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Nutritional adaptation of women in contrasting agricultural environments in Tari, Papua New Guinea

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SUMMARY

The energy expenditure, food consumption and anthropometry of two groups of Huli women are described. The group occupying the highly productive drained margins of the Haeapugua Swamp at Weinani have significantly higher intakes of energy and protein than those at Heli on the Paijaka Plateau. However, both groups of women expend similar amounts of time and energy in agricultural activities. The differences are explained by the contrasting quality of agricultural land at each place. Production per hectare at Heli is only around half of that at Weinani. It is concluded that the nutritional health of Heli women is compromised. This is probably the cause of the significantly lower mean birthweights of children born to women living on the Paijaka Plateau.

Introduction

Papua New Guinea (PNG) highland societies are characterized by both pig husbandry and intensive cultivation of sweet potato. Many investigators have reported that the daily protein intake of the people is low and that most of the dietary protein is derived from traditional vegetable foods (1-5). In many parts of the PNG highlands, a rapid increase in population, land shortages and soil degradation have occurred (6-7). In conjunction with these factors, climatic disturbances, such as drought and extended rain or frost, may lead to deterioration of the diet of PNG highlanders (8).

As in many PNG highland societies, Huli subsistence agriculture depends heavily on women's labour to maintain continuous sweet potato production. Observations in 1994 suggest that, on average, men spend only about one hour per day (59±65 minutes, mean ± SD, n=15) on agricultural activities, while women work for 2.5 hours a day (145±90 minutes, n=12) on food production (9). This paper aims to clarify the nutritional adaptations of women to contrasting agricultural environments by examining the differences in energy expenditure, food consumption and anthropometry between two groups of Huli women living in the Tari area of Papua New Guinea.

Subjects and Methods

Study areas

Two groups of Huli women living in the Tari area of PNG were selected for this study. One group live in Weinani *hamegini* (clan parish or group territory), on the margins of a large, partially drained, alluvial and peaty swamp, the Haeapugua Swamp. The other group live in Heli *hamegini*, on the upland Paijaka Plateau and garden on sloping, weathered volcanic soils. The two locations are less than 20 km apart (Figure 1).

The differences between these environments are perhaps best summarized by figures for sweet potato yields from Wood (7). The drained swamp environments produce on average 13.8 t/ha. This compares to the older volcanic agglomerates on which Heli women must grow food near Paijaka, which average 5.1 t/ha, some of the lowest sweet potato yields in the Tari Basin. The predicted rate of yield decline after 10 years of cultivation is 0.63 t/ha/year for the swamps and 1.03 t/ha/year for the volcanic hills.

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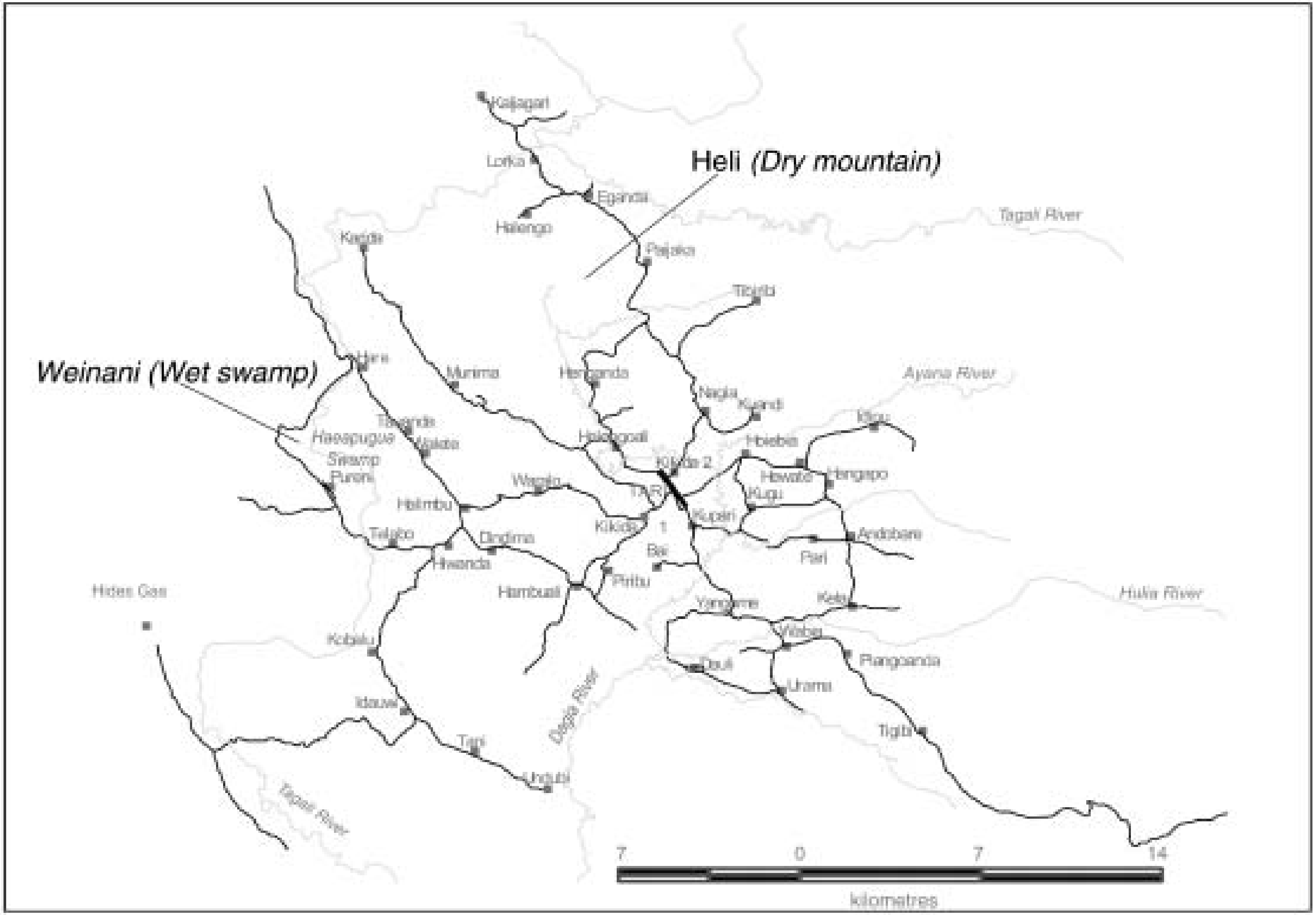

Figure 1. Location of the two study areas in the Tari Basin, in the central part of Southern Highlands Province, Papua New Guinea, at altitudes of 1600 to 1900 m.

Participants

In July and August 1998, the anthropometric dimensions of all married women dwelling in the two *hamegini* (n=33 in Weinani; n=16 in Heli) during the survey period were measured. Previously, from June to September 1994, married females (n=6 in Weinani; n=6 in Heli) were selected for heart rate (HR) monitoring, activity observations and dietary survey.

Anthropometry

Anthropometric dimensions were measured following a standard protocol (10). Stature was measured to the nearest 1 mm using a field anthropometer (GPM, Switzerland) and weight was measured to the nearest 0.1 kg using a portable digital scale (Tanita model 1597, Japan). Skinfold thickness was measured at the triceps and subscapular sites to the nearest 0.2 mm, using Holtain skinfold calipers (Holtain, Briberian, UK). The two-site skinfold equation of Durnin and Womersley (11) was used in combination with the equation of Siri (12) to estimate body fat percentage. Body mass index (BMI; kg/m^2) was calculated as body weight (kg)/stature $(m)^2$.

Heart rate monitoring and dietary survey

Heart rate (HR) monitoring was conducted once (consecutive 24 hours) for each participant. The cardiofrequency meter (Vantage XL, Polor Electro, Kempele, Finland) used as the HR monitoring system consists of an electrode-belt transmitter and a wrist microcomputer receiver. Pulse is recorded at a 1-minute interval and stored in the microcomputer receiver. HR monitoring started around 18:00 after the participant ended her outdoor activities and lasted for 24 hours.

Dietary consumption was studied for each participant on the same day as HR monitoring. All foods consumed throughout the daytime period were weighed with a portable beam scale or spring scale before cooking. In addition, the participants were asked in the morning about the types and amounts of foods consumed during the previous night. Sweet potatoes and green leaves, which were most frequently eaten in the villages, were sampled in the Huli villages and their food compositions were determined in the laboratory in Japan. For other foodstuffs, the energy and major nutrient contents were estimated using the food composition tables of Hongo and Ohtsuka (13,8).

Step tests and estimation of total energy expenditure

On the day of investigation, each participant was requested to do two different step tests, stepping-1 and stepping-2, after instructions in the Huli language. The duration of each step test was 3 minutes and the height of the step was 0.3 m. In the stepping-1 and stepping-2, each participant stepped up and down at a constant pace of 15 times and 30 times per minute, respectively. The HR value in the last minute was used for analysis.

Total daily energy expenditure (TEE) was estimated by the flex-HR method (9,14-17). In the present study, the flex-HR was determined as the mean of the mean HRs of the three resting activities (lying, sitting and standing) and the lowest HR during the stepping exercise (ie stepping-1). The recorded HR values were then converted to energetic equivalents using each participant's EE-HR regression line.

EE during sleeping was assumed to equal BMR (18). For the HR values equal to and below the flex-HR point, the resting metabolic rate (RMR), determined by the average of lying, sitting and standing EE, was assumed to represent the energy costs (9,17,19-21). The values above the flex-HR point were converted to energy costs, based on the regression line which was calibrated for each participant. The TEE was then calculated as follows:

$$TEE=\Sigma \text{ (sleeping EE)}+\Sigma \text{ (sedentary EE)}+\Sigma \text{ (active EE)}$$

Physical activity level (PAL=TEE/BMR) was also determined for each participant. The use of PAL values allows a comparison of individuals of different body size.

BMR and energy expenditure at rest (lying, sitting and standing) and during step tests were determined using corresponding energy costs that were obtained from similar samples of Huli-speaking people, based on participants'

TABLE 1

PHYSICAL CHARACTERISTICS OF HULI WOMEN AT WEINANI AND HELI, TARI, PAPUA NEW GUINEA, 1998

Anthropometric measure	Weinani n=33 Mean	Weinani n=33 SD	Heli n=16 Mean	Heli n=16 SD	Difference p
Stature (cm)	147.0	6.1	150.7	4.0	<0.05
Weight (kg)	50.2	6.9	47.3	5.2	ns
BMI	23.1	2.1	20.8	1.9	<0.05
Arm circumference (cm)	23.4	1.6	22.6	1.6	ns
Waist (cm)	82.7	5.7	80.9	5.7	ns
Hip (cm)	90.1	5.8	87.2	5.8	ns
Triceps sf (cm)	8.7	3.0	7.5	3.0	ns
Subscapular sf (cm)	16.3	4.0	13.4	4.0	ns
Body fat (%)	24.9	4.3	22.1	4.4	<0.05

ns = not significant; BMI = body mass index (kg/m^2)
sf = skinfold

body weight and sex (22). In that study, the energetic values were measured using the Douglas bag technique of indirect calorimetry (23).

Statistical analyses

Differences between groups were examined for statistical significance using the Student's t-test. All analyses were conducted with a JMP statistical package (SAS Institute Inc., Cary, NC, USA) and $p < 0.05$ was accepted as the level of significance.

Results

The 1998 anthropometry reveals that, except for stature, all anthropometric values were higher in Weinani women than in Heli women. Statistically significant differences were found in stature, body mass index (BMI) and body fat percentage (Table 1). The results suggest that the nutritional status of Heli women is worse than that of Weinani women.

Another member of the research team made anthropometric observations in 1993 on almost the same sample population being reported on here (24). Those results are very similar to the 1998 results. In 1993, Weinani women had higher values in body weight, BMI and skinfolds than Heli women. This strongly suggests that the Weinani women were better nourished than the Heli women in 1993 and that the observations made in 1998 represent the long-term situation.

Table 2 shows dietary energy, protein and fat intakes for females in Weinani and Heli. The Food and Agricultural Organization of the United Nations (FAO), World Health Organization (WHO) and United Nations University (UNU) have jointly suggested that extra energy and protein are needed for lactation (25). Norgan et al. have reported that lactating women in the PNG highlands (Lufa) had a significantly higher energy intake (by 0.75 MJ per day) than women who were not pregnant or lactating (3). Adjustments were made for lactating women (two in Weinani, two in Heli) for energy intake and protein intake according to FAO/WHO/UNU standards (2.1 MJ in energy and 17.5 or 13.0 g in protein, in the first month or after six months of lactation, respectively). All values were higher for the Weinani women. Significant differences were found in total energy intake and protein intake. According to

TABLE 2

DIETARY ENERGY, PROTEIN AND FAT INTAKES, WEINANI AND HELI WOMEN, TARI, PAPUA NEW GUINEA, 1994

	Weinani n=6		Heli n=6		Difference
	Mean	SD	Mean	SD	p
Weight (kg)	56.2	3.8	50.5	9.6	ns
Energy (MJ/day)	12.2	1.8	8.8	1.4	<0.05
Protein (g/day)	62.0	21.0	34.0	17.0	<0.05
Fat (g/day)	31.0	16.0	29.0	18.0	ns

FAO/WHO/UNU, the minimum safe level of daily protein intake is 0.75 g/kg body weight/day. Heli women consumed less protein than their minimum safe level of 37.9 g/day, whereas Weinani women were well over their minimum of 42.2 g/day.

No significant differences were found in the two groups in body weight, basal metabolic rate (BMR), total daily energy expenditure (TEE) and physical activity level (PAL) (Table 3). The lighter Heli women tended to have the lower values in BMR, TEE and PAL. According to the guidelines of FAO/WHO/UNU, the PAL for Weinani women corresponded to the 'heavy level', and for Heli it was the 'moderate-heavy level'.

Figure 2 illustrates total daily energy intake (TEI), TEE and the energy balance (TEI – TEE). The Weinani women showed a positive energy balance (+0.03 MJ/day), but the Heli subjects showed a negative balance (–1.10 MJ/day). Such differences, of more than 1.0 MJ per day, cannot be explained by possible seasonal fluctuations in work output and food availability (26). However, a household dietary survey conducted in October-November 1994 (8), three months after the present study, demonstrated a similar gap in energy intake between males from Weinani (12.93 MJ/day) and from Heli (7.75 MJ/day). Therefore, the considerable negative energy balance found in Heli women probably reflects the actual situation during the study period.

Both Weinani and Heli women showed similar patterns for time and energy

TABLE 3

BODY WEIGHT, BASIC METABOLIC RATE (BMR), TOTAL DAILY ENERGY EXPENDITURE (TEE) AND PHYSICAL ACTIVITY LEVEL (PAL), WEINANI AND HELI WOMEN, TARI, PAPUA NEW GUINEA, 1994

	Weinani n=6		Heli n=6		Difference
	Mean	SD	Mean	SD	p
Weight (kg)	56.2	3.8	50.5	9.6	ns
BMR (MJ/day)	6.1	0.4	5.5	1.1	ns
TEE (MJ/day)	10.4	2.4	9.9	2.4	ns
PAL*	1.98	0.32	1.78	0.15	ns
Level**	H		M-H		

*Physical activity level (PAL) = TEE/BMR
**Level of work classified by PAL into L = light, M = moderate and H = heavy (25)

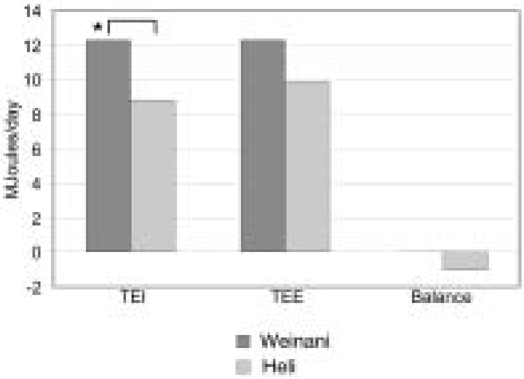

Figure 2. Total daily energy intake (TEI) and expenditure (TEE), and balance (TEI–TEE) in Weinani and Heli women, Tari, Papua New Guinea, 1994; *indicates p<0.05 for the difference between Weinani and Heli.

expenditure. They both spent about 14%-15% of the 24 hours in agricultural activities (Table 4). Agricultural activity assumes even more importance for energy expenditure: 26%-27% of the TEE was spent in agricultural activities.

TABLE 4

PROPORTION OF TOTAL TIME AND ENERGY EXPENDED IN AGRICULTURAL ACTIVITIES, WEINANI AND HELI WOMEN, TARI, PAPUA NEW GUINEA, 1994

	Weinani (n=6)	Heli (n=6)
Time (%)	14.7	13.6
Energy (%)	26.1	27.2

Discussion

Heli women, dwelling in a poorer agricultural environment, spent a similar amount of time and expended a similar amount of energy in agricultural activities as Weinani women in the better agricultural environment. However, Heli women consumed less energy and protein than Weinani women and, as a result, had a poorer nutritional status than the Weinani women. Wood (27) has shown significant differences in sweet potato yields between the drained swamp environments and the older volcanic hills. It is probable that Heli women, working similar hours and expending much the same energy, are producing only around half as much food as Weinani women. Furthermore, Heli women are working under conditions of rapidly falling per hectare yields. After 10 years of cropping, the yields in Heli women's gardens are falling 1.6 times faster per year than yields in Weinani women's gardens.

It also seems likely, as a result of these conditions, that the nutritional status of Heli women is being compromised. During the survey period in 1994, there were no outstanding nutritional problems at Weinani but at Heli the protein intakes of women were below the prescribed minimum safe level and they were in a situation of negative energy balance. Furthermore, it is probable during periods of severe food shortage, such as those described by Allen et al. for 1941 and 1982-1983 (28) and the more recent 1997-1998 drought, that every 10 to 15 years Heli women are subjected to even greater nutritional stresses than the chronic problems described here.

These findings also explain the findings of Allen (29) who has shown significant differences in birthweight between children born in the swamp environments and those born on the older volcanic hills environments.

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