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ORIGINAL ARTICLE

Maternal fish consumption in the nutrition transition of the Amazon Basin: Growth of exclusively breastfed infants during the first 5 years

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Abstract

Background: Changes in fish-eating habits due to rapid urbanization in Western Amazon was used as model to investigate whether maternal fish-intake rate impacts on children’s weight and height during the first 5 years.

Aim: The study examined the growth of 82 breastfed children, and maternal fish consumption (hair mercury concentrations, HHg) during pregnancy and lactation.

Subjects and methods: Fish consumption in mothers and children was estimated through HHg. The children were measured and weighed at birth and at 6 (exclusive breastfeeding), 36 and 60 months.

Results: Fish consumption rate (HHg) had no significant impact on children’s growth at the specified ages ($p = 0.35$). After 6 months of exclusive breastfeeding, children had the highest proportion of $Z$-scores $<-1$ SD; however, weaning (with extended breastfeeding) had a substantial impact in moving up the attained growth at 3 years. The duration of breastfeeding was significantly correlated with attained $Z$-scores for weight-for-age ($r = 0.26; p = 0.02$) and weight-for-height ($r = 0.22; p = 0.04$) but not for height-for-age. At 3 years most children had improved $Z$-scores ($>-1$ SD) for height-for-age (70/82), weight-for-age (74/82) and weight-for-height (74/82). At 5 years, all but one child attained $Z$-scores $>-1$.

Conclusion: The apparently good nutritional status of subjects is more likely due to a well balanced diet composition than to only one dietary protein source – fish.

Keywords: Nutrition transition, Amazon, growth, breastfeeding, fish
Introduction

The population that inhabits the Amazon Basin shows a wide diversity: Currently, native peoples living traditional lifestyles (in dense forests) contrast with a new urbanization profile. Piperata (2007) has recently described differences between traditional lifestyles and those found among the new Amazonian populations. The more urbanized environment caused by recent Amazonian growth is exemplified in the city of Porto Velho. Gradually replacing riverside communities, the new inhabitants no longer depend on the traditional dominance of fish as the source of animal protein, but instead use markets for their food supply. This fast urbanization has changed the traditional food supply chain and, as a consequence, the typical diet has shifted away from high fish consumption (Dorea 2004) to dependency on industrial or mass processed foods (Piperata 2007). The key challenge in studies of nutrition transition is the ability to characterize which dietary item has substantially changed and its impact on health.

Fish is an abundant natural resource in Amazonian Rivers that is well utilized by riverside populations (Dufour 1991); in traditional communities its consumption is high and this tends to increase the farther these communities are from urban centres (Alves et al. 2006). In the context of traditional riverine diet, the high protein content of fish balances high starch food consumption (Dorea 2004). Fish are a good source of sulphur amino acids and bioavailable iodine, both crucial to counterbalance cassava goitrogens and low iodine foods produced in iodine-depleted soils of tropical rain forests (Dorea 2004). Indeed, dietary fish enhances absorption of zinc (Garcia-Arias et al. 1993) and iron from plant foods (Layrisse et al. 1990; Gibson and Hotz 2001); dietary fish has been positively associated with women’s iodine status (Zollner et al. 2001) and children’s ferritin stores (Michaelsen et al. 1995; Gunnarsson et al. 2007). Additionally, Amazonian fish is a good source of selenium (Dorea et al. 1998), known to counteract the toxic effects of Hg. Other essential nutrients, such as zinc, are significantly higher in protein foods like fish when compared to food with low protein content (Terres et al. 2001).

As a specific source of omega-3 polyunsaturated fatty acids (Inhamuns and Bueno Franco 2001), fish is nutritionally important for people living on cassava-dominant diets, especially during breastfeeding (Rocquelin et al. 1998). Tanzanian women with high intakes of freshwater fish (as the only animal lipid source) had milk arachidonic acid (AA) and docosahexaenoic acid (DHA) contents that were well above present recommendations for infant formulae (Muskiet et al. 2006); such findings inspired Muskiet et al. to hypothesize that the ‘optimal homeostasis’ of AA and DHA is lacking in Western diets and is causing subtle signs of unbalanced maternal glucose homeostasis. Indeed, breast-milk DHA of women from the marine region was higher compared to other regions and twice as high as any reported previously; it was comparable to the amounts found in the milk of women fed fish oil (Ruan et al. 1995).

Fish protein has good biological value (Sikka et al. 1979) that is well utilized by children (Hofvander 1973); porridge containing dried fish has been successfully used to treat undernourished children (Greco et al. 2006). It is not surprising that per se, addition of fish powder supported growth just as well as a nutritional supplement fortified with vitamins and minerals (Lartey et al. 1999). The effects of maternal fish consumption on infant growth may start early during pregnancy; Olsen et al. (1993) noticed that the weight and length of the newborn increased with the frequency of seafood meals consumed in pregnancy. After reporting that infant size at birth increased with fish consumption, Thorsdottir et al. (2004) hypothesized that constituents of fish and fish oil might affect birth size. Indeed, increasing fish intake during pregnancy might increase foetal growth rate (Rogers et al. 2004) and cognitive functions (Hibbeln et al. 2007) of British infants.
Fish are complex nutrient-dense foods with exceptional functional characteristics: Increasing maternal fish intake during pregnancy from once a week to 2.5 times per week decreased the risk of eczema at age 1 year by 37%, and the risk of positive skin prick test at age 6 years by 35% (Romieu et al. 2007). Furthermore, regular fish consumption in infancy (before age 1) is associated with a reduced risk of allergic disease and sensitization to food and inhalant allergens during the first 4 years of life (Kull et al. 2006).

One underappreciated problem in dietary surveys is error in recalling meal size. This has been documented in several settings where portions and cultural standards could be favourable; Nelson et al. (1996) showed that small portion sizes tended to be overestimated, and large portion sizes underestimated. That is the reason many studies use intake biomarkers to evaluate the extent of protein misreporting (Kipnis et al. 2002; Subar et al. 2003). Using hair mercury (HHg) we accomplish reduction of intraindividual and interindividual variability; this is particularly important in longitudinal studies subjected to seasonal variations in urban socio-economically limited populations. These variations are amply documented in the epidemiologic literature (Wu et al. 1986). The methylmercury (MeHg) consumed in fish is easily absorbed, binds to protein sulphydryl groups, and accumulates preferentially in human hair; the proportion of blood to HHg is estimated at 250 times (Clarkson 2002). This particular characteristic of hair, coupled with its easy collection and preservation, makes HHg a first-choice marker of fish consumption in Amazonian populations (Barbosa et al. 1997, 1998; Dorea et al. 2003); the attendant changes in fish consumption rates for native Amer-Indians have been successfully assessed by HHg determination (Dorea et al. 2005a,b). Mean daily fish consumption rates of subsistence communities from the Rio Tapajós have shown a variation of 115–171 g day\(^{-1}\) (Passos et al. 2007); this is in close agreement with 170 g day\(^{-1}\) derived from HHg concentrations of Rio Negro mothers (Dorea et al. 2003). It should be noticed that carnivorous fishes are more likely to have higher mercury content than non-carnivorous fishes (Dorea 2003).

The importance of adequately supplying protein during pregnancy and lactation to ensure full reproductive success is well recognized. Traditionally Amazonians have relied heavily on fish to complement their starch-based diet (Giugliano et al. 1978). Population studies dealing with nutrition transition in the Amazon are rare, and the most recent one has focused on nutritional outcomes (Piperata 2007). In a previous publication we reported mothers as moderate or high fish consumers (Marques et al. 2007); however, our present construct is not typical of a nutrition survey. This study was created to test a selected aspect (shift of fish consumption) in the nutrition transition in the Amazon Basin and its impact on growth of breastfed children.

**Materials and methods**

**Background**

The nutrition transition of Porto Velho is typical of many conurbations along the most remote Brazilian frontier. Agricultural projects and a gold rush have changed the face of this Rio Madeira city in the last 30 years, attracting people from different parts of the country. Incomers brought different food habits, and rapid urbanization accompanied social and economic trends that impacted on fish consumption. During the last 30 years the city of Porto Velho, capital of the state of Rondonia (Western Amazonia), has experienced significant demographic changes; as a result of gold prospecting and agricultural development it has changed its traditional Amazonian characteristics. With people coming
from many other Brazilian regions, the present population has both traditional families that base their diets on fish and starchy foods and city dwellers with more cosmopolitan food habits. In this changing environment, we investigated the growth of a sample of urban breastfed infants with special reference to family fish consumption.

The study protocol was approved by the Ethics Committee of Studies for Humans of the Universidade Federal de Rondonia. During routine visits to the pre-natal clinics of three hospitals in Porto Velho pregnant mothers between the ages of 15 and 45 years were initially recruited; the mothers were selected among those in good health, reporting no illness or complaints at the time of the study and who were willing to breastfeed. Excluding factors were occupational exposure to toxic chemicals and hereditary neurological illnesses. Written consent (stating that participation was voluntary and confidentiality was assured) was signed by the participant mother, who could withdraw from the study at any time.

This is part of an ongoing cohort study conceived to study (a) fish Hg exposure of urban Amazonian mothers; (b) to associate maternal tissue Hg with factors relevant to neuro-motor development of breastfed infants; and (c) to examine the association between generated dimensions of infant neurodevelopment and maternal socio-economic and Hg exposure features. A component of the study focusing on the 6-month-old infants has already been published (Marques et al. 2007). Briefly, recruitment of 100 mothers began in 2000; detailed information concerning diet and anthropometry (and infant growth and development) was completed for 82 mother–infant pairs. For each mother a complete clinical evaluation was obtained from medical records. The newborns were clinically examined with special attention to vitality, perinatal reflexes, maturity, and congenital malformations; weight, length, head circumference, and Apgar scores were recorded.

**Data collection**

We recorded the maternal diet only during the first post-selection visit; this constitutes an assessment of the principal fish consumption characteristics at the time of the study. Participants were interviewed about diet; a questionnaire that could identify frequency and preference of fish was completed. Eighty-two women carried out their intention of breastfeeding exclusively for 6 months, and some extended lactation to 36 months. Exclusive breastfeeding was supported throughout the first 6 months and defined according to the WHO: ‘the infant received breast milk only and allowed supplementation of drops and syrups such as vitamins, minerals, and medicines’.

At birth and at ages of 6, 36 and 60 months anthropometric measurements of mothers and infants were taken; weight and height were measured by trained nurses and monitored regularly according to standard procedures. Weight (kg) and height (cm) of mothers were measured at each observation and were used to calculate body mass index (BMI, weight/height²). Length of newborn babies and of 6-month-old infants was measured in recumbent position with a 0.1 cm stadiometer. At 36 months and 60 months the children were measured and weighed barefoot and dressed in underwear only; standing height was measured to the nearest 0.1 cm and weight was measured to the nearest 0.1 kg with an electronic scale.

Both recumbent length (at birth and 6 months) and standing height (at 36 months and 60 months) were measured for all children. At the same time as recording anthropometry, data were collected on feeding practices, child morbidity, perinatal factors, and socio-economic, demographic and environmental characteristics. Z-scores for attained weight-for-age, length-for-age, BMI-for-age and weight-for-length were based on the WHO Child Growth Standards (WHO Multicentre Growth Reference Study Group 2006).
Therefore, the weight-for-height Z-scores (WHZ) were calculated using EPI-INFO (version 4.1; Centers for Disease Control and Prevention, Atlanta) and the WHO recommended growth curves. Infant growth rate up to 6 months was estimated as weight gain percentage (IWG%) after Xiong et al. (2007): (infant weight – birth weight)/birth weight × 100. At the specified age, we also collected samples of hair from mothers and respective children during the anthropometric measurements.

**Hair Hg determination**

Hair sample preparation and analytical procedures were carried out according to our standardized laboratory procedure for Hg determination (Marques et al. 2007). Briefly, the hair samples were comminuted with stainless steel scissors, weighed, and digested before analysis. Human hair samples were washed with EDTA 0.01%, dried in an oven at 50°C and weighed. Samples were then digested using a digestion block at 80°C for 40 min with concentrated HNO₃ (3 mL) and KMnO₄ (5%; 6 mL) in a microwave oven system for 35 min (CEM-Coorporation, MDS 2000, Matthews, NC, USA). The determination of total Hg in the digested samples was done by cold vapour atomic absorption spectrometry with a flow injection system FIMS (CV-AAS, Perkin-Elmer, FIMS 400, Ueberlingen, Germany).

All glassware used in the analytical protocol was washed clean, rinsed with 5% EDTA and double distilled, and left to rest in 5% HNO₃ overnight. Then it was rinsed again in double distilled water, and dried at 100°C for 12 h. Precision and accuracy of Hg determinations were assured by the use of internal standards, use of triplicate analyses of samples and certified reference materials (IAEA-085 and 086, Vienna, Austria) with recoveries of 92%. The limit of detection for the procedure was determined at <0.01 μg g⁻¹ and there was no HHg determination below the limits.

**Statistical analysis**

The statistical packages, contained in Excel and Prism, were used for data summarization (means, standard deviation, changes in variables) and correlation analysis. The Shapiro–Wilk test of normality was applied and data transformed when required. Statistical analysis to test children’s attained growth at 0, 6, 36 and 60 m was carried out using the Statistica (StatSoft, Inc., v.6.0) statistical package. During data analysis, children were classified into two groups on the basis of reported maternal fish consumption (Marques et al. 2007). The General Linear Model of Statistica used a factorial design with repeated measured factors. Pearson’s (p) correlation was also used to examine the strength of association between the fish consumption marker (HHg) and anthropometric measures. A value of <0.05 was accepted as statistically significant.

**Results**

A previous publication has already partially discussed results of maternal fish consumption and infant neurodevelopment at 6 months (Marques et al. 2007); the influence of maternal fish consumption rates on mean HHg concentrations was not statistically significant (Table I). These contemporary urban mothers purchased fish from open markets and food stores.
Table I. Maternal and infant HHg (mean ± SD; values in parentheses are SD) concentrations (μg g⁻¹) as a frequency of fish consumption of mothers.

<table>
<thead>
<tr>
<th>Fish servings per week</th>
<th>Birth</th>
<th>6 months</th>
<th>3 years</th>
<th>5 years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mother</td>
<td>Infant</td>
<td>Mother</td>
<td>Infant</td>
</tr>
<tr>
<td>0–1</td>
<td>49</td>
<td>6.02 (5.54)</td>
<td>2.61 (2.48)</td>
<td>2.39 (2.59)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.97 (2.31)</td>
<td>3.09 (4.56)</td>
<td>2.53 (4.16)</td>
</tr>
<tr>
<td>≥2</td>
<td>33</td>
<td>9.35 (11.8)</td>
<td>4.06 (5.09)</td>
<td>3.39 (3.92)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.14 (3.80)</td>
<td>4.96 (6.67)</td>
<td>2.63 (2.96)</td>
</tr>
<tr>
<td>p</td>
<td>0.09</td>
<td>0.08 (5.90)</td>
<td>0.13 (6.67)</td>
<td>0.21 (3.79)</td>
</tr>
</tbody>
</table>

Table II. Summary (means) of attained growth and length/height (Z-scores) as a function of maternal fish consumption; no statistically significant difference between groups (p = 0.36).

<table>
<thead>
<tr>
<th>Fish servings, groups</th>
<th>0–1 per week (n = 49)</th>
<th>≥2 per week (n = 33)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Weight-for-age&lt;sub&gt;Birth&lt;/sub&gt;</td>
<td>−0.23673</td>
<td>0.93</td>
</tr>
<tr>
<td>Weight-for-age&lt;sub&gt;6 months&lt;/sub&gt;</td>
<td>−0.87061</td>
<td>0.69</td>
</tr>
<tr>
<td>Weight-for-age&lt;sub&gt;36 months&lt;/sub&gt;</td>
<td>0.50041</td>
<td>0.98</td>
</tr>
<tr>
<td>Weight-for-age&lt;sub&gt;60 months&lt;/sub&gt;</td>
<td>0.35653</td>
<td>0.46</td>
</tr>
<tr>
<td>Length-for-age&lt;sub&gt;Birth&lt;/sub&gt;</td>
<td>0.20755</td>
<td>0.91</td>
</tr>
<tr>
<td>Height-for-age&lt;sub&gt;6 months&lt;/sub&gt;</td>
<td>0.31224</td>
<td>1.30</td>
</tr>
<tr>
<td>Height-for-age&lt;sub&gt;36 months&lt;/sub&gt;</td>
<td>0.10612</td>
<td>0.97</td>
</tr>
<tr>
<td>Height-for-age&lt;sub&gt;60 months&lt;/sub&gt;</td>
<td>−0.69245</td>
<td>0.65</td>
</tr>
<tr>
<td>Weight-for-length&lt;sub&gt;Birth&lt;/sub&gt;</td>
<td>−0.57</td>
<td>1.15</td>
</tr>
<tr>
<td>Weight-for-height&lt;sub&gt;6 months&lt;/sub&gt;</td>
<td>−1.31</td>
<td>1.17</td>
</tr>
<tr>
<td>Weight-for-height&lt;sub&gt;36 months&lt;/sub&gt;</td>
<td>0.63</td>
<td>1.24</td>
</tr>
<tr>
<td>Weight-for-height&lt;sub&gt;60 months&lt;/sub&gt;</td>
<td>1.15</td>
<td>0.74</td>
</tr>
</tbody>
</table>
is shown in Table II and the profiles of attained \( Z \)-scores are shown in Figure 2. The cumulative differences between linear and ponderal \( Z \)-score outcomes are clear. At birth, most children showed adequate \( Z \)-scores \((\geq -1)\) for length-for-age \((74/82)\), weight-for-age \((68/82)\) and weight-for-length \((56/82)\). However, attained growth at 6 months showed remarkable differences; the infants grew much more in height than in weight. After 6 months of exclusive breastfeeding the proportion of infants with attained growth \((Z \text{-scores } \leq -1)\) was \(14/82\), \(36/82\) and \(52/82\), respectively, for length-for-age, weight-for-age, and weight-for-length. Most children showed \( Z \)-scores \((\geq -1)\) for height-for-age \((70/82)\), weight-for-age \((74/82)\) and weight-for-height \((74/82)\). However, it should be noted that only one child had a \( Z \)-score \(\leq -2\) for length-for-age during breastfeeding, but five showed stunting at 36 months. Malnutrition \((\text{weight-for-age }\leq -2)\) was seen in only two breastfed infants. All but one child attained \( Z \)-scores \(\leq -1\) at 60 months. Part of the nutritional outcome due to the quality of the weaning diets was due to extended lactation.

![Figure 1. Association between infant HHg and \( Z \)-scores (weight-for-height) at 6, 36 and 60 months.](image_url)

Table III. Maternal and infant characteristics (mean ± SD) as a function of reported frequency of fish consumption (adapted from Marques et al. 2007).

<table>
<thead>
<tr>
<th>Fish servings per week</th>
<th>( n )</th>
<th>Gestation (weeks)</th>
<th>Length at birth (cm)</th>
<th>Infant weight at birth (kg)</th>
<th>Infant weight at 6 months (kg)</th>
<th>IWG%*</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–1</td>
<td>49</td>
<td>39.3 ± 1.3</td>
<td>50.0 ± 1.7</td>
<td>3.21 ± 0.4</td>
<td>6.97 ± 0.5</td>
<td>121 ± 3</td>
</tr>
<tr>
<td>≥2</td>
<td>33</td>
<td>39.4 ± 1.4</td>
<td>49.9 ± 1.9</td>
<td>3.29 ± 0.4</td>
<td>7.07 ± 0.5</td>
<td>119 ± 4</td>
</tr>
<tr>
<td>( p )</td>
<td>0.76</td>
<td>0.76</td>
<td>0.41</td>
<td>0.32</td>
<td>0.82</td>
<td></td>
</tr>
</tbody>
</table>

*IWG%: Infant weight gain at 6 months divided by birth weight.
Exclusive breastfeeding for 6 months was accomplished by all mothers. After that, many mothers extended breastfeeding throughout the first year (Figure 3); 10 extended even further and there was one child still breastfeeding at 5 years. The duration of breastfeeding did seem to interact with the dietary patterns of weaning; there was significant correlation with attained \( Z \)-scores at 36 months for weight-for-age \( (r=0.26; p=0.02) \) and weight-for-length \( (r=0.22; p=0.04) \) but not for length-for-age (Figure 3). There was a wide spread in birth weight (range: 2.2–4.3 kg); however, exclusive breastfeeding substantially reduced (by 50%) the range of body mass at 6 months (6.1–8.5 kg). Indeed, the IWG\% was inversely proportional to birth weight in a very high and significant correlation \( (r=-0.88; p=0.00) \) illustrated in Figure 4.

![Cumulative frequency of Z-scores of attained growth during sampling times.](image-url)
The possible taxing of mothers caused by milk demanded to sustain increased infant growth is illustrated in Figure 5; maternal BMI showed no significant association with breastfeeding duration. Mothers with higher BMI at the end of pregnancy had returned to pre-pregnancy levels at 6 months (exclusive breastfeeding) and 3 years (extended breastfeeding). Figure 5 illustrates that the BMI profile is indistinguishable between pre-pregnancy, 6 and 36 months post-natal.

**Discussion**

Quality of the diet for pregnant and lactating women is a key issue in public health nutrition, especially in poor communities with economic constraints. The mothers of Porto Velho,
with respect to levels of dietary fish consumption, showed no significant impact on the attained growth of their young children; this indicates that changes from traditional fish-dominated diet to other animal or vegetal-source food have occurred without consequences for infant development. By examining the longitudinal growth of their children it was revealed that mothers’ milk, irrespective of level of fish consumption, could compensate for low birth-weights; furthermore, the length of lactation (beyond 6 months) was an important nutritional supplement measurable at 3 years (Figure 2).

Fish is a differentiator of the survival strategy of some Amazonian villages (Dorea et al. 2005b); it is consumed more in isolated communities (Alves et al. 2006). Early dietary studies of poor Amazonian families showed that they can consume 151 g fish per day comprising 37% of their dietary protein (Giugliano et al. 1978). HHg is a specific and reliable indicator of fish consumption that has been used to study Amazonian populations and successfully employed to quantify the amount of freshwater fish consumed (Dorea et al. 2003). Our study showed that in urban population, no longer following traditional food habits, HHg was higher (although not significantly) in the group reporting higher fish consumption rate. Therefore, HHg can be valuable to understand fish-MeHg exposure as well as to trace beneficial outcomes of fish consumption in Amazonians (Dorea et al. 2005a,b). However, because of concerns for neurodevelopmental disorders due to intrauterine exposure to MeHg, recommendations to reduce fish intake have been made (Cohen et al. 2005). For economically stressed families, especially in regions accustomed to high frequency of fish consumption, such recommendations may not take into account the effect that reducing fish consumption will have on the nutritional status of vulnerable infants and young children. Indeed, Arnold et al. (2005) have questioned whether it is worth curtailing fish Hg exposure because this can tax the consumption of an important source of nutrients; beneficial effects on foetal neurological outcome have been shown as a result of maternal fish consumption (Hibbeln et al. 2007). Additionally, animal-source foods have been less appreciated in studies of economically strained urban families in developing nations. We, therefore, took into consideration the changing habits arising from fast urbanization of an Amazonian city to assess the role of HHg (marker of fish consumption) and outcomes of exclusively breastfed-infant development.

We speculate that dominance of fish consumption, although important for some specific nutrients, was successfully replaced by other animal-food sources. The lack of significant association between HHg and WHZ (especially at 5 years) indicates that difference in protein quality (fish vs other sources) was not a determinant of attained growth in these children. This is in agreement with our studies in Amer-Indian children inhabiting the banks

![Figure 5. Maternal BMI (body mass index); (a) profile changes during the study; (b) scatter plot as a function of length of lactation.](image-url)
of the Xingu-basin Rivers in Eastern Amazonia (Dorea et al. 2005a); in these subsistence-level communities of indigenous people a clear change in dominance of fish consumption between the tribes (Kayabi and Munduruku) was not associated with infant growth; other factors like infectious diseases, may influence the health of subjects.

Infant weight at birth (intrauterine growth rate) is directly influenced by maternal constitutional (size) and environmental factors (nutrition). Weight and linear growth of breastfed infants are influenced by human-milk output and nutritional profile (Fornes and Dorea 1995); although genetic factors may be significant, infant postnatal growth is also greatly influenced by illnesses. In the case of exclusive breastfeeding, weight gain is indirectly a result of breastfeeding protection against the nutritional consequences of illness; by decreasing the number of days with gastrointestinal and respiratory tract illnesses (Launer et al. 1990), infant food efficiency is optimized with growth maximization.

Infant growth is the key to assessing nutritional status; while cross-sectional growth data are useful to identify infants whose weight and length outcomes are considered substandard they are limited in assessing the dynamics of breastfeeding in support of the growing child. In this context monitoring infant growth to understand true growth potential is better when based on longitudinal data (Xiong et al. 2007). Several papers have drawn attention to the supposition that infants born with low birth weight may remain lighter and shorter (Xiong et al. 2007); however, in our study, breastfeeding showed a growth rate inversely proportional to birth weight. Overall, our results showed an accelerated rate of length gain in the first few months. These results are in agreement with others (Cole et al. 2002), showing that prolonged and exclusive breastfeeding accelerated weight and length gain in early weeks. Infants in our study showed an apparent increase in thinness at 3 years but no detectable deficit at 5 years.

The infants with lower birth weight – or small size – reflected poor intrauterine growth (or shorter gestational age); however, in the present study, they grew at a faster rate during exclusive breastfeeding. At 5 years, it was not the birth weight but the rate of change in body mass that modulated the attained growth. The very high linear correlation (Figure 4) between birth weight and IWG% indicates a catch-up process. We do not yet understand how the compensatory mechanism operates in breastfeeding to promote the faster move-up of centiles in the smaller babies. Considering that the breast-milk nutrients originated from the (same) maternal sources, higher rates of growth indicate more efficient transfer of nutrients (mother) or more efficient utilization (infant) or, most probably, both.

Differences in placental function (birth weight) and milk supply (postnatal growth) with regard to maternal nutrient transfer are not yet understood. Weaver (2006) has differentiated rapid weight-gain catch-up (after intrauterine restriction) and accelerated growth as a result of excessive energy intake in formula-fed infants. In our study, however, the self regulating (breastfeeding) milk supply does not seem to lead to an excessive energy intake; but the same mother, who apparently produced a smaller foetus, is capable of compensating post-natal infant growth through breast milk. After birth, the (active) infant is apparently more efficient in nutrient acquisition (sucking) and utilization than the (passive) foetus. Indeed, Karaolis-Dancckert et al. (2006) recently reported that relatively smaller and lighter babies grow faster than their larger-at-birth counterparts; they appeared to diverge in growth patterns as early as 6 months. In their study only 30% of fast growers were breastfed for more than 4 months.

Rich in nutrients, hormones and complex non-nutritional factors, human milk is better suited to meet specific requirements for infant development; such a complexity of bioactive substances and neuro-stimulation factors modulates neonatal adaptation and provides protection and immunity; exclusive breastfeeding is also finely tuned to regulate infant
growth (Weaver 2006). In certain circumstances, infant growth is associated with breast-
milk fat content (Fornes and Dorea 1995); however, in regard to birth weight, breast-
milk’s intrinsic nutritional-attributes are not sufficient to explain the inverse relationship of infant
growth and birth weight.

In epidemiological studies the differences in attained growth between bottle- and breast-
fed infants have been attributed to reverse causality (feeding choice influenced by child
health/weight). Cole et al. (2002) discussed reverse causality in the context of feeding-mode
differences: ‘slow-growing infants who are ‘falling off’ their growth curve trajectories may be
deliberately supplemented or weaned in an effort to reverse those trends’. Apparently, this is
not the case in our study; our infants showed an inverse correlation (birth weight vs IWG%,
Figure 4) and a direct association of extended breastfeeding (beyond 6 m) and attained
Z-scores at 3 years (Figure 4). It is amply reported that in the developing world, absence of
or insufficient breastfeeding or early weaning are all frequently associated with diarrhoea and
other infections that can tax growth rate.

In poor urban environments in underdeveloped countries breastfeeding is intertwined
with maternal capability to lactate and infant growth rate and health. Regardless of whether
the mother lactates or not, postpartum weight and body fat changes are maternal
physiological occurrences. We (Fornes and Dorea 1995) have shown that poor urban
mothers (in Goiania, Brazil) can sustain a successful exclusive breastfeeding of 3 months
with BMI values comparable to the present study. The socio-economically disadvantaged
urban mothers of that study, taxed by milk supply demanded by the growing infant, did not
show significant BMI changes (from 15 to 90 days) but showed significant differences in
subcutaneous fat change (Fornes and Dorea 1995). Indeed our study did not show
significant association between maternal BMI (at 36 months) and attained infant weight.
Collectively, there is a distinct pattern of postpartum changes in body weight and adiposity
between affluent and socially disadvantaged mothers (in developing countries): Lactating
mothers in less developed countries lose subcutaneous fat when measured singly (triceps,
more sensitive) or as a sum of several skin-fold measurements. Comparing different studies
of different countries it was shown that these effects tend to occur mainly during the second
trimester of lactation, but will occur in the first semester of lactation in circumstances of
relative maternal malnutrition (Dorea 1997). This is in agreement with the changes observed
in the BMI of the mothers in the present study: The profile between pre-pregnancy and at 6
months and 3 years are indistinguishable.

Fish is important in the diets and health of many poor people suffering from vitamin and
mineral deficiencies, and yet we lack studies of its consumption by populations most
vulnerable to nutrient deficiencies (Roos et al. 2007). The unique feature of this study is to
be able to evaluate the impact of a dietary item (fish consumption) on critical periods of
infant development (gestation, breastfeeding) which is sensitive to the maternal effects of
nutritional factors. Although HHg – the signature of fish consumption – was not significantly
associated with infant growth, the study revealed that extended breastfeeding had a
statistically significant impact on profiles of attained height and weight at 3 years thus
indicating that breastfeeding can be an important modifying factor of weaning.

Conclusion

Fish consumption rates can be traced through HHg; this biomarker showed that nutrient
intakes in tandem with maternal fish consumption rate had no impact on outcomes of growth
and development of breastfed children. In the food transition scenario of Porto Velho, regardless of the animal-source food, the habitual plane of nutrition of these urban mothers was sufficient to sustain satisfactory Z-scores for weight and height at 5 years.

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