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Impact of Breastfeeding on Anthropometric Changes in Peri-Urban Toba Women (Argentina)

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ABSTRACT We present an analysis of the effect of lactation on average maternal anthropometric and body composition measures in a population of Toba women in Formosa, Argentina. This indigenous population is undergoing a continuing transition from a seminomadic hunter–gatherer lifestyle to a sedentary, peri-urban one. Using a mixed-longitudinal design, we measured monthly maternal body mass index (BMI), body fat percentage, and triceps and subscapular skinfold thickness between birth and the 18th month postpartum in 113 breastfeeding women. The pattern of change in postpartum body composition varied with maternal age. Adult women (20 years old and older) did not show significant changes in any of the anthropometric measures during the entire study. Older adult women (30 years old and older) consistently had the highest values in measures of BMI and percentage fat, and tended to retain weight postpartum. Adolescent subjects (19 years old and younger) tended to lose weight during the first 6 months postpartum but regain their prepregnancy weight by 12 months postpartum. The same patterns were observed for changes in body fat percentage and in skinfold thickness. We conclude that in this population the energetic stress of lactation does not pose a serious challenge to the maintenance of long-term maternal energy balance or to short-term energy balance in women over 20 years of age. From a public health perspective, postpartum weight retention in older women may represent a more serious health threat. The low level of energetic stress associated with lactation may also contribute to the relatively short duration of lactational amenorrhea in this population despite a cultural pattern of intensive breastfeeding. Am. J. Hum. Biol. 15:717–724, 2003.

In the last two decades, several studies have assessed the energetic impact of lactation by measuring anthropometric changes in breastfeeding women under a variety of circumstances (for a review, see Butte and Hopkinson, 1998). These studies demonstrate high variability, between and within populations, in changes in anthropometric and body composition measures during the postpartum period. Although the general trend in most populations seems to be to lose weight and body fat during the first 6 months after delivery (Dewey et al., 1993; Barbosa et al., 1997; Vinoy et al., 2000), some studies have found no association between time postpartum and anthropometric measures (Dugdale and Eaton-Evans, 1989; Chou et al., 1999). This variability can be partially explained by differences in research methods used (i.e., research designs, definition of breastfeeding, length of postpartum time considered). The heterogeneity of results can also be interpreted as reflecting changes in maternal energy availability and the individual physiological strategies employed to meet the metabolic demands of lactation (Goldberg et al., 1991; Dewey, 1997).

Most studies of postpartum anthropometric changes have focused either on women with surplus energy availability (affluent populations with moderate breastfeeding intensity; Manning-Dalton and Allen, 1983; Goldberg et al., 1991; Dewey et al., 1993) or women with energy deficiency (populations in developing countries with intense breastfeeding patterns; Prentice et al., 1980; Adair et al., 1983; Adair, 1992). However, an increasing number of populations throughout the developing world are

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experiencing what has been termed the "nutritional transition" (Popkin, 2001). This transition involves a shift towards a diet rich in fats, sugars, and refined foods (the "Western diet"), and towards a decrease in physical activity levels. This pattern has been observed in countries as diverse as China, Brazil, and South Africa (Popkin, 2002).

The pace of change in diet and lifestyle has been particularly fast in Latin America (Peña and Bacallao, 1997; Uauy et al., 2001). In many indigenous communities in South America the nutritional transition has occurred over just one or two generations. People whose grandparents, and even parents, relied on hunting and gathering for their subsistence are now immersed in a Western lifestyle. In many cases, the nutritional transition is accompanied by drastic changes in cultural patterns. Intensive breastfeeding, however, seems to be quite resistant to modification. Prolonged and intense breastfeeding is still the norm in most indigenous populations in developing countries (Gray, 1994; Vitzthum, 1994). How the energetic demands of intensive lactation in such populations interact with changes in diet quality and physical activity patterns to determine energy balance during the postpartum period remains an important question.

Using a mixed-longitudinal design, we investigated how breastfeeding affects postpartum nutritional status and body composition in a population undergoing a nutritional transition. We report here on cumulative changes in maternal anthropometric and body composition measures with time postpartum in a peri-urban population of Toba women in Formosa, Argentina. This study was part of a larger project that investigated the relationship between energetics and postpartum fertility in lactating women.

SUBJECTS AND METHODS

Study population

The Toba are one of the three major indigenous groups inhabiting the Argentine Chaco. Until the 1930s, Chacoan Indians, including the Toba, were seminomadic hunter–gatherers (Métraux, 1946; Miller, 1999). Changes in their traditional environment together with the social pressures of the nation-state contributed to the settlement of many of these indigenous communities in peri-urban villages. Today, peri-urban communities rely mainly on wage labor of men and government subsidies for their subsistence. The study was conducted in the peri-urban village of Namqom, located 11 km NE of the city of Formosa (58° 2′ W, 26° 2′ S), northern Argentina. Namqom has a population of ~2,500 people distributed over 100 hectares. Women's activities include household chores, childcare, and basket weaving. A few women are employed as cooks or as teaching assistants. Some women go to the city once a week to sell their weavings or wild herbs door to door.

The typical Namqom diet is based on rice or noodle stews, white breads, fried dough, and small amounts of beef. In addition, their usual active nomadic lifestyle has been replaced with sedentarism and their physical activity levels can be described as low to moderate (Valeggia and Ellison, 2001). As a consequence of the increase in calorie intake and the reduction in energy output, 50% of the adults in this population are overweight (body mass index (BMI) > 25) and 25% are obese (BMI > 30; Chamorro and Valeggia, unpubl.).

This population has relatively good access to health services provided by the local health center and the city's hospitals. The provincial government offers pre- and postnatal care programs. Nearly all infants are born at hospitals. The total fertility rate for women is 6.8 ($\pm$3.4) live births (Valeggia and Ellison, 2001). Toba women breastfeed their infants for 2–3 years, or until the second trimester of their next pregnancy. Co-sleeping also allows for on-demand nighttime nursing. Semisolid and solid supplements are usually introduced around 6 months of age. The use of bottles and commercial formula is infrequent (Valeggia and Ellison, 1998). A preliminary study showed that the average nutritional status of adult women in Namqom was relatively high (average BMI $\pm$ SD $= 26.3 \pm 3.2$) (Valeggia and Ellison, 1998).

Subjects

Our subjects included 113 breastfeeding mothers participating in the Lactation, Nutrition, and Fecundity Study (Valeggia and Ellison, 2001). These women represented 90% of all the breastfeeding, amenorrheic women in the village at the beginning of the study.

Most subjects were recruited during a village-wide demographic census conducted in July 1998. The remaining ones were approached by the research team during their first postnatal visit to the local health center. Subjects were recruited within 6 months of their last delivery. With one exception, they were all still breastfeeding at the end of the study (March, 2000). The median duration of exclusive breastfeeding (i.e., breast milk as the sole nutritional intake) was 5.6 months. All participating women had a full-term birth (birthweight > 2500 g, gestational age > 37 weeks), were amenorrheic at the beginning of the study, and were not using hormonal contraceptives. None of the subjects smoked or were voluntarily dieting to lose weight. Informed consent was obtained from all the subjects after the study was explained to them. The protocol for this study was reviewed and approved by the Harvard University Standing Committee on the Use of Human Subjects in Research (1998).

Study design

A mixed-longitudinal design was used to evaluate anthropometric changes with time postpartum. Subjects were asked to go once a month to the health center for anthropometric measurements and were followed until they experienced their third postpartum menses. A short interview was conducted during the monthly measurements. This interview consisted of four structured questions aimed at recording: 1) breastfeeding patterns (exclusive, semi-exclusive, no breastfeeding); 2) timing of first introduction of supplements; 3) timing of first postpartum menses; and 4) use of contraceptives.

Anthropometry

Maternal prepregnancy weights were obtained from the village Health Center records and from a preliminary study conducted in 1997 (Valeggia and Ellison, 1998). Weight and height were measured using a beam balance and a portable aluminum standiometer, respectively. The subjects were barefoot and lightly clothed during weighing. All weights were corrected for clothing by subtracting the weight of standard sets of clothing. Triceps and subscapular skinfold thickness was measured in triplicate on the left arm using a calibrated Lange skinfold caliper accurate to 0.5 mm. Percent body fat was estimated using bioelectrical impedance (BEI). BEI values were obtained using a BEI meter (BIA RJL Model 101S, RLJ-Systems, Detroit, MI) after a rest period of at least 15 minutes in a ventilated room. Percentage of body fat was estimated from bioimpedance values using previously derived equations (Lukaski and Bolonchuk, 1987). The primary author and two trained assistants performed all measures. Interobserver reliability (IOR) values were calculated at the beginning and half-way through the study by calculating the percentage of concordant measures between two observers. The mean IORs were 87.2% (±2) and 89.5% (±2), respectively.

Data analysis

Sample sizes varied for each month postpartum because some subjects were not measured at all postpartum months. In other words, anthropometric measures were taken consecutively in all subjects, but not all subjects contributed data for each of the 18 months postpartum analyzed here.

To evaluate the effect of time postpartum on anthropometric changes, we used univariate ANOVAs. To assess the effect of prepregnancy body mass index (PP-BMI) we assigned the subjects to one of three groups according to the value of their PP-BMI: low (PP-BMI < 22.9, n = 41), normal (PP-BMI 23–24.9, n = 43), and high (PP-BMI > 25, n = 29). To evaluate age effects, we divided the sample into three groups: "Adolescents," consisting of women 19 years old and younger (n = 36); "20–29," consisting of women 20–29 years of age (n = 49); and "30+," consisting of women 30 years of age and older (n = 28). To evaluate the effects of age on changes in anthropometric measures and in percentage of body fat with time postpartum, we used univariate ANOVAS, treating age category and time postpartum as main effects, including an age-by-time interaction. Dunnett's T3 (equal variances not assumed) post-hoc tests were used to evaluate differences among age categories. Paired *t*-tests were used to compare PP-BMI with BMI at the 1st, 6th, 12th, and 18th month postpartum. Differences were considered statistically significant at $P < 0.05$ in all the tests performed. We used SPSS Base 10.0 (Chicago, IL) for all data analysis.

TABLE 1. Selected characteristics of participating breastfeeding women

	n	Mean ± SD (range)
Age (yrs)	113	24.5 ± 6.2 (14.1–40.6)
Parity	113	3.7 ± 2.4 (1–10)
Pregnancy weight gain (kg)	75	9.9 ± 4.0 (5.0–27.2)
Prepregnancy BMI (kg/m^2)	113	25.3 ± 3.0 (19.0–32.5)
Height[a] (cm)	113	155.9 ± 4.7 (142.0–166.5)
Birthweight of index infant (g)	111[b]	3415 ± 459 (2500–4400)

[a]Height was recorded at the beginning of the study.
[b]The sample included two home deliveries for which the birthweight was not recorded, but which was certainly >2,500 g.

RESULTS

Women in our sample began the study in relatively good nutritional status. Mean PP-BMI was above 24 kg/m^2 (Table 1) and none of the women were considered undernourished (BMI $<$ 18.5 kg/cm^2) (WHO, 1986). Pregnancy weight gain was adequate and infant birthweight was within the normal range for Argentine children (Lejarraga and Orfila, 1987). Maternal age was not associated with PP-BMI nor with infant birthweight ($P > 0.05$).

When the population of breastfeeding women was taken as a whole, there were no changes with time postpartum in any of the recorded anthropometric and body composition measures (Table 2): BMI ($F_{(17)} = 0.29$, $P = 0.99$), triceps skinfold ($F_{(17)} = 0.46$, $P = 0.97$), subscapular skinfold ($F_{(17)} = 0.49$, $P = 0.96$), and percentage body fat ($F_{(17)} = 0.18$, $P = 0.99$). While the absence of any significant cumulative trend in body composition measures with time postpartum was true for the population as a whole, individual women did show significant variation. To explore these patterns we grouped women by prepregnancy weight and by age for further analysis.

Prepregnancy BMI did not significantly affect the pattern of postpartum anthropometric changes. There was a tendency in the high PP-BMI group to gain body mass and in the low PP-BMI group to lose body mass during the first months postpartum (Fig. 1), but the tendency did not reach statistical significance. Women in the normal PP-BMI group did not show differences over time (Fig. 1). The same result was obtained when skinfold thickness and body fat were analyzed (all P values > 0.05).

TABLE 2. Postpartum changes in body mass index (BMI), triceps skinfold thickness, subscapular skinfold thickness, and percent body fat in Toba lactating women

Months postpartum	n	Mean BMI ± SD (range)	Mean triceps thickness ± SD (range)	Mean subscapular thickness ± SD (range)	Mean % body fat ± SD (range)
0	35	26.3 ± 3.0 (19.0–32.5)	20.1 ± 4.9 (9.8–31.6)	24.6 ± 6.9 (11.9–38.8)	29.9 ± 4.1 (20.1–38.6)
1	57	26.0 ± 3.6 (18.8–33.8)	20.2 ± 5.0 (8.5–32.9)	24.0 ± 7.0 (12.1–41.0)	29.8 ± 4.8 (20.5–40.8)
2	60	26.0 ± 3.7 (18.0–33.0)	20.5 ± 5.5 (8.5–30.0)	23.9 ± 7.4 (9.0–37.2)	29.2 ± 5.2 (20.3–39.9)
3	66	25.6 ± 3.6 (17.7–32.6)	20.7 ± 5.6 (8.9–32.8)	24.0 ± 8.3 (8.6–40.5)	29.0 ± 5.2 (19.2–40.1)
4	62	25.6 ± 4.1 (17.7–37.5)	20.9 ± 5.9 (10.1–38.5)	23.36 ± 7.7 (8.8–39.8)	29.5 ± 5.7 (16.0–42.6)
5	59	25.1 ± 4.1 (17.8–37.8)	20.6 ± 6.2 (9.5–38.9)	23.3 ± 8.4 (9.1–41.3)	28.7 ± 6.1 (15.5–41.9)
6	68	25.4 ± 4.5 (17.6–37.6)	19.9 ± 6.1 (7.9–34.1)	23.3 ± 8.3 (8.7–40.6)	29.3 ± 6.5 (17.9–42.6)
7	60	25.5 ± 4.0 (17.8–35.0)	21.2 ± 6.2 (8.7–37.1)	23.6 ± 8.0 (7.0–40.6)	29.3 ± 5.8 (17.3–42.7)
8	73	25.5 ± 4.3 (17.5–35.3)	20.8 ± 6.0 (9.3–34.3)	23.4 ± 8.3 (8.6–40.4)	29.0 ± 5.8 (17.8–43.1)
9	54	26.1 ± 4.5 (17.5–36.7)	22.0 ± 6.6 (11.4–35.6)	25.2 ± 8.7 (8.2–42.1)	30.3 ± 6.2 (18.4–42.5)
10	63	25.4 ± 4.5 (18.0–36.8)	20.7 ± 7.1 (8.9–36.6)	24.6 ± 9.6 (7.9–46.5)	29.4 ± 6.2 (19.0–43.0)
11	51	25.6 ± 4.5 (18.2–36.6)	21.8 ± 7.4 (8.9–40.4)	25.4 ± 10.1 (7.5–45.9)	29.5 ± 5.9 (19.0–41.8)
12	54	25.9 ± 4.4 (18.8–36.9)	21.5 ± 7.5 (9.2–37.1)	25.4 ± 9.5 (10.4–42.0)	30.0 ± 5.9 (18.1–42.0)
13	40	25.6 ± 4.8 (17.9–37.0)	20.0 ± 8.4 (8.4–33.7)	24.1 ± 10.4 (6.5–39.7)	28.3 ± 7.0 (12.3–40.9)
14	42	26.6 ± 5.0 (18.9–37.9)	22.4 ± 8.0 (7.7–38.5)	27.1 ± 9.5 (7.5–40.7)	28.8 ± 6.5 (19.1–42.3)
15	32	26.2 ± 4.3 (18.6–37.3)	20.0 ± 5.9 (8.2–32.4)	25.6 ± 8.5 (6.6–38.8)	29.5 ± 5.2 (19.4–36.7)
16	29	26.2 ± 3.8 (20.2–35.1)	21.7 ± 5.8 (9.7–31.8)	26.1 ± 7.9 (12.5–39.9)	31.3 ± 5.2 (21.9–41.4)
17	24	26.1 ± 4.4 (18.9–36.3)	23.5 ± 6.3 (14.1–36.2)	26.5 ± 7.5 (16.3–38.5)	31.8 ± 5.4 (22.6–42.2)
18	18	26.3 ± 4.5 (19.8–37.1)	23.3 ± 7.6 (12.9–38.0)	25.1 ± 8.8 (11.8–39.1)	31.6 ± 6.0 (22.9–42.7)

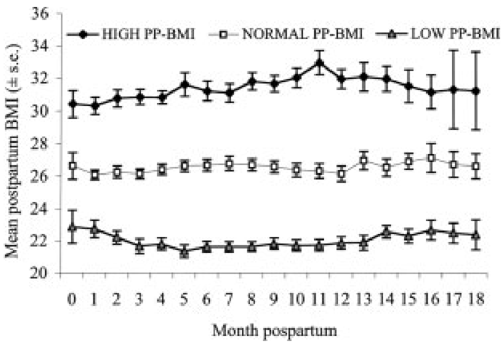

Fig. 1. Postpartum changes in body mass index (BMI) in women with low, normal, and high prepregnancy BMI.

Maternal age did influence the pattern of postpartum anthropometric changes. Significant age effects on postpartum changes were observed for all the body composition variables, including BMI ($F_{(2)} = 19.2$, $P < 0.001$), triceps skinfold ($F_{(2)} = 5.4$, $P = 0.004$), subscapular skinfold ($F_{(2)} = 4.3$, $P = 0.01$), and percentage body fat ($F_{(2)} = 6.9$, $P = 0.001$). Adolescents tended to lose weight and fat mass during the first 6 months postpartum, to remain stable for some months, and then, usually slowly, to regain their early postpartum values (Fig. 2).

In adolescent women, changes in all the measures with time postpartum fit a quadratic regression (BMI: $F_{(309)} = 9.65$, $P < 0.001$; percent body fat: $F_{(261)} = 4.17$, $P = 0.016$; triceps thickness: $F_{(256)} = 3.86$, $P = 0.22$; subscapular thickness: $F_{(256)} = 9.86$, $P < 0.001$). Women 20–29 years of age showed no changes with time postpartum for any of the anthropometric measures. Older women (30+) tended to show an inverted-U pattern in most measures, which was statistically not significant. Older women consistently had the highest values for most months in measures of BMI and percentage of body fat (Dunnett's test, $P < 0.01$ for all measures).

Adolescent and adult women also differed in changes in their postpartum BMI relative to their PP-BMI (Table 3). While most adult women retained weight during the entire postpartum period, adolescent subjects tended to lose weight and returned to their

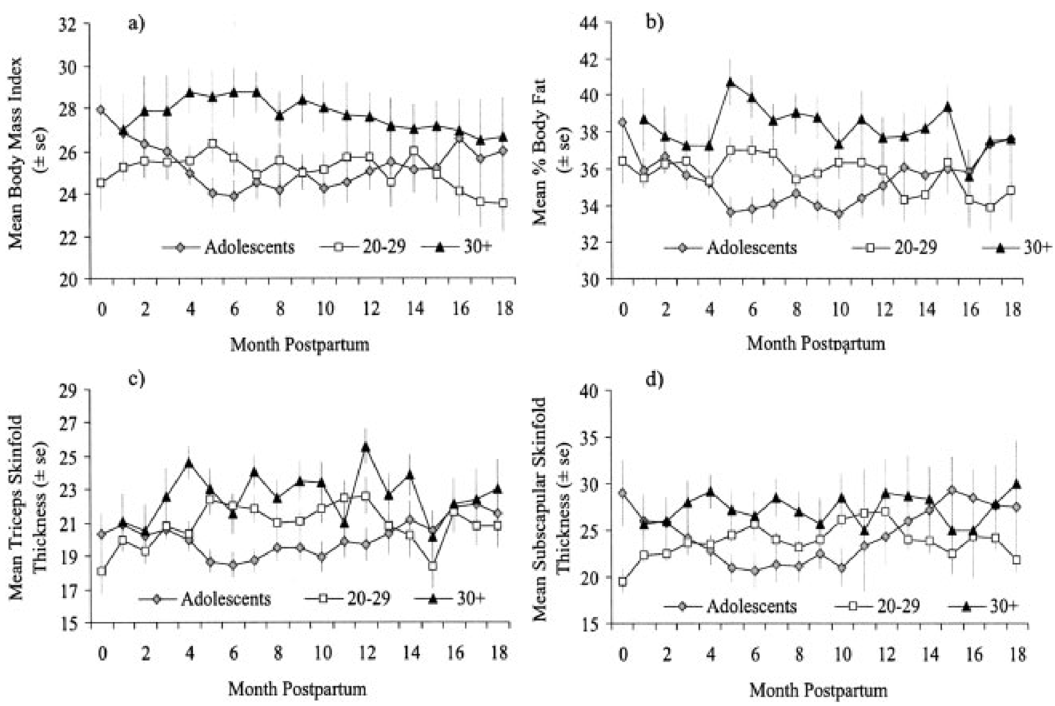

Fig. 2. Postpartum changes in anthropometric measures according to maternal age. See text for age categories.

TABLE 3. Percentage change in postpartum BMI (with respect to prepregnancy BMI) and (in italics) percentage of overweight (BMI > 25) women in women 19 years old and younger (Adolescents), women 20–29 years old (20–29), and women 30 years old and above (30+)

	Adolescents				20–29				30+			
Month postpartum	n	Mean % BMI change	SD	% BMI >25	n	Mean % BMI change	SD	% BMI >25	n	Mean % BMI change	SD	% BMI >25
1	18	4.0[a]	0.7	*69.6*	23	6.4[a]	0.9	*46.3*	6	4.4[a]	0.3	*83.3*
6	22	−1.1	0.7	*34.8*	33	4.9[b]	0.5	*50.0*	13	3.3[a]	0.4	*84.6*
12	14	0.1	0.1	*35.7*	27	4.9[a]	0.4	*44.1*	12	4.5[a]	0.3	*75.0*
18	9	0.8	0.3	*34.2*	7	2.3	0.4	*28.6*	9	3.0[b]	0.2	*55.6*

Significantly different from prepregnancy BMI: [a]$P < 0.05$; [b]$P < 0.001$.

PP-BMI faster. There was a significant effect of maternal age on the percentage change from PP-BMI ($F_{(2)} = 13.1, P < 0.001$). Post-hoc tests revealed a significant difference between adolescents and women in the two adult age categories ($P < 0.001$). Paired *t*-tests performed at selected months postpartum (months 1, 6, 12, and 18) indicated that women in all age categories had significantly higher postpartum than prepregnancy BMI at the first month postpartum (adolescents, $t(22) = -2.3, P = 0.032$; 20–29 group, $t(22) = -3.4, P = 0.002$; 30+ group, $t(5) = -3.3, P = 0.02$). Adult women's postpartum BMI was significantly higher than their PP-BMI at months 6 and 12 (20–29 group/6 months, $t(32) = -5.9, P < 0.001$; 30+ group/6 months, $t(12) = -2.6, P = 0.022$; 20–29 group/12 months, $t(26) = -3.9, P = 0.001$; 30+ group/12 months, $t(11) = -2.3, P = 0.036$). The 30+ group also showed higher BMI at the end of the study than before the last pregnancy ($t(8) = -7.8, P < 0.001$) and showed the highest percentage of overweight (BMI > 25; WHO, 1998) women in each of the 18 postpartum months (Table 3).

DISCUSSION

This study focused on postpartum anthropometric changes in intensively breastfeeding women in a population undergoing a considerable shift in energy availability. Overall, lactation did not have a cumulative impact on indices of maternal energetics over 18 months postpartum. Average indices of body composition showed no change with time postpartum for the population as a whole. The relatively flat trajectory of change in body composition with time postpartum masks the fact that adult Toba women retain a portion of their pregnancy weight gain for more than a year postpartum. This weight retention may contribute to the pattern of increasing BMI with age observed among the women in this population. The overall trend to gain weight during this putatively more energy-demanding period differs from previous reports from both affluent and underprivileged populations (Butte and Hopkinson, 1998). Even if mild, most women in these previous reports experienced weight loss.

It is possible that breastfeeding Toba women in Namqom increase their calorie intake and/or decrease their energy output during the first 6 months postpartum. However, an analysis of behavioral observations (Valeggia and Ellison, unpubl.) indicated that Toba mothers tended to decrease their level of physical activity with time postpartum. In addition, there was no evidence that the quality or quantity of diet items changed with time postpartum.

Only adolescent women show a transitory period of postpartum weight loss. The same pattern is observed in body fat percentage and in skinfold thickness. These adolescents were in good nutritional status (mean PP-BMI = 24 kg/ m^2) and, thus, not at immediate risk of maternal depletion. Nevertheless, lactation represents a higher metabolic demand for adolescent mothers than for their adult counterparts. An evaluation of dietary quality and physical activity patterns suggested no significant differences between adolescent and adult breastfeeding mothers (Valeggia and Ellison, unpubl.).

On the other hand, an analysis of breastfeeding patterns in this population of Toba women indicated that during the first 6 months postpartum, the frequency of nursing episodes was negatively correlated with maternal age ($r^2 = -0.173, P = 0.004$), i.e., adolescent mothers seemed to be nursing their infants more frequently than older mothers. Adolescent mothers tend to live with their extended family group, do not have the same responsibilities as adult mothers, and, in general, enjoy more free time during the day. Because of this lighter activity pattern, it seems likely that they can afford to breastfeed their infants more frequently than adult mothers. Lactation may thus represent a higher relative metabolic load for adolescents than for older mothers. However, the impact of lactation on adolescent energy reserves is only transient. By 12 months postpartum, most young mothers have regained their prepregnancy weight.

The increase in weight with age and parity points to a set of health risks that are different from the risk of maternal depletion, which is more characteristic of less acculturated populations. Weight retention can represent a health hazard in itself, as it may contribute to obesity (Lovelady et al., 2000). The WHO/PAHO's special survey of nutritional transition in Latin America (Peña and Bacallao, 1997) has pointed to an increasing trend in the prevalence of overweight and obesity, especially in urban areas. Obesity has long been recognized as a risk factor for the development of chronic diseases, such as diabetes and cardiovascular disease. The nutritional transition experienced by most indigenous communities as they change their traditional diets and activity patterns has profound effects on their short- and long-term health (Popkin, 2001). This represents a challenge for public health officials, who are confronted with increasingly large numbers of families in which undernourished and overweight members coexist.

The fact that intensive breastfeeding does not appear to be associated with weight loss may have important implications in the fecundity and fertility of these women. According to the Relative Metabolic Load hypothesis (Ellison, 2001; Valeggia and Ellison, 2001), the duration of the period of lactational subfecundity may depend on the relative metabolic burden that lactation poses on the mother. The higher the relative metabolic load of lactation, the longer the period of lactational subfecundity. Poorly nourished mothers, for whom lactation represents a high relative metabolic load, should have longer periods of lactational subfecundity. Likewise, well-nourished women should have shorter periods of lactational subfecundity. In fact, this seems to be the case in Namqom and in other well-nourished, intensively breastfeeding populations (Worthman et al., 1993; Tracer, 1996). In our study population the duration of lactational amenorrhea is relatively short (10.2 $\pm$ 4.3 months; Valeggia and Ellison, 2001) and hormonal indicators of energy availability show close correlation with both weight and resumption of menses (Ellison and Valeggia, 2002; in press). If prenutritional transition populations were selected for the ability to buffer lactation from maternal energetic status, postnutritional transition populations like the Namqom Toba may suffer from the fact that lactation does not exert enough of a metabolic burden to prevent excess weight accumulation associated with parity.

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LITERATURE CITED

Adair L, Linda S. 1992. Postpartum nutritional status of Filipino women. Am J Hum Biol 4:635–646.

Adair L, Pollitt E, Mueller WH. 1983. Maternal anthropometric changes during pregnancy and lactation in a rural Taiwanese population. Hum Biol 55:771–787.

Barbosa L, Butte NF, Villalpando S, Wong WW, Smith EO. 1997. Maternal energy balance and lactation performance of Mesoamerindians as a function of body mass index. Am J Clin Nutr 66:575–583.

Butte NF, Hopkinson JM. 1998. Body composition changes during lactation are highly variable among women. J Nutr 128(2 Suppl):381S–385S.

Chou T-W, Chan GM, Moyer-Mileur L. 1999. Postpartum body composition changes in lactating and non-lactating primiparas. Nutrition 15:481–484.

Dewey KG. 1997. Energy and protein requirements during lactation. Annu Rev Nutr 17:19–36.

Dewey KG, Heinig MJ, Nommsen-Rivers LA. 1993. Maternal weight-loss patterns during prolonged lactation. Am J Clin Nutr 58:162–166.

Dugdale AE, Eaton-Evans J. 1989. The effect of lactation and other factors on post-partum changes in body-weight and triceps skinfold thickness. Br J Nutr 61:149–153.

Ellison PT. 2001. On fertile ground: a natural history of human reproduction. Cambridge, MA: Harvard University Press.

Ellison PT, Valeggia CR. 2002. Postpartum changes in urinary C-peptide levels in relation to resumption of menses in lactating Toba women of northern Argentina. Am J Hum Biol 14:115.

Ellison PT, Valeggia CR (in press). C-peptide levels and the duration of lactational amenorrhea. Fertil Steril.

Goldberg GR, Prentice AM, Coward WA, Davies HL, Murgatroyd PR, Sawyer MB, Ashford J, Black AE. 1991. Longitudinal assessment of the components of energy balance in well-nourished lactating women. Am J Clin Nutr 54:788–98.

Gray SJ. 1994. Comparison of effects of breast-feeding practices on Birth-spacing in three societies: nomadic Turkana, Gainj, and Quechua. J Biosoc Sci 26:69–90.

Lejarraga H, Orfila G. 1987. Estándares de peso y estatura para niñas y niños argentinos desde el nacimiento hasta la madurez. Arch Argent Pediatr 85:209–222.

Lovelady CA, Garner KE, Moreno KL, Williams JP. 2000. The effect of weight loss in overweight, lactating women on the growth of their infants. New Engl J Med 342:449–460.

Lukaski HC, Bolonchuk WW. 1987. Theory and validation of tetrapolar bioelectrical impedance method to assess human body composition. In: Ellis K, Yasamura S, Morgan W, editors. Proceedings of an International Symposium of in vivo body composition studies. London: Institute of Medicine and Physics. p 410–414.

Manning-Dalton MS, Allen LH. 1983. The effects of lactation on energy and protein consumption, postpartum weight change and body composition of well nourished North American women. Nutr Res 3:293–308.

Métraux A. 1946. Ethnography of the Chaco. In: Steward J, editor. Handbook of South American Indians. Washington DC: Smithsonian Institution, Bureau of American Ethnology.

Miller ES (ed.). 1999. Peoples of the Gran Chaco. In: Native peoples of the Americas. Westport CT: Bergin & Garvey.

Peña M, Bacallao J (eds.). 1997. Obesity and poverty: a new public health challenge. Washington DC: Pan American Sanitary Bureau, Regional Office of the WHO.

Popkin BM. 2001. The nutrition transition and obesity in the developing world. J Nutr 131:871S–873S.

Popkin BM. 2002. An overview on the nutrition transition and its health implications: the Bellagio meeting. Public Health Nutr 5:93–103.

Prentice AM, Roberts SB, Watkinson M, Whitehead RG, Paul AA, Prentice A, Watkinson AA. 1980. Dietary supplementation of Gambian nursing mothers and lactational performance. Lancet 25:886–888.

Tracer DP. 1996. Lactation, nutrition and postpartum amenorrhea in lowland Papua New Guinea. Hum Biol 68:277–292.

Uauy R, Albala C, Kain J. 2001. Obesity trends in Latin America: transiting from under- to overweight. J Nutr 131:893S–899S.

Valeggia CR, Ellison PT. 1998. Nursing patterns, maternal energetics, and postpartum fertility among Tobas of Formosa, Argentina. Am J Phys Anthropol Suppl 26:54.

Valeggia CR, Ellison PT. 2001. Lactation, energetics, and postpartum fecundity. In: Ellison PT, editor. Reproductive ecology and human evolution. New York: Aldine de Gruyter.

Vinoy S, Rosetta L, Mascie-Taylor CGN. 2000. Repeated measurements of energy intake, energy expenditure and energy balance in lactating Bangladeshi mothers. Eur J Clin Nutr 54:579–585.

Vitzthum VJ. 1994. Comparative study of breastfeeding structure and its relation to human reproductive ecology. Yrbk Phys Anthropol 37:307–349.

WHO (World Health Organization). 1986. Use and interpretation of anthropometric indicators of nutritional status. Bull WHO 64:929–941.

WHO (World Health Organization). 1998. Obesity: preventing and managing the global epidemic. Report of a WHO consultation on obesity. Geneva: WHO.

Worthman CM, Jenkins CL, Stallings JF, Lai D. 1993. Attenuation of nursing-related ovarian suppression and high fertility in well-nourished, intensively breast-feeding Amele Women of Lowland Papua New Guinea. J Biosoc Sci 25:425–443.