Nutritional Status of Papua New Guinea Highlanders¹

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Summary A nutritional survey was held in August, 1978, at Kalugaluvi (altitude: 1,500 m) near Lufa, which is 60 km from Goroka, in the Eastern Highland Province of Papua New Guinea. Anthropometric measurements were carried out on 55 males and 37 females aged from 7 to 64 years. Whereas the physiques of the children looked as good as those of Japanese of a comparable age, the adult men were shorter than Japanese males, but body weight and chest girth were similar. The skinfold thickness was less than that of the Japanese. From the data collected, it was shown that the physique of the Highlanders was more muscular than that of the Japanese.

The food intakes and energy balances of 18 healthy men (20–40 years old) were measured over 2 or 3 consecutive days. The average consumption of sweet potatoes, the staple food, was 956 ± 305 g per day. The average consumption of taro and yam was 93 ± 124 g/day and 36 ± 99 g/day, respectively. Various green leaves, sugar canes, corn, bananas and other foods (*i.e.*, rice and tinned fish) purchased from trade stores were sometimes eaten. The mean daily energy intake was $2,390 \pm 540$ kcal, which was about the same as the daily energy expenditure. The daily protein intake was 35.2 ± 10.7 g. These results are probably exceptionally high, because the survey was unfortunately held during the yearly festival season of the village when the people often ate fatty pork.

Nevertheless, it is noteworthy that the growth of children and the physique of adults are normal in spite of the extremely low intake of protein.

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Many nutritionists the world over have recently become interested in nutritional problems in Papua New Guinea. This is because, people in the New Guinea highlands who live mainly on sweet potatoes, have a fairly good physique and rarely show signs of malnutrition in spite of their very low energy and protein intakes (1-9). There are few papers in which the nutritional status of the Papua New Guinea highlander has been examined by the individual weighed intake method (5, 7).

This study is part of our survey program started in 1977 to determine how these people are nutritionally adapted to a low protein diet. Our first preliminary study was carried out in 1977 at Goroka hospital in the Papua New Guinea highlands. A negative nitrogen balance for adults was deduced from analysis of hospital meals (10). It was also shown that ^{15}N -urea given orally was incorporated into plasma proteins, suggesting recycling of urea (11, 12) in the Papua New Guinea highlanders (10).

Next we carried out nutritional studies in August, 1978 in a small village near Goroka. These studies consisted of 1) a dietary survey; 2) anthropometric measurements; 3) an examination of the nitrogen balance (13); 4) biochemical tests on the blood (13); 5) an examination of physical characteristics (14) and 6) measurements of body temperature (unpublished observations). This paper reports the nutritional status of people in the highlands of Papua New Guinea examined using the 24-hr individual weighed-intake method and nutritional anthropometric studies on these people.

Description of the area and population

We made a nutritional survey in August, 1978, at Kalugaluvi (altitude: 1,500 m) in Beha Village in the Eastern Highland Province. Beha Village is located on the northwestern slopes of Mt. Michael (3,750 m) at an altitude of 1,500 to 2,100 m. There are about 1,000 inhabitants of the village. There is one medical aid post and one community school with 118 pupils established in 1976.

There are 40 families (about 150 individuals) in Kalugaluvi; 51% of the population are below 10 years of age, 7% are adolescents, 28% are adults and 14% are over the age of 40. Most of the people have been Christians for about five years. In Beha the standard level of living is low and sanitary conditions are extremely poor.

The ambient temperature in Kalugaluvi during the survey in August was 15-17°C at 6 a.m. In the daytime it was hot in sunny places and 22-27°C in the shade. One third of the children were naked, even at night and in the early morning (14).

Pigs are the only domestic animals of any value: they are symbols of wealth and are used in marriage for gifts and land exchange. They are also killed and eaten, but only on special occasions, such as the traditional festivals in July and August, marriage feasts, the purging of diseases and memorial services for the dead. Each family has about three pigs.

The staple food is sweet potatoes. Taros, yams, sugar canes, corn, bananas and various green leaves are also planted in garden plots surrounded by wooden fences on the steep hillsides. Coffee was introduced recently as a crop.

The only method of cooking is baking, steaming and boiling. The staple food, sweet potatoes, is cooked on a fire or in hot ashes. Traditionally, utensils are used for neither food preparation nor consumption except for wooden drum ovens and bamboo pots. However, nowadays people use knives, saucepans, wire-gauze mats and enamel dishes purchased from trade stores. Empty cans with holes in them are also sometimes used for cooking.

Like other highlanders, the people are short in stature, stocky, with skin colour varying from light to dark brown. Their hair is tightly curled and kept short, their noses are broad, their eyes are dark brown and their lips are full.

METHODS

Subjects. We informed the village headman of the purpose, nature, and medical importance of the investigation and received his consent to proceed.

We took pictures of all the members of each family in front of their houses and collected general information from them, such as the name and order of rank of each person in the family and the presence of pregnant or nursing mothers.

Ages were assessed by a medical assistant working at the Medical Center in Lufa on the basis of order of rank in the family, physical appearance and written records of the local province. This medical assistant also helped us with our experiments and acted as an interpreter.

The subjects for anthropometric measurements were 55 boys and men and 37 girls and women, ranging in age from 7 to 65 years. They all lived in Kalugaluvi, or neighboring villages.

The dietary survey was made on 18 healthy men of 20 to 40 years of age living in Kalugaluvi (Table 1). Fifteen of these subjects were examined for 3 consecutive days, and 3 for 2 consecutive days. During the examination period one of us was with the subject from early morning just after he got up until late at night before he went to sleep.

We carried out dietary surveys and time studies and collected 24-hr urine samples, 2-3 day feces samples and early morning blood specimens. The results of the nitrogen balance study and biochemical tests on blood specimens have been described elsewhere (13).

Anthropometric measurements and physical examination. The height and chest girth of subjects were measured with a flexible tape measure with 0.1 cm gra-

Table 1. Physical characteristics of the subjects examined in the nutrition survey.

	Kalugaluvi	Japan 1977 ^a	
Number	18	433	1,034
Age (years)	20–40 (30.6)	26–29	30–39
Height (cm)	158.3 ± 5.4 ^b	167.4 ± 6.3	165.2 ± 6.0
Body weight (kg)	59.1 ± 5.4	61.1 ± 8.0	61.0 ± 8.3
Rohler index	149.0 ± 11.3	130.2	135.3

^a National Nutrition Survey by the Ministry of Health and Welfare of Japan (20).

^b Mean ± SD.

duations. For measurement of body weight the subjects were light clothes but had bare feet. Weight was measured on a spring balance with 0.5 kg graduations. The skinfold thickness was measured with an Eiken-type caliper to the nearest millimeter at two different points on the left side of the body in the triceps and subscapular regions.

Handgrip force was determined in the standing position using a grip dynamometer with 0.5 kg graduations. Back strength was measured with a muscle dynamometer with 1 kg graduations.

Time study. Activities of the subjects were recorded on special diary cards in an attempt to account for every minute of the day. The subjects were under observation all day long. The total daily energy expenditure of each individual was calculated from the detailed record of the time spent on each activity throughout whole 24-hr periods for 2–3 consecutive days. The energy values for each activity of each subject were taken from the literature (5, 15).

Food intake. Dietary surveys were carried out by the 24-hr individual weighed-intake method. All the food eaten by each individual, both raw foods before cooking and cooked foods before eating, were weighed on a scale with 10 g graduations. Left-overs and inedible portions were weighed and subtracted from the initial weight. From these data, the weight of raw food eaten by each subject was calculated. Representative samples were collected, dried to constant weight and transported to Japan for analysis. The contents of nitrogen, fat, fiber and ash were determined by chemical analysis (16). Intakes of other nutrients were calculated from recent standard tables (17, 18), and other literature (19).

RESULTS AND DISCUSSION

Anthropometric measurements and physical examination

The relations of height, weight, Rohler index, chest girth, skinfold thickness, grip strength and back strength of the male and female subjects to their age are shown in Figs. 1 and 2. The values are shown in comparison with those for Japanese in 1950 and 1977 (20).

Fig. 1. Anthropometric measurements and physical examination of Kalugaluvi males compared with those of Japanese males (20).

The growth curve of boys of up to 20 years of age is similar to that of Japanese (20) and Lufa children (6), but better than that of the highland children reported by Malcolm (21–23). The curve for the increase in chest girth of boys with age is very similar to that for increase in weight. Males reach adult stature by the age of 20. The eleven male subjects in their twenties have average height of 160.4 cm, weight of 62.6 kg, chest girth of 90.5 cm and the sum of the triceps and subscapular skinfold thickness is 15.1 mm. Males of this age group are shorter than Japanese men, but their average body weight is slightly greater. The nine male subjects in their thirties have an average height of 154.7 cm and weight of 55.6 kg. They show a

Fig. 2. Anthropometric measurements and physical examination of Kalugaluvi females compared with those of Japanese females (20).

slight decrease in height and body weight with advancing age. The values for skinfold thickness are comparable to those for other New Guinea populations (8, 21) and are far less than those of Japanese (20). These data indicate that these people have a muscular body build.

Findings on females are similar except that the average body weight of adult women is less than that of Japanese women.

Sinnett reported that both the bicycle ergometer and the Harvard Pack test demonstrated satisfactory levels of physical fitness in Papua New Guineans (7). However, the results of grip strength and back strength in this survey which seems

to show the level of physical fitness are slightly lower than with Japanese, because this is the first time such a test has been used on the Papuans.

Time study

The mean energy expenditure of the 18 adult men during 2- or 3-day survey periods and an analysis of how these men spent their time are shown in Table 2. About half the time was spent on inconspicuous leisure, such as talking and wandering about and 40% of the time on sleeping. Labor, such as walking, cutting trees, making fences and growing coffee plants, occupied very little of the time, but there was a considerable expenditure of energy on body movement for these activities. It seems that the people did not work very much at the time of this survey because it was carried out during the festival season.

The mean energy expenditures for physiological activities, labor and inconspicuous leisure were 662 ± 99 kcal, 607 ± 355 kcal and $1,051 \pm 247$ kcal, respectively.

Table 2. Times (as percentages of 24 hr) and energies expended by subjects on various activities.

	Time (% of 24 hr)	Energy (kcal)
Physiological activity		
Sleeping	40.0 ± 5.1^a	602 ± 98
Eating	2.1 ± 1.2	46 ± 26
Others	0.5 ± 0.2	14 ± 8
Total	42.6 ± 5.1	662 ± 99
Labor		
Walking	3.8 ± 3.1	238 ± 205
Cutting trees, making fences and spears	1.8 ± 3.3	113 ± 193
Coffee culture	1.4 ± 1.9	65 ± 87
Cultivating	1.1 ± 1.7	50 ± 82
Nursing children	1.5 ± 3.1	47 ± 94
Preparing food	0.6 ± 1.2	18 ± 38
Others	2.2 ± 4.1	76 ± 159
Total	12.4 ± 6.0	607 ± 355
Inconspicuous leisure		
Talking	33.5 ± 7.5	691 ± 163
Wandering about	7.0 ± 5.7	262 ± 202
Playing cards	3.3 ± 4.7	70 ± 97
Festival	1.1 ± 2.1	26 ± 46
Others	0.0 ± 0.1	1 ± 3
Total	45.0 ± 8.6	$1,051 \pm 247$
Total	100.0	$2,320 \pm 420$

^a Mean $\pm$ SD. Some standard deviations showed greater variability because some subjects did not carry out any activities during the experiment.

The energy expenditure per day varied from 1,570 to 3,140 kcal, with a mean of $2,320 \pm 420$ kcal (39.5 ± 3.8 kcal/kg). This value is comparable with values for other New Guinea highlanders (5).

The calculated value for intake of energy was 20% less than that for expenditure in 3 of the 18 subjects, but was positive in 3 subjects. The calculated mean energy balance was $+55 \pm 599$ kcal/day, that is, almost equivalent.

Feeding pattern

The group formed for the main meal of the day is generally based on the family. Occasionally, it is practical for several families to combine to form an eating group. Two or three meals are eaten daily, the bulk of the energy intake occurring in the morning and evening.

Most families rise at 6 a.m. and sit around a fireplace in the house, eating baked sweet potatoes for breakfast between 7 and 8 a.m. They are used to taking lunch or a snack of baked sweet potatoes, corn or bananas at the place of work or in the home between 11 a.m. and 2 p.m. When they feel hungry, they sometimes nibble sugar cane. The evening meal is eaten between 4 and 7 p.m. when the husband returns from the bush with firewood and the wife comes back from the garden with fresh sweet potatoes. They eat sweet potatoes, taros, some vegetables and pork and fat, cooked just boiled or baked in bamboo. Sometimes they cook with heated stones in a wooden oven called a Mu-Mu. This is the most common feeding pattern.

Dietary intake

The intakes of different kinds of foods are shown in Table 3. The Highlanders have a food consumption pattern which is completely different from the Japanese's, both qualitatively and quantitatively. The staple foodstuff, potatoes, constitutes the bulk of the food consumed, but the average consumption of green leaves and other supplements is small. This story is nutritionally important.

The daily intake of potatoes per head was very high ($1,120 \pm 260$ g); about 77% of the food was in the form of potatoes and, in particular, sweet potatoes, which were eaten every day by 98% of the subjects. The average daily consumption of sweet potatoes per head was 956 ± 305 g. This seems to be a slightly smaller intake compared with that in the reports of 1947 (1) and 1967 (7). The intakes of taros and yams, eaten every day by 35% and 8% of the subjects, respectively, were one tenth of those of sweet potatoes. Tapioca potatoes were eaten only rarely.

The main cereal is rice, but its consumption during the survey was very small. Rice is not a traditional staple food. Recently, money in the form of wages has become available from the coffee plantation and is spent on rice or commercial foods, but the traditional food pattern is kept. Various green leaves and other vegetables often formed a moderate part of the diet (corn 29 ± 57 g/day). Sugar canes and bananas were eaten once or twice a week, but papaya and coconuts seldom.

The average daily per-capita consumption of pork fat, pork and tinned fish

Table 3. Mean daily intake of foods per capita (in grams).

Food group	Kalugaluvi	Japan 1977 ^a	Japan 1950 ^a
Potatoes	1,120 ± 260 ^b	62 ± 46	127
Cereals	50 ± 58	329 ± 93	477
Green leaves	34 ± 41	59 ± 44	76
Other vegetables	49 ± 60	203 ± 93	120
Meat	28 ± 55	68 ± 39	8
Oil (pig fat)	45 ± 49	18 ± 12	3
Fruits	24 ± 55	181 ± 126	27
Sugar (sugar cane)	84 ± 148	14 ± 11	7
Fish	13 ± 18	89 ± 51	62
Seeds and nuts	1 ± 3	1 ± 5	
Egg	0	41 ± 25	6
Milk	0	107 ± 86	7
Total	1,450 ± 320	1,407 ± 370	

^a National Nutrition Survey by the Ministry of Health and Welfare of Japan (20).

^b Mean ± SD. Some standard deviations showed greater variability because some subjects did not take certain food during the experiment.

(mackerel and sardine) was 45 ± 49 g, 28 ± 55 g and 13 ± 18 g, respectively. During the survey the subjects ate fatty pork every two days, but this was unusual. This was because the survey was carried out during the festival season. The people seemed to prefer pork fat to pork.

Commercial products, such as beer, peanuts, salt and fried cake made of wheat, were eaten only rarely and in negligible amounts. Salt had been sold at the trade store from about 5 years previously, but was seldom used for cooking.

None of the subjects were found eating pulses, eggs, fungi or sea-weeds, drinking milk, or taking any seasoning other than salt. The main fluids they took were cooking water (as soup) of vegetable and sweet potato. They did not drink coffee or tea, and the daily water intake was much less than that of the Japanese. The foods were very simple and there were few varieties; in fact, only 30 different kinds of foods were eaten during the survey.

On talking to the families in this village, we found that birds, snakes, marsupials, small rodents and insects were also occasional sources of animal protein, but it was questionable whether they contributed appreciably to the daily diet.

Nutrient intakes

The daily ingestions of the various nutrients are summarized in Table 4. Energy intake ranged from 1,266 to 5,348 kcal/day, with an average of 2,390 kcal/day, or 40.4 kcal/kg/day, which is somewhat lower than that of Japanese (20) and the Japanese recommended allowances (1980). The mean daily energy intake, however,

Table 4. Mean daily intakes of calories and nutrients.

		Kalugaluvi	Japan 1977 ^a	Japan 1950 ^a
Total calories	(kcal)	2,390 ± 540 ^b	2,694 ± 603	2,530
	(kcal/kg)	40.4		
Calories from				
Carbohydrate	(%)	78.1		
Fat	(%)	16.8		
Protein	(%)	5.2		
Fat	(g)	44.6 ± 30.4	53.8 ± 19.2	18
Carbohydrate	(g)	467 ± 103	326 ± 81	418
Fiber	(g)	8.5 ± 2.3		
Protein	(g)	35.2 ± 10.7	84.6 ± 21.0	80
	(g/kg)	0.595		
Amino protein	(%)	32.6 ± 18.7	49.0	25.0
Protein score	(%)	68.2 ± 7.3		
Ash	(g)	11.8 ± 2.4		
Calcium	(mg)	365 ± 61	550 ± 183	
Sodium	(mg)	443 ± 387		
Phosphorus	(mg)	693 ± 141		
Iron	(mg)	10.7 ± 1.9	13.8 ± 4.0	
Vitamin A	(I.U.)	617 ± 697	1,810 ± 918	
B ₁	(mg)	1.90 ± 0.38	1.19 ± 0.46	
B ₂	(mg)	0.62 ± 0.15	1.04 ± 0.31	
C	(mg)	328 ± 94	124 ± 56	
Nicotinic acid	(mg)	13.1 ± 2.5		

^a National Nutrition Survey by the Ministry of Health and Welfare of Japan (20).

^b Mean ± SD. Some standard deviations showed greater variability because some subjects did not take certain food during the experiment.

was about the same as the daily energy expenditure (Table 2). During the survey 78.1% of the total energy intake was from carbohydrate, largely from sweet potatoes, 16.8% from fat and 5.2% from protein. Animal foods from all sources contributed only 4.2% of the energy. Fat of animal origin, mainly pork fat, amounted to 80.2% of the total fat consumed.

The subjects had an average daily intake of 44.6 g of fat, 476 g of carbohydrate and 8.5 g of fiber. The daily per-capita intake of protein was 35.2 ± 10.7 g or 0.595 g per kg of body weight and was a half the Japanese recommended allowances (1980). The small protein intake, which is half that of the Japanese, was noteworthy. Potatoes contributed 47.6% of the total protein consumed. Pork was the main source of animal protein in the diet, but even during the festival season when pigs were killed, only 25.8% of protein came from pork. The percentage of animal protein in the diet was 32.6 ± 18.7, which was much lower than that in the Japanese diet. The protein score, according to the FAO pattern (1975), and the chemical score, according to the criteria of FAO/WHO, were 68.2 ± 7.3 and 83.7 ± 10.6,

respectively, and the first limiting amino acids were S-containing amino acids.

The protein score obtained from the nutrition survey conducted of children in Osaka was 74 in 1956 and 81 in 1974, and the first limiting amino acids were S-containing amino acids in both cases (24). The values obtained from this survey are lower than those in 1956 when the dietary condition of the Japanese was bad.

The subjects had an average daily intake of 10.7 mg of iron, 1.90 mg of thiamine and 328 mg of vitamin C. Sweet potatoes have a low protein content, but they contain significant quantities of iron, calcium, thiamine and vitamin C in contrast with rice. Thus, the intakes of iron, thiamine and vitamin C were more than enough, and were the same as, or higher than those of Japanese (20). The intakes of calcium and riboflavin were moderately low, being two-thirds of those of the Japanese (20). The vitamin A intake was very low, even though most subjects ate some leafy, green vegetables every day.

Therefore, it is possible that the small intakes and poor quality of protein are the most limiting factors regarding the nutritional problems in this area.

These results are in keeping with the findings of other dietary surveys carried out in Papua New Guinea (1, 5, 7) a difference being that the subjects ate a little commercial food.

It is noteworthy that although the protein intake and quality were very low, the growth rate of children and adult physique were satisfactory except for a shortness in stature. Hipsley reported that Papua New Guineans have established a life within an ecosystem from which some obtain as little as 4% of their food energy from protein and that one of the ways in which people adapt to low protein diets is by a slow rate of growth and achievement of a smaller adult body size with delayed sexual maturity (1). Malcolm reported that growth of the highland populations of Bundi (21) and Lumi (22), who lived almost entirely on sweet potatoes, was slower than that of people in any other part of the world. Malcolm has also shown that over a period of 7 years from 1959 to 1967 there was dramatic improvement in the death rate and malnutrition of children without any obvious change in the dietary patterns or growth patterns, because of improved medical treatment. On the other hand, when the children in Bundi were given extra protein in the form of skimmed milk powder, for ten weeks, they showed considerable increase in weight and height compared with the controls (23).

The growth curve of Kalugaluvi children was similar to those of children in Lufa (6) and Kaiapit (25), but was better than that of the highland population reported by Malcolm (21-23). Moreover, the young men in Kalugaluvi tended to be taller and heavier than the adult men (Fig. 1). Recently people in Lufa (5), Kaiapit (25) and Kalugaluvi have been able to obtain rice and canned goods and this may have resulted in the improvement in growth and development of young adults, as noted in many other countries.

The mean urinary and fecal nitrogen were 81.9 ± 18.7 and 26.8 ± 12.5 mg/kg/day, respectively in this survey (13). The mean daily nitrogen balance was slightly negative (-13.5 ± 24.9 mgN/kg, -0.789 ± 1.427 gN/day). In spite of the

low protein intake and negative nitrogen balance, results of hematological analysis were satisfactory (13), and the hematocrit, hemoglobin concentration and serum protein concentration were significantly higher than those for normal Japanese (13). These data showed that these people are extremely well adapted to their low protein intake. It is proposed that recycling of urea may play a more important part in adaptation to low protein diets (4, 10). Several workers have shown that more ^{15}N was incorporated into plasma protein and less isotope was excreted during the intake of protein restriction whether ^{15}N was given as ammonium chloride or as urea. In 1977, we carried out nearly the same survey at Goroka and in Japan (10). It was found that ^{15}N urea may be utilized in Papua New Guinea highlanders and Japanese fed on low protein diet and this produces amino acids, especially lysine, in the intestine where the bacterial species are changed by a long-continued protein-deficient diet (10). Now we are working on the possibility of the existence of ^{15}N urea recycling systems in Kalugaluvi subjects.

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