Original Article

Nutritional and anthropometric assessment of a sample of pregnant women and young children in Palau

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This study examines the diet and body constitution of a small sample of pregnant women, *n* = 27, and children, *n* = 32, enrolled in the Maternal and Child Health program at the Public Health/Community Health Center in Koror, Palau. Twenty-four hour diet recalls were collected from both groups, 17 anthropometric and body composition measurements were made on the women and a range of body measurements from height to a full battery of 28 measures were obtained from the children. Diets were found to be low in energy, calcium and zinc. Women consume micronutrients primarily from fish, traditional starches, vegetables and fruits, while children rely more on fortified grain products and milk. The energy distribution is higher in protein and fat and lower in carbohydrate than earlier reports of adult Palauans. A significant minority of the women (27%) have body fat or body mass index profiles indicative of clinically significant obesity or energy storage deficit, both problematic in terms of pregnancy outcomes. While sample sizes of infant and young child cohorts are very small, our findings indicate that a relatively high proportion of these younger children, have experienced inadequate growth and development This is especially true of females, among whom stunting (height deficients) and especially wasting (weight and arm circumference deficits) were in greater evidence.

Key words: anthropometry, diet and nutrition, Palau, pregnant women, young children.

Introduction

Data about the dietary habits of many Pacific Island peoples are limited, and this is no less true for the people of the western Pacific Republic of Belau (Palau), the westernmost of the western Caroline Islands. Prior to sustained European influence, which did not begin until the late 18th century, [1,2] mainstays of the Palauan diet were probably root crops like *Alocasia* and *Colocasia* taro, Polynesian arrowroot and possibly some yams, and indigenous fruits such as bananas, coconuts, keam, some citrus, cannonball fruits, mango, breadfruit (seasonally), wax apples and other assorted fruits and vegetables, such as kangkum (*Ipomoea aquatica*). Protein sources included fish, *cheled* (food items from the sea, such as sea urchin ((*ibuchel*)) eggs, sea cucumbers ((*eremrum, irimd*)), clams ((*kim, orewer, esechol, kikoi*)), sea cucumber intestines ((*ngimes, molech*)), squid and octopus), pigeons, fruit bats and sea turtles. Over time, other crops and animals were introduced, including *Cyrtosperma* and *Xanthosoma* taro, sweet potatoes, cassava, papaya, soursop, avocado, *Bixa orellana* (for making red rice), cucumber, melons, corn, eggplant, okra, rice, beans, pumpkin, pigs, dogs, chickens, goats and cattle (M McCutcheon, pers. comm., 1998 and VM Yano, pers.comm. 1999).

A 'traditional' meal today might include any of these foods (except dog) though some of these foods are viewed as more 'traditional' than others. In addition, canned foods are widely available today, as are soft drinks, processed flours, imported rice, packaged ramen and other non-indigenous food.[3] Various authors have studied and critically reviewed the relationship between the introduction of prepackaged foods and the transition to a more 'modern' lifestyle and adverse health consequences for Pacific Islanders.[4–7] Increased adiposity, high rates of diabetes mellitus type II and heart disease are well-established consequences of modernization in the Pacific.[6–11]

In 1970, Hankin *et al.*[12] reported on the dietary intake of a group of Palauans in an isolated village of Ngarchelong. A 1972 follow up to that study,[5] the most complete to date, compared diets, including intakes for 14 nutrients, of Palauans living in Ngarchelong, Peleliu and Koror, representing a gradient of urbanization from least to most. In 1973, Labarthe *et al.*[13] published protein, carbohydrate and fat intake of 261 Palauan adults. That same year a nutrition survey commissioned by the High Commissioner of the Trust Territory of the Pacific Islands described a Palauan diet still high in local staples like taro, tapioca, banana and fish.[14] Data are sparse, however, on the adequacy of diets in terms of the vitamins and minerals essential to good health. Such

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information is needed to form a more complete picture of diets in modern Micronesian societies.

Published anthropometric data on Palauans are scarce and restricted to adults. The Japanese physical anthropologist Hasebe produced anthropometric data on large numbers of Palauans in the 1920s,[15] but the data are restricted to stature, chest girth and six cephalometric measures, and only the adult male data are available to us. The most extensive published data with bearing on the present study are based on fieldwork done in 1968/70 by Darwin Labarthe, Dwayne Reed and colleagues. Labarthe *et al.*[13] report mean values (age adjusted) for height, weight, triceps and subscapular skinfolds, and percentage body fat for male and female adults from Koror, Peleliu and Ngarchelong. Other published data draw on the same database, but report on mean estimated percentage body fat only.[11,16] Reed *et al.*[16,17] also report correlations and partial correlations of weight, skinfolds and percentage body fat with other chronic disease risk factors.

In 1994, a team from the University of Guam visited the Palauan capital of Koror to conduct a nutritional and anthropometric survey of a convenience sample of pregnant women and children. The visit was funded through the Agricultural Development in the American Pacific (ADAP) Project. The ADAP is an ongoing extension effort by the US Department of Agriculture to conduct research and training in a variety of areas, including adapting dietary guidelines for regional diets and continuing diet assessment of the people of the Western Pacific and Hawaii. The objectives of the study were to generate baseline data and describe the nutritional and anthropometric profiles of a purposively selected group of pregnant women and children.

Methods

With the assistance of officials and staff at the Public Health/Community Health Center (PH/CHC) in Koror, Palau, pregnant women and children enrolled in the Maternal and Child Health (MCH) program with appointments at the clinic for prenatal and well-baby services, respectively, were asked to participate in the survey in July and August 1994. This is the only public health centre in Koror, and the MCH clinics for prenatal and well-baby services are the only clinics for children, thus all children in Palau, rich or poor, are received there. Although the sample is a convenience sample, the Director of the Bureau of Public Health in Koror (CO) estimates that the subjects are similar to the general population of pregnant women and young children in Palau. The Palauan Minister of Health and the Committee on human research subjects at the University of Guam granted permission for the study. Researchers worked closely with the public health nurses and nutritionist, who explained the study to prospective participants and sought their informed consent.

Participants were nutritionally assessed via 24-hour recall. Anthropometric assessment involved the production of 17 body measurements and near-infrared interactance estimation of three body composition components (% body water, % body fat and fat-free weight), using a Futrex-5000A body composition analyser (Futrex; Gaithersburg, MD, USA).[18] All assessments were conducted at PH/CHC. Most participants received feedback about their nutritional profile before leaving the clinic.

Subjects

All participants in this analysis are of Palauan or partial Palauan ancestry, and were clients in the Maternal and Child Health clinic at PH/CHC in Koror. Twenty-six women participated in the nutritional assessment, and 27 in the anthropometric assessments. We obtained self-declared ethnic background information on the participants and their four grandparents. The maximum (n = 27) sample consists of 21 Palauans (that is all four grandparents are Palauan) and six genetically admixed women of one-half or greater Palauan ancestry (that is, with two or three Palauan grandparents). The distribution of village/state of longest occupancy for each woman is Koror (15), Airai (6), Peleliu (3), and Kayangel, Ngatpang and Ngiwal (1 each). The average (± SD) length of the pregnancy at the time of the survey was 30.2 (± 9.4) weeks with the majority of the women (68%) being in the latter part of the third trimester. This was the first pregnancy for 60% of the women. The average age was 24.6 (± 4.8) years.

Thirty-two children of Palauan (n = 24) or part-Palauan (n = 8) ancestry (as above) participated in the survey. One child was not nutritionally assessed and another child who was nutritionally assessed did not participate in the anthropometric session. Of the 31 children nutritionally assessed, 17 are male and 14 female; 16 male and 15 female children were assessed anthropometrically. Sixteen of the children were aged 3–6 years and, with their mothers, were the principal respondents in the nutritional survey; for the 15 children aged 1–2 years, their mothers were the principal respondents. The mean age was 3.0 (± 1.4 years) and the range was 1–6 years. Twenty children lived in Koror, four in Airai, three in Ngaraard and one child resided in each of the state/island/areas of Ngatpang, Ngeremlengui, Ngchesar, Kayangel, and Ibobang. These children are not the offspring of the pregnant female subjects reported on herein.

Standard prenatal vitamin and mineral supplements were used by all but one of the pregnant women. Supplements issued include 4000 IU vitamin A, 100 mg vitamin C, 400 IU vitamin D, 11 IU vitamin E, 1.84 mg thiamin, 1.7 mg riboflavin, 18 mg niacin, 2.6 mg vitamin B6, 800 µg folate, 4 µg vitamin B12, 200 mg calcium, 60 mg iron (ferrous fumarate), and 25 mg zinc (zinc oxide). Prenatal mothers are supplied with a daily supplement of 300 mg ferrous sulphate also. The supplements are taken by the prenatal mothers during their pregnancy and up to 1 month after delivery (pers. comm., Clarette Matlab, 1998). Most of the children (87%) did not consume nutritional supplements. The nutrients provided by the supplements are not included in the calculations of nutrient intake in order to provide an estimate of nutrients provided by diet alone.

Diet assessment

The 24-hour diet recalls were conducted in either Palauan or English by one of the team's research assistants, a Palauan. Food models (Nasco, Fort Atkinson, WI), plates, cups, utensils (obtained locally), standard measures, a 'dough' (made from flour, salt and water) and actual foods were used to aid quantification. The diet recall and food coding were interactive. Reported food items were recorded and entered immediately into a computer nutrient analysis program, Food Intake Analysis System (FIAS) Version 2.0 (University of

Texas Health Science Center, Houston, TX). Detailed information about foods was obtained, including brand names, food preparation methods and ingredients used in food preparation. Substitutions for local foods not found in the database were made for all foods, except bones and fish eyes. No satisfactory substitution was available for the nutrient content of these items and they were omitted from nutrient analysis. Six of the women reported eating fish bones and one chicken bone. One child reported eating fish eyes. No attempt was made to quantify salt or soy sauce added to food as it was eaten, thus sodium intake is a conservative estimate of actual intake.

Nutrient evaluation

Nutrient intake was evaluated using the Recommended Dietary Allowances (RDA) as set forth by the US National Academy of Sciences.[19] An Index of Nutritional Quality (INQ) also was calculated for 23 nutrients using the following formula: INQ = amount of nutrient in 1000 kcal (4200 kJ) of food/Allowance of nutrient per 1000 kcal (4200 kJ) of food. The allowance of nutrient per food is based on the 1989 revision of the RDA and ‘prudent diet’ recommendations.[20] ‘An INQ value greater than 1.0 for any nutrient indicates that an amount of a particular food or combination of foods that would satisfy the total energy requirement would also provide a sufficient amount of the nutrient. An INQ of less than 1.0 indicates that for that nutrient, an excess of a particular food or groups of foods must be consumed to meet the recommend allowance. Thus, the capacity of an individual’s diet to provide both energy and nutrient needs can be evaluated’.[21] INQ values below 1.0 are recommended for fats, cholesterol and sodium.

Food aggregations

Composite groups were formed on the basis of food type and nutrient content. For example, mixed dishes and sandwiches with meat were grouped together. After the food aggregations were developed, further grouping was done to condense the data into main food groups. For example, ‘milk’ includes whole milk, lowfat milk, chocolate milk, evaporated milk, American processed cheese, ice cream, ice milk, pudding and (for children) infant formula.

Anthropometric measurements and body composition estimates

Seventeen anthropometric measurements were made on the women. Measurement choice was guided by considerations of pregnancy state, privacy, cultural appropriateness, anthropological relevance and known or potential relationship to pregnancy outcome. Height and weight measures were used to calculate the body mass index (BMI). Like any mass/height index, BMI (kg/m^2) does not distinguish between the fat, muscle and bone components of body composition. Discrimination of these components is critical to the evaluation of maternal energy balance and its relationship to pregnancy outcome.[22] Accordingly, additional measures were obtained which consisted of three body breadths (biacromial, biiliac and elbow), three circumferences (upper arm contracted, upper arm relaxed and calf), and two skinfolds (triceps and medial calf).[23,24] Elbow breadth is a useful indicator of skeletal frame size and when coupled with triceps skinfold and relaxed upper arm circumference, allows for the estimation of bone–free upper arm muscle area (AMA).[25] Seven cephalofacial measurements, not reported here, were also made.[23]

In addition to the anthropometrics, women’s percentage body fat, fat-free weight and body water percentage were estimated by near-infrared interactance, using a Futrex-5000A body composition analyser. The measuring site used was the standard midpoint biceps site on the left arm, as described in the manufacturer’s manual. Pre-pregnancy weights for many of the women were obtained in 1995, as part of a follow-up data set for investigating pregnancy outcomes.

The production of cross-sectional anthropometric data on children is important in community health assessments, as child growth patterns reflect a population’s public health and nutritional status, when appropriate allowance is made for differences in genetic potential.[26] Anthropometric data produced on the children ranged from weight only to a full battery of 26 measurements, namely weight, height, sitting height, seven trunk and limb circumferences, six skinfold thicknesses, two trunk breadths, total arm length and seven cephalometric measurements.[23,24] The measurement session ceased at a point when a child indicated that they did not want to proceed further. Given the very young ages of most of the children, such non-cooperation was frequent. Due to the patchiness of the children’s data set, only weight-for-age (W/A), height-for-age (H/A), weight-for-height(W/H), and mid-upper arm circumference (MUAC) are reported herein. These four variables are recommended indicators of health- and nutrition-related disturbances of growth in infants and children.[27]

Weight-for-height is recommended as an indicator of the current state of nutrition deficits, and H/A as an indicator of past nutrition in children.[28] Cole[29] has criticized the W/H index for being more correlated with stature in preschool children than BMI, but the World Health Organization (WHO) Expert Committee[30] does not recommend the use of BMI for young children owing to its ‘variation with age’. Weight-for-age and MUAC-for-age are additional indicators of nutritional status. A limitation of the former is that it does not discriminate between acute and chronic malnutrition.[28] The MUAC-for age, however, has proven to be a superior predictor of childhood mortality in community-based studies when compared to height-and weight-based nutritional indicators.[30]

For purposes of characterizing problematic height deficits (stunting) and weight deficits (wasting), National Center for Health Statistics/World Health Organization (NCHS/WHO) 5th percentile scores[31] are used as cut off points. NCHS/WHO reference data on infants and children are recommended for international use by WHO.[27] Problematic arm circumference deficits (wasting) are defined as values less than ± 2SD units from the reference data’s median. Likewise, we define cases as seriously obese if weight, or W/H index, exceeds the NCHS/WHO 95th percentile. While the NCHS/WHO reference data are based on US children, use of such extreme percentiles/standard deviation unit cut-off points should serve to identify children with anthropometric indicators that are cause for concern, if not indicative of frank nutritional deficiencies.

Statistical analyses

Descriptive statistics for the nutritional data were generated using Windows EXCEL Version 7.0a (Microsoft Corp., Redmond, WA). As many nutrients had skewed distributions, group comparisons were based on non-parametric χ^2 statistics using the Kruskal–Wallis test with Minitab 12.1 software (Minitab; PA, USA). SAS for Windows, Version 6.12 (SAS Institute; Cary, NC) was used to calculate contributions (%) of each food group to the intake of each nutrient and to produce summary statistics and bivariate correlation analysis results for the anthropometric and body composition data. Independent groups *t*-tests, from summary data, and contingency table analysis of frequency data were run using WINKS, Version 4.5 (TexaSoft; Cedar Hill, TX).

Results

Nutrient intake

The mean (SD) and median energy and macronutrient intake for both groups are shown in Table 1. Energy intake below two-thirds of the RDA was noted for a number of women, 11/25 (44%) and children, 11/31 (23%). Median energy intake was 69% RDA for women and 88% RDA for children. Median protein intake exceeded recommendations for women, 138% RDA and children, 227% RDA. Cholesterol intake ranged from 34 to 913 mg/day for the women and 23–559 mg/day for the children with 9/25 (36%) women and 8/31 (25%) children exceeding intake of 300 mg per day. Both groups had diets containing less than 30% of overall kcal from fat. The predominant type of fat for both groups was monounsaturated. Dietary fiber intake ranged from 2–32 g/day for the women and 2–23 g/day for the children, but fiber density was similar for both groups. None of the subjects reported the use of alcohol.

Micronutrient intakes are reported in Table 2 and are expressed as a percentage of the RDA in Fig. 1. For women, median intake of micronutrients was above 80% of the RDA except for three vitamins (A, riboflavin and folate) and three minerals (calcium, iron and zinc). For children, only median intake of vitamin E, calcium and zinc were below the 80% threshold. The median INQ scores (Table 3) for fat and most of the micronutrients are desirable. The median INQ scores for cholesterol and sodium are high and for protein, carbohydrate, fibre, vitamin A, vitamin E, calcium and zinc are low for both groups. The nutrients that were below both 80% of the RDA and had an INQ less than 1.0 for median intake were calcium and zinc for both groups, vitamin A for women and vitamin E for children.

There were significant differences ($P < 0.05$) between women and children for riboflavin, vitamin C and magnesium for INQ (Table 3). However, all of these nutrients are present in adequate amounts, with the possible exception of riboflavin for women, with a median intake of 74% RDA. However, since the median INQ for riboflavin is 1.0, this potential deficiency is probably more related to the low energy content of the diet.

Food sources of nutrients

The food sources of the major nutrients are shown in Table 4. Rice is the most important contributor of energy and carbohydrate in the diets of both women and children and provides large amounts of the dietary iron and zinc. Most women (84%) and children (92%) reported eating rice. Fish and vegetables are a larger component in the adults' than the children's diets, while milk is a larger component in the children's diet. Foods of low nutritional value such as soft drinks, desserts, snacks and candy together contributed 10–14% of energy intake and 10–12% of total fat intake for children and women, respectively. Major sources of calcium, in addition to milk, were fish, vegetables, grains and *ongraol* (breadfruit, taro, tapioca and cooking bananas). Grains, fish, meat and *ongraol* supplied most of the iron and zinc. Vitamin A was obtained primarily from vegetables and fish for the women, but from milk and fortified cereals for the children. While much of the vitamin C was derived from fruits and vegetables, approximately 21% was supplied by fortified fruit-flavored drinks (Table 4).

Anthropometry and body composition

Table 5 presents summary statistical results on selected variables with known or potential relationship to pregnancy outcome. Sample sizes range from 25 to 27 except for pre-pregnancy weight and BMI. Pre-pregnancy weight was

Table 1. Macronutrient intake of Palauan pregnant women and young children

	Pregnant Women (*n* = 25)		Young Children (*n* = 31)	
Nutrient	Mean ± SD [a]	Median	Mean ± SD	Median
Energy (kcal[b])	2055 ± 987	1718.47	1289 ± 584	1165.8
Protein (g)	104.4 ± 71.2	82.6	53.2 ± 34.8	39.5
% energy	19.5 ± 7.2	18.8	16.1 ± 5.2	13.9
Carbohydrate (g)	267.1 ± 127.6	222.7	179.5 ± 69.8	165.4
% energy	53.3 ± 15.8	52.0	57.1 ± 9.3	55.4
Total fat (g)	65.7 ± 52.1	46.6	40.3 ± 25.0	32.2
% energy	27.1 ± 11.8	27	26.8 ± 7.6	29.4
Saturated fat (g)	21.3 ± 17.3	14.2	14.4 ± 9.9	12.9
% energy	8.5 ± 4.1	8.0	9.6 ± 3.1	10.0
Monounsaturated fat (g)	26.6 ± 22.4	18.7	14.8 ± 10.3	11.6
% energy	10.6 ± 5.2	10.1	9.8 ± 3.8	10.1
Polyunsaturated fat (g)	12.6 ± 9.9	9.1	7.3 ± 4.5	5.3
% energy	5.4 ± 3.4	4.9	5.0 ± 2.0	4.4
Cholesterol (mg)	291 ± 233	242	186 ± 148	137
Dietary fiber (g)	14.8 ± 8.8	13.5	8.0 ± 4.6	7.2

[a] SD, standard deviation; [b] 1 kcal = 4.2 kJ.

available for only 12 women (eight descended from four, and four descended from three Palauan grandparents). These data were obtained from medical files and may, in some cases, represent self-reported weights. For heuristic purposes, the present results are arrayed next to NCHS reference data from the first and second National Health and Nutrition Examination Survey (NHANES I and II; hereafter NHANES). The NHANES pooled sample is based on over 43 000 US subjects measured in 1971–74 and 1976–80, and is composed of over 82% US 'whites', 16% US 'black', and less than 2% 'other' subjects.[33]

The Palauan sample mean BMI of 23.7 is greater than the 50th and less than the 75th NHANES percentile values,[33] and falls within the normal BMI range recommended for US pregnant women.[34] The 12 individuals sampled have BMI values categorized as follows: nine normal, two obese and one low, where BMI < 19.8 = low; 19.8–26 = normal; 26.1–29.0 = high; and > 29 = obese. Levels of adiposity were assessed through measurement of subcutaneous fat at two sites and with the use of the Futrex-5000A body composition analyzer (BCA). The BCA estimates yielded a sample mean of 26.78% for total percentage body fat, which approximates

Table 2. Micronutrient intake from 24-hour recalls for Palauan pregnant women and young children.

Nutrient	Pregnant Women (*n* = 25)		Young Children (*n* = 31)	
	Mean ± SD [a]	Median	Mean ± SD	Median
Vitamin A (µg RE)[b]	1070.0 ± 1184.8	591.6	586.9 ± 549.9	449.7
Thiamin (mg)	1.9 ± 1.0	1.9	1.2 ± 0.8	1.0
Riboflavin (mg)	1.3 ± 0.8	1.2	1.1 ± 0.8	0.9
Niacin (mg)	28.2 ± 15.5	24.2	16.9 ± 11.1	15.2
Vitamin B6 (mg)	23.3 ± 1.2	2.14	1.2 ± 1.0	1.0
Folate (µg)	217.7 ± 146.6	175.2	151.8 ± 136.0	116.7
Vitamin B12 (µg)	11.3 ± 23.7	2.8	6.6 ± 25.4	2.0
Vitamin C (mg)	147.5 ± 131.4	114.8	60.3 ± 59.7	41
Vitamin E (mg AT)[c]	11.2 ± 10.2	8.76	4.7 ± 3.4	3.8
Calcium (mg)	537.8 ± 311.1	469.5	423.6 ± 248.4	415.2
Phosphorus (mg)	1269.9 ± 747.3	1069.1	744.8 ± 413.2	687.1
Magnesium (mg)	325.6 ± 173.7	342.9	167.9 ± 101.1	150
Iron (mg)	16.9 ± 11.1	13.5	11.6 ± 10.0	10.3
Zinc (mg)	9.6 ± 7.9	7.0	6.1 ± 3.3	5.6
Copper (mg)	1.4 ± 0.8	1.1	0.7 ± 0.4	0.6
Sodium (mg)	4737 ± 1893	4408	2718 ± 1324	2436
Potassium (mg)	3354 ± 2067	3388	1478 ± 1066	1302

[a] SD, standard deviation; [b] RE, retinol equivalent; [c] AT, α-tocohperol.

Table 3. Index of Nutritional Quality (INQ) for Palauan pregnant women and young children

Nutrient	Women (*n* = 25)		Children (*n* = 31)		H[b]	*P*
	Mean ± SD	Median	Mean ± SD	Median		
Protein (g)	0.7 ± 0.3	0.7	0.6 ± 0.2	0.5	2.97	0.085
Carbohydrate (g)	0.4 ± 0.1	0.4	0.4 ± 0.1	0.4	1.22	0.269
Total fat (g)	0.8 ± 0.4	0.8	0.8 ± 0.2	0.9	0.00	0.961
Saturated fat (g)	0.8 ± 0.4	0.7	0.9 ± 0.3	0.9	0.43	0.232
Monounsaturated fat (g)	1.0 ± 0.5	0.9	0.9 ±0.3	0.9	0.22	0.638
Polyunsaturated fat (g)	0.5 ± 0.3	0.4	0.5 ± 0.2	0.4	0.02	0.889
Cholesterol (mg)	1.3 ± 1.0	1.0	1.6 ± 1.6	1.1	0.00	0.967
Dietary fiber (g)	0.8 ± 0.5	0.8	0.6 ± 0.2	0.6	1.24	0.266
Vitamin A (µg)	1.4 ± 2.0	0.8	1.1 ± 0.7	0.9	0.16	0.686
Thiamin (mg)	2.0 ± 0.7	1.8	1.8 ± 0.5	1.7	0.16	0.692
Riboflavin (mg)	1.1 ± 0.4	1.0	1.4 ± 0.6	1.3	4.42	0.036*
Niacin (mg)	2.0 ± 0.7	2.1	1.8 ± 0.7	1.6	1.78	0.182
Vitamin B6 (µg)	1.4 ± 0.5	1.2	1.2 ± 0.5	1.1	3.20	0.074
Folate (µg)	1.3 ± 1.0	1.0	1.3 ± 0.8	1.0	0.07	0.786
Vitamin B12 (µg)	4.6 ± 8.9	1.5	1.7 ± 0.7	1.8	0.00	0.987
Vitamin C (mg)	2.6 ± 2.3	1.7	1.7 ± 1.7	1.1	3.91	0.048*
Vitamin E (mg)	1.3 ± 1.1	0.9	0.9 ± 0.4	0.8	1.37	0.242
Calcium (mg)	0.5 ± 0.3	0.4	0.6 ± 0.3	0.5	2.01	0.156
Phosphorus (mg)	1.1 ± 0.4	1.1	1.1 ± 0.3	1.0	0.11	0.742
Magnesium (mg)	1.1 ± 0.3	1.0	0.8 ± 0.2	0.8	4.52	0.033*
Iron (mg)	1.2 ± 0.5	1.1	1.2 ± 0.5	1.1	0.01	0.934
Zinc (mg)	0.7 ± 0.3	0.5	0.6 ± 0.2	0.7	1.17	0.190
Sodium (mg)	2.5 ± 10.8	2.3	2.2 ± 0.8	2.1	2.88	0.090

[a] SD, standard deviation; *$P < 0.05$. [b]H, chi-square test statistic from Kruskal–Wallis non-parametric test, $P < 0.05$.

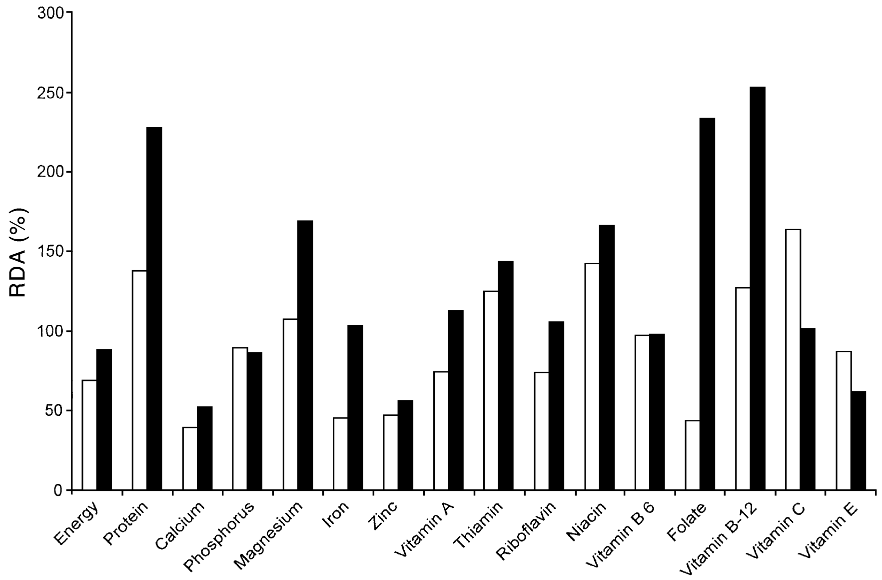

Figure 1. Median nutrient intake as a percentage of the Recommended Dietary Allowance for Palauan women (☐) and children (■).

the NHANES 50th percentile value of 27.0%.[33] Most large, longitudinal and well-designed studies have shown that body fat values between 20% and 30% are associated with lowest morbidity and mortality rates in adult female subjects.[35] Using these cut-off points, 4/26 (15%) subjects had high (> 30%) and 1/26 (4%) low (< 20%) body fat estimates.

Further approximations of fat, as well as bone and muscle components of body mass was allowed by examining measures of the upper limb segment (triceps skinfold, MUAC and elbow breadth), both singly and in combination. Singly, sample means of these three measures all approximate NHANES 50th percentile values. The mean triceps skinfold thickness for the Palauan sample, 18.2 mm, is less than the NHANES sample mean of 20.0 mm, but approximates the NHANES 50th percentile value of 18.5. The elbow breadth sample mean of 6.0 cm approximates the NHANES 50th percentile value of 6.1, indicating an average frame size of medium. Controlling for age cohort,[25] frame size distribution for individuals is 15 small, four medium, and eight large.[33] The MUAC mean of 28.0 is greater than the NHANES 50th percentile value of 26.8 and less than the 75th percentile cut-off point of 29.2.[33] In combination, however, triceps skinfold and MUAC values yield a mean estimated AMA of 33.6 cm^2, which is significantly greater than the NHANES mean of 29.8 cm^2 ($P = 0.02$), and approximates the latter's 75th percentile value of 33.1.[33] Controlling for frame size, 3/27 (11%) women in the present sample exceed the NHANES 85th percentile for arm muscularity, while 2/27 (7%) were under the 15th percentile.[25]

Table 6 presents individual W/A, stature-for-age (S/A), and W/H data for 15 female and 16 male infants and children, ranging in age from 1 to 6 years of age, while MUAC-for-age results are reported in Table 7. Due to the small sample size, height and weight indicators of nutritional status are arrayed for each child next to NCHS/WHO percentiles in Table 6.[31] Similarly, individual MUAC values are presented in Table 7 next to standard deviation units from NCHS/WHO reference data medians.[30]

Weight-for-age results are of concern, as 10/15 (67%) of the girls and 5/16 (31%) of the boys are under the 5th NCHS/WHO percentile. A very different weight deficit characterization, however, is indicated by the W/H results, where only 2/10 (20%) of the girls' and 1/13 (8%) of the boys' indices are under the 5th percentile. At the other end of the weight and W/H spectrum, one macrosomic boy, a 29.5 kg (65 lb) 4-year-old, far exceeds NCHS/WHO 97th percentile values for both weight and W/H index. Growth stunting is indicated for 4/10 (40%) girls and 2/13 (15%) boys, whose statures are below the 5th percentile cut-off point (Table 6). MUAC-for-age results indicate that 3/11 (27%) girls and 1/11 (9%) boys have arm circumferences which are either below the 5th NHANES percentile or below ± 2SD units of the NCHS/WHO median value (see footnotes b and c, Table 7).

Discussion

This study of a small sample of pregnant women and children has highlighted some important strengths and weaknesses of their modern diet, and reports on anthropometric and body composition parameters of relevance to pregnancy outcome and growth adequacy, respectively.

Food and nutrient intake

The first relevant finding is a comparison of the energy composition of the reported diets. Mean energy, 2055 kcal/day (8631 kJ/day), was similar to that found for pregnant Pacific Islander women in a study conducted in the Wellington region[36] and slightly higher than the average, 1600–1800 kcal (6720–7560 kJ), reported for Palauan adults by Hankin and Dickinson,[12] Labarthe *et al.*[13] and Kincaid.[14] Median energy consumption, 1718 kcal (7216 kJ), was similar to these earlier reports. Compared to usual recommendations of energy intake of 2500 kcal/day (10 500 kJ) in pregnancy,[36] the pregnant women's intake appears low. This was especially the case for 44% of the sample whose energy intake was less than two-thirds of requirements. Reduced

Table 4. Food sources of nutrients expressed as a percentage (%) of contribution to the total diet

	Macronutrients (%)							Vitamins (%)					Minerals (%)			
	Energy	Protein	Carbohydrate	Fat	MUFA	Cholesterol	Fiber	A	Riboflavin	Folate	C	E	Calcium	Iron	Zinc	Sodium
Women's food groups																
Breads[1]	8	5	11	4	4	4	9	9	16	12	4	2	6	13	11	14
Rice	20	8	33	1	1	0	10	0	3	4	0	1	7	20	15	23
Subtotal	27	13	44	6	5	4	20	9	19	16	4	4	12	33	25	36
Fish, canned[2]	1	2	0	1	1	3	0	0	1	0	4	0	4	1	1	1
Fish, fresh[3]	15	40	2	21	19	37	1	10	16	10	0	34	11	17	13	14
Meat, canned[4]	4	7	0	9	10	8	0	0	4	1	2	1	1	4	14	6
Meat, fresh[5]	6	15	0	10	11	17	0	2	9	2	0	2	2	4	12	4
Subtotal	27	63	2	41	41	64	2	12	30	13	6	38	17	26	40	25
Fruits[6]	4	1	7	1	0	1	12	4	4	10	27	5	3	2	1	0
Ongraol[7]	8	3	14	2	1	0	20	1	6	9	16	14	14	14	3	6
Vegetables[8]	3	3	3	5	5	1	21	53	9	28	19	14	17	7	4	9
Subtotal	15	6	24	7	7	1	53	58	19	47	62	33	33	22	8	16
Coconut[9]	2	1	1	6	8	0	8	0	2	1	1	1	3	2	2	1
Coffee, condiments[10]	3	1	3	3	2	0	3	2	1	2	2	5	1	2	1	5
Desserts, snacks[11]	9	2	10	12	11	4	5	1	5	3	0	10	4	4	3	2
Eggs	1	1	0	2	2	15	0	2	4	2	0	2	1	1	1	1
Milk[12]	3	3	3	6	4	4	1	2	11	2	1	1	20	1	4	1
Mixed dishes[13]	9	10	3	17	19	8	8	8	8	9	3	8	7	8	15	12
Sweet drinks[14]	5	0	10	0	0	0	1	6	1	7	22	0	3	2	1	1
Totals	101	100	100	100	99	100	101	100	100	102	101	102	101	101	100	100
Children's food groups																
Breads[1]	11	8	16	4	4	5	17	33	26	36	17	4	6	35	13	17
Rice	22	11	35	1	1	0	15	0	3	4	0	2	5	21	16	28
Subtotal	33	19	51	6	5	5	32	33	28	40	17	6	12	57	29	45
Fish, canned[2]	1	4	0	1	1	1	0	0	1	0	0	1	1	1	1	1
Fish, fresh[3]	2	9	0	2	2	6	0	2	2	1	1	9	2	1	2	3
Meat, canned[4]	3	5	0	5	6	5	1		2	1	1	1	0	2	7	5
Meat, fresh[5]	11	28	1	19	20	26	2	4	10	3	2	8	3	7	20	9
Subtotal	17	45	1	27	29	37	3	6	15	5	4	19	6	11	30	18
Fruits[6]	4	1	8	1	0	0	19	7	3	8	28	9	3	2	1	0
Ongraol[7]	4	2	6	2	2	0	12	2	2	4	8	11	4	5	1	3
Vegetables[8]	1	1	1	1	1	0	7	13	2	6	8	3	3	1	1	2
Subtotal	9	3	15	3	3	0	38	21	7	19	44	23	10	8	3	6
Coconut[9]	2	1	1	4	3	0	4	0	1	1	1	2	1	1	2	1
Condiments[10]	2	0	3	0	0	0	0	0	0	0	0	1	0	0	0	4
Desserts, snacks[11]	6	2	6	10	11	3	4	1	3	3	0	10	2	3	2	4
Eggs	2	3	0	4	4	28	0	5	5	3	0	6	1	2	2	2
Milk[12]	15	14	11	22	16	19	5	19	33	10	9	15	59	7	19	6
Mixed dishes[13]	11	13	5	22	27	7	13	2	7	10	4	17	7	9	12	15
Sweet drinks[14]	4	0	8	0	0	0	2	13	1	9	21	0	2	2	1	0
Totals	101	100	101	98	98	99	101	100	100	100	100	99	100	100	99	101

Not all totals are 100 because of rounding.
[1]Breads include white and whole-wheat bread, rolls, crackers, pancakes, cereals (fruit-flavored and sweetened, corn flakes, oat ring cereal and other ready-to-eat cereals), noodles, and noodle soups. [2]Fish-canned includes sardines and tuna. [3]Fish-fresh includes shellfish and fish. [4]Meat-canned includes corned beef and canned luncheon meats. [5]Meat-fresh includes chicken, beef, and pork. [6]Fruits include oranges, apples, bananas, grapes, mango, peaches (canned), orange juice, pineapple juice, apple juice, papaya, and starfruit. [7]*Ongraol* (starches) includes breadfruit, tapioca, cooking bananas, and taro. [8]Vegetables include greens, seaweed, taro leaves, carrots, green beans, cabbage, cucumber, lettuce, onions, eggplant, mixed vegetables, vegetable soup, corn, vegetable tempura, and Kim Chee. [9]Coconut includes coconut, coconut water, coconut milk and mixed nuts. [10]Coffee, condiments includes coffee and tea (for adults only), butter, margarine, cream substitute, catsup, soy sauce, fish sauce, sugar, syrup, mayonnaise and bean paste. [11]Desserts, doughnuts, candy, cookies, cake, popsicle, sweet roll, and salty snacks (chips, pretzels, popcorn). [12]Milk includes whole milk, low-fat milk, chocolate milk, evaporated milk, American processed cheese, ice cream, icemilk (similar to icecream but lower in fat) and pudding. [13]Mixed dishes include *beldakl* (fish soup with greens), peanut butter sandwich, beef stew with vegetables, spaghetti with tomato and meat sauce, cheese sandwich, tuna salad sandwich, frankfurter on a bun and pizza with cheese and meat.
[14]Sweet drinks includes soda, canned fruit-flavored drinks, fruit-flavored drink from powder, lemonade and fruit nectar.

Table 5. Summary statistics for selected anthropometric and body composition variables in adult female subjects

Variable[b]	*n*	Palauan female Mean ± SD	NHANES I and II female[a] Mean ± SD	*P*
Age, years	27	24.7 ± 4.7	See footnote[a]	
Pre-pregnancy weight, kg	12	58.2 ± 11.2	60.8 ± 12.8	0.483
Stature, cm	27	157.8 ± 5.1	163.0 ± 6.5	<0.001
Body mass index (BMI)	12	23.7 ± 4.5	22.9 ± 4.6	0.548
Estimated body fat[c] %	26	26.8 ± 3.9	27.9 ± 7.0	0.169
Elbow breadth, cm	27	6.0 ± 0.5	6.1 ± 0.4	0.198
Upper arm circumference, cm (MUAC)	27	28.0 ± 3.6	27.5 ± 4.0	0.518
Bone-free upper arm muscle area, cm² (AMA)	27	33.6 ± 9.4	29.8 ± 8.4	0.020
Triceps skinfold, mm	27	18.2 ± 4.7	20.0 ± 8.2	0.060
Medial calf skinfold, mm	27	15.3 ± 6.4	—	—

[a]Summary data for 18.0–24.9 age cohort; *n* = 2588–2592.[28] [b]Stature, elbow breadth, upper arm circumference (MUAC) and medial calf skinfold data produced in accordance with Lohman *et al.*,[24] triceps skinfolds were measured following Weiner and Lourie.[23] See text for derivation of computed variables (body mass index (BMI) MUAC and bone-free upper arm muscle area (AMA)). [c]Palauan estimates produced by Futrex-5000A body composition analyzer; NHANES I and II estimates based on skinfold thicknesses.[32] NHANES I and II, National health and nutrition examination survey. —, data not reported.

Table 6. Individual infant/child values, and National Center for Health Services/World Health Organization percentiles (N/W%)[a], for height and weight indicators of nutritional status, according to age (in months) and sex

		Weight		Stature		Weight for Height	
Age (months)	Age (years)	(kg)	N/W%	(cm)	N/W%	(kg/cm)[b]	N/W%
Female							
19	1	8.17	<3	74.8[c]	<3	10.92[c]	95
22	1	6.81	<3				
22	1	9.08	<3				
23	1	9.08	<3				
24	2	9.99	<5	85.6	60	11.67	40
24	2	11.80	50				
26	2	9.53	<3				
28	2	9.53	<3	79.8	<3	11.94	80
35	2	13.17	50	92.1	40	14.30	70
38	3	12.71	10	89.5	<5	14.20	80
45	3	10.90	<3	92.0	<3	11.85	10
63	5	13.62	<3	102.7	5	13.26	<3
63	5	14.53	<5	106.0	20	13.71	<3
66	5	18.16	40	108.1	20	16.80	30
74	6	20.88	60	114.5	40	18.24	20
Male							
24	2	14.07	90	83.2	20	16.91	>97
26	2	11.80	20				
26	2	12.71	50	87.9	60	14.46	90
26	2	9.99	<3	81.4	<5	12.27	70
27	2	12.71	40	86.4	30	14.71	90
32	2	15.89	90	93.2	60	17.05	>97
36	3	13.17	20				
37	3	11.80	<5	90.6	10	13.02	40
37	3	13.62	20	95.3	50	14.29	50
38	3	12.26	<5				
48	4	14.98	20	101.8	40	14.72	10
50	4	29.51	>97	108.4	80	27.22	>97
52	4	16.34	30	101.0	20	16.18	50
58	4	16.34	20	104.4	20	15.65	20
62	5	15.44	<5	104.8	10	14.73	5
65	5	14.07	<3	104.2	<5	13.5	<3

[a]Reference data from Annex 3 in Reference 32. [b]Multiplied by 100. [c]There are no stature-for-age reference data for infants <2 years of age, only (recumbent) length-for-age percentiles. 74.8 cm value is the length equivalent of stature (measured as 73.8 cm), following the conversion recommended by the WHO Expert Committee.[30]

Table 7. Individual infant/child mid-upper-arm circumference[a] values and reference data, according to age (in months) and sex

Age (months)	Age (years)	MUAC (cm)	NH%[c]	NCHS/WHO Reference Data[b] –3SD	–2SD	–1SD	Median	+1SD	+2SD	+3SD
Female										
19	1	12.8	—	11.9	13.2	14.5	15.8	17.1	18.4	19.7
24	2	14.5	—	12.0	13.4	14.7	16.0	17.4	18.7	20.0
26	2	13.9	—	12.1	13.4	14.7	16.1	17.4	18.8	20.1
28	2	14.3	—	12.1	13.4	14.8	16.1	17.5	18.9	20.2
35	2	17.2	—	12.2	13.6	15.0	16.3	17.7	19.1	20.5
38	3	16.9	—	12.2	13.6	15.0	16.4	17.8	19.2	20.6
45	3	13.5	—	12.4	13.8	15.3	16.7	18.1	19.6	21.0
63	5	14.6	<5							
63	5	16.5	25							
66	5	17.9	50							
74	6	17.9	50							
Male										
26	2	16.1	—	12.3	13.6	14.9	16.3	17.6	19.0	20.3
26	2	14.9	—	12.3	13.6	14.9	16.3	17.6	19.0	20.3
27	2	16.2	—	12.3	13.6	15.0	16.3	17.7	19.0	20.4
32	2	18.1	—	12.3	13.7	15.1	16.5	17.8	19.2	20.6
37	3	15.1	—	12.4	13.8	15.2	16.6	18.0	19.4	20.8
48	4	16.0	—	12.6	14.1	15.5	17.0	18.4	19.9	21.4
50	4	25.4	—	12.6	14.1	15.6	17.1	18.5	20.0	21.5
52	4	16.1	—	12.6	14.1	15.6	17.2	18.6	20.1	21.6
58	4	15.6	—	12.6	14.2	15.8	17.3	18.9	20.5	22.1
62	5	16.5	25							
65	5	14.2	<5							

[a]Mid-upper arm circumference; same as upper arm circumference, relaxed.[27] [b]Reference data from Annex 3 in WHO Expert Committee.[30] Data provided only for infants and children aged 6–60 months (see footnote below). [c]For children >60 months of age, MUAC-for-age (in years) values are referenced to NHANES I and II percentiles (NH%).[30] NCHS/WHO, National Center for Health Services/World Health Organization; NHANES I and II, National health and nutrition examination survey. —, data not reported.

energy intake during pregnancy can result in inadequate weight gain, a risk factor for low birthweight.[34]

The small sample sizes and use of only one 24-hour recall limits our ability to quantify usual energy intake for these groups. A further limitation is the under-reporting which can result from either deliberate falsification or measurement errors inherent in dietary assessment. These problems have been reported in children of both genders[37] and in heavier, less well-educated, Euro-American women.[38] Dietary results expressed as a percentage of energy intakes are not affected by underreporting but both absolute and energy density values can be affected.[39] Estimates of the energy costs of pregnancy and changes in energy expenditure vary. Currently the most reliable indicator of energy adequacy during pregnancy is weight gain, which is associated with low rates of low birthweight, small for gestational age and preterm delivery outcomes.[40]

Energy distribution for both sets of participants in the present study generally falls within dietary guidelines.[20] This distribution is only slightly different from that previously reported for a population sample of adults from three areas of Palau, 56–63%, 16–18%, and 18–27% of energy from carbohydrate, protein and fat, respectively.[12] The favourable[41] lipid profile is due to the prominence of fish and coconut in the diet (Table 4). The relatively low saturated fat content is similar to the amount reported previously in a Palauan sample, 6.4–14.7% of energy.[12] For the children, the saturated fat intake is higher than for adults. This difference appears to be due to differences in milk consumption between the groups.

Nutrient adequacy is evaluated by combining results from different measures of sufficiency. The INQ score represents a measure of nutrient density.[21] The RDA is a recommendation that is intended to meet the needs of practically all healthy people which includes a safety factor and exceeds the actual requirements of most individuals.[19] For some nutrients, the actual amount of intake is most related to good health. Comparing the three measures of protein intake, we conclude that for most participants protein intake is adequate, especially if energy needs are met. The needs for certain micronutrients, including folate and iron, increase during pregnancy and are included in the prenatal supplements that most of the women reported taking. Some nutrient estimates, including iron, zinc, vitamin A and vitamin E, by their nature are skewed because food and nutrient intake varies from day to day.[42] This fact, coupled with the small sample size, preclude a definitive estimation of nutrient intake. However, analysis of the diets reveals potential inadequacies for calcium and zinc both for women and for children and for folate for those women consuming insufficient energy.

Discussion of the actual health effects of low dietary calcium is problematic in this population. Bone density is not measured on Palau at this time (VM Yano, pers. comm. 1998). The traditional island diet as described by Coyne[6] was probably adequate in most vitamins and minerals, including calcium. Taro, breadfruit, sweet potatoes, fish with bones (a rich calcium source) and coconut water (a fair calcium source) were widely consumed. Most historical reports describe the islanders of the region as being in good general health, with few, if any, obvious signs of calcium-poor diets such as stunting, poor teeth or conditions such as rickets.[6] In the present study, the contribution of traditional starches, vegetables and fish to the calcium content of the diet was much greater for women than for the children. Very few women (8%) and children (5%) reported drinking coconut water. Approximately one-quarter of the women may have obtained additional calcium from mastication of bones.

The women's low level of calcium is consistent with the low values (365–490 mg) reported previously for adult Palauans,[12] but the median INQ for this mineral is less than half that reported for culturally diverse groups of pregnant women in the US[43] and on average 300 mg/day less than other pregnant Pacific Islander women in Wellington.[36] Calcium intake plays a role in many diseases including pregnancy-induced hypertension and osteoporosis.[40] Morbidity rates for hypertension in pregnancy on Palau were 4.2% in 1998, but the data does not distinguish between pregnancy-induced hypertension and long-standing hypertension. Consuming adequate calcium is important although many factors affect calcium status[44] and the dose and benefits of dietary calcium and supplemental calcium are yet to be clarified in pregnancy.[36]

The median INQ for zinc in this adult sample is much lower than the INQ of other pregnant women[43] and 1 mg/day lower than for pregnant Pacific Islander women.[36] A mild zinc deficiency in pregnancy is associated with increased maternal morbidity, abnormal taste sensation, prolonged gestation, inefficient labour, atonic bleeding and increased risks to the fetus.[45] Zinc deficiency is also associated with poor growth in children.[46] While low protein intake specifically and low energy intake generally have been associated with stunting in some populations, insufficient calcium and zinc intake could certainly contribute to this also. The calcium and zinc status both of the women and of the children requires further investigation.

Folate intake from food sources does not meet the amounts recommended for women of child-bearing age. Folic acid is essential for closure of the neural tube during early stages of fetal development, and inadequate intake in the first trimester is associated with neural tube birth defects, particularly defects in neural tube closure.[47,48] Although folate is included in the prenatal vitamin and mineral supplement all of the women were taking, the data suggesting low intake of folate in this sample generally raise concerns about adequate intake before women begin prenatal supplementation.

A variety of foods are consumed by this sample, yet the benefit of eating unprocessed and traditional foods is evident. For example, while fresh meats contributed approximately twice the protein as canned meats for women, the canned meats contributed a nearly equal amount of fat and considerably more sodium. The children receive many of the important micronutrients from fortified grain products and milk, while the adults gain micronutrients primarily from fruits, vegetables and traditional starches, or *ongraol*, that provide more fibre as well. Dietary recommendations based on the results of this study include ensuring adequate energy intake and choosing foods that supply calcium and zinc such as fish, seafood, vegetables, milk and tofu.

Women's body constitution

For the small subset of adult participants with recorded pre-pregnancy weights ($n = 12$), two had BMI values in the obese and one in the low range. The present BMI mean is greater than the 50th less than the 75th NHANES percentile values but does not indicate excessive body mass. Mean triceps skinfold thickness approximates the 50th percentile, while estimated AMA approximates the NHANES 75th percentile and the frame size proxy, elbow breadth approximates the NHANES 50th percentile (Table 5). Thus, the relatively higher mean BMI generally owes in part to a greater degree of muscularity, not adiposity or bone mass, compared with the US standard. While BMI findings are not problematic for the group, the same cannot be said of estimates of percentage body fat indicate a different result. Using cut-off points for BCA-estimated body fat that relate to adult female morbidity and mortality, across populations, 5/26 (19%) women had measurements out of the normal range, four with high and one with a low total body fat.

The over- and under-fat cases are causes for concern, as such energy imbalance indicators belie problems of maternal nutrition and/or metabolic dysfunction, which can be expected to impact on pregnancy outcome for both mother and neonate. Pre-pregnancy BMI influences maternal risk to under- or over-gain during pregnancy.[49] Maternal obesity is associated with increased chances of developing pre-eclampsia, a pregnancy syndrome characterized by hypertension, oedema and elevated serum protein that can progress to eclampsia, with the risk of seizures and even death.[50] Primarily a disease of young primagravidas, pre-eclampsia is a major cause of maternal and fetal morbidity and mortality.[51] Pacific Island populations are known to have high rates of this disorder.[52]

Ten of the 27 women (37%) who were anthropometrically assessed had abnormal glucose metabolism indicated in their medical history and prenatal screening files. Four were diagnosed with 'probable' or frank gestational diabetes, three with elevated fasting blood glucose and three with 'diabetes'. This subset includes three of the four individuals with > 30% estimated total body fat, and three additional individuals with body fat percentages > 29 < 30%. Diabetic pregnancy, regardless of class, and even moderate elevations in maternal blood glucose levels, places developing fetuses at increased risk of macrosomia and excessive adiposity.[53–57] The creation of abnormal fat stores in the developing fetus not only leads to difficult labour and birth injury, but also may predispose the infant to lifelong obesity.[56]

Two of 27 women (7%) in the present study had indicators of energy storage deficits, namely one with a BMI of 17.7 and another with 19.0% body fat. Two recent studies have indicated that constitutional low weight (that is, pre-pregnancy BMI of < 20) is not a predictor of complications during delivery nor of poor neonatal outcome, as measured by pre-term births, perinatal and childhood deaths up to 4 years of age, low birthweight (< 2500 g), and smallness for gestational age.[58,59] However, lower prepregnancy BMI is consistently associated with lower infant birthweights,[60,61] most probably in cohorts where low BMI reflects a deficit in energy (fat) reserves.

Compared to the three subsamples of adult Palauan women measured in 1968 and 1970,[13] the present sample (Table 5) has the lowest BMI and generally lower subcutaneous fat at the triceps site, as well as lower estimated total body fat. Mean values for the 1968–70 Koror subsample were 26.4, 28.4 mm and 29.7% for BMI, triceps skinfold and estimated body fat percentage, respectively. For Peleliu and Ngarchelong, mean values were 27.0, 25.3 mm and 26.9%, and 27.2, 15.0 mm, and 17.8%, respectively. As Larbarthe *et al.* did not report sample size and standard deviations for these three cohorts, significance testing for temporal and geographical differences cannot be done.

Children's growth

The present study's cross-sectional child growth results are limited. Fifteen of 31 infants and children (48%) have W/A values under the NCHS/WHO 5th percentile, but only 3/23 (13%) of the children have W/H findings under the 5th percentile. This large discrepancy is partly related to growth stunting in these children (see below). Another indicator of nutritional status, MUAC-for-age, presents an intermediate group profile, with 4/22 (18%) having values below the NCHS/WHO 5th percentile. Thus, anthropometric indicators of 'wasting' range from 13% to 48%, using a seemingly conservative cut-off point for defining serious body mass and soft tissue deficits. Using the same threshold for defining growth 'stunting' (H/A), 6/23 (26%) of the infants and children were under the 5th percentile reference data value. Notwithstanding the above indicator discrepancies, present results are cause for public health concern when considered together. Undernutrition in early life is associated with a variety of health problems in later life, including hypertension, stroke, coronary heart disease, impaired glucose tolerance, excessive abdominal fat and high total cholesterol.[62] Additionally, undernutrition during early life has a lasting adverse effect on central nervous system development and, correspondingly, neuropsychological functioning. Impaired learning ability and manual dexterity are the most obvious neurological consequences of such nutritional deprivation.[63]

The discordance of the weight-for-age versus weight-for-height results probably points to an inherent weakness of the latter 'age free' index (W/H ratio). Cole[29] has recommended the use of a relative W/H ratio, where age is taken into account. The advantage of controlling for age is revealed by scrutiny of Table 6, where all of the W/H 'anomalies' (high NCHS/WHO percentiles in individuals with W/A and H/A values indicating wastage) occur among the infants aged 1 and 2 years. As a result of this interpretive weakness of the W/H ratio, we consider the W/A, MUAC and H/A results to be more meaningful indicators of nutritional status.

The high proportion of infants and children in this small sample with problematic W/A (48%), MUAC (18%), and H/A (26%) deficits probably reflect a combination of social, cultural and genetic factors. Socioeconomic circumstances must be considered as a determining factor, as most Palauan families are not affluent. Cultural practices such as the chewing of betel nut during pregnancy, discussed below, could influence fetal development. Sex differentials in the proportion of individuals below the 5th NCHS/WHO percentile for weight-, height- and MUAC-for-age are striking at 67 *vs.* 31%, 40 *vs.* 15%, and 27 *vs.* 9% for female and male children, respectively. Small sample size prevents these differentials from reaching a statistically significant level. It is not known whether these differences can be explained by differences in feeding practices or food access for male versus female children in this population.

The anthropometric deficits in a significant minority of the young children seem to relate to Palau's high proportion of low birthweight infants and high rates of fetal and neonatal deaths. The neonatal death rate, in recent years, has ranged from 8.6 per 1000 live births in 1991 to 21.3 in 1994. Palau's fetal death rate has ranged from 69.5 to 106.9/1000 live births, from 1989 to 1993. The mean Palauan birthweight recorded for 1994 was 2975 g, with distribution of weights skewed to the left (lower weights), in comparison with US babies.[64] Recently reported mean birthweights for 25 global samples[65] range from a high of 3436 g (Ireland) to a low of 2760 g (Nepal, urban). The 1994 Palau mean birthweight approximates the 17th ranked (tie) value for Malawi and Vietnam (see below). No Pacific Islander population was included in the above WHO review, but island and mainland South-East Asian mean birthweights cluster on both sides of the Palau mean, namely Indonesia (2936 g), Myanmar (2852 g), Thailand (3004 g), and Vietnam (2977 g).

Of eight infant deaths recorded in Palau in 1994, five had very low (< 1501 g) or low (> 1500 < 2500 g) birth weights.[64] While the relatively low mean birthweight and, to some extent, high proportions of (at least) low birthweight babies surely has genetic foundations, excessive fetal and neonatal mortality suggests pathophysiological consequences of underdevelopment, in at least some of the underweight babies. This leads one to question the extent to which the generally small body size of the young children has its origins in less than optimal intrauterine environments.[66]

A factor to be considered here, is the chewing of betel nut during pregnancy. In Palau, a strong association (odds ratio of 4.14) has been reported between betel nut chewing (with tobacco) and low birthweight.[64] Low birthweight associations with betel chewing have also been reported for women in Papua New Guinea,[67] where tobacco is not added to the betel quid of areca nut, betel vine and lime.[68] Fetotoxic effects of betel nut preparations, including reduction of average bodyweight and stunted skeletal growth, have been demonstrated in experimental studies of mice and rats.[69,70] Certainly this matter deserves further study, as 17/24 (71%) of the pregnant women in the present sample indicated that they chewed betel nut with tobacco. This is a similar proportion to that reported for female use (79.8%), in a recent large-scale (n = 573) survey of betel nut chewing in Palau.[71]

Conclusions

Although limited in interpretive power applicability by small sample size and the restrictions inherent in a single dietary assessment, the results of this study raise several issues deserving further exploration. Further quantification is needed of the apparent low dietary intake of energy, calcium and zinc both in pregnant women and in young children with exploration of potential effects on health and learning. This low intake is especially noteworthy, as public health professionals in Palau have been of the opinion that the main problem is overconsumption. A significant minority of the pregnant women had anthropometric indicators of excessive adiposity or energy storage deficit. Furthermore, a large majority of them chewed betel nut with tobacco during their pregnancies. Additionally, there was a significant number of young children especially females, who exhibited growth inadequacies by anthropometric assessment, and the underlying causes of this finding remain unclear. A subsequent paper on pregnancy outcomes may add to our understanding of these apparent early-life growth deficits.

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