The precise relations between age and body mass for the New Guinean populations is shown in table 2.

Table 2. Regression equations and correlation coefficients of age (x) and body mass (y) Kaul and Lufa

Kaul			
males	$y = -0.10x+59.4$	$r = -0.23$	$n = 51$ (n.s.)
females	$y = -0.22x+54.1$	$r = -0.38$	$n = 68$ (0.001)
non-pregnant	$y = -0.19x+52.6$	$r = -0.35$	$n = 59$ (0.01)
Lufa			
males	$y = -0.40x+69.0$	$r = -0.43$	$n = 41$ (0.01)
females	$y = -0.33x+58.5$	$r = -0.34$	$n = 38$ (0.05)
non-pregnant	$y = -0.34x+58.1$	$r = -0.37$	$n = 34$ (0.05)

Levels of significance in parentheses.

Methods

Measurements were made on each individual of the food intake and energy expenditure during a period of 5–7 consecutive days. The total duration of the study lasted 9 months in Kaul and 10 months at Lufa.

Normally all of the members of any selected household took part in the study but the foods which were eaten and the activities which were recorded were always done on single individuals within the family. Food intake was measured on 51 men and 69 women in Kaul and, of these, total daily energy expenditure was measured on 42 men and 40 women. The comparable figures for Lufa were 43 men and 41 women for food intake and 40 men and 38 women for energy expenditure. A few of the women in both villages were pregnant while they participated in the study and several women were lactating.

During the study in Kaul village we lived in one of the native huts throughout the 9 months and therefore became well acquainted with the local population and their way of life. In Lufa, although we were accommodated in a local government hut we yet spent long enough in close contact with the local people so that again we became reasonably knowledgeable about their way of life. In both cases much effort was exerted to try and minimize any influence which the study might have on the normal pattern of eating and of physical activity by the subjects. The fact that the survey took place during most of a calendar year in each village meant that seasonal variations were reasonably covered.

The purpose of the investigation, with perhaps a certain emphasis on the medical importance, was explained to the villagers in pidgin English (which is widely understood in these parts of Papua–New Guinea) or else through interpreters. Some local help was enlisted. These helpers were young men and women who had had some elementary school education. Some spoke English. After the first families had been studied the nature of the investigation was, of course, known to everyone in the village and subsequent subjects could make an informed decision as to whether to participate or not. Selection was done on a part-random basis by approaching every fourth household in the village. Apart from this type of selection, a few young men and women were deliberately chosen because they had already taken part in a climatic-tolerance study and were expected to be subjects, later on, of some exercise capacity and respiratory function tests.

The refusal rate of the randomly selected subjects was between 5 and 10%.

Food intake

All of the food eaten by each individual subject was weighed after cooking (where applicable) and immediately before consumption. Food consumed in the house was weighed on a robust Avery balance, weighing to 1 kg in 10 g divisions, using a large bowl scale-pan. The balances were frequently calibrated. Masses were recorded to the nearest 5 g. Left-over portions or inedible portions were also weighed and subtracted from the initial mass. Subjects were followed when they left the immediate vicinity of the house and food eaten away from the house was weighed on a portable Salter dietary balance weighing up to 500 g in 5 g divisions. A light plastic jug and plate were used for liquids such as coconut water.

Subjects were under observation for almost the entire waking day. It was impracticable that this could be performed by us as there were many other duties to be done and the continued presence of a European might have affected the habitual normal activity of the subject. The young assistants of both sexes (mentioned above) were trained as observers. They undertook this role very efficiently in general, and also helped to maintain good relations with the subjects. Because of the complex family interrelationships in the village, these assistants would often have some family connexion with the subjects and their presence in the house was not unusual.

Whenever possible, the weighing of food was performed or supervised by one of us. This was always the case for the main meals of the day, in the morning and in the evening. Apart from this, frequent visits to an individual or to a family, in their house, their garden, or elsewhere, throughout the day ensured that most of the other weighing were either supervised or checked soon after completion. A common method of checking was to compare the given mass and description of a food with a list of masses of standard portions of these food items. This method was also employed to assign a weight to any food which had not been weighed, perhaps having been eaten during the night. Where such recalls contributed more than a third of the food eaten, and therefore might have significantly affected the results, the records were discarded. The possibility that normal eating patterns were disrupted due to these investigations is discussed in the Results.

Recording of foods

Each foodstuff and the method of its preparation was described as comprehensively as possible. English or pidgin-English names were used when these were known or where the foods could be positively identified.

Composition of foods

Samples of all the important foodstuffs were collected for analysis. These were dried to a constant mass using a vacuum oven, packed in sealed plastic containers and flown back to the U.K. for chemical analysis. Details of the particular methods used and of the results appear elsewhere (Durnin & Norgan 1974). Briefly, protein and energy of these foods have been calculated using the appropriate conversion factors of Merrill & Watt (1955). Where values have been taken from the literature, these have been described. They have not been adjusted if different conversion factors were used by the original authors because values in the literature

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invariably applied to uncooked foods and the precision implied by any adjustment would not be warranted. A very large proportion of the nutrient and energy intake of the subjects was derived from foods which have been analysed chemically in this present study.

The energy, protein, fat and carbohydrate intake have been calculated and the statistical analysis of these results, together with the amounts of energy and nutrients derived from various combinations of foodstuffs, have been computed using an I.B.M. 360/50 computer.

Measurement of energy expenditure

Measurement of energy expenditure was done by the technique described by Durnin & Brockway (1959). Total daily energy expenditure was calculated from a detailed record of the time spent in each activity of an individual throughout the whole 24 h of 5–7 consecutive days. The gross energy cost of many of the separate activities of each subject was measured by indirect calorimetry. Total daily energy expenditure was obtained from the sum of the amount of time spent in each activity multiplied by its energy cost.

The technique employed to assess energy expenditure in different 'activities' varied a little. 'Lying' and 'sitting' measurements were done inside the hut used as a laboratory, using the Douglas bag method. Analyses, in duplicate, of the O_2 and CO_2 contents of the expired air were made almost always with the Lloyd–Haldane apparatus. A Servomex paramagnetic oxygen analyser was sometimes employed when its calibration showed it to be accurate to within $\pm 0.05\%$ compared to the Lloyd–Haldane, but the difficult environmental circumstances frequently put it out of action. For 'activities' other than these, the Max–Planck respirometer was used. The sample of expired air, collected into rubber or latex bladders, was either immediately transferred to glass tubes filled with acidulated water by the technique described by Durnin (1955), or the bladder was placed inside a plastic sac which was then filled with expired air to prevent a significant alteration in the gas content of the bladder before it was analysed (Rahaman & Durnin 1964). A calibration factor was applied to the volume, recorded on the respirometer, of the air breathed out by the subject. This calibration factor varied depending on the level of pulmonary ventilation and was obtained by calibrating each Max–Planck respirometer at different flow rates using the technique described by Durnin & Brockway (1959). Energy expenditure was calculated using Weir's (1949) formula.

No measurements of energy expenditure were attempted on the subjects while they were asleep; the value for this was taken as the basal metabolic rate (b.m.r.), according to Fleisch's (1954) tables, with a reduction of 10% applied to the subjects living on the coast (in Kaul) to allow for the diminution in b.m.r. which is supposed to occur in peoples living in hot environments. All of the important or time-consuming activities of each individual were measured. Where no measurement of energy expenditure on a specific activity had been obtained, values were used which were based on results obtained on other individuals, taking into account such factors as body mass, individual idiosyncrasies, etc. Such activities normally occupied a relatively brief average part of the day and error here is not likely to influence significantly the calculation of the total daily energy output.

Recording of activities

Activities were recorded on special diary cards with an attempt to account for each minute of the day. All subjects were under observation throughout the whole waking day, the use of local assistants making this possible without altering the habitual activity of the subject. The authors spent much of each day with the subjects in their houses, gardens and plantations, and walking through the bush. Whenever records were made by the local assistants these could be checked from knowledge of the habits of the villagers as a group or of an individual subject – whether he was energetic or casual – and the paths he might take to different places together with the times for these journeys.

Some of the activities were a little vague – such as, for the coastal group, the *sauntering around* in the daytime and in the evening which made concise description difficult, and *hunting* which was another composite activity sometimes necessitating rather slow and stealthy movement or even standing quite still.

Table 3. The mean daily energy and nutrient intake of the Kaul and Lufa men

Standard deviations given in parentheses.

		energy				protein		animal protein	carbo-hydrate	fat
	n	MJ	kcal	kJ/kg	kcal/kg	g	g/kg	g	g	g
Kaul										
all	51	8.13 (2.01)	1944 (481)	145 (33)	34.6 (7.9)	36.9 (11.5)	0.66 (0.19)	9.1	366 (95)	39 (16)
18–29 years	19	8.91 (1.78)	2130 (425)	155 (28)	37.0 (6.6)	40.3 (10.2)	0.70 (0.17)	8.8	402 (91)	43 (14)
30+	32	(7.67) (2.03)	1833 (484)	139 (35)	33.2 (8.3)	34.9 (12.0)	0.63 (0.20)	9.2	344 (92)	37 (16)
Lufa										
all	43	(10.56) (2.00)	2523 (477)	185 (37)	44.2 (8.9)	47.1 (16.6)	0.82 (0.27)	9.5	529 (102)	29 (26)
18–29 years	28	(10.37) (2.21)	2478 (528)	178 (40)	42.6 (9.6)	48.6 (17.7)	0.83 (0.29)	11.1	507 (107)	33 (30)
30+	15	(10.92) (1.54)	2609 (367)	196 (29)	46.9 (7.0)	44.3 (14.5)	0.78 (0.23)	6.7	570 (82)	23 (17)

Results

The mean daily energy and nutrient intakes of the adult men and women living in Kaul and in Lufa are shown in tables 3 and 4. There are obvious differences between the groups, the coastal people having very much lower intakes than the highland people. Thus, the energy content of the diet of the Kaul men, regarded either in absolute values (8.12 MJ or 1940 kcal/day) or as energy/kg body mass (146 kJ/kg or 35 kcal/kg per day) appears considerably lower than might be anticipated for their moderately active way of life. It is possible, of course, that they were not in energy balance or that the technique of measuring their food intake led to large errors of under-estimation. These points are discussed later in some detail but both of them seem unlikely to us, since we lived for several months in close contact with the subjects and we were able to assess closely these possibilities. The same comments apply to the Kaul women whose mean energy intake was very low by any standard – 5.95 MJ or 1420 kcal/day or, as a function of body mass, 130 kJ or 31 kcal/kg per day. The women of Kaul village frequently did work of moderate severity: they had to walk long distances to and from their gardens, often carrying loads. However, their results are almost uniformly low; all the groups, young, older, and the pregnant women, had intakes which were remarkably similar. Indeed, even within the groups, there was little gross dissimilarity; the maximum energy intake was 10.75 MJ or 2570 kcal/day and few women had intakes of over 8.37 MJ or 2000 kcal/day. Ten of the 69 women had less than 4.18 MJ or 1000 kcal/day, but if their results are excluded, the mean for the remainder rises to only 6.28 MJ or 1500 kcal/day, which is a relatively small increase over the group mean of 5.94 MJ or 1420 kcal/day. The energy values for the men and women living in the highlands are much higher and, while still low by most accepted standards, are nearer to expected levels for their way of life.

TABLE 4. THE MEAN DAILY ENERGY AND NUTRIENT INTAKE OF THE KAUL AND LUFA WOMEN

Standard deviations in parentheses.

		energy				protein		animal protein	carbo-hydrate	fat
	n	MJ	kcal	kJ/kg	kcal/kg	g	g/kg	g	g	g
Kaul										
all	69	5.96	1424	128	30.5	24.5	0.53	3.7	274	29
		(1.71)	(409)	(39)	(9.4)	(9.6)	(0.21)		(75)	(16)
n.p.n.l.†	34	5.87	1402	129	30.8	23.1	0.51	3.1	275	27
		(1.51)	(362)	(38)	(9.1)	(7.4)	(0.18)		(73)	(11)
lactating, 0–1 year	13	5.91	1412	121	28.9	24.1	0.51	3.0	262	33
		(2.02)	(483)	(38)	(9.1)	(10.2)	(0.21)		(77)	(25)
lactating, 1+ year	19	6.24	1491	133	31.9	27.7	0.58	4.4	286	31
		(1.96)	(468)	(45)	(10.7)	(12.5)	(0.28)		(82)	(16)
pregnant	9	5.92	1414	115	27.5	25.4	0.49	3.6	261	34
		(1.54)	(369)	(32)	(7.6)	(8.7)	(0.16)		(68)	(17)
18–29 n.p.	29	5.96	1424	123	29.4	23.8	0.50	3.5	277	28
		(1.59)	(380)	(33)	(8.0)	(8.0)	(0.18)		(68)	(16)
30+ n.p.	31	5.97	1427	136	32.4	24.9	0.57	4.0	274	29
		(1.91)	(456)	(46)	(10.9)	(11.2)	(0.26)		(85)	(15)
Lufa										
all	41	8.81	2105	175	41.8	43.2	0.85	9.9	444	23
		(1.92)	(460)	(40)	(9.6)	(20.7)	(0.38)		(93)	(18)
n.p.n.l.	14	8.65	2068	167	39.8	43.6	0.83	10.4	445	17
		(1.92)	(460)	(37)	(8.8)	(23.8)	(0.44)		(100)	(11)
lactating, 0–1 year	14	8.92	2133	184	43.9	43.0	0.88	9.2	449	23
		(1.23)	(295)	(28)	(7.1)	(19.2)	(0.38)		(58)	(20)
lactating, 1+ year	6	9.40	2247	196	46.8	39.6	0.81	8.2	470	28
		(2.52)	(602)	(52)	(12.5)	(13.1)	(0.22)		(98)	(30)
pregnant	7	8.37	2001	156	37.4	45.9	0.85	10.8	407	25
		(2.72)	(651)	(49)	(11.6)	(25.6)	(0.45)		(134)	(13)
18–29 n.p.	28	9.03	2158	178	42.5	43.8	0.85	11.4	455	23
		(1.83)	(438)	(38)	(9.1)	(21.3)	(0.39)		(84)	(21)
30+ n.p.	6	8.27	1977	204	48.8	37.3	0.83	3.4	433	18
		(1.32)	(315)	(69)	(16.5)	(11.6)	(0.32)		(79)	(9)

† n.p.n.l. = non-pregnant non-lactating.

The intakes of crude protein and of fat were small according to most recommended standards but they represent some of the highest values reported in New Guineans (Oomen 1971). The gross intake of protein was greater in the case of the Lufa populations but relative to the energy intake, all the groups had similar intakes (of the total energy of the diet, 6.7, 6.0, 6.5 and 7.2 % were supplied by the protein of the Kaul men and women and the Lufa men and women respectively). However, the fat content of the diet of the Lufa groups, both as gross and percentage intakes, was very low; the energy from fat was 9.8 % of the total energy of the diet for the men and 9.1 % for the women, compared to 17.2 % for both men and women in Kaul.

The protein intake relative to various standards of recommendations is discussed later. However, it is clear that the amounts of protein from animal sources was very low – 3.7, 9.9, 9.1 and 9.5 g/day for the Kaul and Lufa women and the Kaul and Lufa men respectively. Two Kaul men and 14 Kaul women, and 12 men and 12 women from Lufa ate diets which contained less than 1 g of animal protein per day. For the Kaul groups, the subjects with the lowest and those with the highest intakes of any nutrient (e.g. protein) usually also had the lowest or the highest amounts of all the nutrients and for energy, indicating that these levels reflected the whole food intake and that the balance of the diet was similar for most of the population. This was not the case for the Lufa people where no single individual occupied one end of the range for all the nutrients or energy. An illustration which would not be uncommon in a typical New Guinea *highland* population was the Lufa man with the highest protein intake (97 g/day) accounted for by a gift of pig meat from his parents-in-law as part of an exchange resulting from his second marriage 3 years previously; his intake of pig meat was about 170 g/day over the period of the survey. Such an exchange did not seem extraordinary and, even when shared with others, still accounted for large individual intakes. Obviously, these individuals are few at any one period in the community and it is, at present, difficult to determine the significance for the individual's nutritional status of these infrequent feasts.

The percentage of the total protein intake which was accounted for by animal protein is shown in table 5 for all the groups.

TABLE 5. PERCENTAGE OF TOTAL PROTEIN INTAKE AS ANIMAL PROTEIN

	Kaul		Lufa	
	n	% of animal protein	n	% of animal protein
males 18–29	19	21.9	28	22.8
males 30 and over	32	26.3	15	15.2
females n.p. 18–29	29	14.6	28	26.1
females n.p. 30 and over	31	16.0	6	9.0
females pregnant	9	14.3	7	23.6
females lactating	32	16.8	20	20.3

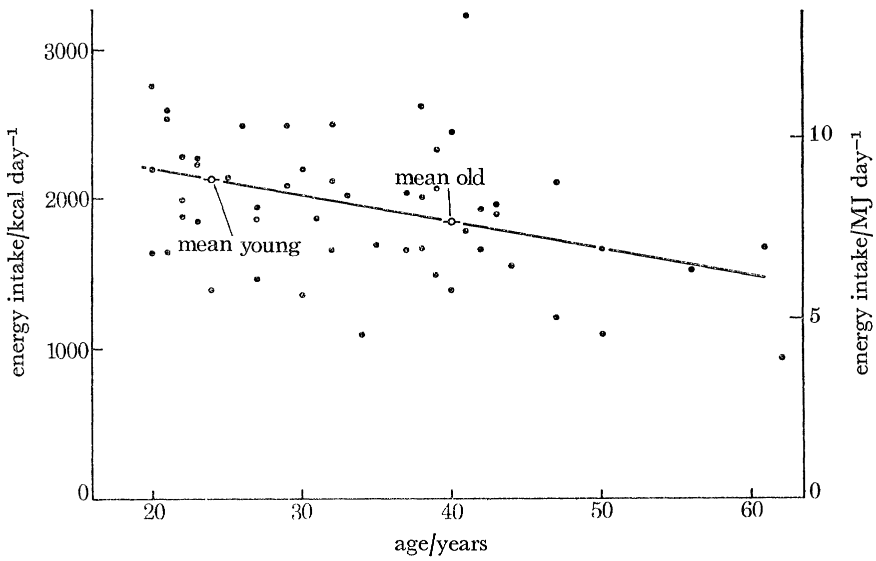

FIGURE 1. Relation of mean daily energy intake and age for the 51 Kaul men. $n = 51$; $r = -0.3933$ ($P < 0.01$); $y = -18.10x+2563$.

Effect of age

The mean intakes of energy and of protein were lower in the older subjects compared to the younger with the exception of the Lufa men, where the older men had a higher intake of energy (see tables 3 and 4). However, the correlation coefficients of age and energy intake for these four groups were $r = +0.03$ for the Kaul women, -0.39 for the Kaul men, -0.18 for the Lufa women and $+0.18$ for the Lufa men. With the exception of the Kaul men, who show a significant ($P < 0.01$) decrease in energy intake with ageing, none of the other relations

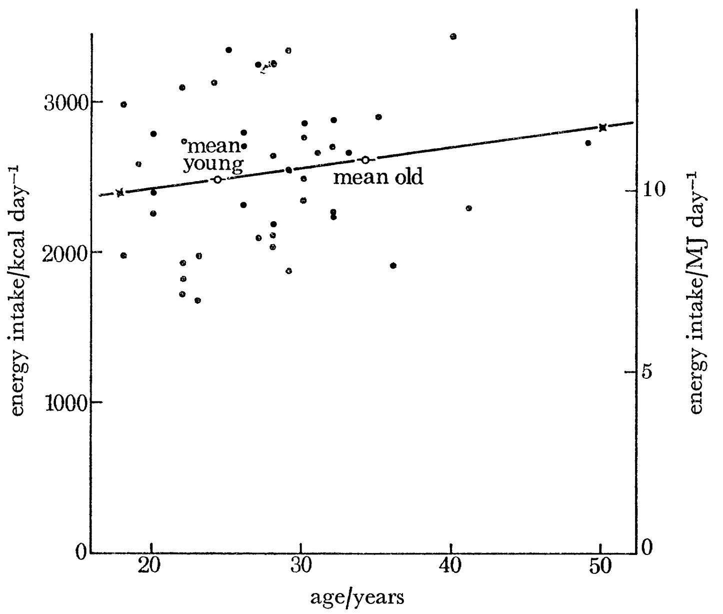

FIGURE 2. Relation of mean daily energy intake and age for the 43 Lufa men. $r = +0.1810$ (n.s.); $y = 13.49x + 2149$.

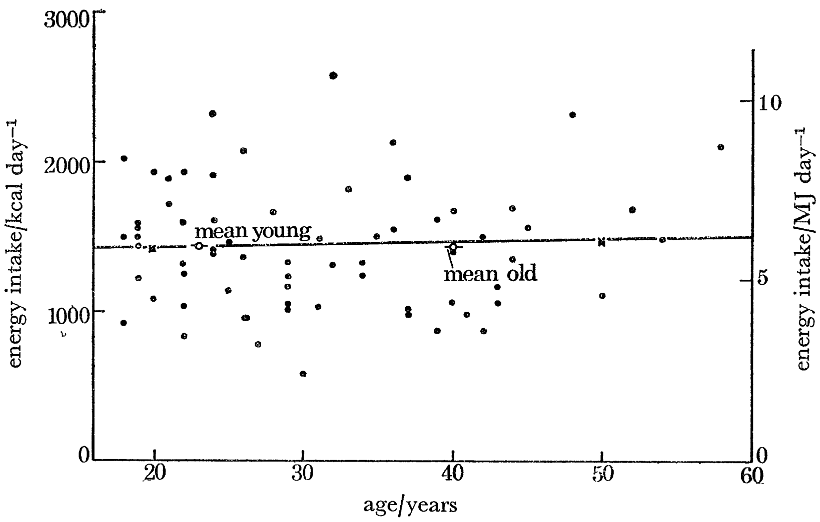

FIGURE 3. Relation of mean daily energy intake and age for the 69 Kaul women. $r = +0.0258$ (n.s.); $y = 1.05x + 1397$.

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is significant, showing that ageing, over the ranges measured in these groups, has little influence on reducing the food intake. This is further emphasized by the small but nevertheless positive correlation between food intake and ageing in the Kaul women and Lufa men.

Since body mass also tended to be less in the older New Guinean groups, these mean decreases of gross intakes by the older groups are altered when the nutrient or energy is expressed as a function of mass, when all groups except the Kaul men show a higher relative intake in the older people. These relations are not statistically significantly affected by age, however, in the case of both groups of women.

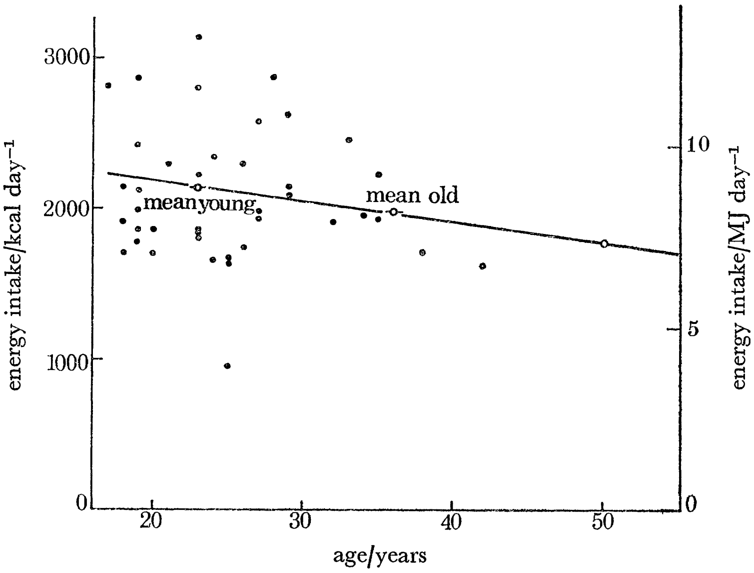

FIGURE 4. Relation of mean daily energy intake and age for the 41 Lufa women. $r = -0.1806$ (n.s.); $y = -13.54x + 2442$.

Effect of body mass on intake

Tables 3 and 4 give the intakes of energy and of protein expressed per kg body mass for the four groups of people. Some of these results are surprising. For example, the highest mean value for the Kaul men – that for the young men – was 155 kJ (37 kcal)/kg. This does not even approach the supposed requirement of energy of the lowest category in the latest F.A.O./W.H.O. Report (1973); this category is for sedentary workers where the recommended energy intake is given as 170 kJ (42 kcal)/kg. The Lufa men just about equal the F.A.O./W.H.O. value for 'moderately active' men – 190 kJ (46 kcal)/kg. In the case of the women, no group in Kaul comes near the lowest F.A.O./W.H.O. value, i.e. 150 kJ (36 kcal)/kg. On the other hand, the Lufa women are almost all within the 'moderately active' (170 kJ or 40 kcal/kg) and some are even in the 'very active' F.A.O./W.H.O. category (200 kJ or 47 kcal/kg).

The correlations of body mass and intake of energy are $r = +0.43$ for the Kaul men, $+0.04$ for the Kaul women, $+0.16$ for the Lufa men and $+0.16$ for the Lufa women. The only one of these correlations which is significant is that of the Kaul men.

These low correlation coefficients are remarkable. Many of the calculations of energy requirements, and much of the basic assumption in relation to factors of importance in energy balance, rely upon the probability that body mass plays a significant role in energy expenditure. All things being equal, a 100 kg man will expend twice as much energy in a day as a 50 kg man.

Assuming that they will each have an energy intake approximately equal to their energy expenditure, the general conclusion should be that there ought to be a high correlation between body mass and energy intake. However, in almost all populations which have been investigated this correlation has been low, seldom showing a coefficient above +0.4. The reason has often been supposed to reflect differing amounts of body fat between individuals and different levels of physical activity, so that a heavy person might also be a fat person and perhaps less active. In these New Guinean populations the circumstances would appear to have been almost ideal for demonstrating the dependence of energy intake on body mass. There were no complicating social factors – everyone lived in the same type of dwelling, ate the same foods, and led the same sort of life. Everyone was moderately active physically and everyone was lean. Yet, even in this homogeneous group the correlations between energy intake and body mass are low. This is an unexpected and upsetting finding and must cast some doubt on the validity of using body mass as a highly important factor in calculating energy requirements.

Effect of pregnancy and lactation on energy and nutrient intakes

Table 4 gives the energy and nutrient intakes of the Kaul and Lufa women, subdivided into groups to show the effects of pregnancy and of lactation both of up to 1 year's duration and of more than 1 year. The pregnant groups in both populations were small in number (9 Kaul and 7 Lufa women) and the state of pregnancy varied – for example, 5 of the 9 Kaul women were also lactating, and of the 9, 5 were in the third trimester, 2 in the second and 2 in the first trimester (although these last 2 did not, at the time of the survey, know that they were pregnant), and of the 7 Lufa women, 5 also were in the third trimester and the other 2 were in the second.

The striking impression from the Kaul results is the uniformity of the energy and nutrient intakes for all the different groups – non-pregnant, pregnant, and lactating. The physiological and nutritional significance of this finding is considerable, particularly since the intakes were so low; this is discussed later in conjunction with the evidence of whether or not physical activity was altered during pregnancy and lactation. In the Lufa women, again there were no differences in intakes between the pregnant and the non-pregnant non-lactating women. However the women who were breast-feeding a child more than 1 year old had a significantly higher energy and fat intake (0.75 MJ or 180 kcal/day of energy and 11 g of fat) than the non-pregnant non-lactating women.

In general, these results agree with those of Hipsley & Kirk (1965), who also found a relatively constant intake between pregnant and non-pregnant women in two groups of New Guineans. The amounts of protein and energy taken by the Kaul women were similar to those of both the coastal and the highland women studied by Hipsley & Kirk, and also to those of the taro-eating subjects of Oomen & Malcolm (1958), but all of these intakes were considerably lower than those of the Lufa women of the present study.

None of the present results fits in with recommendations of the extra requirements of energy for pregnancy and lactation. For example, the F.A.O./W.H.O. Report (1973) suggests an extra 1.2 MJ (285 kcal) per day during pregnancy and 2.3 MJ (550 kcal) per day for lactation. In both Kaul and Lufa the intake of the pregnant and non-pregnant women were the same. The intake of the Lufa women, as an average, was moderately high by most standards and there did not appear to be a deficiency of food: it was simply that when they became pregnant they did not eat more. In Kaul, it was not the same: the intake of the women on average was very low.

Yet they were living in perhaps the most fertile region of Melanesia and food was moderately plentiful. It has also been reported (Hornabrook 1974) that menstruation continues and pregnancy occurs in these women in their middle and late 40s. Again, the absence of an increase in food intake during pregnancy seems paradoxical. The comparatively small rise in energy intakes among the *lactating* women whose babies were more than 1 year old are almost as inexplicable.

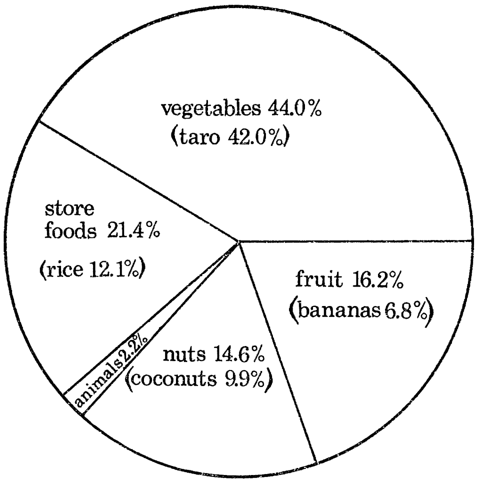

FIGURE 5

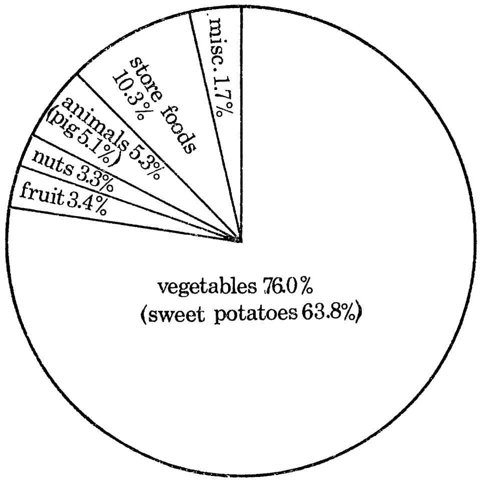

FIGURE 6

FIGURE 5. Contribution of the principal foods and food groups to the total mean daily energy intake of the Kaul people.

FIGURE 6. Contribution of the principal foods and food groups to the total mean daily energy intake of the Lufa people.

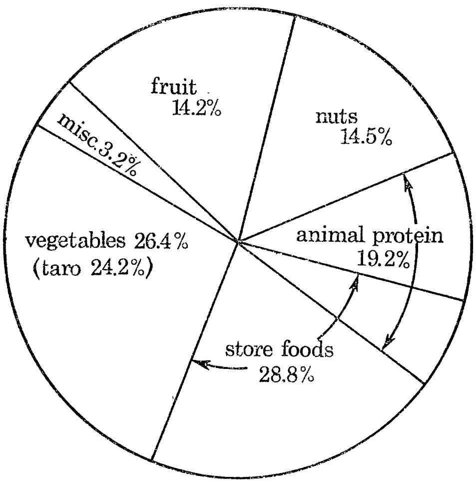

FIGURE 7

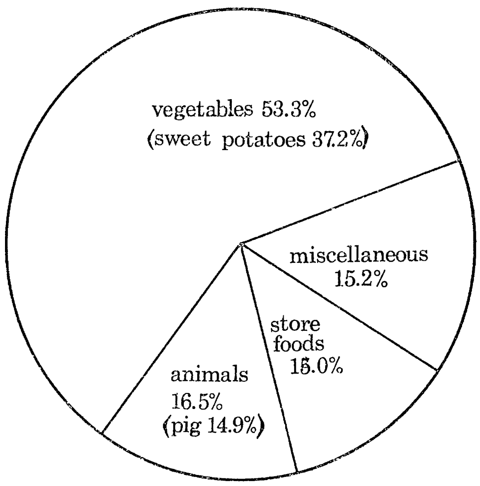

FIGURE 8

FIGURE 7. Contribution of the principal foods and food groups to the total mean daily protein intake of the Kaul people.

FIGURE 8. Contribution of the principal foods and food groups to the total mean daily protein intake of the Lufa people.

The sources of energy and protein in the diet

The contribution of various food groups to the total energy and protein content of the diet of the Kaul and Lufa populations is shown in tables 6 and 7; figures 5–8 give a diagrammatic

TABLE 6. PERCENTAGE OF THE TOTAL ENERGY INTAKE FROM FOODS AND FOOD GROUPS

Kaul

	n	taro	other vegetables	fruits	banana†	nuts (excluding coconut)	coconuts	animals‡	pig	'store' foods	tinned meat and fish	rice	all animal sources
males													
18–29	19	38.8	1.3	13.9	4.5	2.8	9.0	3.8	2.3	30.5	1.7	13.9	5.7
30+	32	45.3	2.5	12.5	5.8	4.8	7.9	3.1	0.7	22.4	1.7	13.9	4.9
females													
n.p. 18–29	29	43.8	1.6	18.0	8.9	3.8	12.1	1.5	0.3	17.6	0.8	10.3	2.4
n.p. 30+	31	41.2	2.4	17.6	7.6	5.5	9.9	1.3	0.2	20.0	1.2	11.9	2.6
pregnant	9	36.8	1.4	23.3	5.1	11.1	9.1	1.6	0.5	15.7	1.4	8.0	2.9

Lufa

	n	sweet potato	other roots	other vegetables	fruits	nuts	karuga	animals‡	pig	'store' foods	tinned meat and fish	rice	all animal sources
males													
18–29	28	57.3	7.8	4.3	2.4	3.8	3.0	5.7	5.7	16.2	1.5	7.2	7.8
30+	15	72.2	5.1	4.4	3.5	2.7	2.2	4.2	4.2	5.9	0.4	2.2	4.9
females													
n.p. 18–29	28	64.7	9.0	2.8	3.7	2.6	1.1	6.2	5.8	8.5	1.0	4.7	7.5
n.p. 30+	6	72.6	4.3	7.0	4.2	4.3	2.0	3.0	2.9	1.3	0.2	0.7	3.2
pregnant	7	60.9	4.8	4.6	4.8	4.9	4.0	5.0	4.1	10.9	0.9	9.1	6.7

† Included in 'fruits'. ‡ Also includes 'pig'.

TABLE 7. PERCENTAGE OF THE TOTAL PROTEIN INTAKE FROM FOODS AND FOOD GROUPS

Kaul

	n	taro	leaves	fruits	banana†	nuts	coconuts	animals‡	pig	'store' foods	tinned meat and fish	all animal protein foods	rice
males													
18–29	19	20.5	2.1	11.6	3.4	3.6	6.8	14.6	4.1	39.1	6.9	21.9	12.6
30+	32	24.2	3.7	9.8	4.3	7.2	6.0	18.0	2.6	28.5	8.2	26.3	12.7
females													
n.p. 18–29	29	27.1	4.9	16.6	7.6	4.8	9.5	10.3	1.1	24.4	4.0	14.6	10.4
n.p. 30+	31	24.3	4.6	15.9	6.1	6.9	7.9	9.5	1.3	28.5	6.2	16.0	11.8
pregnant	9	22.1	2.8	21.8	4.0	14.7	7.0	7.7	0.3	22.7	6.6	14.3	7·8

Lufa

	n	sweet potato	other roots	other vegetables	beans	green leaves	fruits	nuts	karuga	animals‡	pig	'store' food	tinned meat and fish	all animal protein foods	rice
males															
18–29	28	31.9	6.2	7.0	3.8	6.2	1.4	4.6	3.9	15.0	14.6	23.9	6.7	22.8	6.9
30+	15	47.4	4.7	9.7	0.9	10.1	2.0	4.0	3.3	12.7	12.3	8.3	2.2	15.2	2.4
females															
n.p. 18–29	28	36.8	7.6	5.1	2.3	9.4	2.2	2.4	1.4	21.2	18.8	12.9	4.5	26.1	4.5
n.p. 30+	6	44.1	3.6	14.1	1.4	17.4	2.6	6.4	2.6	8.2	7.8	2.1	0.8	9.0	0.7
pregnant	7	32.4	3.2	7.7	4.5	11.2	2.4	5.8	5.0	18.4	12.0	13.9	4.3	23.6	8.5

† Included in 'fruits'. ‡ Also includes 'pig'.

representation of the relative importance of the different groups of foods. A considerable proportion of the energy content of the Kaul diet came from taro (over 40 %), which is the staple food, from fruits and bananas (16 %), from nuts and coconuts (15 %), and – perhaps strangely – from foods purchased from a store (21 %). Animal foods from all sources contributed only about 4 % of the energy. Rice, purchased at the local store, supplied over 12 % of the total energy of the diet.

To provide these intakes, the bulk of food eaten was not very large – about 500 g/day of taro for the women and about 750 g/day for the men. There was less dependence on a single staple (taro) in Kaul than has been previously described for other New Guinean people. Green leaves were eaten frequently but were an unimportant source of energy (and also of protein). Breadfruit and bananas were important items of diet and, in some individuals, supplied over 60 % of both the energy and the protein. Coconuts, which were abundant, did not assume such importance as might have been anticipated: large quantities of the dry or of the green 'meat' of the coconut are difficult to consume.

There were small fluctuations between the different populations in Kaul in these percentage contributions: for example, the women ate relatively more fruit and bananas than the men (19 % of the energy content compared to 13 %) and less 'store' food (18 % compared to 26 %).

Protein was supplied by foods in different proportions than was energy in the Kaul men and women. Taro provided only 24 % of the protein, fruits and bananas 14 %, 'store' foods 29 %, and animal sources of all kinds (sea-foods, small bush animals, pig and including tinned meat and fish) 19 %. Nuts and coconuts were relatively important and supplied about 15 % of the protein. The negligibly small amount of sea-food in the diet of this population, living close to the sea, is astonishing. It is difficult to be sure of all of the reasons but it is not a reflexion of any difficulty in the catching of fish; it appears to indicate the general adequacy of their diet and the absence of any necessity to supplement that diet with extra sources of either energy or protein or to make it more attractive for their palate.

The considerable amounts of energy and protein from 'store' foods was much more a feature of the diets of the young men than of the other groups. These men constituted the group most likely to seek paid employment in plantations so that, although at the time of the study none of the subjects was resident outside the village, they may have been supplied with European-style food in the past and have become used to buying these 'convenience' and 'prestige' foods.

Alcohol was not regularly consumed except by two individuals, although beer and spirits were beginning to be drunk at ceremonies and parties.

The highland population of Lufa had a significantly different pattern of diet. Vegetables, the great bulk of which was sweet potato, provided almost 80 % of the energy, the remainder coming from fruits and nuts (7 %), animal sources (including tinned meat and fish) 6 %, and 'store' foods (10 %).

While the dominant role of the sweet potato as a source of energy and of protein is evident from these results, it is not so large as has been reported on other highland groups in New Guinea. This may reflect not so much a difference between Lufa and other highland regions as a shift away from almost complete reliance on the sweet potato towards other sources – notably, although still relatively small in importance, to foods bought from a local store: this has not previously been described in the diets of highland dwellers in New Guinea. The quantity of sweet potato eaten was about 1.4 kg/day by the men and 1.2 kg/day by the women. Tubers other than sweet potato – such as taro, yams and tapiok, provided small but perhaps noteworthy quantities (7 % of the energy and 6 % of the protein intake).

Fruits, even bananas, played a small part in the diets of the Lufa peoples, possibly because the soil and climate are not so conducive to good growth as at the coast and also that bananas have a relatively long period of maturation at these altitudes. Alcohol, as with the Kaul population, played little part in the normal diet of the people.

Differences between the populations in Lufa were small with the exception that the younger men received about 10 % less energy from vegetables and about 10 % more from 'store' foods than the older men or the women. The protein in the diet of the Lufa people came from vegetables (53 %), of which sweet potato accounted for 37 %, green leaves (about 9 %), fruits and nuts (6 %), animals (17 %), tinned meat and fish (5 %) and other miscellaneous sources. For both the Kaul and the Lufa people, animal protein constituted 9–26 % of the total protein intake (table 5). Pig plays a particularly large part in this supply of animal protein in the Lufa populations, especially in the men, where it is almost the sole 'fresh' animal source. Partly this is due to social custom since some other small animals are condemned as unfit for the men to eat.

Pattern of food consumption throughout the day

The pattern of eating was assessed by dividing the day into three periods: (1) from waking (05–06 h) until 10 h, (2) from 10 to 16 h, and (3) from 16 h until next morning. Food eaten in period (1) would be before the person went to work in the gardens, during (2) would normally be in the garden or plantation or at the beach, and (3) would be after work was finished and would include the main meal of the day. In Kaul, about 25 % of the energy intake occurred before 10 h, another 25 % between 10 and 16 h, and the remaining 50 % in the evening. In Lufa, the pattern was similar although slightly more food was eaten before 10 h and slightly less between 10 and 16 h.

Seasonal variations

During the 9 months of the study in Kaul, from early May until late January, both dry and wet seasons were encountered. Tending the gardens and the collection of food seemed little influenced by season although the availability of some fruits and nuts was affected and sometimes this changed the composition of the diet; for example, breadfruit during its main season, in September and October, replaced taro as the staple. Galip nuts made an important contribution to the diet in July and August and in January and February.

The quantity of food eaten possibly showed changes during the year but the numbers of subjects in each month were small for satisfactory statistical analysis. In men, energy and protein intakes seemed to increase from May–June to September–October and then fall towards the end of the year. In women, intakes were significantly higher in the wet season ($P = 0.02$) and since more women were studied in the dry season (48 versus 21), this may help to explain part of the apparent negative energy balance of the group.

In Lufa, several articles of the diet were seasonal – for example, the highly regarded round pandanus nut (Karuga) in March and April, peanuts in July and August, winged beans and the long pandanus (Marita) from December to March, passion fruit after the wet season began about October – but they did not exert a marked influence on the energy and protein intake. There were differences, although fairly small ones, between the Lufa men and the women in their pattern of energy and protein intake; the men had slightly higher intakes in the wet season than in the dry (11.00 MJ or 2630 kcal/day compared to 10.42 MJ or 2490 kcal/day) whereas the women showed about the same degree of difference in the opposite direction, the dry season having the higher values.

Possible effect of investigation on eating pattern

It is, of course, always possible that by attempting a high degree of accuracy in the assessment of food intake by such close supervision as described above, the end-result may have been a disruption in the normal eating pattern of the subjects. If such were the case, it is likely that as the survey continued over the 5 or 6 days for each subject and the contacts between us became more friendly and informal, the eating pattern might have changed back to the normal. There might therefore, if a measurable alteration in diet had occurred due to our presence, be significant differences between the intake on the first day of the study for the individual subject and on the last day.

A statistical analysis was therefore made to determine, by Student's t test, whether there were significant differences between the intake of energy and of the different nutrients on the first day compared to the last day (usually the 5th day but sometimes the 6th or 7th) for the men and women of Kaul and Lufa. No significant difference was found in the case of any of the four groups.

It may thus be concluded that the investigation was causing little apparent influence on the feeding habits of the subjects.

An independent analysis was made, also by Student's t test, to see whether there were significant differences between energy and nutrient intakes on different weekdays and between weekdays and the weekend. In no group was any significant difference detected.

Table 8. Mean daily energy expenditures

Standard deviation is given in parentheses.

	men				women			
	n	kg	MJ	kcal	n	kg	MJ	kcal
Kaul								
total	42	56.3	9.82 (1.64)	2347 (392)	40	48.1	7.66 (1.08)	1830 (259)
18–29 years	17	57.7	10.96 (1.79)	2619 (428)	23	49.8	8.08 (1.12)	1932 (267)
30–48 years	25	55.3	9.05 (0.96)	2162 (229)	17	45.9	7.08 (0.73)	1692 (174)
					(7 pregnant)	51.0	7.77 (1.07)	1857 (255)
Lufa								
total	40	57.8	10.75 (1.10)	2570 (264)	38	50.5	9.39 (0.98)	2245 (235)
18–29 years	25	58.8	10.74 (1.03)	2567 (245)	31	51.1	9.49 (1.02)	2268 (243)
30–49 years	15	56.0	10.78 (1.26)	2577 (302)	7	46.3	8.96 (7.45)	2141 (178)
					(7 pregnant)	53.5	9.53 (0.81)	2277 (194)

Energy expenditure

Not all of the subjects whose food intake was measured participated in the energy expenditure study. However, the majority did take part and on all of the subjects in table 8, 42 men and 40 women in Kaul and 40 men and 38 women in Lufa, both sets of measurements were made.

In all, 1162 measurements of energy expenditure by indirect calorimetry were made on these subjects. Although not every single activity of each person was assessed individually, enough information was accumulated to allow as accurate an assessment of mean daily energy expenditure as would normally be the case, in our experience, with any European population. The mean daily energy expenditures of the four groups of subjects are shown in table 8. Although the relative positions of the four groups are similar to those of the energy intakes, with the Lufa men having the highest levels and the Kaul women the lowest, the absolute quantities differ considerably; the large differences between the men of Kaul and those of Lufa and between the women of Kaul and the women of Lufa have been greatly reduced. The possible reasons for the discrepancies between the food intake and the energy expenditure results in the Kaul populations will be discussed later.

The mean value for the Lufa men (10.75 MJ or 2570 kcal/day) is higher than the value (9.82 MJ or 2350 kcal/day) for the Kaul men, but this is due entirely to the much reduced energy expenditure of the older Kaul men (9.05 MJ or 2160 kcal/day). The young men of Kaul expended just as much energy as the young men of Lufa. The reasons why the older men are less active in the coastal villages are probably mixed – in part due to social customs and in part to the physical environment, the highland men being physically fitter (Cotes, Anderson & Patrick 1974) and continuing to work in much the same fashion as they grew older whereas in Kaul older men shed some of their physical tasks.

The different pattern of energy expenditure and age in the two groups of men is shown in figure 9.

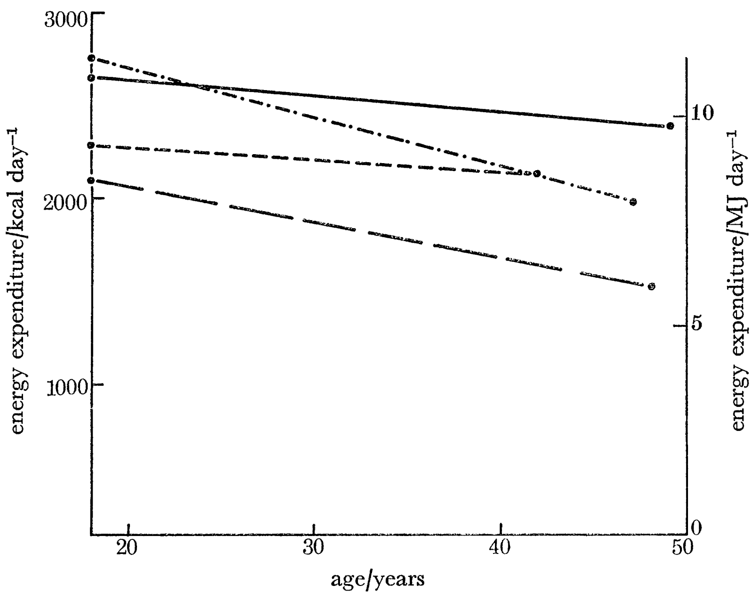

FIGURE 9. Regressions of mean daily energy expenditure and age for the Kaul and Lufa men and women. —·—, Kaul males, $r = -0.53$; — —, Kaul females, $r = -0.54$; ——, Lufa males, $r = -0.19$; ------, Lufa females, $r = -0.15$.

With the women there was a much larger difference in energy output, the mean value for the Lufa women being 1.73 MJ or 415 kcal/day higher. As with the men, the older Lufa women decreased their energy less, relative to the younger women, than the older Kaul women (see figure 9). The pregnant women, both in Kaul and in Lufa, had the same gross daily expenditures as their non-pregnant companions, indicating that their way of life had apparently not greatly altered.

The mean results for all the groups in Kaul and in Lufa might appear to represent higher outputs of energy than those actually recorded because of the lower body masses of the populations relative to equivalent European groups. However, the main component which differentiates the body masses of these New Guineans from Europeans is the amount of fat in the body, and the 'lean body mass' or fat-free mass is approximately similar, so it might be less likely that total daily energy output would be affected proportionately.

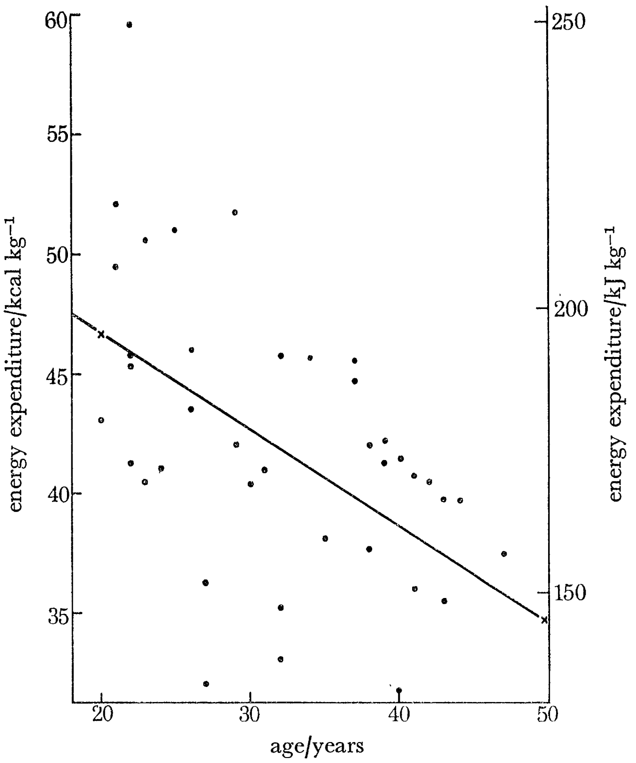

FIGURE 10. Relation of mean daily energy expenditure (per kg body mass) and age for the Kaul men. $n = 42$; $r = -0.5062$ ($P < 0.001$); $y = -0.388x + 54.12$.

It has already been shown that body mass apparently had less significance, even in this relatively lean and physically active group, than might have been anticipated. Nevertheless, if a proportionate allowance is made to bring the results on these groups of men and women up to the equivalent levels for people of 65 kg and 55 kg for men and women, the energy expenditures of the Kaul men and of the Lufa men would increase to about 11.30 MJ or 2700 kcal/day and 12.13 MJ or 2900 kcal/day respectively, and for the women would become 8.37 MJ or 2000 kcal/day and 10.46 MJ or 2500 kcal/day for the Kaul and Lufa groups. These are still low for the particular way of life of the populations but are now approaching results on European populations leading moderately active lives.

When energy expenditure per unit of body mass is related to age, some interesting differences appear between the groups. Figures 10 and 11 show opposite tendencies of the male Kaul and Lufa results, the older Lufa men actually showing higher relative values than the younger men. A similar pattern is present in the female results (figures 12 and 13), emphasizing once more the influence of the social factors together with the superior physical fitness of the highland people.

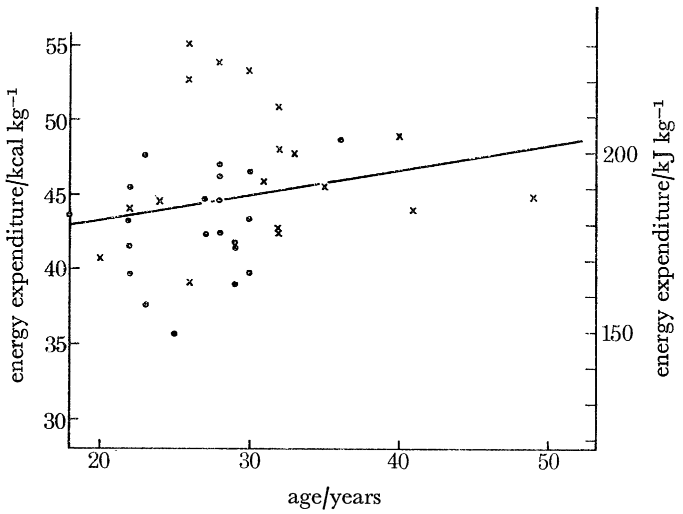

FIGURE 11. Relation of mean daily energy expenditure (per kg body mass) and age for the Lufa men. The men are differentiated according to the position of their village although this has no significant effect: ●, lower villages; ×, high villages. $y = 0.170x + 39.89$; $r = 0.236$ (n.s.); $n = 40$.

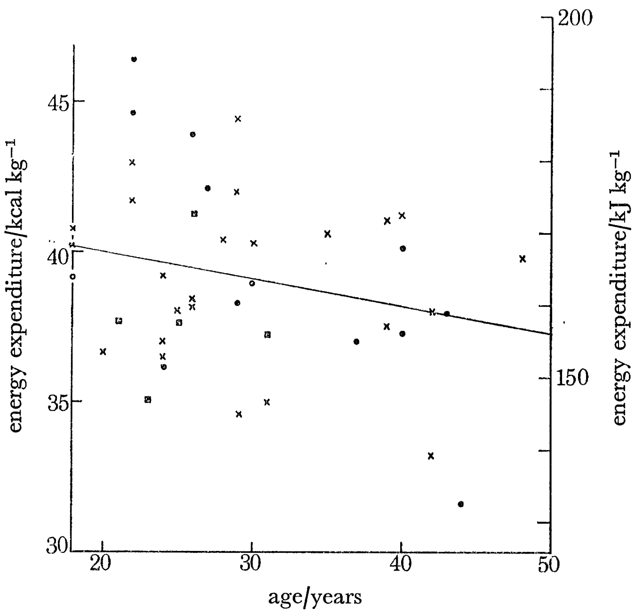

FIGURE 12. Relation of mean daily energy expenditure (per kg body mass) and age for the Kaul women: ×, lactating; ▪, pregnant. $y = -0.0938x + 40.96$; $r = -0.2152$ (n.s.); $n = 40$.

The actual equations relating body mass (M) to total daily energy expenditure (E) are as follows:

		r	P
Kaul men	$E = 38.2\,M + 201$	+0.50	< 0.001
Kaul women	$E = 38.5\,M + 23$	+0.79	< 0.001
Lufa men	$E = 18.0\,M + 1504$	+0.34	n.s.
Lufa women	$E = 23.5\,M + 1063$	+0.57	< 0.001

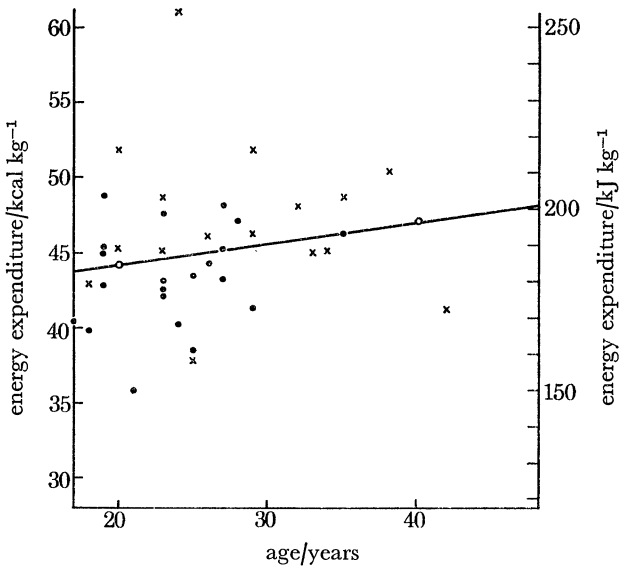

FIGURE 13. Relation of mean daily energy expenditure (per kg body mass) and age for the Lufa women: ●, low villages; ×, high villages. $y = 0.148x + 41.23$; $r = 0.197$ (n.s.); $n = 38$.

The constants in these equations – that is, the component unrelated to mass – are so variable that again the usefulness of body mass as a parameter of general applicability appears doubtful.

Energy expenditure in different activities

In spite of the fact that body mass and *total daily* energy expenditure correlate rather poorly, it is probably justifiable to use body mass as a parameter in describing the energy expenditure in different forms of activity – for example, sitting, walking, and some forms of work – of a heterogeneous population. The relationship between body mass and a specific activity is usually high, and there is no other convenient way of comparing data from different people of varying body masses. The use of any refinement of gross body mass, for example $M^{0.75}$, is quite unnecessary and gives precisely the same relationships as those with M (Durnin 1959; Kleiber 1961). In the present study, mean values for an activity have been calculated by adjusting measurements on individuals of varying body masses to a standard body mass of 65 kg for men and 55 kg for women. The purpose of this adjustment was to make the results of more general usefulness to other populations. A second calculation was then made to reduce the mean value to the proportional equivalent for the body mass of the group; for example, the value for 'cutting grass' was 27 kJ or 6.4 kcal/min/65 kg man and readjusted for the mean body mass of 56.3 kg for the Kaul men, was 24 kJ or 5.7 kcal/min. This value was then used for any Kaul man who had spent some time 'cutting grass' but on whom no measurement of this activity had been made, provided his body mass was within ± 5 kg of the mean mass of the group, i.e. 56.3 kg. If his mass was outside this range then a separate recalculation was made.

Resting – 'lying' or 'sitting' or 'standing'

Measurements on the Kaul and Lufa subjects at rest were made (1) lying on a table in the village laboratory (this was not a particularly artificial way of lying for many of these people since they normally lay on hard floors), (2) sitting on a chair in the laboratory, (3) sitting or squatting in their own house or in the gardens, and (4) standing, usually also in the laboratory.

These results are given in table 9. In general, the results on the Lufa men and women were always slightly higher (103 and 108 % of mean Kaul values).

Lying

The mean values were considerably higher than the calculated b.m.r. of the subjects. However, the b.m.r. and our measured values on 'lying' are not strictly comparable, as there was no attempt to measure 'lying' in basal conditions. Also, for the people living in the hot humid conditions on the coast in Kaul, a deduction of 10 % was made from the tables of Fleisch in the calculation of their b.m.r. In the study by Hipsley & Kirk (1965), a deduction was made for both the coastal and the highland populations; no alteration was made in the present study for the highland men and women since their environment, while often hot during the day was not always so and the nights were normally quite cool.

Table 9. Energy expenditure in 'resting' situations

	no. of subjects	kJ/min per 65 kg	kcal/min per 65 kg	kcal/min per group mass†	kcal/min per 55 kg	kJ/min per 55 kg	% b.m.r. (Fleisch)	% Durnin & Passmore values (1967)
lying								
Kaul men	42	5.52	1.32	1.14	—	—	129	—
Lufa men	34	5.94	1.45	1.28	—	—	127	—
Kaul women	41	—	—	1.03	1.18	4.94	138	—
Lufa women	31	—	—	1.11	1.22	5.10	132	—
sitting								
Kaul men	41	5.98	1.43	1.23	—	—	—	103
Lufa men	34	6.32	1.54	1.36	—	—	—	109
Kaul women	41	—	—	1.08	1.24	5.19	—	108
Lufa women	29	—	—	1.21	1.34	5.61	—	113
standing								
Kaul men	40	6.40	1.53	1.32	—	—	—	87
Lufa men	32	6.82	1.66	1.47	—	—	—	93
Kaul women	41	—	—	1.19	1.36	5.69	—	99
Lufa women	30	—	—	1.29	1.42	5.94	—	104

† Group mass = 56.3 kg for men and 48.1 kg for women in Kaul.
= 57.5 kg for men and 50.5 kg for women in Lufa.

Nevertheless, the measurements here indicate higher values than might have been expected. Perhaps a very small part of this might have been mild apprehension or nervousness – this may explain why the results on the women are proportionately higher than on the men – but part is probably due to the different body composition, with the higher relative fat-free mass of these people when compared to the average Caucasian population on whom b.m.r. standards have been obtained.

The mean total amount of time and energy spent in bed is shown in table 10. For communities living in a near-equatorial environment, with night occupying about 12 h out of the 24, the results are not unusual; the reason why the Lufa people remained roughly half an hour longer in bed was probably due to the cooler evenings in the highlands which necessitated fires to keep the people warm and lamps, of which there were few in Lufa.

The times when each individual subject went to bed and rose in the morning were often estimated but are unlikely to be much in error. The estimate is of small significance as a source of error in the calculation of total energy expenditure as 'bed' was always preceded and followed by periods of 'sitting around' in the house.

As mentioned earlier, the value for 'sleep' was not taken as the measured value for 'lying' but as the b.m.r. from Fleisch's (1954) tables with a deduction, for the coastal people, of 10 %.

As well as the time spent in bed at night, there was also a certain amount of 'lying down' during the day, because of fatigue or as a leisure pastime – usually a prerogative of the unmarried adult male. The duration was short, 15 min/day for Kaul men, 18 min/day for Lufa men, 4 min/day for Kaul women and 5 min/day for Lufa women.

TABLE 10. MEAN DURATION (% OF TOTAL) OF VARIOUS TYPES OF ACTIVITIES AND THEIR CONTRIBUTION TO TOTAL MEAN DAILY ENERGY EXPENDITURE

	Kaul				Lufa			
	males		females		males		females	
	% time	% e.e.	% time	% e.e.	% time	% e.e.	% time	% e.e.
bed	34.4	20.7	35.7	22.8	37.3	20.9	37.2	20.3
sitting	36.9	27.8	33.4	27.7	26.7	20.2	29.5	23.1
standing	4.8	3.9	3.1	2.9	6.9	5.6	3.7	3.1
walking around (strolling)	2.2	3.3	2.1	2.9	—	—	—	—
all other walking	7.7	19.4	6.5	17.1	10.9	27.3	9.8	25.4
gardening	1.2	2.2	2.8	5.3	1.8	4.0	6.4	12.2
fence making	—	—	—	—	2.5	4.9	0.1	0.1
cash cropping	0.8	2.6	0.2	0.3	1.5	2.1	0.9	1.2
house building	1.8	4.4	0.1	0.2	0.6	1.0	0.3	0.4
hunting and gathering	1.5	2.3	—	—	0.4	0.7	—	—
paid employment	2.1	3.8	—	—	1.3	2.0	0.3	0.6
handicrafts	0.5	0.6	2.0	2.0	0.7	0.7	2.9	2.5
food preparation	0.3	0.3	5.5	6.4	1.8	1.4	3.0	2.5
sitting and standing activities	1.5	2.3	2.4	3.7	2.4	3.4	2.8	4.5
conspicuous leisure	0.9	1.7	0.2	0.4	2.3	2.2	1.2	1.5
miscellaneous	3.4	4.6	6.0	8.3	2.9	3.6	1.9	2.7
total	100.0	99.9	100.0	100.0	100.0	100.0	100.0	100.1

Sitting

While the values obtained on 'sitting' in the laboratory were consistently higher than those measured in the house or in the garden, the differences were very small – only 2–5 % higher – and were insignificant. 'Sitting' has therefore been taken as the mean of all the values on any one individual.

The values on the Kaul men and women are very similar to those on the highland people in the Chimbu district of New Guinea studied by Hipsley & Kirk (1965), although their results were slightly lower, by about 0.4 kJ (0.1 kcal)/min, than those of the Lufa populations. The values on European groups quoted by Durnin & Passmore (1967) – which are a conglomerate from various sources and were measured on people in a variety of circumstances – are similar to the present New Guinean values although the latter again were slightly higher (table 9).

The time spent 'sitting' includes sitting in any situation and on occasion includes some very light activity such as holding or feeding a baby, eating or chewing betel nut. Other variants of 'sitting' are incorporated in separate tables (e.g. sitting weaving, etc.). The total time spent 'sitting' by the Kaul people was much more than by the people in Lufa. The Kaul men sat for 531 min/day (± 100 min) whereas the time for the Lufa men was 385 min (± 64), and the equivalent times for the women were 481 min/day (± 78) for Kaul and 425 min/day (± 83) for Lufa. The combined times for lying and sitting were 1026 min/day for Kaul men, 922 min/day for Lufa men, 995 min/day for Kaul women, and 960 min/day for Lufa women – that is, two-thirds or more of the day. The longer duration of sitting by the Kaul men probably reflected their greater propensity for indulging in prolonged communal discussion.

As in the case of other groups leading a moderate or hard physical life (Edholm, Fletcher, Widdowson & McCance 1955), the amount of time in 'sitting' constitutes a surprisingly large part of the waking day.

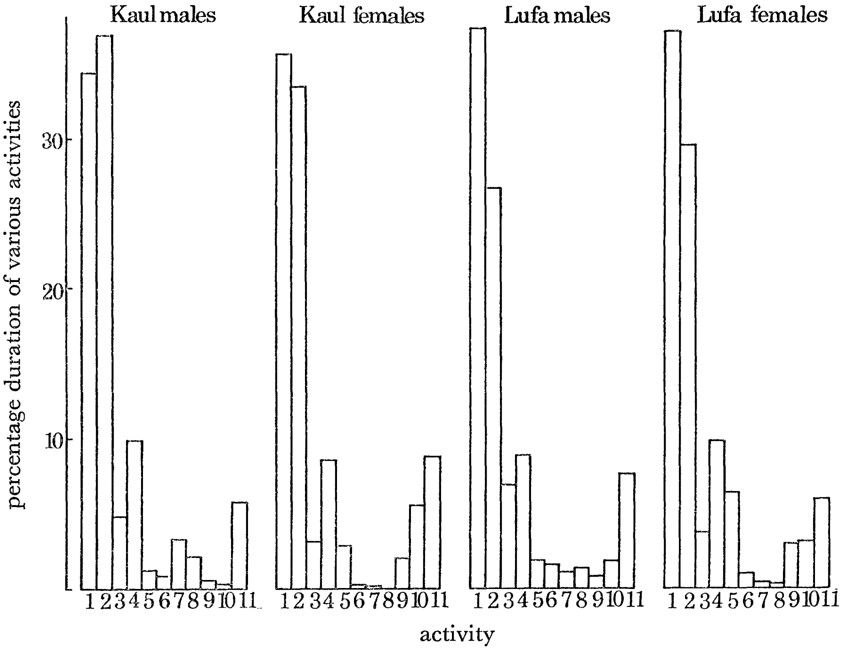

FIGURE 14. Duration of the principal activities of the Kaul and Lufa men and women as a percentage of the 24 h. Activities: (1) bed, (2) sitting, (3) standing, (4) walking, (5) gardening, (6) cash cropping, (7) house building, hunting and gathering, (8) paid employment, (9) handicrafts, (10) food preparation, and (11) miscellaneous, including sitting and standing activities.

Standing

Again the energy values for the Lufa people are higher than for Kaul (table 9) but, possibly because the New Guineans seem to stand in a more relaxed way than Europeans, the values for all groups are somewhat lower than the standards given by Durnin & Passmore (1967). The relatively slightly higher values for the women in both villages may be due to their frequently having also to hold a baby. The times spent 'standing' are longer than would usually be the case in Europeans, but the New Guineans would sometimes stand for considerable periods, perhaps at a meeting, if there were no convenient place to sit.

Figures 14 and 15 show a representation of the duration and of the percentage contribution to the total daily energy expenditure, of lying, sitting and standing. Together, they accounted for about 70 % of the total time in the day and about 60 % of the total daily energy output. There was little difference between groups.

The regression lines and equations for the metabolic rates of lying, sitting and standing are shown plotted against body mass in figure 16 and against body mass 0.75 in figure 17. All the men have been combined in one group and all the women in another. The correlation coefficients in all cases are between +0.53 and +0.62. The size of the constant is relatively small,

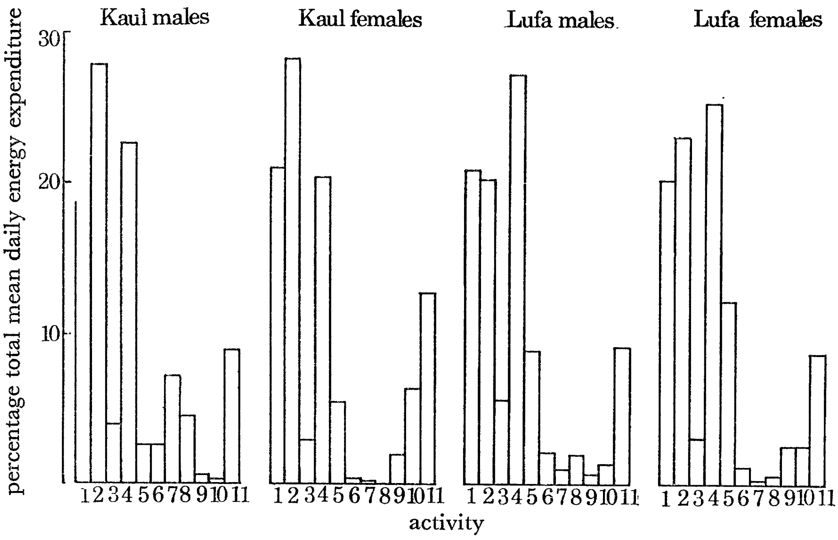

FIGURE 15. Contribution of the principal activities of the Kaul and Lufa men and women as a percentage of the mean total daily energy expenditure. Activities: (1) bed, (2) sitting, (3) standing, (4) walking, (5) gardening, (6) cash cropping, (7) house building, hunting and gathering, (8) paid employment, (9) handicrafts, (10) food preparation, and (11) miscellaneous, including sitting and standing activities.

demonstrating the greater importance of body mass, especially mass$^{0.75}$, when the metabolic rate of only single activities is concerned.

'Personal' activities – washing, dressing, etc.

The times spent in these were so small that they do not form a significant part of the day. They may have been slightly underestimated but, in any case, are likely to be low for several obvious reasons – the dress was simple, there was often a lack of water for washing, and the water in the highlands was cold.

Sitting and standing activities

These are groups of miscellaneous activities, carried out by most individuals but which were measured on only a few occasions. The total duration, and the contribution to the total daily energy expenditure are shown in table 10. The total time spent and the energy expended in these several activities were relatively small but the variety of the tasks involved is wide. They also represent part of the pattern of the life-style of the people and tables 11, 12 and 13 present results on individual measurements of many of the common activities. House building, various activities concerned with coconut plantations, gardening activities, together with hunting are given in a separate table. Many of the sitting and standing activities are self-explanatory and formed part of the normal daily routine. However, some items require extra information. In the *preparation of a mumu* in Lufa, several activities may be involved for both men and women, such as preparing the pit in the ground, getting firewood and lighting fires, heating stones, loading and unloading the food etc. *Work in the house* includes general sweeping and maintaining the house, washing plates and clothes, etc. *Handicraft*: Kaul men traditionally made baskets and carved combs and the women of both Kaul and Lufa wove bilums (attractive net bags) and mats, whereas the Lufa men made their bows and arrows. *Tobacco* cutting and the treatment of the plant for smoking was an important activity in Kaul although not in Lufa where most tobacco was bought at the store. *Leisure* games of the Kaul men included, perhaps strangely, 'fishing' since this was rarely a serious food-gathering occupation. Active games such as soccer were played both in Kaul and in Lufa, mostly by the young men and averaged about 25 min/week. In Kaul, traditional 'sing-sings' occurred from time to time (32 min/week). In Lufa almost 20 min/day were spent, on average, in games of chance (inactive sitting games) by the men. The women of both villages spent a very small amount of time (only about 7 min/week) in any active recreation.

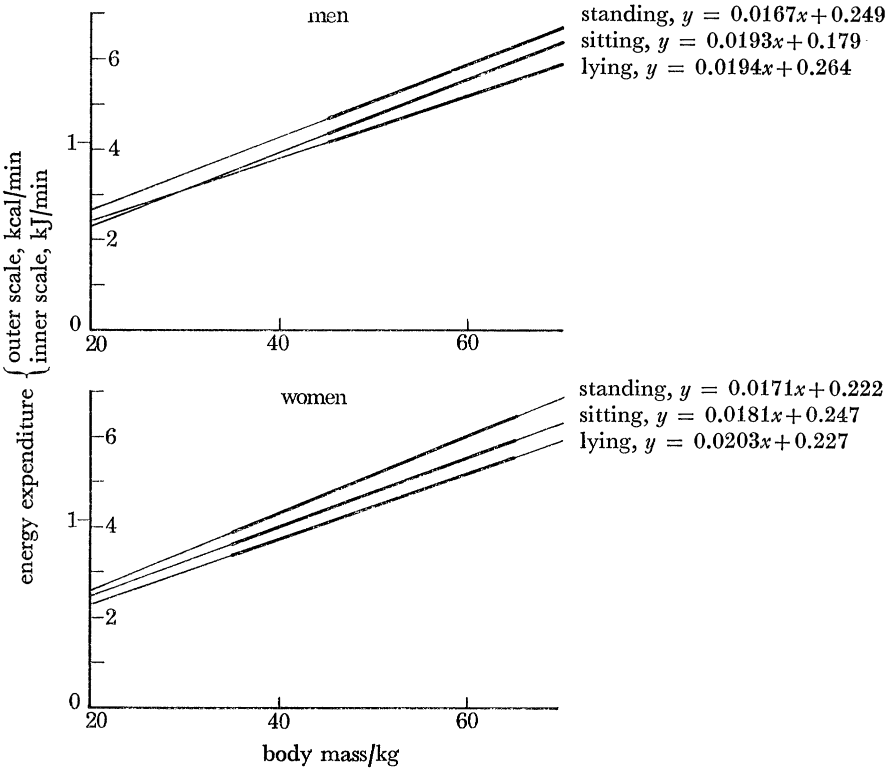

FIGURE 16. Regressions of energy expenditure on body mass for lying, sitting and standing. The Kaul and Lufa men have been combined in one group and the women in another.

Walking

This was an activity which occupied considerable periods of time. Table 10 shows that, in all groups, approximately 10 % of the 24 h was spent walking. It assumes even more importance for energy expenditure: 23 % (Kaul men), 20 % (Kaul women), 27 % (Lufa men) and 25 % (Lufa women) of the total day's energy output were attributable to walking.

The measurement of the energy expended in walking was not made under standardized conditions. The individual man or woman was encouraged to pursue the particular activity in the habitual manner. In Kaul, walking included all forms of the activity, to and from the gardens, in the bush, etc., apart from 'walking around' – which was a slow wandering usually in the village or at the market. 'Walking' represents the average pace but there is also a subdivision into a 'slow' category. The number and age of the children, who often accompanied the adults, determined the pace of walking. Most of the areas traversed were either flat or had a gentle gradient. The proportion of time carrying a load was much greater for the women – 4 % of the time spent walking for the men and 35 % for the women. These loads included food carried from the gardens and often the baby as well, and weighed on average 10–20 kg and might, on occasion, be up to 30 kg.

In Lufa, there was little 'walking around', 1 min/day for the men and 7 min/day for the women, probably because the evenings, when strolling would tend to occur, are cool and sometimes wet. Again, carrying loads was usually done by the women, 10% of the time of walking by the men but 30% by the women. Walking uphill and downhill was normal for these highland people; 60 min/day of uphill walking and 48 min/day downhill by the men, and 58 min/day uphill and 47 min/day downhill by the women. For the women 48% of the time spent walking uphill was carrying a load. The tables show that the energy expenditures of the Lufa men and women were higher than the Kaul groups because of the extra effort required by uphill walking.

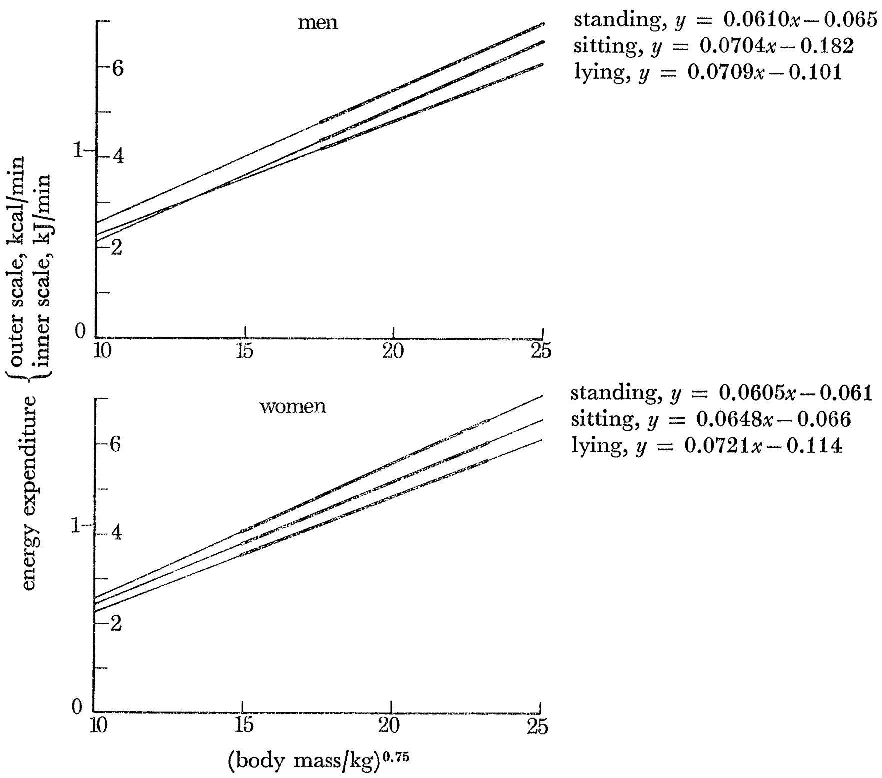

FIGURE 17. Regressions of energy expenditure on body mass$^{0.75}$ for lying, sitting and standing. The Kaul and Lufa men have been combined in one group and the women in another.

Tables 14 and 15 show the results of the measurements on the individual men and women. The centre columns in each table give mean values for the separate groups. However, these values have been converted to the appropriate results for groups of men with a mean body mass of 65 kg and of women of 55 kg, in order that comparisons may be made with results on other types of population. In the present series, although all groups did not show statistically significant relationships, the correlation coefficients between the energy expenditure of walking and body mass were generally between +0.3 and +0.7, the average value being +0.4. These are perhaps remarkably high values for a non-standardized exercise.

Gardening

This was a complex operation. It involved firstly clearing the bush, sometimes by burning, then by means of knives or axes, and was mostly done by the men. The ground surface was then

Table 11. Energy expenditure (per group body mass) in sitting and standing activities – Kaul men

activity	*n*	kJ/min	kcal/min
sitting			
weave 'bombom' mat	1	5.9	1.4
tie morotta	1	6.3	1.5
separate copra and shell	1	7.5	1.8
sew morotta	2	7.9	1.9
carve plate, drum or comb	3	8.4	2.0
fish from canoe	2	8.8	2.1
weave bamboo wall	2	11.7	2.8
cut copra	1	13.0	3.1
paddle canoe	2	13.8	3.3
standing			
clean gun	1	6.7	1.6
mend lamp	1	7.9	1.9
fish with line	1	8.4	2.0
tie fence	1	8.4	2.0
plant tobacco	1	9.6	2.3
chop firewood	1	10.5	2.5
fish with spear	1	10.5	2.5
work in store	1	10.9	2.6
prune cocoa	1	10.9	2.6
cut tobacco	1	11.3	2.7
clear light bush	4	11.7	2.8
disbud tobacco	1	12.1	2.9
weed with shovel or hoe	2	13.0	3.1
at 'sing-sing'	1	13.0	3.1
make fence	1	14.6	3.5
collect Daka (piper)	1	15.1	3.6
cycling	1	18.8	4.5
cut saplings	3	16.7	4.0

n = no. of measurements. group body mass = 56.3 kg.

Table 12. Energy expenditure (per group body mass) in sitting and standing activities – Kaul women

activity	*n*	kJ/min	kcal/min
sitting or squatting			
sewing	2	5.0	1.2
prepare tobacco	3	5.4	1.3
remove beans	2	5.4	1.3
split cocoa	1	7.1	1.7
break galips	4	6.7	1.6
squeeze coconut	2	8.8	2.1
weaving bilum	6	5.0	1.2
preparing rope	6	5.4	1.3
peeling taro	33	6.3	1.5
standing			
collect tulip leaves	1	6.7	1.6
put on rope	1	8.4	2.0
cut tobacco	3	8.8	2.1
sweeping	7	9.2	2.2
wash clothes	3	10.0	2.4
disbud tobacco	2	10.0	2.4
collect cocoa	1	10.5	2.5
cut weeds w. sarif	1	10.9	2.6
collect leaves along path	1	10.9	2.6
dig holes for planting	2	15.5	3.7
catch crabs	1	16.3	3.9

n = no. of measurements. group body mass = 48.1 kg.

Table 13. Energy expenditure (per group body mass) in sitting and standing activities

activity	n	kJ/min	kcal/min
Lufa males			
sitting			
make arrows	5	7.5	1.8
play 'matches'/cards	3	6.3	1.5
weave pitpit wall	2	7.9	1.9
unload mumu stones	1	7.5	1.8
sharpen axe	1	7.5	1.8
prepare food (peel tubers)	1	5.9	1.4
string loom	1	8.4	2.0
standing			
pick coffee	10	10.9	2.6
chop firewood	7	21.8	5.2
collect bush rope	1	17.6	4.2
play football in village	1	13.8	3.3
Lufa females			
sitting or squatting			
sew clothes	1	5.4	1.3
skin coffee	3	5.9	1.4
sew pandanus mat	2	5.9	1.4
load mumu with food	1	10.0	2.4
preparing rope	9	5.4	1.3
weaving bilum	1	5.9	1.4
peeling sweet potato	7	5.4	1.3
roasting corn	1	5.0	1.2

n = no. of measurements. group body mass = 57.5 kg for men, 50.5 kg for women.

Table 14. Energy expenditure in walking

activity	Kaul men per 65 kg			per group body mass		Kaul women per 55 kg		
	n	kJ/min	kcal/min	kJ/min	kcal/min	kJ/min	kcal/min	n
walking	37	20.3	4.9	17.6	4.2 ♂			
				14.6	3.5 ♀	16.7	4.0	26
walking slowly	17	15.9	3.8	13.8	3.3 ♂			
				10.9	2.6 ♀	12.5	3.0	10
'walking around'	15	11.5	2.8	10.0	2.4 ♂			
				7.5	1.8 ♀	8.6	2.1	16
walking with load	—	—	—	14.2	3.4 ♀	16.2	3.9	19

n = no. of measurements. 'group body mass' = 56.3 kg for men, 48.1 kg for women.
♂, values only on men. ♀, values only on women.

cleared by both women and men, perhaps several months later. During the clearing of the bush, trees were felled. On Karkar, these trees were sometimes large and they were left lying on the ground, perhaps acting as a boundary or a fence. In Lufa, trees were cut up into fence posts.

Planting of the staple required that the ground be dug over with a spade only in the Lufa gardens: on Karkar it was sufficient to dig holes using a pole about 150 cm long and 5–8 cm in diameter and sharpened at one end. Drainage ditches (barats) were often dug in Lufa.

Planting was usually the work of the women. Taro tops were put into the holes dug by the pole. In Lufa, sweet-potato vines were planted in heaps of finely broken-up soil. Weeding needed to be done frequently. The duration and the proportion of the day's energy expenditure in these gardening activities is shown in table 10.

TABLE 15. ENERGY EXPENDITURE IN WALKING

activity	Lufa men per 65 kg n	kJ/min	kcal/min	per group body mass kJ/min	kcal/min	Lufa women per 55 kg kJ/min	kcal/min	n
walking	7	19.9	4.7	17.6	4.2 ♂			
				13.8	3.3 ♀	15.0	3.6	3
walking slowly	1	14.7	3.5	13.0	3.1 ♂			
'walking around'	—	—	—	10.0	2.4 ♀	10.9	2.6	2
walking with load	—	—	—	29.3	7.0 ♀	31.9	7.6	1
walking uphill								
slowly	2	23.6	5.7	20.9	5.0 ♂			
				15.1	3.6 ♀	16.4	3.9	1
average	19	28.4	6.8	25.1	6.0 ♂			
				21.3	5.1 ♀	23.2	5.6	17
fast	5	37.4	8.9	33.1	7.9 ♂			
				25.1	6.0 ♀	27.3	6.5	2
walking downhill								
slowly	3	14.3	3.4	12.6	3.0 ♂			
				8.8	2.1 ♀	9.6	2.3	4
average	18	15.6	3.7	13.8	3.3 ♂			
				11.3	2.7 ♀	12.3	2.9	13
fast	3	18.0	4.3	15.9	3.8 ♂			
				13.0	3.1 ♀	14.2	3.4	5
walking with load								
uphill	3	29.1	8.0	25.7	7.1 ♂			
				23.0	5.5 ♀	25.0	6.0	10
downhill				17.6	4.2 ♀	19.2	6.6	1

n = no. of measurements. 'group body mass' = 57.5 kg for men, 50.5 kg for women.
♂, values only on men. ♀, values only on women.

TABLE 16. ENERGY EXPENDITURE IN GARDENING, HUNTING AND HOUSE-BUILDING

activity	Kaul men per 65 kg n	kJ/min	kcal/min	per group body mass kJ/min	kcal/min	Kaul women per 55 kg kJ/min	kcal/min	n
weeding	4	13.0	3.1	11.3	2.7 ♂			
				9.6	2.3 ♀	11.0	2.6	12
clean garden	2	15.0	3.6	13.0	3.1 ♂			
				14.6	3.5 ♀	16.7	4.0	4
plant taro	—	—	—	13.0	3.1 ♀	14.9	3.5	6
dig taro	—	—	—	10.9	2.6 ♀	12.5	3.0	10
cut grass	17	27.5	6.6	23.8	5.7 ♂			
				18.0	4.3 ♀	20.6	4.9	5
coconut activities								
collect	2	21.7	5.2	18.8	4.5 ♂			
husk	4	29.4	7.0	25.5	6.1 ♂			
bag	3	18.8	4.5	16.3	3.9 ♂			
bag and split	6	20.3	4.8	17.6	4.2 ♂			
hunting								
flying fox	2	15.5	3.7	13.4	3.2 ♂			
pigs	2	16.9	4.0	14.6	3.5 ♂			
house building								
cut bamboo	1	15.0	3.6	13.0	3.1 ♂			
cut limbom trunks	2	19.3	4.6	16.7	4.0 ♂			
collect bom bom	1	19.3	4.6	16.7	4.0 ♂			
dig post holes	1	29.0	6.9	25.1	6.0 ♂			
lay floor	1	19.3	4.6	16.7	4.0 ♂			
nailing	1	15.5	3.7	13.4	3.2 ♂			

n = no. of measurements. 'group body mass' = 56.3 kg for men, 48.1 kg for women.

Tables 16 and 17 give details of measurements on individual men and women while they were undertaking some of the different gardening activities. The arrangement of these tables is similar to that of tables 14 and 15, values being given as an average for the group and also converted to 'standard' body masses.

None of the measurements indicates that gardening was a particularly strenuous activity; they are all in the 'light' to 'moderate' category.

Table 17. Energy expenditure in gardening, hunting and house-building

	Lufa men per 65 kg			per group body mass			Lufa women per 55 kg		
activity	*n*	kJ/min	kcal/min	kJ/min	kcal/min		kJ/min	kcal/min	*n*
clearing ground	6	23.2	5.5	20.5	4.9	♂			
				13.8	3.3	♀	15.0	3.6	6
dig ground	4	27.9	6.7	24.7	5.9	♂			
				17.6	4.2	♀	19.2	4.6	9
cut pitpit	1	14.7	3.5	13.0	3.1	♂			
cut tree	1	27.5	6.6	24.3	5.8	♂			
split wood for posts	5	21.3	5.0	18.4	4.4	♂			
sharpen posts	2	19.9	4.7	17.6	4.2	♂			
put in fence posts	3	21.7	5.2	19.2	4.6	♂			
tie fence posts	4	15.6	3.7	13.8	3.3	♂			
shovelling – road work	1	23.6	5.7	20.9	5.0	♂			
dig barat	1	30.7	7.3	27.2	6.5	♂			
tie sugar cane	2	15.1	3.6	13.4	3.2	♂			
tie banana stem	2	16.5	4.0	14.6	3.5	♂			
clean garden	6	23.2	5.5	20.5	4.9	♂			
weeding	5	15.1	3.6	13.4	2.6	♂			
				10.9	2.6	♀	11.9	2.8	8
plant sweet potato	—	—	—	17.6	4.2	♀	19.2	5.4	3
collect sweet potato	—	—	—	11.3	2.7	♀	12.3	2.9	9
pick coffee	—	—	—	13.0	3.1	♀	14.2	3.4	10
hunting birds	1	17.1	4.1	15.1	3.6	♂	—	—	—
pull Kunai grass	1	12.8	3.1	11.3	2.7	♂	—	—	—
roof house	1	14.7	3.5	13.0	3.1	♂	—	—	—

n = no. of measurements. 'group mass' = 57.5 kg for men, 50.5 kg for women.

Hunting and fishing

The men in Kaul spent 44 min/week hunting and 63 min/week fishing; in Lufa, hunting was not a frequent activity. Table 10 indicates the general importance and tables 16 and 17 give some values for this essentially moderate exercise consisting mostly of rather slow stealthy walking through the bush.

Cash cropping

In Kaul this was related to coconut plantations but included a large amont of time grass cutting. The mean times were 81 min/week for the men and 24 min/week for the women and the duration and energy expenditures of the different activities required is shown in tables 10 and 16.

The various cash-cropping activities, mostly in coffee plantations, in Lufa occupied more time than in Kaul (156 min/week for the men and 78 min/week for the women) and information about these is given in tables 10 and 17.

House building

In Kaul, the men spent 181 min/week in house building and the results obtained are shown in tables 10 and 16. The houses were quite complicated in design and building one was a communal effort of considerable social importance.

In Lufa, less time was taken up by this activity – 60 min/week for the men. The results are given in tables 10 and 17.

TABLE 18. MEAN ENERGY EXPENDITURE IN SOME NEW GUINEANS

	Kaul						Lufa					
	men			women			men			women		
body mass	56.3			48.1			57.5			50.5		
	n	kJ/min	kcal/min	*n*	kJ/min	kcal/min	*n*	kJ/min	kcal/min	*n*	kJ/min	kcal/min
lying	42	4.77	1.14	41	4.31	1.03	34	5.36	1.28	31	4.64	1.11
sitting – in house or garden	74	5.14	1.23	75	4.52	1.08	{34	5.73	1.37	29	5.18	1.24
							25}	5.61	1.34	21	4.94	1.18
standing	40	5.52	1.32	41	4.98	1.19	32	6.15	1.47	30	5.40	1.29
walking	37	17.6	4.2	26	14.7	3.5	7	17.6	4.2	3	13.8	3.3
slowly	17	13.8	3.3	10	10.9	2.6	1	13.0	3.1	—	—	—
around	15	10.0	2.4	16	7.5	1.8	—	—	—	2	10.0	2.4
+ load	—	—	—	19	14.2	3.4	—	—	—	1	29.3	7.0
walk uphill												
slowly	—	—	—	—	—	—	2	20.9	5.0	1	15.1	3.6
average	—	—	—	—	—	—	19	25.1	6.0	17	21.3	5.1
fast	—	—	—	—	—	—	5	33.1	7.9	2	25.1	6.0
walk downhill												
slowly	—	—	—	—	—	—	3	12.6	3.0	4	8.8	2.1
medium	—	—	—	—	—	—	18	13.8	3.3	13	11.3	2.7
fast	—	—	—	—	—	—	3	15.9	3.8	5	13.0	3.1
walk + load												
uphill	—	—	—	—	—	—	3	29.7	7.1	10	23.0	5.5
downhill	—	—	—	—	—	—	—	—	—	1	17.6	4.2
clean garden	2	13.0	3.1	4	14.6	3.5	6	20.5	4.9	—	—	—
weeding	4	11.3	2.7	12	9.6	2.3	5	13.4	3.2	8	10.9	2.6
plant taro/kau kau	—	—	—	6	13.0	3.1	—	—	—	3	17.6	4.2
collect/dig taro/kau kau	—	—	—	10	10.9	2.6	—	—	—	10	11.3	2.7
cut grass	17	23.7	5.7	5	18.0	4.3	—	—	—	—	—	—
sit/squat												
weave bilum	—	—	—	6	5.0	1.2	—	—	—	1	5.9	1.4
prepare rope	—	—	—	6	5.4	1.3	—	—	—	9	5.4	1.3
kitchen activities												
sit/squat												
peel taro/kau kau	—	—	—	33	6.3	1.5	—	—	—	7	5.4	1.3
roast corn	—	—	—	—	—	—	—	—	—	1	5.0	1.2

Summary of energy-expenditure results

In table 18 is given a composite collection of the mean results on specific activities of the four groups of individuals. In the assessment of the average daily energy output of groups of individuals it is often perhaps of more importance to obtain a detailed record of the pattern of the daily life than to undertake the laborious and expensive measurement of energy expenditure on all the separate activities throughout the day of each individual. The use of data such as are given in table 18 may facilitate further studies of energy expenditure on other New Guinean or similar populations.

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Daily variations in energy expenditure

In contrast to the results of energy intake, there were occasional significant differences between days, although only in relation to the weekends. In Kaul, Saturday was the day for many of the people to go to the beach and Sunday was a day of comparative rest. The energy expended on Saturday was thus slightly higher than average and on Sunday was considerably lower, and these two days were significantly different in this respect ($P < 0.001$). In Lufa, both Saturday and Sunday were days of lower levels of total activity and each of these days was significantly different from weekdays in energy expenditure ($P < 0.01$).

The 'extractive ratio' or energy yield

The total amount of energy expended by a family (of two adults and three children) to produce the total energy of their diet has been assessed. The energy expended in food production – the 'input' – has been calculated from the duration of gardening activities, walking to and from the gardens, hunting and gathering, and from the energy cost of these activites. For a typical Kaul family this energy input was about 3.20 MJ or 765 kcal/day and for a Lufa family about 5.73 MJ or 1370 kcal/day. The requirements of energy for these families were about 33 MJ or 8000 kcal/day. Thus the ratio between energy input (3.20 and 5.73 MJ) and output (33 MJ) is 1:10 for Kaul and 1:6 for Lufa. Since some food purchased from stores was eaten in both Kaul and Lufa, the true extractive ratios will be less – about 1:9 in Kaul and 1:5 in Lufa.

Table 19. Mean values for pulmonary ventilation (V_e/l min^{-1}) and respiratory quotients (in parentheses) in various activities

activity	men Kaul	men Lufa	women Kaul	women Lufa
lying	6.7 (0.97)	6.4 (1.00)	6.6 (0.97)	5.9 (1.03)
sitting	7.2 (0.94)	7.1 (0.99)	7.4 (0.98)	6.8 (1.04)
standing	8.0 (0.95)	7.7 (0.96)	7.8 (0.99)	7.0 (1.00)
walking	19.2 (0.87)	— —	17.6 (0.84)	— —
walking with load	— —	— —	18.6 (0.85)	— —
walking uphill	— —	24.6 (0.92)	— —	21.6 (0.91)
walking uphill with load	— —	— —	— —	22.5 (0.90)
walking downhill	— —	14.5 (0.91)	— —	13.2 (0.89)

Pulmonary ventilation and respiratory quotient

Values for V_e and for r.q. in different activities are given in table 19. A reasonable conclusion from these values is that there is little evidence of marked hyperventilation, so that the likelihood of the results having been much influenced by nervousness or anxiety on the part of the subjects is small. The r.q., on average, is high but probably no more so than would be expected by reason of the very high carbohydrate diet.

None of the results seem remarkable and are similar to those found in comparable circumstances on other populations.

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Discussion

There are several unexpected results in these studies. Among the more striking are the considerable differences between the energy intake and energy expenditure values in the Kaul men and women but *not* in the Lufa men and women, the absence of an increased energy intake in the pregnant and in most of the lactating women, and the apparently low protein intakes of all groups.

Differences between intake and expenditure

No completely satisfactory explanation can be offered for these differences in the Kaul men and women. In the case of the men, the measured intake of energy was, on average, 1.69 MJ (403 kcal) per day less than expenditure (or 21 % of the energy intake), and for the women the difference was 1.70 MJ (406 kcal) per day (29 % of intake). The mean intakes of both groups were low but especially so in the women.

There are several possible reasons for these differences between intake and expenditure. First, they may be real examples of negative energy balance. This is unlikely since 83 % of the women and 74 % of the men had lower intakes than expenditures. They therefore occurred throughout the year and were not due to lack of food at any particular period – in any case, there was no such deficiency. A real negative energy balance of such dimensions lasting throughout a period of almost a year would have been accompanied by other signs. This explanation is thus not acceptable.

A second reason which is possible, although improbable, is that all, or almost all, of the Kaul subjects deliberately ate less than their normal food intake while they were being studied. We had very friendly contacts with the people and we could detect no difference in behaviour in those subjects whom we studied, after their own particular participation had finished. We are reasonably convinced that the measured food intakes reported here approximate to the normal for the individual subjects.

A third reason for the differences between intake and expenditure in the Kaul people might be because of technical errors or misjudgements. The chance of appreciable error in the technique used for measuring food intake was small, and there was, in the calculation of the results, virtually no reliance on tables of the composition of foods since several samples of all the foods eaten – other than a few of the very minor items – were collected and analysed. Superficially, a similar degree of reliance could be put on the results of energy expenditure. The technique used was exactly as we have previously employed on many hundreds of individuals. However, some of the results obtained – for example, for 'lying' and 'sitting' – were perhaps high and it is possible that this may also have been the case with others. Nevertheless, even by looking carefully at all of the measurements and assessing the effect of reducing each to the minimum, there is still an unexplained gap between intake and output. Also, the strong argument that it is not the technique which was responsible for the discrepancy is the fact that the Lufa populations, measured in exactly the same way, showed excellent agreement between these results.

There are some variations in the standard deviations of the mean values for energy intake and expenditure which may reflect differences in the validity of the techniques. The standard deviations for energy expenditures of all groups, excluding the young Kaul men, were only about half of those for energy intakes. While this may be a correct guide to energy output, it may also partly result from the method of assessing daily energy expenditure, which perhaps reduces the variability of those assessments. Until much more acceptable and reliable techniques become available for measuring total daily energy output, the interpretation of apparently negative or positive energy balances of this nature should be approached with reservation.

Thus no explanation seems to be entirely plausible for the unusual results on the Kaul people. We are reasonably confident about those for food intake and would thus tend to be less certain of the validity of the energy expenditures, although there is little undisputed basis for this uncertainty.

Pregnancy and lactation

The absence of an increase in food intake in the pregnant and in most of the lactating women has already been mentioned. Indeed, as energy per kg body mass, the pregnant women in both Kaul and Lufa have the lowest intakes of all groups. In a physiological state, this can be acceptable only if physical activity was reduced. There is some evidence of a slight reduction since the energy expenditure of both the Kaul and the Lufa women who were pregnant is less, as energy per kg body mass, than that of the young non-pregnant women (by about 8.37 kJ or 2 kcal/kg). However, the difference is quite inadequate to cover the supposed energy costs of pregnancy. A solution might be a decrease in body mass with repeated pregnancies but this has not been observed (Greenfield, personal communication). Therefore, again there is a low result which we are unable to explain satisfactorily.

Adequacy of protein intake

This was assessed using the 'safe levels' proposed in the F.A.O./W.H.O. booklet on *Energy and protein requirements* (F.A.O./W.H.O. 1973). The chemical scores for the Kaul and Lufa populations, following the F.A.O./W.H.O. recommended amino acid scoring pattern, were:

Kaul men	86	Lufa men	84
Kaul women	80	Lufa women	92

These scores are high for vegetable diets. Partly this may be an overestimate since apparent supplementation of different proteins may not be real. Thus, in Kaul, breadfruit protein is supplemented by the amino acid pattern of taro, but these foods are often eaten as alternatives, not both simultaneously, and the supplementation would therefore be lost.

The net dietary protein:energy ratios calculated from the monogram of Miller & Payne (1961) were:

Kaul men	6.0	Lufa men	5.5
Kaul women	5.0	Lufa women	6.5

As percentages of the F.A.O./W.H.O. safe levels, the protein intakes of the groups were as follows:

Kaul men	98 %	Lufa men	121 %
Kaul women		Lufa women	
non-pregnant, non-lactating	77 %	non-pregnant, non-lactating	150 %
pregnant	56 %	pregnant	118 %
lactating	51 %	lactating	88 %

Thus, in spite of the low absolute quantities of protein in the diet, apparently both groups of men and most of the Lufa women had adequate protein intakes. The lactating women in Lufa were slightly below the recommended level, but the non-pregnant, non-lactating Kaul women were well below the safe-level, while the pregnant and lactating Kaul women had intakes which were so inadequate that marked signs of protein insufficiency should have been evident. No such signs were detected.

These were not the only unusual findings in relation to protein. It has for long been a commonly held tenet that people will choose a diet where the protein contributes about 14 % of the energy, if protein, especially animal protein, foods are available. The mean proportion of energy derived from protein varied between 6 and 7 % in the diets of the Kaul people, who had ample protein available in the form of fish; yet they showed no particular desire to include fish in their diet.

Conclusion

The results from these studies have again shown low intakes of energy, protein and fat in New Guinean populations. However, because of changing standards of requirements, it is only the energy intake of the older Kaul men and the energy and protein intakes of all the Kaul women which fall appreciably below the recommendations. It seems therefore unnecessary to postulate a special adaptation which results in a significant addition to the available nitrogen from a source of 'nitrogen fixation' in the gut. None the less, the unusual findings in relation to protein intake and to energy balance in the pregnant and lactating women of Kaul may be of wide significance and ought to be further investigated.

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