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Original Research Article

Diet, Energy Expenditure, and Body Composition of Lactating *Ribeirinha* Women in the Brazilian Amazon

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ABSTRACT Lactation is the most energetically demanding part of human reproduction; yet, compared with pregnancy, we know little about the strategies women in different settings employ to cope with these increased energy demands. This paper takes a biocultural approach and reports longitudinal data on the anthropometry, dietary intakes and energy expenditure of a sample of 23 rural, lactating *Ribeirinha* women living in subsistence-based communities in the eastern Amazon. The dietary intakes of these lactating women were insufficient to meet their lactating energy needs and were least sufficient during *resguardo*, a 40-day period in the immediate postpartum when the women observed a series of food taboos and work restrictions. Instead, the women in this study met the increased energy demands of lactation by drawing on their energy reserves and reducing their energy expenditure in physical activity. The women showed a significant reduction in weight ($P < 0.001$), BMI ($P < 0.001$) and in circumferences (hip, $P = 0.01$; waist, $P = 0.03$) and skinfolds (thigh, $P = 0.03$) in the gluteal femoral region. Total daily energy expenditure (TDEE) was lowest during *resguardo* and increased as lactation progressed ($P = 0.01$). While the practice of *resguardo* reduced maternal energy expenditure and allowed women more time to spend with their newborn infants, it came at a cost (low dietary intake), which appears to be related to the loss of the adult woman from subsistence activities. By taking a biocultural approach this study illustrates the role the social environment plays in shaping the experience of lactating women. Am. J. Hum. Biol. 19:722–734, 2007.

Lactation is the most energy-demanding phase of human reproduction, increasing maternal energy needs by 25–30% (500–750 kcal/day) (Dewey, 1997). How women in different physical and social environments cope with these increased energy demands is not well understood. Theoretically, women can meet the energy demands of lactation by increasing their dietary energy intake, decreasing their energy expenditure or drawing on their energy reserves (primarily body fat). Therefore, in order to understand the strategies lactating women utilize, it is necessary to consider all aspects of the energy balance equation (energy intake − energy expenditure ± changes in body stores = energy balance).

However, relatively few studies have actually addressed all parts of the energy balance equation. Of those that have, most are focused on women in developed countries (Brewer et al., 1989; Butte et al., 1999; Forsum et al., 1992; Goldberg et al., 1991; Sadurskis et al., 1988; van Raaij et al., 1991) or among women in urban settings in developing nations (Dufour et al., 2002; Madhavapeddi and Roa, 1992; Piers et al., 1995). Generally, these studies have shown that women in urban and (or) more affluent conditions tend to meet their additional energy needs by increasing their dietary energy intakes.

One of the few studies that has focused on rural women in subsistence-based economies,

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where the options available to lactating women can be more restricted than in urban environments and/or more affluent settings, also showed an increase in energy intake as a major strategy for meeting the energy demands of lactation (Guillermo-Tuazon et al., 1992). Two others, a study of poor rural women in Guatemala (Schutz et al., 1980) and one among tea pluckers in Bangladesh (Vinoy et al., 2000), found that the women relied upon their fat stores rather than increasing their energy intake. The third potential strategy, a reduction in physical activity, has not been demonstrated in any of the studies that considered all aspects of energy balance, but has been reported in studies with a more limited focus: the early postpartum period among Gambian women (Roberts et al., 1982) and the non-monsoon season among Nepalese women (Panter-Brick, 1993).

Although the studies of Gambian (Prentice et al., 1981; Roberts et al., 1982; Thomson et al., 1966) and Nepalese women farmers (Panter-Brick, 1989, 1993) did not consider all aspects of energy balance simultaneously, they provide the most complete data on the energetics of lactation among rural women in subsistence economies. However, a major problem in interpreting some of these data has been the marked seasonality in food availability and workloads found in both locations (Lawrence et al., 1987; Panter-Brick, 1993; Thomson et al., 1966).

This paper reports longitudinal data on the energetics (dietary intake, energy expenditure and body composition) of lactating *Ribeirinha* (mixed Indigenous/Portuguese/African ethnicity) women living in rural communities in the eastern Amazon who practice subsistence-based agriculture. The goal is to further our understanding of the strategies rural women in subsistence-based economies use in meeting the energy demands of lactation. By conducting this study among *Ribeirinha* women who do not live in a highly seasonal environment or depend on a seasonally available staple crop, we felt that the confounding variables associated with seasonality encountered in The Gambia and in Nepal could be avoided. Finally, this paper takes a biocultural approach, placing the energetics data in perspective by considering the interplay of cultural practices and subsistence patterns on maternal strategies. Based on what we know from the literature on the energetics of lactation among other populations and the living conditions of *Ribeirinha* women, we hypothesized that: (1) lactating women would draw on their body fat reserves, especially those in the gluteal/femoral region, to meet the extra energy demands of lactation, (2) dietary intake would be insufficient to meet energy demands and (3) during the early stages of lactation these women would be closest to energy balance due to the cultural practice of *resguardo*, a 40-day period when women in this region observe food taboos and work restrictions. During *resguardo* women practiced a type of seclusion. They remained mostly indoors and did not conduct any physically demanding tasks. Other family members and local midwives provided assistance with housework and childcare. The women's diets were also carefully monitored by family, especially older women, and while they did avoid taboo foods, they were expected to be well fed and not to experience hunger.

METHODS

Background and subjects

The women included in this study self-identified as *Ribeirinhas* and lived in seven, upper-land (*terra firme*) communities located in and around the Caxiuanã National Forest in the Brazilian State of Pará. The communities were rural, located ~8–10 h by boat from the nearest town, Portel, and two days by boat from Belém, the state capital. Houses sat on stilts, were made of wood and covered with one of three materials, palm fronds, ceramic tile or an industrialized, fire retardant material referred to as *Brasilite*. None had electricity or running water; water for cooking was collected from the river or, in a few cases, from hand-dug wells. A few households had pit toilets, but the majority used the forest and river for waste disposal. Trash was burned, buried or dumped in the river.

Ecologically the region is classified as humid tropics (Am in the Köppen system (Lisboa, 2002) and considered part of a black-water river system, although there was variability in water pH and clarity due to the influence of the Caxiuanã Bay (Costa et al., 2002). Rainfall averaged about 2,060 mm per year, and temperature averaged about 26.7°C. Two seasons are distinguished by rainfall: a wet season (*inverno* or winter, January through May) during which over 70% of all precipitation occurs and a dry season (*verão* or summer, June through November). Average monthly temperature varies less than 2°C seasonally.

All the people practiced slash and burn agriculture with bitter manioc (*Manihot esculenta*

Crantz) as their staple crop. Manioc was consumed primarily in the form of *farinha*, a toasted meal, and was the most important source of calories and carbohydrates in the diet (Murrieta and Dufour, 2004; Piperata, 2005). Fish, and to a lesser extent hunted game, were the most important sources of protein, and *açai* (*Euterpe oleracea*), a local palm fruit consumed primarily in the form of a juice, was an important source of calories and fat (Piperata, 2005). Seasonal variation in rainfall did not affect the availability of *farinha*, fish or game meat in the diet. *Açai*, is a seasonal fruit most commonly consumed between May and November (Melo Valente, 2002). However, people actively managed their *açai* groves and had extended the fruiting season from March to November. Work associated with the cultivation, harvest and processing of manioc was shared between men and women and often included the help of older children. Most households had two to three manioc gardens with staggered ages to ensure a constant supply of the root crop. Fishing and hunting, as well as the collection of *açai* were primarily male activities. However, it was the women who prepared the fish and wild game and extracted the *açai* juice. All household chores (cooking, washing, childcare) were the responsibility of females.

This population of *Ribeirinhos* recognizes the first 40 days postpartum as a special period and refers to it as *resguardo.* During *resguardo*, women are seen as being in a fragile state and therefore need to observe a number of food taboos and activity restrictions. Generally, fatty foods, such as some species of fish and fruits, acidic fruits, and foods that are the color red are avoided. Women also avoid all forms of strenuous activity including working in their manioc gardens, processing manioc into *farinha* and processing *açai*. In addition they avoid entering the forest and river, as these locations are considered dangerous and, consequently, spend most of their time inside their homes. During *resguardo* it is common for adult relatives such as the mother, mother-in-law and (or) husband to assist women with household chores and the care of other children. These cultural practices have the potential of altering maternal energetics in the early postpartum period and were therefore of interest in this study.

Women were recruited for the study during the latter stages of pregnancy. All pregnant women (2nd to 3rd trimester) living within a one-hour radius of the Estação Científica Ferreira Penna (ECFPn) (Ferreira Penna Scientific Station), located in the Caxiuanã National Forest, were invited to join the study. Participation was voluntary. Both the individual women and their communities were compensated for participation. Individual women received small gifts (pressure cookers, glassware, dishes, fishing nets) and communities received assistance with the installation of manual pumps for their hand-dug water wells. The research protocol was approved by the University of Colorado's Human Research Committee (HRC no. 1001.2) and the Comite de Ética at the University of São Paulo in Brazil.

Study design

The study was longitudinal and followed a group of 23 women from early lactation through ~15 months postpartum. Anthropometric measurements and data on dietary intake, energy expenditure and activity patterns were collected during each of three measurement rounds. The first measurement round occurred during *resguardo* (22.5 ± 11.4 days postpartum). The second measurement round was between 2 and 4 months postpartum, a period often referred to as peak lactation (10.5 ± 1.7 weeks). This time period was chosen because it has been suggested that during this stage the infant places the greatest energetic burden on the mother due to intense and prolonged breastfeeding bouts (Prentice et al., 1996). At this stage, most women had not yet begun to supplement their infants. Supplementation typically began when the infant was about 6 months of age. The third measurement round, late lactation, was at 14–16 months postpartum (15.1 ± 0.8 months), which was close to the average time women in these communities weaned their infants (14.2 months) (Piperata, 2005). None of the women reported being pregnant at the time of the third measurement round. For each of the 3 days in each measurement round the researcher arrived in the woman's home between 7:30 and 8:00 am and left after dinner, sometime between 5:30 and 6:30 pm, and remained in visual contact with the women over the entire period of time.

Anthropometry

Anthropometric measurements on each woman were collected on the first day of each round and followed standardized procedures (Lohman et al., 1988). Height and sitting

height were measured to the nearest 0.1 cm using a Seca portable stadiometer (road-rod model), and weight to the nearest 0.5 kg using a Taylor spring balance. Skinfolds (triceps, biceps, subscapular, suprailiac and thigh) were measured to the nearest 0.5 mm using a Lange caliper. Circumferences (mid-upper arm, waist, hip, thigh) were measured to the nearest 0.1 cm using a flexible tape measure. Skinfolds were collected in triplicate and circumferences in duplicate and average values were used in all analyses. Women were barefoot and lightly clothed (t-shirt or tank top and knee-length skirt) when they were measured. For the skinfolds and circumferences, clothing was removed from the location of the measurement site.

The above measures were used to calculate other anthropometric indices. Percentage body fat was calculated using the Durnin and Womersley (1974) equations for four skinfolds (triceps, biceps, subscapular, and suprailiac). Upper-arm muscle areas (UMA) was calculated using the equation (Circumference $-$ ($\pi \times$ triceps skinfold (cm^2)/12.57) (Frisancho, 1990). The upper-arm fat area (UFA) was defined as the difference between the total upper arm area and the upper arm muscle area ($C^2/(4\pi) -$ UMA) (Frisancho, 1990).

Dietary intake

Maternal dietary intake was measured by the weighed-inventory method (Gibson, 1990) for 3 consecutive days in each measurement round. This involved weighing all food served to the subject, and at the end of the meal weighing all uneaten foods (typically bones, rinds and seeds) and subtracting them from the weight of food served. Qualitative data (i.e. species of fish, part of fish, species of fruit) on the women's diets were collected at the same time the foods were weighed.

The daily energy and nutrient consumption of each woman was calculated using Nutribase IV Clinical Nutrition Manager version 4.71. Many of the local foods were not included in the software program and their nutritional composition was taken from one of three additional sources (FAO, 2005; Franco, 2003; or nutritional analyses performed by Multianalysis Lab, Belém) and entered into the software program. In addition, for composite dishes cooked while the researcher was in the home, the entire recipe was recorded, the energy and nutrient composition for the entire dish calculated and the portion consumed by the subject weighed. On occasions when composite dishes were prepared either outside of the home or prior to the arrival of the researcher, an estimated recipe was collected based on the recall of the person who prepared the dish and/or the researcher's direct observation of the completed dish. Due the rural nature of the field site, packaged foods were rare. When packaged foods were consumed, nutritional information was taken from the packaging label or estimated from the Brazilian food composition table (Franco, 2003). On those instances where the women ate or drank prior to the arrival of the researcher or after the researcher had left in the evenings, the data recorded were based upon the woman's recall of what she had consumed.

Adequacy of dietary energy intake was based on each woman's total daily energy expenditure (TDEE) estimated using the factorial method (see activity diary method below) plus the additional cost of lactation. The latter was based on theoretical estimates of the energy cost of milk production: an additional 480 kcal in *resguardo* and peak lactation when women were breastfeeding exclusively, and an additional 285 kcal in late lactation when all women were giving their infants supplementary foods (Prentice et al., 1996). Adequacy of dietary protein intake was determined by comparing each individual woman's average protein intake in each measurement round to the FAO/WHO/UNU (1985) recommendations for women at the appropriate stage of lactation.

Energy expenditure and activity patterns

Continuous activity diaries were recorded during the same three consecutive days as the dietary intake in each of the three measurement rounds in order to calculate energy expenditure and document maternal activity patterns over the course of lactation. The activity diaries included time, body position (lying, sitting, standing, milling about ($<$2.0 mph), walking slowly (2.5 mph), walking at a moderate pace (3.0 mph) and walking at a fast pace ($\geq$3.5 mph)) and the primary and, when relevant secondary, and tertiary activities of the women. Data collection began in the morning upon the researcher's arrival in the home ($\sim$7:30 am) and continued until after the evening meal and the onset of dusk when the women had completed the majority of their household tasks. Upon arrival in the household, a brief interview was conducted to note

any significant activities that might have been missed earlier that morning. On occasions where the researcher was returning to the home during the consecutive-day visits, data were also collected on any significant activities the woman had participated in after the researcher left the house the previous day.

Total daily energy expenditure (TDEE) was calculated using the factorial method (Durnin and Passmore, 1967) as the sum of energy expended in all activities in a 24-h period. The energy expenditure values for the different activities were taken from four sources: Ainsworth et al. (1993), Dufour (1984), FAO/WHO/UNU (1985), and James and Schofield (1990). Energy expenditure during all sleeping hours was calculated as the basal metabolic rate (BMR) of the individual women as per the recommendation of James and Schofield (1990). The BMR of each woman in each measurement round was estimated using the equations of Henry and Rees (1991) for tropical populations. Energy expenditure in the morning hours, prior to the researcher's arrival, was calculated based on the mean value of the first hour of the observed period for all days of observation in that measurement round. Energy expenditure in the early evening hours, the time between the researcher's departure and the late evening hours, was calculated as the mean energy expenditure of the woman during the last hour of observation for all days in that measurement round. Late evening (7:30 to 9:00 pm) energy expenditure was calculated as 1.2 times the BMR for each individual woman since it was dark by 7:30 pm and most people were sitting or lying around inside their homes conversing or doing minor household activities. According to James and Schofield (1990), a physical activity ratio (PAR) of 1.2 is a reasonable estimate of energy expenditure for a person conducting a range of activities such as sitting or standing quietly, conducting laboratory work, or eating. Most people were asleep or at least lying in their hammocks by 9:00 pm.

The amount of time women dedicated to different types of culturally defined activities in the different measurement rounds was taken from the activity diaries. A total of 96 different activities were recorded (Piperata, 2005). For the analysis here these 96 activities have been grouped into twelve broader categories (resting, breastfeeding, infant care, care of another child, personal care, food preparation, all other housework, agricultural work, manioc processing, *açai* processing, fishing, and miscellaneous). The amount of time a woman spent in a specific type of activity was calculated and converted to a percentage of the total observed time in order to control for the fact that the total observation period varied by woman and day. These values were then used to compare activity patterns within the same woman over time, as well as between individual women.

Data analysis

Descriptive statistics including the mean and standard deviation were used to describe the anthropometric characteristics (weight, height, skinfolds, and circumferences), dietary intake (energy, carbohydrate, protein, and fat) and TDEE of the women in each measurement round. In addition, the anthropometric characteristics of the lactating women were compared with USA reference values (Frisancho, 1990) in order to gain a better sense of the nutritional status of these lactating women.

In order to identify significant changes in anthropometry, dietary intake and energy expenditure over the three measurement rounds (time), a general linear model (GLM) for repeat measures was used. When the GLM was significant in the time dimension, it was followed by the Bonferroni post-hoc test in order to identify when in time the significant change took place (i.e. between *resguardo* and peak lactation, peak lactation and late lactation or *resguardo* and peak lactation). Finally, the coefficient of variation (CV) was used to describe inter-subject variation in dietary intake and energy expenditure. Statistical significance was defined as alpha ≤ 0.05 and was used for all analysis. SPSS version 13.0 was used for all statistical analyses.

RESULTS

Anthropometry

Table 1 summarizes the anthropometric characteristics of all the women in each of the three measurement rounds, and when available, compares their measurements with the National Center for Health Statistics (NCHS) reference values (Frisancho, 1990). Overall, the women in this study were short, with an average stature below the NCHS 5th percentile. Average BMI values fell on the 50th percentile indicating that while stunted these women were not underweight. In terms of overall percent body fat, these women fall into the 25th percentile. However, when specific fat depots are considered, differences in body

*TABLE 1. Anthropometric characteristics of lactating women (*n = 23*) over the course of lactation*

Variable	*Resguardo*, mean ± SD	Peak, mean ± SD	Late, mean ± SD	GLM, time	Comparison with reference, percentile
Time (weeks postpartum)	2.4 ± 1.6	10.5 ± 1.7	15.1 ± 0.8	–	–
Age (years)	27.0 ± 9.6	–	–	–	–
Height (cm)	149.6 ± 3.4	149.9 ± 3.2	150.1 ± 3.4	$F = 8.8$; p = 0.01	
Weight (kg)	50.5 ± 7.4	49.7 ± 7.8	47.6 ± 7.3	$F = 24.8$; $P < 0.001$	10th
BMI (kg/m^2)	22.6 ± 3.2	22.2 ± 3.5	21.1 ± 3.3	$F = 69.7$; $P < 0.001$	25–50th
Skinfolds (mm)					
Biceps	5.3 ± 2.2	4.8 ± 2.1	4.9 ± 2.4	n.s.	–
Triceps	10.3 ± 3.9	11.2 ± 4.7	11.6 ± 4.5	$F = 4.6$; $P = 0.05$	5–10th
Subscapular	12.2 ± 5.0	11.6 ± 5.2	12.1 ± 6.1	n.s.	25–50th
Suprailiac	17.8 ± 6.2	16.0 ± 5.7	16.1 ± 7.1	n.s.	–
Thigh	13.1 ± 3.4	13.6 ± 3.6	11.9 ± 3.9	$F = 5.9$; $P = 0.03$	–
Circumferences (cm)					
Mid-upper arm	24.9 ± 3.0	25.0 ± 3.2	25.4 ± 3.5	$F = 4.7$; $P = 0.05$	25th
Waist	77.3 ± 6.5	76.4 ± 7.3	75.8 ± 7.5	$F = 5.6$; $P = 0.03$	–
Hip	90.7 ± 6.3	89.4 ± 6.6	89.0 ± 7.2	$F = 10.6$; $P = 0.01$	–
Thigh	43.3 ± 4.4	44.1 ± 4.2	43.4 ± 4.1	n.s.	–
% Body fat	25.7 ± 5.6	25.0 ± 5.6	25.1 ± 6.2	n.s.	25th
UMA (cm^2)	37.6 ± 7.4	37.1 ± 7.6	38.0 ± 7.7	n.s.	85th
UFA (cm^2)	12.4 ± 5.7	13.4 ± 6.8	14.2 ± 7.0	$F = 6.5$; $P = 0.02$	5–10th

Reference is NCHS percentile (Frisancho, 1990).
BMI, body mass index; UMA, upper-arm muscle area; UFA, upper-arm fat area.

fat patterning between these women and USA women emerge. For example, the average triceps skinfold, a peripheral fat depot, for these women falls between the 5th and 10th percentiles while the average subscapular skinfold, a centralized depot, falls between the 25th and 50th percentiles. Average values for the upper-arm muscle area fell on the 85th percentile, indicating that these women were more muscular, at least in the upper body, than US women.

The women showed significant changes in height, weight, BMI, triceps and thigh skinfolds, the waist, hip and mid-upper arm circumferences and the upper-arm fat area (UFA) over the course of lactation (Table 1). No significant changes were seen in the biceps, subscapular or suprailiac skinfolds, in the upper-arm muscle area (UMA) or in percentage body fat.

The average height of the women showed a slight (0.5 cm), but significant, increase over the course of lactation ($F = 8.8$, $P = 0.01$). The subjects under 20 years of age ($n = 5$) showed a significant increase in stature with time ($F = 7.4$, $P = 0.04$) while no significant change in height was seen among women over 20 years of age ($F = 1.8$, $P = 0.21$). The women showed a significant loss in weight ($F = 24.8$, $P < 0.001$), which averaged 3.3 ± 1.5 kg over the course of lactation and in BMI ($F = 69.6$, $P < 0.001$). There was, however, variation in weight loss between individual women, which ranged from 1.4 to 6.4 kg loss between *resguardo* and late lactation.

Generally, the women showed increases in skinfold thicknesses and circumferences in the upper-body and decreases in the gluteal-femoral region (Table 1). For example, the triceps skinfold increased over the course of lactation ($F = 4.6$, $P = 0.05$) as did the MUAC ($F = 4.7$, $P = 0.05$) and the UFA ($F = 6.5$, $P = 0.02$). The concurrent increase in MUAC and UFA and lack of significant change in UMA indicates an increase in fat deposition, not muscle mass, in the upper arm. The thigh skinfold ($F = 5.9$, $P = 0.03$), waist ($F = 5.6$, $P = 0.03$) and hip ($F = 10.6$, $P = 0.01$) circumferences, on the other hand, all showed a significant decline. While there was no significant decrease in the suprailiac skinfold for the group as a whole, a subgroup of 13 women showed a consistent decrease at this site which was statistically significant ($F = 11.1$, $P = 0.01$). Together, these data indicate that the weight loss was due primarily to losses from the lower portion of the body around the pelvic girdle.

Dietary intake

For all measurement rounds combined, the diets of these lactating women were 73% carbohydrate, 12% protein, and 15% fat. Manioc (and manioc-based products) was the most important source of energy (50%) followed by *açai* (14%), fish (10%), beans (5%), and rice

TABLE 2. Macronutrient and energy intake of lactating women (n = *23) over the course of lactation*

	Resguardo		Peak		Late		
	Mean ± SD	% intake	Mean ± SD	% intake	Mean ± SD	% intake	GLM, time
Carbohydrate (g)	239 ± 54	70	330 ± 114	75	332 ± 92	74	$F = 5.7$; $P = .01$
Protein (g)	51 ± 15	15	47 ± 13	11	46 ± 14	10	$F = 4.1$; $P = .05$
Fat (g)	24 ± 15	15	29 ± 16	14	34 ± 17	16	$F = 8.6$; $P = .01$
Total (kcal)	1385 ± 268	100	1760 ± 591	100	1812 ± 536	100	$F = 5.4$; $P = .03$

Significant differences in carbohydrate intake between *resguardo* and peak $P < 0.01$ and between *resguardo* late lactation $P < 0.01$; in protein intake between *resguardo* and peak $P = 0.04$ and between *resguardo* late lactation $P = 0.03$; in fat intake between *resguardo* and late lactation $P = 0.01$; in total (kcal) between *resguardo* and peak $P = 0.03$ and between *resguardo* late lactation $P = 0.03$.

(5%). Fish was the most important source of protein (47%), followed by hunted game (14%) and beans (10%). Manioc was also by far the greatest source of carbohydrates (66%) but, *açai* (13%), rice (5%) and sugared coffee (5%) also contributed to total carbohydrate intake. *Açai* and fish (and the soybean oil it was fried in) were the most important sources of fat in the diet accounting for 29% and 27% of total fat intake, respectively. The general dietary pattern was altered only slightly during *resguardo* during which consumption of *açai* was only 3% of dietary energy as compared to the 14% of dietary energy in the other rounds.

Table 2 summarizes the average energy and macronutrient intake of the women by measurement round. There was a significant increase in daily energy intake over the course of lactation ($F = 5.4$, $P = 0.03$). The average energy intake for the women in *resguardo* (1385 ± 268 kcal) was significantly lower than at peak lactation (1760 ± 591 kcal) and in late lactation (1812 ± 536 kcal) ($t = 2.3$, $P = 0.03$; $t = 2.3$, $P = 0.03$, respectively). There was no significant difference in energy intake between peak and late lactation ($t = 0.2$, $P = 0.9$). Carbohydrate ($F = 7.1$, $P = 0.04$) and fat intakes ($F = 8.6$, $P = 0.01$) also showed a significant increase over time, with the lowest intakes in both nutrients occurring during *resguardo*. Protein intakes, on the other hand, were highest in *resguardo* and declined from *resguardo* to late lactation ($F = 4.1$; $P = 0.05$). Average protein intakes in the three rounds were 51 g, 47 g and 46 g per day, respectively.

Figure 1 compares the mean energy intakes of the women in each measurement round with their mean energy expenditure in that round, as well as to their mean energy expenditure with the additional, theoretical energy demands of lactation added (Prentice et al., 1996). For *resguardo*, peak lactation and late lactation dietary intakes provided 96, 99, and 102%, respectively, of estimated need based on TDEE. However, when the additional theoretical energy needs of lactation are considered, the women's dietary intakes fell short of their energy needs and provided only 72, 79, and 86% of their lactating energy needs in *resguardo*, peak and late lactation, respectively.

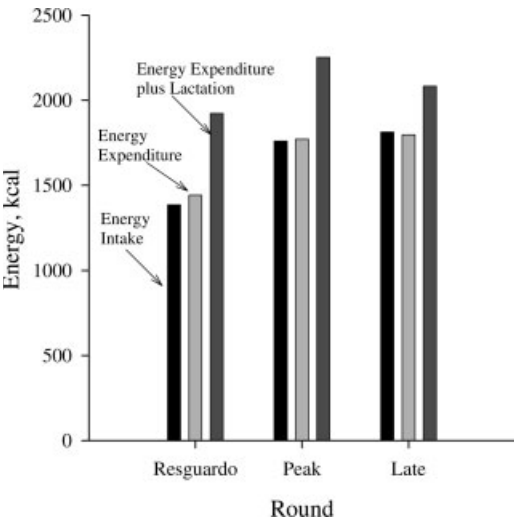

Fig. 1. Comparison of energy intake to energy expenditure and energy expenditure plus theoretical costs of lactation (additional 485 kcal in *resguardo* and peak, additional 285 kcal in late lactation) for lactating women ($n = 23$).

Figure 2 compares the average protein intakes in each measurement round with the estimated protein needs of non-pregnant, non-lactating (NPNL) women, and lactating women based on the FAO/WHO/UNU (1985) recommendations. Protein intake in all rounds exceeded requirements for NPNL women, and also exceeded or met the recommendations for lactating women during *resguardo* (51 g vs. 50 g) and late lactation (46 g vs. 46 g). However, aver-

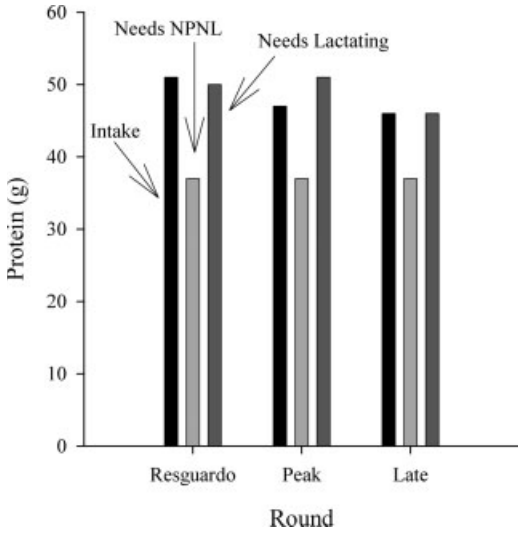

Fig. 2. Protein intake of lactating women ($n = 23$) compared with recommendations (FAO/WHO/UNU, 1985) for NPNL and lactating women.

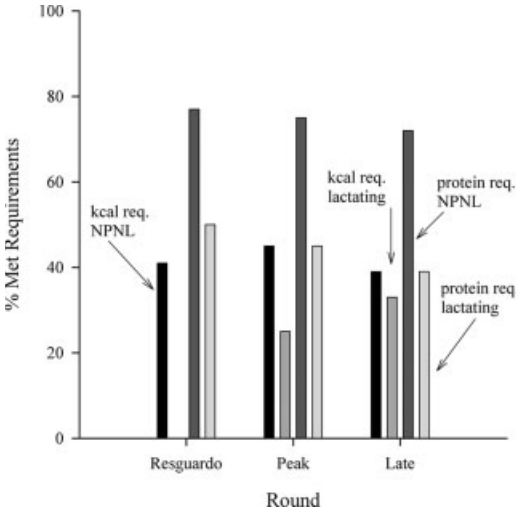

Fig. 3. Percent of women meeting the energy and protein needs of NPNL women and lactating women (note: 0% of women met lactating energy requirements in *resguardo*).

age intake fell short of the recommended intake during peak lactation (47 g vs. 51 g). While the average energy and protein intakes of these women provide information on how well their diets met their energy and protein needs during lactation, they obscure some of the variability in dietary intake among individual women. For example, in peak lactation, average energy intake ranged from 982 kcal to 3,204 kcal and average protein intake during late lactation ranged from 20 to 72 g. The least amount of variability in energy intake was seen in *resguardo*. The coefficient of variation (CV) for total energy intake in *resguardo* was 19% compared with 33% in peak lactation and 30% late lactation.

Figure 3 plots the percentage of women who met their energy and protein needs in the three measurement rounds. Overall, few women were able to meet the additional energy needs of lactation. In fact, during *resguardo* none of the women met these additional energy demands and only 25% and 33% were able to meet their lactating energy needs in peak and late lactation, respectively. More women were able to meet their protein needs. In *resguardo*, 77% of the women met NPNL protein requirements while 50% met the protein requirements of lactating women with the same average body size. In peak lactation 75% met the NPNL protein requirements and 45% met the additional requirements for a lactating woman. Finally, in late lactation, 72% of the women consumed enough protein to meet their NPNL requirements and 39% met the additional requirements imposed by lactation.

Energy expenditure and activity patterns

The average number of hours per day of observation with the individual women during the three measurement rounds was: *resguardo* (9.4 ± 0.5 h), peak (9.5 ± 0.7 h) and late lactation (9.6 ± 0.6 h).

The women showed a significant increase in TDEE as lactation progressed ($F = 29.7$, $P < 0.01$). Average TDEE during *resguardo* was 1,441.5 ± 172.5 kcal, this rose to 1,771.6 ± 178.4 kcal by peak lactation and was 1,798.9 ± 222.1 kcal in late lactation. There was a significant increase in energy expenditure between *resguardo* and peak lactation ($P < 0.01$) and between *resguardo* and late lactation ($P < 0.01$) but no difference in TDEE between peak and late lactation ($P = 0.6$).

The women also showed variability in energy expenditure, but somewhat less than in dietary intake. For example, during *resguardo* TDEE ranged from 1,032 to 1,755 kcal (1.0–1.4 PAL), during peak lactation the range was 1,413–2,138 kcal (1.3–1.8 PAL) and in late lactation ranged from 1,354 to 2,262 kcal (1.4–1.8 PAL). For the group as a whole, the CV for *resguardo*, peak and late lactation were 12, 10, and 12%, respectively.

TABLE 3. Percentage time by body position in resguardo, peak and late lactation during the observed period for lactating women (n = 23)[a]

	Resguardo (%)	Peak (%)	Late (%)
Laying	7.1	10.0	6.3
Sitting	49.0	43.8	42.9
Standing	15.0	21.6	27.0
Milling about	20.4	20.7	19.9
Walking slowly	1.7	3.8	3.6
Walking, moderate pace	0.1	0.1	0.4
Total time (hours)	100.0	100.0	100

[a]Values given are percent of total.

TABLE 4. Percentage time by activity category in resguardo, peak and late lactation during the observed period for lactating women (n = 23)

	% Time		
	Resguardo	Peak	Late
Resting	19.4	17.0	25.4
Infant care	27.1	22.5	14.1
Breastfeeding	15.3	12.0	7.2
Child care (other than infant)	3.1	1.9	1.9
Self care	5.8	5.3	5.3
Housework	19.1	20.9	21.4
Food preparation	9.4	9.4	8.0
Agricultural work	0.0	3.4	4.3
Manioc processing	0.0	5.1	9.7
Açai processing	0.1	1.0	1.4
Fishing	0.0	0.2	0.0
Miscellaneous	0.7	1.3	1.3
Total	100%	100%	100%

Changes in activity patterns

The women spent most of their time sitting regardless of measurement round (Table 3). In general, there was an increase in the percentage time spent standing, walking slowly and walking at a moderate pace as lactation progressed and hence the percentage time spent sitting decreased over the course of lactation as time in the standing postures increased. The percentage time spent laying actually increased between *resguardo* and peak lactation and declined in late lactation.

In terms of culturally defined activities (Table 4), the women spent most of their time in infant care, housework and resting, regardless of measurement round. There was a considerable decrease over the course of lactation in the amount of time women spent in infant care, as well as in breastfeeding. In *resguardo,* women spent 27% of their time in infant care, but this dropped to 14% by late lactation, a decrease of almost 50%. As expected, there was more than a 50% reduction in the amount of time the women spent breastfeeding between *resguardo* and late lactation.

There was a dramatic increase in the amount of time the women spent in agricultural work between *resguardo* and late lactation (0% vs. 4.3%). There was also a substantial increase in time women spent processing manioc as lactation progressed. Not a single woman was observed processing manioc in *resguardo,* however, by late lactation the group as a whole spent an average of 9.6% of their time in this activity. The time women spent in *açai* processing, showed a substantial increase from *resguardo* to late lactation (0.1% vs. 1.4%).

On the other hand, the time women spent in "self care," which included activities such as bathing and eating showed little change over time. There was a small (2.4%) increase in the amount of time women spent conducting housework and a decrease (1.2%) in the time women spent in food preparation over the course of lactation. Finally, the time women spent resting showed a decrease between *resguardo* and peak lactation followed by a substantial increase in late lactation.

DISCUSSION

In humans, lactation induces a substantial increase in energy needs (25–30%). However, compared with more rapidly growing mammals and those that give birth to litters, the relatively dilute nature of human milk (Ben Shaul, 1962) means that the cost of milk production per unit time is relatively low and therefore should allow for greater flexibility in how women can respond to the energy stress of lactation. While women may have more flexibility in how they respond, their options are constrained by their socioeconomic context, making the biocultural approach particularly useful for understanding maternal strategies (Stuart-Macadam and Dettwyler, 1995). Unfortunately, with the exception of the work of Panter-Brick (1993) and research from The Gambia (Prentice et al., 1981, 1996; Roberts et al., 1982; Thomson et al., 1966) few studies have provided this biocultural context in studies of lactational energetics.

The women in this study, as a group, met the additional energy demands of lactation by drawing on their body reserves and reducing their energy expenditure, especially during the early stages of lactation (*resguardo*) although, for some women this reduction lasted for much longer. This decrease in energy ex-

penditure was only possible because of the supportive nature of the social group.

Anthropometry

The women in this study lost an average of 3.3 kg between *resguardo* and late lactation (~15 month period) but total weight loss ranged between 1.4 kg and 6.4 kg indicating that all women were in negative energy balance during lactation. While differences in study design and data collection period make it difficult to directly compare these weight loss patterns to those of other lactating women, several other studies in rural, subsistence-based populations have noted the mobilization of energy stores as a maternal strategy (Butte et al., 1997; Guillermo-Tuazon et al., 1992; Schutz et al., 1980; Valeggia and Ellison, 2003). As the site-specific anthropometric measures indicate, the women mobilized fat stores from the lower portion of the body, specifically in the gluteal/femoral region (suprailiac and thigh skinfolds, hip circumference). This finding supports the first hypothesis which was based on laboratory studies indicating that while fat in the gluteal/femoral region is relatively metabolically inert during adolescence and early pregnancy, these same fat depots become more metabolically active during late pregnancy and lactation (Lindberg et al., 1991; Rebuffé-Scrive et al., 1985). Interestingly, the women also exhibited an increase in fat deposition in an upper body skinfold (triceps) during the course of lactation. Although few studies have reported data on changes at different skinfold sites over the course of lactation, an increase in the triceps skinfold was also seen among Australian (Dugdale and Eaton-Evans, 1989) and USA women (Brewer et al., 1989), despite weight loss at other sites.

Dietary intake

When the women's dietary intakes are compared to their NPNL energy needs, the energy and protein intakes appear sufficient. However, as a group, the women were unable to consume enough calories to meet the additional energy demands of lactation supporting the second hypothesis. In terms of protein, the average diet was sufficient or exceeded NPNL needs in all rounds, as well as lactating protein needs during both *resguardo* and late lactation.

Despite their low levels of physical activity during *resguardo* and the fact that all the women were cared for by relatives, they had their lowest dietary energy intakes and were in the most negative energy balance during this measurement round. This finding rejects the third hypothesis. On the other hand, protein intakes were highest during *resguardo*, an unexpected finding. There are a number of potential explanations for these dietary patterns.

With regard to low energy intake, we might first consider the impact of food taboos during *resguardo*, a practice that has also been noted among other cultural groups (Malinowski, 1929; Manderson, 1981; Maúes and Motta Maúes, 1978) in the immediate postpartum. Considering that among *Ribeirinhos*, many taboo foods (fish, game, fruit) could be important sources of energy and protein, their avoidance could lower total energy and protein intakes. However, a detailed look at the actual foods consumed in all measurement rounds indicated that most taboo foods were uncommon in the diets of these *Ribeirinho* people in general and therefore, their avoidance did not have a significant effect on energy or protein intakes. The logic of food taboo systems has been questioned, especially for individuals in vulnerable situations such as during pregnancy and lactation (Harris, 1985). To our knowledge, this is the first study to collect quantitative and qualitative dietary intake data both during and outside of the taboo period and thus look at the impact of these practices on intakes.

An alternative explanation for women's low energy intakes during *resguardo* could be that they had less of an appetite due to the recent stress of giving birth and the fact that they were very sedentary during this period of time. However, direct observations of and conversations with these women and those who helped them during *resguardo* do not support this idea. When food was available women ate well. It was also common for women to express concern that there was insufficient food available to feed them and their children.

A more satisfying explanation for women's low energy intakes during *resguardo* has to do with women's work restrictions. Because men and women in these *Ribeirinho* communities tend to share the work of subsistence, the loss of an adult women from subsistence activities due to the observance of work restrictions during *resguardo* meant that the adult male was left to conduct all subsistence work alone or with the help of older children or relatives. It appears that alone, men were unable to meet their family's subsistence needs. The fact that women do not process *açai* during *resguardo* also appears to be a significant factor in alter-

ing energy intake. In terms of the overall diet and in both peak and late lactation, *açai* was the second most important source of the energy (14%) and the most important source of fat (29%). However, none of the women consumed *açai* during *resguardo*, not because it was a taboo food, but rather because the processing of *açai* into a juice was a restricted activity. While all women received the help of relatives during *resguardo*, this assistance was typically limited to childcare and maintenance of the home. Helpers were never observed assisting with subsistence work like manioc or *açai* processing. Therefore, it appears that the loss of the female household head from subsistence activities, including the processing of *açai*, played a significant role in reducing overall dietary intake during *resguardo*.

The higher protein intakes during *resguardo* are harder to understand but direct observations of the behaviors of and conversations with household members offer some possible explanations. Because protein capture is primarily men's work and men are expected, especially during *resguardo*, to provide protein rich resources for their wives it is possible that men spent more time hunting and fishing during *resguardo*. Research that includes data on the time allocation of other family members during *resguardo* will be necessary to explore this idea. Further, it was obvious that women received preferential treatment in terms of food allocation during *resguardo*. Generally, men are fed first; however, on a number of occasions during *resguardo*, the new mother was given the first serving of fish/game as well as the most prized parts (i.e. center/tail of the fish). Women also seemed more likely to take second helpings even if it was the last of what was available, something that was uncommon to generally see women doing.

Energy expenditure and activity patterns

Total daily energy expenditure (TDEE) among these lactating women was lowest during *resguardo* and increased significantly with time as women returned to their normal activities. These low activity levels are related to the observance of work restrictions during *resguardo*, which include most subsistence activities. Many cultures recognize the immediate postpartum as a special time when the mother and infant bond and lactation is initiated. Numerous studies have provided qualitative descriptions of maternal behaviors in the immediate postpartum that seem to indicate lower levels of physical activity (Acosta-Johnson, 1980; Benedict, 1976; Bringa, 1995; Launer, 1993; Malinowski, 1929; Manderson, 1981; Roberts et al., 1982; Sich, 1981). However, only the studies by Launer (1993) among Indonesian women and Roberts et al. (1982) among Gambian women provide detailed and (or) quantitative data on the actual activities of women during this period of seclusion and none compare them with the activity and dietary patterns of women outside this defined period of time making it difficult to understand the significance of these cultural practices from an energetics perspective.

As lactation progressed, these *Ribeirinha* women spent less time in infant care and breastfeeding and more time in agricultural work and manioc processing. While the women showed a marked increase in TDEE between *resguardo* and peak lactation, some women continued to refrain from strenuous, subsistence oriented activities for as long as 6 months postpartum. The major reason given was the reluctance to bring the new baby to the manioc gardens where it would be exposed to the sun and biting insects; leaving a breastfeeding infant behind for more than 2 h was not considered an option. It was more common for women to begin assisting in manioc processing since this typically was done right next to their homes and allowed women to continue to care for their infants. By 6 months postpartum infants were breastfeeding much less frequently and all were consuming other foods such as boiled, mashed fish mixed with *farinha* and gruels and mothers were increasingly willing to leave them with other care givers for longer periods of time while they worked in the gardens. By late lactation the activity patterns of the lactating women were again typical of NPNL women in the communities.

While field conditions did not allow for the collection of metabolic data, it is possible that the lactating women in this study increased their metabolic efficiencies as a strategy for meeting the demands of lactation. Basal metabolism (BMR) is expected to increase by about 10% due to the cost of milk synthesis (Prentice et al., 1996). The fact that this increase has not been demonstrated in the majority (Goldberg et al., 1991; Guillermo-Tuazon et al., 1992; Illingsworth et al., 1986; Madhavapeddi and Roa, 1992; Schutz et al., 1980; Singh et al., 1989) of studies has been interpreted as evidence of increased metabolic efficiency (Goldberg et al., 1991). In addition, two studies (Spaaij et al., 1994; Spurr et al.,

1998) have found increased muscular efficiency in lactating women. While increased metabolic efficiency only appears to provide a small (~5%) reduction in daily energy needs (Goldberg et al., 1991; Spurr et al., 1998), such a reduction could be important for women who are energetically stressed as were some of the women in this current study.

CONCLUSIONS

Overall, the strategies these *Ribeirinha* women utilized to meet the additional energy demands of lactation were similar to what was expected. The dietary intakes of these women were insufficient to meet their energy needs and thus they relied on their body stores, specifically those in the gluteal/femoral region. While *resguardo* played a protective role, reducing women's energy expenditure in physical activity and allowing them more time to care for their infants, it came at a cost as their loss from subsistence work lowered food availability and thus their energy intakes. Considering that these women lived in rural, subsistence-based communities, their generally low physical activity levels were unexpected and appear to be related to their cultural ideals regarding women's work. The lactating women in this current study showed a high degree of variation in dietary intake, physical activity level and weight loss illustrating that even in the same setting, individual women's strategies can vary. Future research focused on inter-individual variation has the potential to further our understanding of the interplay between biology and culture in lactation.

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