Original Article

Intakes from non-breastmilk foods for stunted toddlers living in poor urban villages of Phnom Penh, Cambodia, are inadequate

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Abstract

In Cambodia, the energy and nutrient densities of the traditional rice-based complementary diets used for infant feeding are very low. Whether the adequacy improves after the first year of life is uncertain. Therefore, we examined the feeding practices and the energy and nutrient intakes from non-breastmilk foods (NBMFs) of two groups: partially breastfed (PBF) ($n = 41$) and non-breastfed (NBF) ($n = 210$) stunted toddlers aged 12–42 months from poor villages in Phnom Penh, Cambodia. Intakes of NBMFs were estimated from 24-h recalls and a specially constructed Cambodian food composition table. All the toddlers were breastfed initially, but more than 50% received complementary foods before 6 months of age (mainly rice porridge). Many PBF toddlers received mixed feeding and were often bottle-fed diluted sweetened condensed milk. Unresponsive feeding was widespread. Inappropriate snacks, such as crisps, were the major source of energy, calcium, iron, zinc and vitamin A from NBMFs for the PBF group, and energy and iron for the NBF group. The snacks were often purchased and consumed without any adult supervision. For both groups, intakes of energy, calcium, iron and zinc were consistently below recommendations, as a result of the low micronutrient density of NBMFs and the small amounts fed per feeding. Increasing intakes of animal-source foods and dark-green and yellow fruits and vegetables would enhance micronutrient densities, although this may be neither feasible nor sufficient to overcome the existing deficits. Instead, the feasibility of micronutrient fortification of the rice-based diets of Cambodian toddlers should be explored.

Keywords: Cambodia, toddler, complementary food, nutrient intake, breastfeeding, calcium, iron, zinc, vitamin A, rice.

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Introduction

Many factors have been associated with linear growth faltering during early childhood. They include the effect of maternal malnutrition on fetal growth, alterations in fetal psychosocial conditions, frequent infections, limited household food availability, and poor child feeding practices (Gibson & Hotz 2001). Poor child feeding practices are especially critical for infants from 6 months of age, when breastmilk alone is no longer sufficient to meet their nutritional needs (WHO 1998). Consequently, the World Health Organization (WHO 2002) recommends the introduction of safe and nutritionally adequate complementary foods together with continued breastfeeding until children are at least 2 years of age.

There are no current quantitative data on complementary feeding patterns or energy and nutrient intakes from non-breastmilk foods (NBMFs) of infants and young children in Cambodia, one of the most disadvantaged countries in South-East Asia. Of the children aged <5 years in Cambodia, approximately 37% are stunted and 7% are wasted (CDHS 2006). These estimates are higher than in several other countries in South-East Asia, notably Thailand, Laos Peoples' Democratic Republic (PDR), Vietnam and the Philippines (UNICEF 2007). Likewise, the prevalence of anaemia (i.e. haemoglobin <110 g l^{-1}) is also higher in Cambodia among children aged 6–59 months (64%) than that reported in these South-East Asia countries (CDHS 2006).

Earlier research on child feeding patterns in Cambodia indicates that although most infants are breastfed initially, they often receive fluids other than breastmilk in the first few days after birth (e.g. unboiled water, sugary water and honey), and complementary foods before 6 months of age (Stone *et al*. 1989; Anderson *et al*. 2008; CDHS, 2006). Rice porridge (*borbor*), followed by soups, are the traditional complementary foods given, both of which have a low energy density (Stone *et al*. 1989; Anderson *et al*. 2008). Whether the nutrient adequacy of complementary diets in Cambodia improves after the first year of life is uncertain. Clearly, therefore, there is a need to characterize current child feeding practices, and to provide quantitative data on the adequacy of the energy and nutrient intakes among Cambodian toddlers, especially those who are malnourished. Such information can be used to adapt the WHO guiding principles for feeding breastfed (PAHO/WHO 2003) and non-breastfed (WHO 2005) children to local feeding practices and conditions. The aim would be to enhance growth and development and thus reduce the high rates of malnutrition among young Cambodian children.

Therefore, in this cross-sectional study, we present data on intakes from NBMFs of partially breastfed (PBF) and non-breastfed (NBF) stunted Cambodian toddlers aged 12–42 months. Our objectives were: (i) to compare the feeding practices and energy and nutrient intakes from NBMFs of PBF and NBF stunted toddlers residing in poor urban villages in Phnom Penh, Cambodia; and (ii) to evaluate the adequacy of the energy and nutrient intakes by comparison with the appropriate recommendations.

Subjects and methods

Subjects

The study was conducted in the Mean Chey District of Phnom Penh, Cambodia, home to some of the poorest families in Phnom Penh: in this district, 69% of the children aged <5 years were stunted based on a community survey (Servants, Nutrition Program Baseline Survey, unpublished observations) compared with a national average of 45% (CDHS 2006). The subjects of this study ($n = 251$) were drawn from a group of children aged 6–36 months who had participated in an earlier study. Inclusion criteria for the original study included children permanently residing in the study area with a length or height-for-age Z score < –2 SD and no evidence of chronic disease (e.g. active tuberculosis, symptomatic HIV or hepatitis), whose parents or caretakers agreed to allow their child to attend special clinics for blood testing. Of the 322 stunted children who were recruited for the earlier study, only 251 participated in the dietary study reported here because some families had moved away, others did not agree to the 24-h recall interviews in the homes, and some children had died. All the participating children were assumed to be particularly at risk to poor feeding practices. Written informed consent was obtained from the parents or guardians of the children, and the study protocol was approved by the National Ethics Committee for Health Research of the Ministry of Health, Cambodia, and the Human Ethics Committee of the University of Otago (New Zealand).

The dietary intake study reported here was carried out during the dry cool season – from November to December 2003 – on 251 children (141 male; 110 female) whose parents or guardians agreed to their participation. Data on socio-demographic and health status, early breastfeeding patterns, anthropometric and biochemical micronutrient status of the children measured in May 2003 are reported in detail elsewhere (Anderson *et al*. 2008). Here we present data on anthropometry, feeding patterns, and energy and nutrient intakes collected in November to December 2003.

Anthropometry

Details of the anthropometric methods used have been reported earlier (Anderson *et al*. 2008). Briefly, measurements of weight and length or height were taken in triplicate using calibrated equipment and standardized techniques, with children wearing light clothing and no shoes (Lohman *et al*. 1988). The same anthropometrist conducted each measurement to eliminate interexaminer error. Z-scores for length-for-age (LAZ) or height-for-age (HAZ), weight-for-age (WAZ), weight-for-length (WLZ) or weight-for-height (WHZ), and body mass index (BMI) were calculated using the WHO 2006 multicentre growth reference data and the computer program WHO Anthro 2005 [WHO, Geneva, Switzerland]. A number of toddlers ($n = 15$ for weight; $n = 17$ for length/height) had unacceptably extreme anthropometric values; these observations and the associated Z-scores were assumed to result from operator error and were excluded from the subsequent analyses of the anthropometric data.

Assessment of energy and nutrient intakes

A single interactive 24-h recall was conducted with the caregiver of each child using the multiple-pass technique validated earlier (Gibson & Ferguson 1999); all days of the week were represented in the final sample. Trained research assistants conducted interviews in the participant's homes to encourage participation, improve the recall of foods consumed, and permit the calibration of family utensils. Caregivers were instructed not to change the dietary patterns of their child on the recall day. During the interviews, research assistants observed whether the mothers or caregivers used the strategies for responsive feeding outlined by the PAHO/WHO (2003). These include: assisting toddlers to eat when they feed themselves; encouraging them to eat if they refuse many foods by experimenting with different food combinations, tastes and textures; talking to them while feeding with eye-to-eye contact; and ensuring that there are minimal distractions during meals if the toddlers lose interest easily.

Graduated food models, common household measures, and actual portions of cooked rice, fruits and snacks were used to estimate portion sizes consumed. For the estimates of rice, fruits and snacks consumed by the child, caregivers were requested to spoon the portions consumed by the child into the child's bowl, which was then weighed on dietary scales (Soehnle, CMS Weighing Equipment, London, UK). To estimate the weight of rice porridge (i.e. *borbor*) consumed, a volume of water equivalent to the volume of *borbo* consumed was measured, and then converted into grams using a specific gravity factor derived for rice porridge. For composite dishes, household recipe data were collected from the caretakers and used to calculate the nutrient composition, with adjustments based on local food preparation practices for nutrient retention and yield factors, where appropriate, as outlined by Gibson & Ferguson (1999). The yield factors used were those compiled by Banjong *et al*. (2001) for Thai foods because no Cambodian data were available. The amount of each ingredient of the composite dish was then estimated from the portion consumed by the child as a fraction of the amount prepared. In cases where recipe data were not available, data for an average recipe were used.

A Cambodian nutrient composition database containing 238 food and beverage items consumed by the children was compiled using Microsoft Excel, based on a database developed earlier for north-east Thai schoolchildren (Gibson *et al*. 2007). Additional sources of nutrient values were obtained from food composition tables for Thailand (Puwastien *et al*. 2000; INMU, 2002), Malaysia (Siong *et al*. 1997) and the Philippines (FNRI 1997), and values for Indonesian foods from the World Food Dietary Assessment System (Bunch & Murphy 1997). The values for phytate, iron, zinc and calcium for the traditional rice porridge (*borbor*) were based on direct chemical analyses of samples purchased from vendors in the study area in Phnom Penh, Cambodia, and analysed in our laboratory; details of the analytical methods used have been published earlier (Krittaphol *et al*. 2007). Adjustments were made to the food composition values obtained by chemical analyses or from the alternative databases to take into account differences in the moisture content. For vitamin A, levels in plant-based products were based on concentrations of β-carotene only; data were not available for the other provitamin A carotenoids (i.e. α-carotene, or α- and β-cryptoxanthins). The vitamin A activity of foods was expressed as retinol equivalents (REs) for comparison with the WHO (Dewey & Brown 2003) and the FAO/WHO (2002) recommendations.

Average daily intakes and major food sources of energy, macro- and micronutrients, and phytate from the major food groups were calculated from the 24-h recall results for the PBF children aged 12–23 and 24–36 months, and for the NBF children aged 12–23, 24–36 and 37–42 months. Average phytate : zinc molar ratios for the diets of each age group were also calculated to estimate zinc bioavailability (Hotz & Brown 2004). The amount of haem iron in the diet was calculated assuming that 40% of the iron from meat, poultry and fish was haem iron.

Assessment of energy and nutrient adequacy

The median daily intakes from NBMFs for the PBF children aged 12–23 months were compared with the estimated needs for energy and nutrients and desired levels for nutrient densities (WHO 1998; Dewey & Brown 2003), assuming an average breastmilk intake, and breastmilk composition based on data from industrialized countries, with the exception of vitamin A. For the latter, estimates for the concentration in breastmilk of women in low-income countries was used (Underwood 1994).

For the PBF and NBF children aged 24–36 months, and the NBF children aged 37–42 months, average daily intakes were compared with the FAO/WHO/UNU energy and protein requirements (1985; 2004) and the WHO/FAO (2004) recommended nutrient intakes (RNIs). Caution must be used when interpreting the adequacy of the energy and nutrient intakes for the PBF children aged 24–36 months, because the intakes did not include the energy and nutrient contribution from breastmilk.

Statistical analyses

All continuous data were checked for normality using the Kolmogorov-Smirnov test. Differences in the selected socio-demographic variables, immunization status and feeding patterns by feeding group were tested using the chi-square test. Differences in the anthropometric *Z*-scores by age for the PBF and NBF toddlers were examined using an independent sample *t*-test (equal variances not assumed). Dietary intake data (per day and per 100 kcal) for the PBF and NBF groups were expressed as medians (interquartile range, IQR) for consistency because of non-normal distributions of some nutrients for both PBF and NBF children. Differences in the median intakes, nutrient densities and selected indices of dietary quality between the two age groups of PBF children and among the three age groups of the NBF children were examined using the non-parametric Mann–Whitney *U*-test and the Kruskal–Wallis test, respectively. Statistical analyses were carried out using SPSS version 12 (USD Inc., Stone Mountain, GA, USA).

Results

Socio-demographic factors, immunization status and feeding patterns

The median household size consisted of two adults and three children. Other socio-demographic characteristics of the households of the PBF and NBF children are shown in Table 1. Of the toddlers aged 12–23 months,

Table 1. Selected socio-demographic factors, immunization status and feeding patterns of partially breastfed and non-breastfed Cambodian toddlers

	Partially breastfed		Non-breastfed		Significant difference
	n	%	*n*	%	
Age					
12–23 months	22	53.7	39	18.6	
24–36 months	16	39.0	108	51.4	
>36 months	3	7.3	63	30.0	
Sex					
Male	24	58.5	114	55.1	NS
Female	17	41.5	93	44.9	
Source of drinking water*					
River/canal	21	52.5	120	58.0	NS
Well	6	15.0	21	10.1	
Hand/treadle pump	5	12.5	31	15.0	
Water traders	8	20.0	35	16.9	
Boiling of drinking water*					
Yes	17	42.5	130	63.7	NS
No	8	20.0	25	12.3	
Sometimes	15	37.5	49	24.0	
Sewerage*					
Home latrine	8	20.0	104	50.5	0.01
Public latrine	2	5.0	3	1.5	
Garden	11	27.5	34	16.5	
Field	16	40.0	47	22.8	
River	3	7.5	18	8.7	
Immunizations*					
No immunizations	7	17.5	18	8.7	
Partly immunized	19	47.5	61	29.5	
Fully immunized	14	35.0	128	61.8	
Introduction of complementary foods*					
Infant <4 months old	8	20.5	40	19.5	NS
Infant 4–6 months old	23	59.0	104	50.7	
Infant >6 months old	8	20.5	61	29.8	
Bottle-feeding*					
Yes	9	22.5	77	37.7	
No	20	50.0	84	41.2	
Sometimes	11	27.5	43	21.1	

*Variables with a few missing values; NS, not significant.

36% were still breastfed, but only 13% of the age group of 24–36 months. More than 50% of the households in each feeding group used the river or canal as their primary source of drinking water. Regardless of the source, the drinking water was boiled in 42.5% and 63.7% of the households of the PBF and NBF toddlers, respectively. Fewer households in the PBF compared with the NBF group (i.e. 20% vs. 50.5%) had a home latrine. Of the toddlers, 17.5% in the PBF group and 8.7% in the NBF group had not been immunized at the time of the study (Table 1). This difference was in part associated with the younger age distribution of the PBF compared with the NBF toddlers: more of the older children were fully immunized than their younger counterparts ($P = 0.008$).

Anthropometry

Table 2 presents the mean and SD for the LAZ or HAZ, WAZ, WLZ or WHZ, and BMI *Z*-scores for the

Table 2. Mean, SD (*n*) for anthropometric growth indices of partially breastfed and non-breastfed Cambodian toddlers by age

Age (months)	Partially breastfed	Non-breastfed	*P**
Length- or height-for-age *Z*-score			
12–23	–2.55, 1.02 (20)	–1.78, 1.13 (36)	0.015
24–36	–1.97, 1.06 (14)	–2.18, 1.14 (104)	0.520
37–42	–	–2.29, 0.80 (60)	–
Weight-for-age *Z*-score			
12–23	–2.09, 0.91 (20)	–1.52, 1.04 (36)	0.049
24–36	–1.86, 0.95 (14)	–1.85, 0.89 (105)	0.948
36–42	–	–1.97, 0.71 (61)	–
Weight-for-length or height *Z*-score			
12–23	–1.07, 0.88 (21)	–1.00, 0.91 (35)	0.819
24–36	–1.20, 0.75 (16)	–0.94, 0.86 (103)	0.254
37–42	–	–0.91, 0.76 (61)	–
BMI-for-age *Z*-score			
12–23	–0.61, 0.91 (21)	–0.73, 0.93 (35)	0.658
24–36	–0.84, 0.74 (16)	–0.68, 0.93 (103)	0.508
37–42	–	–0.64, 0.79 (61)	–

*Significance of the difference in the mean of the partially breastfed and non-breastfed subjects calculated using an independent sample *t*-test (equal variances not assumed). BMI, body mass index.

PBF and NBF toddlers by age group based on anthropometric measurements taken in November and December 2003. Mean LAZ (or HAZ) and WAZ scores for the PBF children aged 12–23 months were significantly lower ($P < 0.05$) than those for their NBF counterparts. Differences were not observed for the mean WLZ (or WHZ) and BMI-for-age *Z*-scores. There were no significant differences in the *Z*-scores of the PBF and NBF children aged 24–36 months.

At the time of this dietary study, 64% of the children were still stunted and 47% were underweight. In contrast, the prevalence of wasting (i.e. WLZ score < –2 SD) was much lower (i.e. 11%). Of the children, 9% ($n = 19$) were both stunted and wasted. The prevalence of stunting and wasting was not significantly different in the PBF and NBF groups.

Feeding patterns

Rice products, mainly as rice porridge, were the major NBMFs for all the toddlers, irrespective of age and feeding group, providing 45–50% of the total intake (in grams), followed by soups (12–16%), and then fruits (11–12%) and snacks (7–10%). Intakes of meat and poultry, fish, eggs and vegetables were low for both groups regardless of age (i.e. <4% total food intake in grams). Not surprisingly, intake of breast-milk substitutes (in grams) was higher among the NBF compared with the PBF toddlers, especially among those aged 12–23 months.

Mixed feeding was frequent: in 50% of the PBF toddlers, bottle-feeding with commercial milk formulas or sweetened condensed milk was practised. Other beverages, such as tea, coffee and/or sugary drinks, were also given to both PBF and NBF toddlers in feeding bottles or plastic cups. Unlike immunization status, however, the practice of bottle-feeding was not significantly associated with age, and was similar in the PBF and NBF toddlers.

The majority of the urban Cambodian mothers or caretakers in this study did not practise responsive feeding, as judged by their failure to adopt the guidelines recommended by the PAHO/WHO (2003), including encouraging their toddlers to eat, talking to their child during feeding with eye-to-eye contact, and avoiding distractions during meals. Instead, many adopted a more laissez-faire approach, allowing their toddlers to consume inappropriate snacks, often purchased and eaten with minimal adult supervision. Of the 12 snacks consumed, those most frequently eaten were crisps, followed by plain or sweet biscuits, and sponge cake.

Major sources of energy and nutrients

The food groups providing at least 15% of the energy, protein and the micronutrients classified as 'problem nutrients' (vitamin A, calcium, iron and zinc) by the WHO (1998) are shown in Table 3 for the PBF and NBF groups aged 12–23 and 24–36 months. Snack foods were the most important source of energy for both the PBF and NBF toddlers, regardless of age, followed by rice products. Snacks were also the major source of all four of the problem micronutrients for the PBF toddlers, and iron for the NBF toddlers. In contrast, dairy products were the primary source of calcium, zinc and vitamin A for the younger group of NBF toddlers (reflecting their consumption of commercial milk formulas). However, for their older counterparts, soft-boned fish was the primary source

Table 3. Food groups providing at least 15% of intakes of energy and selected nutrients for partially breastfed and non-breastfed Cambodian toddlers, listed in order of importance with the contribution (%)

	Age group (months)	Partially breastfed	Non-breastfed
Energy			
	12–23	Snacks (42), rice products (20)	Snacks (36), rice products (16)
	24–36	Snacks (40), rice products (26)	Snacks (34), rice products (16)
Protein			
	12–23	Fish (29), snacks (24), M & P (16)	Fish (25), M & P (23), snacks (16)
	24–36	Fish (35), snacks (25), M & P (16)	Fish (28), M & P (27)
Calcium			
	12–23	Snacks (34), soup (23)	Dairy (58)
	24–36	Snacks (34), fish (25)	Fish (21), dairy (18)
Iron			
	12–23	Snacks (39), fish (15)	Snacks (30), dairy (20)
	24–36	Snacks (42)	Snacks (28), fish (16)
Zinc			
	12–23	Snacks (35), rice (26)	Dairy (27), snacks (21), rice (18)
	24–36	Snacks (40), rice (26)	M & P (24), snacks (20), rice (16)
Vitamin A			
	12–23	Snacks (31)	Dairy (51), eggs (15)
	24–36	Snacks (33)	M & P (80)

Percentage contribution of food group to energy or nutrient intakes. M & P, meat and poultry.

of calcium, and meat plus poultry was the primary source of zinc and vitamin A. River fish was the primary source of protein from non-milk foods for all the groups, with the exception of the NBF group aged 37–42 months (data not shown), for whom the primary protein source was meat plus poultry.

Amount and adequacy of daily energy and nutrient intakes

Within the two feeding groups, differences in intake between the sexes were mostly small or insignificant. Table 4, therefore, shows the median intakes of energy and selected nutrients from NBMFs for the PBF and NBF toddlers classified by age group but with the sexes combined. Intakes for PBF children aged 37–42 months are not included because of the small number of children in this age group ($n = 3$). Within each feeding group, there were no significant differences in median intakes of energy and nutrients by age group. Not surprisingly, the median intakes of energy and most nutrients for the NBF toddlers aged 12–23 and 24–36 months (Table 4) seemed to be higher than intakes from complementary foods alone for the PBF toddlers of comparable age.

Median energy intake for the younger PBF toddlers aged 12–23 months was 86% of the estimated energy need from complementary food set by the WHO (1998), but 117% of the energy need based on the US longitudinal data on energy requirements (Butte *et al*. 2000). Median intakes of thiamine, calcium, iron and zinc for the same group were below the WHO (2002) estimated needs from complementary foods based on the FAO/WHO (2002) RNIs (Dewey & Brown 2003). The shortfalls were especially marked for iron and zinc (assuming moderate bioavailability), and calcium. Median nutrient intakes that met or exceeded the WHO estimated needs were protein, vitamin A, vitamin C, riboflavin, niacin, copper and phosphorus. The median energy intakes of the older PBF toddlers aged 24–36 months and the two older age groups of NBF toddlers were below the corresponding FAO/WHO/UNU (2004) energy requirements assuming moderate physical activity, although when the median energy intakes were expressed per kg bodyweight, the energy requirements for the older PBF toddlers and all the NBF groups were met. In contrast, median intakes of protein and niacin for the older PBF toddlers and the three groups of NBF toddlers met or exceeded the

Table 4. Median (interquartile range) intakes of energy and selected nutrients from non-breastmilk foods for partially breastfed (PBF) and non-breastfed (NBF) Cambodian toddlers

PBF toddlers	12–23 months ($n = 22$)	WHO estimated needs for PBF toddlers	24–36 months ($n = 16$)
Energy (kcal)	640 (513, 947)	746*, 548†	770 (581, 1114)
Protein (g)	17.6 (13.0, 23.3)	5	19.1 (14.3, 28.1)
Retinol (μg RE)	133 (68, 248)	126	74 (33, 296)
Thiamine (mg)	0.3 (0.2, 0.4)	0.4	0.4 (0.2, 0.5)
Riboflavin (mg)	0.3 (0.2, 0.5)	0.3	0.4 (0.2, 0.6)
Niacin‡ (mg)	5.1 (3.4, 6.5)	5	5.6 (4.6, 6.1)
Vitamin C (mg)	26.6 (16.5, 41.9)	8	17.4 (5.1, 34.6)
Calcium (mg)	132 (95, 201)	346	112 (88, 186)
Phosphorus (mg)	243 (171, 303)	193§	255 (146, 356)
Iron (mg)	4.0 (2.8, 5.3)	5.8¶	4.6 (2.6, 6.2)
Zinc (mg)	1.5 (1.2, 1.9)	3.7**	1.6 (1.4, 2.2)
Copper (mg)	0.4 (0.3, 0.5)	0.3§	0.4 (0.2, 0.5)
NBF toddlers	**12–23 months ($n = 39$)**	**24–36 months ($n = 108$)**	**37–42 months ($n = 63$)**
Energy (kcal)	972 (733, 1391)	952 (692, 1307)	958 (747, 1449)
Protein (g)	29.4 (19.5, 43.5)	27.5 (20.9, 40.8)	31.2 (20.5, 45.6)
Retinol (μg RE)	149 (87, 287)	159 (89, 289)	164 (109, 267)
Thiamine (mg)	0.6 (0.4, 0.8)	0.6 (0.4, 0.8)	0.5 (0.4, 0.7)
Riboflavin (mg)	0.5 (0.3, 0.9)	0.5 (0.4, 0.8)	0.5 (0.3, 0.7)
Niacin‡ (mg)	7.8 (5.7, 10.0)	7.6 (5.6, 10.6)	9.0 (6.8, 11.7)
Vitamin C (mg)	31.6 (18.1, 53.8)	21.8 (10.8, 51.8)	30.1 (18.0, 45.8)
Calcium (mg)	164 (88, 258)	154 (107, 250)	158 (117, 246)
Phosphorus (mg)	317 (247, 671)	380 (246, 559)	356 (240, 554)
Iron (mg)	6.8 (3.6, 10.2)	5.8 (4.2, 8.7)	6.3 (3.9, 8.7)
Zinc (mg)	2.4 (1.7, 3.9)	2.8 (1.9, 3.6)	2.9 (1.9, 3.9)
Copper (mg)	0.6 (0.4, 1.0)	0.5 (0.4, 0.8)	0.6 (0.4, 0.8)

* World Health Organization (WHO, 1998). † Butte *et al*. (2000) ‡Excluding the contribution of dietary tryptophan to niacin synthesis. § WHO (1998). ¶Assuming medium (10%) bioavailability of iron. **Based on zinc content of breastmilk at 9-month lactation from Krebs *et al*. (1995); assuming moderate bioavailability of zinc. N.B. For energy and all the nutrients, differences in the median intakes by age group for the PBF and the NBF groups are not significant (Mann–Whitney *U*-test for PBF and Kruskal–Wallis test for NBF). RE, retinol equivalent.

WHO/FAO (2004) RNIs, whereas those for thiamine for the PBF aged 24–36 months, and vitamin C for both the PBF and NBF toddlers aged 24–36 months, were below the RNIs. Likewise, median intakes of vitamin A, calcium, zinc (assuming moderate bioavailability) and iron (assuming 5% bioavailability) for the PBF toddlers aged 24–36 months and all three groups of NBF toddlers fell short of the WHO/FAO (2004) RNIs.

Dietary quality

Table 5 presents the median energy (kcal g^{-1}) and nutrient densities (intakes per 100 kcal) for both the complementary diets for the PBF toddlers and the diets of the NBF toddlers by age group. The energy density was lowest for the complementary diets of the PBF group aged 12–23 months (1.0 kcal g^{-1}), and highest for the diets of the NBF children aged 12–23 months (1.3 kcal g^{-1}). The protein density of the complementary diets for the PBF toddlers aged 12–23 months was markedly greater than the desired protein density (Dewey & Brown 2003). In contrast, the nutrient densities for thiamine, calcium, iron and zinc (assuming moderate bioavailability) for the complementary diets were all less than 80% of the desired level, with the greatest shortfall being for calcium (i.e. 38%). There were no significant differences in the median nutrient densities of the complementary diets of the two groups of PBF toddlers or

Table 5. Median (interquartile range) nutrient densities of the complementary diets of the partially breastfed (PBF) toddlers and diets of the non-breastfed (NBF) Cambodian toddlers. Desired nutrient densities are for PBF toddlers aged 12–23 months only*

PBF toddlers	12–23 months ($n = 22$)	24–36 months ($n = 16$)	Desired density*
Energy density (kcal g^{-1})	1.0 (0.8, 1.4)	1.2 (1.0, 1.8)	
Protein (g 100 $kcal^{-1}$)	2.8 (2.3, 3.3)	2.4 (2.1, 3.2)	0.9
Retinol (μg RE 100 $kcal^{-1}$)	21.7 (10.5, 30.8)	16.9 (5.0, 27.6)	23
Calcium (mg 100 $kcal^{-1}$)	18.7 (16.6, 24.6)	13.6 (9.7, 23.2)	63.0
Iron (mg 100 $kcal^{-1}$)	0.6 (0.5, 0.8)	0.5 (0.4, 0.8)	1.0†
Zinc (mg 100 $kcal^{-1}$)	0.2 (0.2, 0.3)	0.2 (0.2, 0.2)	0.6
Thiamine (mg 100 $kcal^{-1}$)	0.05 (0.03, 0.07)	0.05 (0.03, 0.08)	0.07
Riboflavin (mg 100 $kcal^{-1}$)	0.05 (0.03, 0.06)	0.05 (0.03, 0.06)	0.06
Niacin‡ (mg 100 $kcal^{-1}$)	0.8 (0.6, 1.0)	0.7 (0.5, 1.0)	0.9
Vitamin C (mg 100 $kcal^{-1}$)	4.4 (2.0, 6.2)	2.4 (0.7, 4.9)	1.5
NBF toddlers	**12–23 months ($n = 40$)**	**24–36 months ($n = 108$)**	**37–42 months ($n = 62$)**
Energy density (kcal/g)	1.3 (1.0, 1.6)	1.2 (1.0, 1.4)	1.1 (0.9, 1.3)
Protein (g 100 $kcal^{-1}$)	3.0 (2.5, 3.4)	3.1 (2.5, 3.7)	3.0 (2.5, 3.6)
Retinol (μg RE 100 $kcal^{-1}$)	14.2 (8.9, 26.4)	16.4 (10.0, 28.3)	17.0 (12.9, 25.1)
Calcium (mg 100 $kcal^{-1}$)	15.1 (10.5, 23.5)	17 (13.0, 22.5)	16.1 (11.5, 22.8)
Iron (mg 100 $kcal^{-1}$)	0.6 (0.5, 0.9)	0.6 (0.5, 0.8)	0.6 (0.5, 0.8)
Zinc (mg 100 $kcal^{-1}$)	0.3 (0.2, 0.3)	0.3 (0.2, 0.3)	0.3 (0.2, 0.3)
Thiamine (mg 100 $kcal^{-1}$)	0.05 (0.04, 0.08)	0.06 (0.04, 0.08)	0.05 (0.04, 0.07)
Riboflavin (mg 100 $kcal^{-1}$)	0.05 (0.04, 0.06)	0.05 (0.04, 0.07)	0.05 (0.04, 0.06)
Niacin‡ (mg 100 $kcal^{-1}$)	0.9 (0.7, 1.0)	0.8 (0.7, 1.0)	0.9 (0.7, 1.1)
Vitamin C (mg 100 $kcal^{-1}$)	3.0 (1.9, 4.7)	2.2 (1.2, 4.3)	2.7 (1.8, 5.1)

*Average desired nutrient density for the complementary diets of children aged 12–23 months based on World Health Organization (WHO) recommended nutrient intakes (Dewey & Brown 2003). †Medium bioavailability of iron. ‡Excluding the contribution of dietary tryptophan to niacin synthesis. N.B. For all the nutrients, differences in the median densities by age group for the PBF and NBF groups are not significant (Mann–Whitney *U*-test for PBF and Kruskal–Wallis test for NBF).

the diets of the NBF toddlers across the three age groups.

Table 6 compares the median intakes (IQR) for additional indices of dietary quality for the PBF and NBF groups. Again, these indices of dietary quality did not differ significantly either between the two groups of PBF toddlers, or among the three groups of NBF toddlers.

Discussion

To our knowledge, this is the first study to quantify and compare the energy and nutrient intakes from NBMFs of PBF and NBF toddlers in Cambodia. To our knowledge, comparable data for children in adjacent areas in Laos PDR, Vietnam and Thailand are also lacking.

Feeding practices

Several of the feeding practices identified in this study were not in accordance with the WHO guidelines for breastfed (PAHO/WHO 2003) and NBF (WHO 2005) children and probably contributed to the poor growth of these stunted toddlers. These include the introduction of complementary foods before 6 months of age and failure to practise responsive feeding. Indeed, lack of encouragement to eat may have contributed to the absence of any significant differences in intakes of energy and nutrients in the older PBF and NBF toddlers compared with their younger counterparts. Such a practice is especially detrimental after illness, when anorexia often places the child at high risk for inadequate dietary intakes.

Table 6. Median (interquartile range) dietary quality indices of the non-breastmilk foods for partially breastfed (PBF) and non-breastfed (NBF) Cambodian toddlers

PBF toddlers	12–23 months ($n = 22$)	24–36 months ($n = 16$)	
Animal protein (g)	6.7 (3.6, 10.8)	7.9 (6.1, 9.6)	
Iron from meat, poultry, fish (mg)	0.5 (0.3, 0.7)	0.4 (0.2, 0.8)	
Haem iron (mg)	0.2 (0.1, 0.3)	0.1 (0.1, 0.3)	
Phytate (mg)	115 (75, 133)	130 (114, 182)	
Phytate : zinc molar ratios	6.9 (4.7, 8.8)	8.0 (5.9, 9.2)	
NBF toddlers	**12–23 months ($n = 39$)**	**24–36 months ($n = 108$)**	**37–42 months ($n = 63$)**
Animal protein (g)	13.3 (8.7, 22.3)	13.7 (8.3, 22.2)	14.7 (6.2, 24.6)
Iron from meat, poultry, fish (mg)	0.7 (0.3, 1.2)	0.9 (0.4, 1.7)	0.9 (0.5, 1.9)
Haem iron (mg)	0.3 (0.1, 0.5)	0.4 (0.2, 0.7)	0.4 (0.2, 0.8)
Phytate (g)	142 (112, 188)	138 (93, 221)	155 (134, 222)
Phytate : zinc molar ratios	6.3 (4.1, 7.3)	5.7 (3.7, 7.5)	6.2 (4.7, 7.2)

N.B. For all the dietary quality indices, differences in the medians by age group for the PBF and the NBF groups are not significant (Mann–Whitney U-test for PBF and Kruskal–Wallis test for NBF).

The major role of inappropriate snacks in the diets of these Cambodian toddlers is also of concern. Both the purchase and consumption of these snacks were frequently not supervised by an adult, and highlights the laissez-faire feeding style. Such a practice is disturbing. In Ghanaian children, for example, a care practices scale that included two attributes of responsive feeding was positively associated with anthropometric status even for children whose mothers, like the Cambodian mothers studied here, had little or no schooling (Ruel *et al*. 1999).

Mixed breast- and bottle-feeding was practised by almost one-third of the breastfeeding mothers in this study. Although the reasons for mixed feeding were not explored, it is possible that mothers introduced bottle-feeding when they were working outside the home, perhaps for financial reasons. Sweetened condensed milk was often used for mixed feeding and as a source of milk for the NBF children instead of the acceptable milk sources recommended by the WHO (2005), such as full-cream animal milk, preferably boiled before use, ultra high-temperature milk, reconstituted evaporated milk or fermented milk, or yogurt.

Tea, coffee and sugary drinks were also frequently given to the toddlers, despite the WHO (2005) recommendation that such drinks should be avoided. Besides their low energy and nutrient density, the caffeine in tea and coffee may suppress a child's appetite (Olness 1985), while the polyphenols compromise non-haem iron absorption (Mennen *et al*. 2005). In contrast, vitamin A-rich foods, such as orange/yellow vegetables and fruits and dark-green leafy vegetables, were rarely consumed. Indeed, many mothers reported that children disliked vegetables, although small amounts were included in watery soups.

In this study, the younger PBF toddlers appeared to be more stunted and underweight than their NBF counterparts, a trend also reported by others. It is possible that reverse causality, a phenomenon whereby the mother's decision to continue breastfeeding is influenced by the child's poor nutritional status, and/or the existence of a 'beneficial survival effect' or bias arising from the immuno-protective and anti-infectious factors in breastmilk may be implicated in this finding (Marquis *et al*. 1997a; Simondon & Simondon 1998), although uncertainties associated with the cross-sectional nature of this study and the anthropometric measurements cannot be excluded.

Adequacy of energy and nutrient intakes

The low energy intake of these Cambodian toddlers consuming rice-based diets is not unique to South or South-East Asia, and has been reported by others

(Perlas *et al*. 2004; Kimmons *et al*. 2005; Miyoshi *et al*. 2005; Kennedy *et al*. 2007). Such energy deficits may explain in part the low WLZ (or WHZ) scores (Table 2). Indeed, the actual energy deficits were even greater because the energy requirements used do not provide for catch-up growth for these malnourished toddlers. Increases of 5% and 3.5% over the energy requirement for a well-nourished population have been estimated as needed to facilitate catch-up growth for toddlers aged 12–18 and 18–24 months, respectively (FAO/WHO/UNU 2004).

Theoretically, the energy requirement of the NBF toddlers aged 12–23 months should have been met, because they were fed three times daily with a diet with a higher energy density (i.e. 1.3 kcal g^{-1}) (Table 4) than the minimum energy density (i.e. 1.08 kcal g^{-1}) stipulated by the WHO (2005) for three feedings per day. However, because of their below-average bodyweight (i.e. 9.2 kg) and hence smaller gastric capacity, the amount of food consumed at each feeding was probably not adequate, especially given the widespread practice of unresponsive feeding by the caregivers of these Cambodian toddlers.

Micronutrient inadequacies, notably in vitamin A, zinc, calcium, and to a lesser extent, iron, were a feature of the diets of both the PBF and NBF stunted toddlers studied here (Table 4), exacerbated by the low micronutrient densities. This suggests that even if their energy needs were met by increasing the amount and/or feeding frequency, intakes of these four 'problem' micronutrients would probably still be limiting, as reported elsewhere (Chusilp *et al*. 1992; Murphy *et al*. 1992; Calloway *et al*. 1993; Hotz & Gibson 2001; Perlas *et al*. 2004).

Of the few nutrients that exceeded the recommended levels, protein (per day and per 100 kcal) was the most consistent irrespective of feeding group or age, as noted by others for toddlers (Beaton *et al*. 1992; Hautvast *et al*. 1999; Hotz & Gibson 2001; Perlas *et al*. 2004; Kimmons *et al*. 2005). In contrast, reports on the adequacy of B-vitamins in the diets of toddlers are more variable (Chusilp *et al*. 1992; Calloway *et al*. 1993; Perlas *et al*. 2004). Of the B-vitamin intakes assessed in this study, only thiamine was below the recommended level for the two age groups of PBF toddlers.

Dietary quality of NBMFs

Several earlier reports have emphasized that the nutritional status of toddlers may be governed more by the overall dietary quality than the frequency of breastfeeding (Briend & Bari 1989; Onyango *et al*. 1998). In this study, the quality of the diets of the PBF and NBF Cambodian toddlers was poor, based on their micronutrient density. Deficits in vitamin A, iron and calcium for the complementary diets were similar to those reported elsewhere (Jackson *et al*. 1992; Hautvast *et al*. 1999; Hotz & Gibson, 2001; Perlas *et al*. 2004). However, the zinc density was much lower (Hotz & Gibson 2001; Perlas 2002), and only one-third of the desirable level. This is cause for concern, especially because 6 months earlier, more than 70% of these stunted Cambodian toddlers had low serum zinc concentrations indicative of zinc deficiency (Anderson *et al*. 2008). Hence, shortfalls in intakes of zinc probably contributed to the high rates of stunting noted here, because adequate intakes are critical for lean tissue synthesis and full catch-up growth (Golden & Golden 1992).

The micronutrient densities of the diets of the NBF Cambodian toddlers were comparable to those reported for NBF toddlers in other low-income countries (Chusilp *et al*. 1992; Murphy *et al*. 1992; Calloway *et al*. 1993), with the exception of preformed niacin and phosphorus. Not surprisingly, the density for preformed niacin was higher, whereas the phosphorous density was lower for these rice-based diets than for maize-based diets, as was the phytate content and thus the phytate : zinc molar ratio (Murphy *et al*. 1992; Hotz & Gibson 2001; Perlas 2002; Gibson *et al*. 2007). Hence, absorption of zinc, as well as calcium and iron, will not be compromised by high phytate levels as these are rice-based diets, although polyphenols from any tea or coffee consumed will inhibit non-haem iron absorption (Mennen *et al*. 2005).

Diets of toddlers with low micronutrient densities typically have a low content of animal protein, and thus haem iron (Table 6), and provitamin A-rich plant-based foods (Allen *et al*. 1992; Murphy *et al*. 1992; Calloway *et al*. 1993), as noted here, a trend that may also be associated with the poor growth of these Cambodian toddlers. Indeed, meat, poultry and fish each provided less than 10% of the energy for the PBF and NBF toddlers, irrespective of age, and in other toddler studies, a relatively high proportion of energy from animal-source foods has been positively associated with improved growth (Allen *et al*. 1992; Marquis *et al*. 1997b).

Some uncertainties exist in the evaluation of the adequacy of micronutrient intakes for the toddlers in this cross-sectional study. For example, for the PBF group aged 12–23 months, comparison with the WHO estimated needs (Dewey & Brown 2003) assumed that the breastmilk was of average amount and composition (with the exception of vitamin A), even though concentrations for riboflavin and thiamine also have the potential to be reduced by poor maternal status (WHO 1998). Consequently, although not evident here (Table 4), shortfalls in intakes of riboflavin and thiamine may have also existed for the younger PBF toddlers. A further limitation is our failure to apply the estimated average requirement (EAR) cut-point method to calculate the proportion of toddlers at risk of nutrient adequacy, as recommended by Murphy and Poos (2002). This approach was not possible because only single 24-h recalls were obtained. Instead, we compared the intakes with the RNIs (WHO/FAO 2004). However, even when the median nutrient intake for a group equals the RNI, a proportion of the group will still have usual intakes below the EAR because of their wide variation in nutrient intakes. Indeed, to ensure a low prevalence of intakes below the EAR, the mean intake of a group should exceed the RNI, often by a considerable amount (Murphy & Poos 2002). Finally, we recognize that the energy and nutrient intakes for the PBF toddlers aged 24–36 months are underestimated because we did not include the energy and nutrient contribution from breastmilk.

Conclusions

Notwithstanding the limitations discussed above, we believe this study has several strengths. This is the first study to quantify energy and nutrient intakes of both PBF and NBF toddlers living in poor urban villages in Phnom Penh, using a unique food composition table compiled especially for use in Cambodia. We have highlighted several factors that may contribute to the poor growth of these stunted Cambodian toddlers, which could be readily addressed by educating caregivers on appropriate feeding practices and behaviours. These include: introduction of complementary foods before 6 months of age; failure to practise responsive feeding and use boiled water for child feeding; consumption of tea, coffee, sugary drinks and inappropriate snacks; frequent mixed breast- and bottle-feeding, often with sweetened condensed milk; and poor micronutrient density of non-milk-based foods. Of special concern are the deficits in vitamin A, iron, calcium and zinc, which cannot be rectified by increasing the amount or frequency of the NBMFs currently provided. Instead, access to affordable animal-source foods, dark-green and yellow fruits and vegetables, and/or low-cost micronutrient fortified complementary foods is urgently needed to enhance the nutritional quality of the diets of Cambodian toddlers, and thus enhance their growth and development.

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