Maternal & Child Nutrition

DOI: 10.1111/j.1740-8709.2011.00380.x

Original Article

World Health Organization (WHO) infant and young child feeding indicators: associations with growth measures in 14 low-income countries

Bernadette P. Marriott*†‡, Alan White*, Louise Hadden*, Jayne C. Davies§ and John C. Wallingford§

*Abt Associates, Inc., Durham, North Carolina, USA, †Samueli Institute, Alexandria, Virginia, USA, ‡Univeristy of North Carolina, Chapel Hill, North Carolina, USA, and §Pfizer Nutrition, Collegeville, Pennsylvania, USA

Abstract

Eight World Health Organization (WHO) feeding indicators (FIs) and Demographic and Health Survey data for children <24 months were used to assess the relationship of child feeding with stunting and underweight in 14 poor countries. Also assessed were the correlations of FI with country gross national income (GNI). Prevalence of underweight and stunting increased with age and ≥50% of 12–23-month children were stunted. About 66% of babies received solids by sixth to eighth months; 91% were still breastfeeding through months 12–15. Approximately half of the children were fed with complementary foods at the recommended daily frequency, but <25% met food diversity recommendations. GNI was negatively correlated with a breastfeeding index ($P < 0.01$) but not with other age-appropriate FI. Regression modelling indicated a significant association between early initiation of breastfeeding and a reduction in risk of underweight ($P < 0.05$), but a higher risk of underweight for continued breastfeeding at 12–15 months ($P < 0.001$). For infants 6–8 months, consumption of solid foods was associated with significantly lower risk of both stunting and underweight ($P < 0.001$), as was meeting WHO guidance for minimum acceptable diet, iron-rich foods (IRF) and dietary diversity ($P < 0.001$); desired feeding frequency was only associated with lower risk of underweight ($P < 0.05$). Timely solid food introduction, dietary diversity and IRF were associated with reduced probability of underweight and stunting that was further associated with maternal education ($P < 0.001$). These results identify FI associated with growth and reinforce maternal education as a variable to reduce risk of underweight and stunting in poor countries.

Keywords: infant feeding, WHO feeding indicators, underweight, stunting.

Correspondence: Bernadette P. Marriott, Samueli Institute, 1737 King Street, Suite 600, Alexandria, VA 22314-2847, USA. E-mail: BMarriott@siib.org

Introduction

Recent analyses have found a decrease in child deaths under 5 years of age worldwide to 8.795 million in 2008 (Black *et al*. 2010) and 7.7 million in 2010 (Rajaratnam *et al*. 2010), yet undernutrition remains one of the key factors associated with global loss of life in young children (Black *et al*. 2003, 2010; Jones *et al*. 2003; UNICEF 2009; Rajaratnam *et al*. 2010). In 2000, the United Nations (UN) crafted eight millennium development goals (MDGs) focused on reducing poverty, and extreme hunger, and improving education by 2015 (UN 2000). An objective of the first MDG was to halve the prevalence of underweight children under 5 years of age (under-5 children) as the primary measure of undernutrition by 2015 (UN 2000). Measures of height and weight, stunting (low height-for-age), wasting (low weight-for-height) and underweight (low weight-for-age) are used to assess undernutrition. Stunting in under-5 children is viewed as an indicator of chronic undernutrition (WHO Multicentre Growth Reference Study Group 2006). A recent study has underscored the importance of assessing both underweight and stunting to present a more comprehensive picture of global advancement towards the first MDG (Lutter *et al*. 2011).

In the mid-1990s, the World Health Organization (WHO) engaged in an iterative evidence-based process, which led to the development of new growth standards (de Onis *et al*. 2004). Beginning in 2002, the WHO sponsored the development of child feeding guidance for young children, breastfed and non-breastfed, to underscore the need for improvement in early feeding practices (Dewey 2003, 2005; Dewey *et al*. 2004. Based on these guidelines, scientists from the WHO and the International Food Policy Research Institute developed a set of indicators to assess feeding patterns at the population level (Arimond & Ruel 2002; Working Group on Infant and Young Child Feeding Indicators 2007). The new WHO feeding indicators (FIs) coupled with the WHO growth standards enable assessment of feeding practices related to global feeding guidance.

Undernutrition, concomitant illnesses such as diarrhoea and high infant mortality in under-5 children are most prevalent in the poorest countries (Black *et al*. 2003; Jones *et al*. 2003; Victoria *et al*. 2003; Blakely *et al*. 2005). The World Bank provides comparative indicators to describe the status of all countries in the world on different parameters such as economic indicators, infant mortality and child health, education, health care delivery, etc. In the last 10 years, the World Bank has revised its major economic indicators and currently uses gross national income (GNI) per capita as its principal means of ranking country economies globally. Based on the GNI per capita, the World Bank categorizes the countries of the world into four economic income groups: low, lower middle, upper middle and high income. The low-income economies ($n = 53$) have a GNI per capita of $936 to $3705, compared with $11 456 or more for the high-income economies ($n = 65$) (World Bank 2008).

Van dePoel *et al*. (2008) analysed stunting, wasting and socio-economic inequalities related to malnutrition in 47 developing countries using Demographic and Health Survey (DHS) data and the WHO growth standards (WHO Multicentre Growth Reference Study Group 2006). This study found that stunting and wasting disproportionately affected the poor; however, in multivariate models there was no relationship between socio-economic status and stunting.

Blakely *et al*. (2005) used World Bank poverty levels and selected risk factors including measures of undernutrition using data from DHS and other surveys. These authors reported a strong association between poverty and malnutrition (assessed by underweight) in children who were exposed to unsafe water, poor sanitation and indoor air pollution. The authors concluded that 37% of global childhood malnutrition could be avoided if the risk factors of children living on <$US2 per day could be improved to match the risk profile of those children living on >$US2.

Key messages

- The prevalence of underweight and stunting increased with age.
- Gross national income was negatively correlated with a combined breastfeeding index, but not with other WHO feeding indicators (FI).
- Significant associations were found between early initiation of breastfeeding and a reduction in risk of underweight, and a higher risk of underweight for babies currently breastfed at 12–15 months.
- For infants aged 6–8 months, consumption of solid foods was associated with significantly lower probabilities of both stunting and underweight.
- Mothers with a higher educational attainment, who initiated breastfeeding within the first hour after birth and who met the WHO guidelines for dietary diversity, had infants at lower risk of underweight and/or stunting.
- Among this sample from 14 low-income countries where 50% of 12–23-month-old children were evidencing stunting, meeting the WHO FI of introduction of solids at 6–8 months, intake of diverse complementary foods and sufficient intake of iron-rich foods were associated with reduced risk of stunting.

Findings about the relationship between feeding practices and growth have been mixed. A national probabilistic survey in Mexico found that measures of recommended breastfeeding and complementary feeding practices were not associated with growth when family economics and other factors were included in logistic regression models (Gonzalez-Cossio *et al*. 2006). Ruel & Menon (2002) reported that recommended child feeding practices were positively associated with height-for-age in seven Latin American countries, with a stronger effect for children of lower socio-economic status. Arimond & Ruel (2004) found dietary diversity among 6–23-month-old children was positively associated with height-for-age in seven of 11 countries when other variables were included in the models.

An association between higher maternal education, better feeding practices and growth outcomes has been demonstrated in Peru (Ruel & Menon 2002), Ghana (Armar-Klemesu *et al*. 2000; Monteiro *et al*. 2010), Brazil (Monteiro *et al*. 2010) and Thailand (Limwattananon *et al*. 2010). Using DHS data in Peru, better child feeding practices were associated with higher height-for-age Z scores (HAZ) if the mothers had attained a primary education (Ruel & Menon 2002). Attainment of a high school education was also associated with higher HAZ and good child nourishment, but improved child feeding practices had no effect (Ruel & Menon 2002). In Ghana, lower maternal educational attainment was shown to be the primary factor associated with poorer child feeding practices, hygiene and poor preventive health seeking (Armar-Klemesu *et al*. 2000). Decline in prevalence of stunting in Brazil over an 11-year period was associated with improvements in four factors: maternal schooling, family purchasing power, maternal and child health care, and sanitation (Limwattananon *et al*. 2010). In Thailand, education was deemed one of the most important 'social determinants of health inequities' in terms of child malnutrition (Limwattananon *et al*. 2010).

Relative wealth was associated with reduced stunting in Cambodia in an earlier study (Marriott *et al*. 2010), and when modelling adjusted for relative wealth, a protective effect of dietary diversity at 6–8 months was no longer significant. The purpose of the current study was to assess and evaluate the association of the same WHO FIs (Working Group on Infant and Young Child Feeding Indicators 2007) with underweight and stunting as growth measures in 14 low-income countries. The general correlation of combined age-specific FI with GNI also was assessed. The study hypothesis was that meeting the core FI would be associated with reduced risk of underweight and stunting, especially within the poorest countries. The modelling analyses included a number of variables previously shown to be associated with undernutrition including infant's age, gender, maternal education, urban/rural status and country identifiers.

Methods

Survey instrument

Those countries grouped among the World Bank's 53 low-income economies for which DHS data were available using the most recent 'MEASURE DHS+' model instrument for low contraceptive countries and completed since 2000, were identified. The DHS instruments include country-specific modifications of questions and response options that are culturally specific. As a result, we were concerned about correct interpretation for comparison of response options among the countries. Therefore, we secondarily selected only those countries for which an English language version of the survey instrument was included in the final country report. These criteria thus limit the countries in the study. Fourteen countries were available, which had DHS data that included nationally representative samples of women of childbearing age. The countries and the year of the surveys were: India (2005–2006), Zambia (2001–2002), Nigeria (2003), Kenya (2003), Ghana (2003), Cambodia (2005), Bangladesh (2004), Tanzania (2004), Zimbabwe (2005–2006), Nepal (2006), Uganda (2006), Rwanda (2005), Malawi (2004) and Ethiopia (2005).

Study sample

The country-specific counts for each survey were calculated and compared with reports on the DHS website (http://www.measuredhs.com/) to insure that the complete data sets for each country were used. The youngest living child up to 24 months of age in each family, excluding children who were deceased or missing age information, was selected. Multiple children from one mother were only included in the analysis if the children were born at the same time (e.g. twins). Separate analyses were conducted for different age groups of children using the WHO core indicator age specifications (Dewey *et al.* 2004). Stunting and underweight were calculated for the subsample for each country for whom height and weight information was collected, using WHO growth standards (Garza & de Onis 2004), and –2 Z score as the cut-off for underweight and stunting (WHO Multicentre Growth Reference Study Group 2006).

Variables

Eight WHO core indicators for assessing healthy infant and young child feeding were tested (Working Group on Infant and Young Child Feeding Indicators 2007) (Table 1). Definitions and parameters for child feeding associated with each indicator were used to disaggregate the data by the specified age groups (Working Group on Infant and Young Child Feeding Indicators 2007). All variables in the model survey at the household, mother and child levels

Table 1. Eight World Health Organization indicators* for assessing infant and young child feeding[†]

1. Early Initiation of breastfeeding:
Children born in last 23.9 months and put to breast within 1 h of birth
Disaggregated and reported for live births in the last 11.9 months and live births occurring between the last 12 and 23.9 months*
2. Exclusive breastfeeding under 6 months:
Infants 0–5.9 months of age who received only breast milk during the previous day
Infants 0–5.9 months of age
Disaggregated for the age groups: 0–1.9, 2–3.9, 4–5.9 months
3. Continued breastfeeding at 1 year:
Children 12–15.9 months of age who received breast milk during the previous day
Children 12–15.9 months of age
4. Introduction of solid, semi-solid foods or soft foods:
Infants 6–8.9 months of age who received solid, semi-solid or soft foods during the previous day
Infants 6–8.9 months of age
5. Minimum dietary diversity:
Children 6–23.9 months of age who received foods from ≥4 food groups during the previous day
Children 6–23.9 months of age
Disaggregated for age group 6–11.9, 12–17.9, 18–23.9 months
6. Minimum meal frequency:
Breastfed children 6–23.9 months of age who received solid, semi-solid or soft foods the minimum number of times or more during the previous day
Breastfed children 6–23.9 months of age
Disaggregated for age group 6–11.9, 12–17.9, 18–23.9 months where minimum equals: two times for breastfed infants 6–8.9 months and three times for breastfed children 9–23.9 months
7. Minimum acceptable diet:
Breastfed children 6–23.9 months of age who received at least the minimum dietary diversity and the minimum meal frequency during the previous day
Breastfed children 6–23.9 months of age
Disaggregated for age group 6–11.9, 12–17.9, 18–23.9 months
8. Consumption of iron-rich or iron-fortified food:
Children 6–23.9 months of age who received an iron-rich food or a food that was specially designed for infants and young children and was fortified with iron, or a food that was fortified at home with a product that included iron during the previous day
Children 6–23.9 months of age
Disaggregated for age group 6–11.9, 12–17.9, 18–23.9 months

*Indicators for assessing infant and young child feeding practices, conclusions of a consensus meeting held 6–8 November 2007 in Washington DC, USA (Working Group on Infant and Young Child Feeding Indicators 2007). [†]Underlined text = definition of indicator.

that were relevant to the WHO eight core FIs were identified. Across the surveys for each country, the variable coding was carefully reviewed to ensure comparability.

Analytical methods

DHS interviewers asked mothers how many times their infant consumed a liquid or complementary food in the prior 24 h. Following the WHO definition (Anonymous 2001), breastfed children were classified as exclusively breastfed if they received no liquid or complementary foods other than breast milk in the prior 24 h. Exclusive breastfeeding was calculated in this manner for all DHS surveys in this model series (http://www.measuredhs.com/). Food variables were recoded so any consumption was set to 1 and responses of 'no consumption' or 'do not know' were set to 0. Missing values were treated as missing.

To calculate the minimum food diversity in the last 24 h for children 6–23.9 months of age, food types were grouped into six food groups: (1) grains, roots, tubers; (2) legumes and nuts; (3) dairy products (milk, yogurt, cheese); (4) meat and eggs (meat, fish, poultry, snails, liver/organ meats); (5) vitamin A-rich fruits and vegetables; and (6) other fruits and vegetables. Note that meat and eggs were combined into a single group, because in eight of the 14 countries, eggs were combined with flesh foods in the DHS survey instrument. In Cambodia, dairy foods were not a response variable. The available food groups (six in all countries except for Cambodia, for which five food groups were available) were used to calculate the minimum dietary diversity, which was defined as receiving foods from four or more groups during the previous day.

Sample weights were used for all analyses following the sample design information in the DHS statistical manual (Rutstein & Rojas 2006). The sampling frame for the DHS model surveys was complex and included multistage, clustering, stratification and unequal probability sampling.

To facilitate the comparisons of the performance of countries across multiple indicators, each country's overall mean compliance across all of the indicators was calculated using the age categories specified by the WHO FI and with each indicator/age category combination given equal weight. Each country's overall mean for the subset of breastfeeding (initiation of breastfeeding, exclusive breastfeeding, continued breastfeeding at 12–15 months) and solid food indicators [introduction of solid foods at 6–8 months, feeding diversity, feeding frequency, minimum acceptable diet, consumption of iron-rich foods/iron-fortified foods (IRF/IFF)] also were calculated. These combination indexes were assessed for their correlation with each country's GNI.

Statistical analysis

Statistical Analysis Systems statistical software package version 9.2 (SAS Institute, Cary, NC, USA) (SAS Institute Inc 2004) was used for the analysis. Standard errors were estimated using Taylor series linearization method that incorporated sampling weights and used variance formulas appropriate for the DHS sample design.

A series of person-level logistic regression models were estimated to examine the relationship between the FI, stunting and underweight using data from all 14 countries. Separate models were estimated for the breastfeeding indicators (initiation of breastfeeding, exclusive breastfeeding: 0–5.9 months), solid foods disaggregated to the recommended age groups (feeding frequency, dietary diversity, IRF: 6–23.9 months), currently breastfeeding at 12–15.9 months and consumption of solid foods for those aged 6–8.9 months. Similar to Marriott *et al*. (2007), following Hatt and Waters (2006) and Peng *et al*. (1998), pooled analyses were performed by combining data from all 14 countries and including country identifiers in the logistic regression models. Our main interest was in the overall average effect of FIs observed over all of the countries in the study rather than measuring impacts for individual countries. Use of pooled analyses increased our ability to detect overall trends that may be obscured by noise in individual data sets. A limitation of the use of pooled analyses is that the DHS survey sample is not representative in a uniform manner across countries. To adjust for the differences in sample size across countries, we weighted the data based on the country population as used by the DHS at the time of each survey. These country population figures were used by the DHS as the basis for each country's sampling design and included in the final report for each country survey. We present the multivariate analyses here that included these sample weights.

In addition to FI, the models included infant's age, gender, whether the mother had any secondary education and urban/rural status. To adjust for country-specific factors that are related to the FIs, the models also included a set of country-fixed effects.

India was selected as the comparison country because it had the highest per capita GNI and largest sample size. Two versions of each model were estimated – one that included the FI as a covariate and a second model that included interaction terms between the FI and mother's education level. For these models, low education was defined as attainment of an education level of primary school or less while high education was defined as attainment of a secondary school or higher level of schooling. The models that included interaction terms allowed examination of how the relationship between feeding practices and outcomes differed across population subgroups.

T-tests with weighted percentages were used to compare breastfeeding prevalence in children between 1 and 5 months of age for each country. Spearman (rank) correlations were used for comparison of the country-level measures reported in Table 5.

Results

Tables 2–5 present the 14 countries in descending order based on the World Bank 2006 per capita GNI (World Bank 2008). Table 2 presents the prevalence of underweight and stunting for the age groups 0–5, 6–11, 12–17, 18–23 and 12–23 months calculated using the WHO reference standards, the sample sizes of the children in the age groups for each country and the sample sizes for the age groups used in the undernutrition calculations for each country. Note that height and weight information was only collected for a subsample in some countries.

Considerable variation existed in underweight prevalence across countries; for example, among 12–23 months, underweight ranged from 12.5% in Zimbabwe to 43.3% in India and Bangladesh. Overall and for each country, prevalence of stunting was higher with each successive increase in age group (0–5, 6–11, 12–17, 18–23 months). Among 18–23 months, the prevalence of stunting ranged from 44.1% (Uganda) to 69.5% (Malawi).

Table 3 provides the prevalence of meeting the breastfeeding guidelines and the introduction of solid foods as measured by the FI among the 14 countries. Overall, 38% of mothers reported that they initiated breastfeeding within their child's first hour of life. These rates varied considerably across countries. For example, 9.0% of mothers in Bangladesh initiated breastfeeding within the first hour compared with almost 67.5% of mothers in Zimbabwe. Overall, there was no difference ($P = 0.397$) in the timing of breastfeeding initiation for 0–11- and 12–23-month-old children.

Rates of exclusive breastfeeding reported for infants in their first two months varied greatly among the countries, ranging from 27.3% in Nigeria to 94.4% in Rwanda. For all countries, the prevalence of exclusive breastfeeding was lower for 2–3-month-old children than it was for 0–1-month-old children, and lower for 4–5-month-old children than for those aged 2–3 months. These differences were highly significant for all countries ($P < 0.0001$). Variation in exclusive breastfeeding was observed for the older infants – for example, by months 4–5, rates of exclusive breastfeeding remained at almost 80% in Rwanda but fell to 8.7% in Nigeria.

Over 65% of 6–8-month-olds received solid foods in the day preceding the survey. Across countries, this prevalence ranged from approximately 50% in Ethiopia to 90% in Tanzania. Across all countries, more than 88% of mothers reported that they continued to breastfeed their infants through months 12–15. This prevalence of continued breastfeeding was above 90% in all but four countries and was above 95% in five countries (Bangladesh, Malawi, Nepal, Rwanda and Zambia).

Table 4 shows the prevalence of compliance with the WHO solid food FIs. Overall, nearly half of currently breastfed children aged 6–11 months or 12–23 months received solid foods the minimum number of times per day for their age (Table 1). For

Table 2. Gross national income (GNI) per capita, country, GNI equivalent in US dollars, number of children in different age categories used in this study from Demographic and Health Surveys, 2001–2006, in 14 countries and prevalence [%(SEM)] of underweight and stunting by World Health Organization (WHO) standards

GNI per capita*	Country (year)†	GNI ($US)*	Full sample (height and weight sample)				
			0–5 months‡	6–11 months‡	12–17 months‡	12–23 months‡	18–23 months‡
161	India (2005–2006)	820	4275 (4282)	4521 (4509)	4566 (4555)	9025 (8965)	4459 (4410)
172	Zambia (2001–2002)	630	651 (650)	645 (645)	665 (663)	1306 (1295)	641 (632)
173	Nigeria (2003)	620	611 (612)	623 (619)	571 (566)	998 (990)	427 (424)
175	Kenya (2003)	580	600 (601)	608 (608)	591 (578)	1084 (1054)	493 (476)
177	Ghana (2003)	510	338 (314)	399 (399)	405 (411)	724 (722)	319 (311)
180	Cambodia (2005)	490	770 (346)	790 (387)	794 (381)	1 552 (772)	758 (391)
182	Bangladesh (2004)	450	681 (678)	589 (587)	720 (719)	1241 (1237)	521 (518)
188	Tanzania (2004)	350	744 (744)	805 (805)	775 (774)	1474 (1457)	699 (683)
188	Zimbabwe (2005–2006)	340	490 (491)	490 (483)	507 (498)	907 (877)	400 (379)
192	Nepal (2006)	320	418 (422)	466 (465)	490 (488)	979 (973)	489 (485)
195	Uganda (2006)	300	752 (253)	750 (267)	758 (266)	1492 (517)	734 (251)
199	Rwanda (2005)	250	863 (433)	803 (401)	843 (417)	1598 (780)	755 (363)
201	Malawi (2004)	230	1099 (1103)	1183 (1178)	1175 (1174)	2208 (2195)	1033 (1021)
204	Ethiopia (2005)	170	1015 (495)	896 (441)	984 (506)	1686 (858)	702 (352)
	Weighted total		13 307 (11 424)	13 568 (11 794)	13 844 (11 996)	26 274 (22 692)	12 430 (10 696)

GNI per capita*	Country (year)†	GNI ($US)*	Underweight WHO % (SEM)				
			0–5 months‡	6–11 months‡	12–17 months‡	18–23 months‡	12–23 months‡
161	India (2005–2006)	820	30.7% (0.76)	36.3% (0.74)	39.5% (0.75)	47.1% (0.78)	43.3% (0.54)
172	Zambia (2001–2002)	630	12.6% (1.31)	21.5% (1.63)	26.0% (1.71)	27.2% (1.79)	26.6% (1.24)
173	Nigeria (2003)	620	13.6% (1.40)	24.3% (1.74)	33.3% (2.01)	30.0% (2.25)	32.0% (1.50)
175	Kenya (2003)	580	6.4% (1.03)	13.7% (1.41)	17.6% (1.62)	20.4% (1.89)	18.9% (1.23)
177	Ghana (2003)	510	7.1% (1.48)	19.4% (2.01)	17.9% (1.92)	23.8% (2.45)	20.4% (1.52)
180	Cambodia (2005)	490	9.8% (1.64)	17.6% (1.95)	21.5% (2.14)	30.5% (2.35)	26.3% (1.60)
182	Bangladesh (2004)	450	26.9% (1.74)	31.5% (1.93)	42.6% (1.86)	44.2% (2.20)	43.3% (1.42)
188	Tanzania (2004)	350	8.4% (1.02)	15.2% (1.27)	15.1% (1.29)	17.4% (1.46)	16.2% (0.97)
188	Zimbabwe (2005–2006)	340	8.2% (1.33)	11.6% (1.49)	9.9% (1.37)	15.6% (1.91)	12.5% (1.14)
192	Nepal (2006)	320	18.2% (1.89)	29.8% (2.13)	30.8% (2.10)	41.5% (2.25)	36.1% (1.55)
195	Uganda (2006)	300	10.3% (1.96)	23.2% (2.59)	24.5% (2.67)	14.4% (2.25)	19.7% (1.77)
199	Rwanda (2005)	250	7.8% (1.30)	18.8% (1.96)	24.0% (2.09)	22.9% (2.22)	23.5% (1.52)
201	Malawi (2004)	230	7.7% (0.83)	20.4% (1.21)	17.7% (1.14)	20.0% (1.29)	18.8% (0.86)
204	Ethiopia (2005)	170	10.1% (1.45)	26.8% (2.16)	34.3% (2.13)	39.4% (2.65)	36.3% (1.66)
	Weighted total		18.7% (0.38)	26.8% (0.42)	30.0% (0.43)	35.3% (0.47)	32.5% (0.32)

GNI per capita*	Country (year)†	GNI ($US)*	Stunting WHO % (SEM)				
			0–5 months‡	6–11 months‡	12–17 months‡	18–23 months‡	12–23 months‡
161	India (2005–2006)	820	26.9% (0.73)	29.8% (0.71)	47.9% (0.77)	60.6% (0.76)	54.3% (0.55)
172	Zambia (2001–2002)	630	21.7% (1.64)	36.5% (1.91)	52.9% (1.95)	64.3% (1.93)	58.4% (1.38)
173	Nigeria (2003)	620	23.7% (1.75)	30.2% (1.87)	49.5% (2.14)	56.5% (2.43)	52.3% (1.61)
175	Kenya (2003)	580	15.8% (1.59)	19.8% (1.64)	41.2% (2.09)	51.7% (2.35)	45.9% (1.57)
177	Ghana (2003)	510	12.4% (1.92)	15.1% (1.84)	28.6% (2.29)	45.8% (2.92)	35.9% (1.83)
180	Cambodia (2005)	490	17.2% (2.08)	17.5% (1.95)	37.4% (2.52)	52.6% (2.55)	45.4% (1.82)
182	Bangladesh (2004)	450	22.6% (1.67)	26.1% (1.84)	48.8% (1.89)	60.7% (2.20)	53.7% (1.45)
188	Tanzania (2004)	350	20.5% (1.49)	28.2% (1.59)	41.2% (1.78)	54.9% (1.92)	47.6% (1.32)
188	Zimbabwe (2005–2006)	340	22.7% (2.06)	27.5% (2.08)	35.3% (2.19)	53.0% (2.63)	43.2% (1.71)
192	Nepal (2006)	320	17.5% (1.87)	24.4% (2.00)	38.4% (2.22)	57.0% (2.27)	47.6% (1.61)
195	Uganda (2006)	300	17.7% (2.47)	22.6% (2.57)	37.6% (3.02)	44.1% (3.18)	40.7% (2.19)
199	Rwanda (2005)	250	22.6% (2.03)	29.2% (2.28)	55.0% (2.44)	59.7% (2.58)	57.1% (1.78)
201	Malawi (2004)	230	25.3% (1.43)	38.8% (1.47)	55.4% (1.50)	69.5% (1.49)	62.0% (1.07)
204	Ethiopia (2005)	170	23.1% (2.13)	33.5% (2.31)	48.3% (2.26)	66.1% (2.57)	55.5% (1.72)
	Weighted total		23.3% (0.42)	29.0% (0.43)	46.4% (0.47)	59.4% (0.49)	52.6% (0.34)

SEM, standard error of the mean. *Source: World Bank Country Profiles, accessed May 2008 (http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/0,,pagePK:180619~theSitePK:136917,00.html). †Demographic and Health Survey year. ‡Most recent living breastfed children, including multiple births; age group ranges represent child age through and including the last day of the second month.

Table 3. Mean prevalence [% (SEM)] of concordance with four World Health Organization (WHO) breastfeeding indicators* for infants and young children† from 14 countries based on Demographic and Health Surveys, 2001–2006

Country (year)‡	Initiation of breastfeeding in the first hour		Exclusive breastfeeding			Introduction of solid foods	Continued breastfeeding
	Age 0–11 months§	Age 12–23 months§	Age 0–1 months§	Age 2–3 months§	Age 4–5 months§	Age 6–8 months§	Age 12–15 months§
India (2005–2006)	23.0% (0.45)	23.3% (0.45)	70.8% (1.45)	51.5% (1.28)	27.5% (1.10)	55.0% (1.01)	88.1% (0.59)
Zambia (2001–2002)	40.0% (1.36)	46.4% (1.39)	65.5% (3.67)	45.3% (3.09)	15.5% (2.45)	87.3% (1.82)	96.8% (0.85)
Nigeria (2003)	27.4% (1.28)	28.6% (1.45)	27.3% (3.44)	20.4% (2.79)	8.7% (1.88)	58.3% (2.65)	89.2% (1.56)
Kenya (2003)	47.8% (1.44)	50.3% (1.57)	35.4% (3.64)	15.3% (2.41)	10.4% (2.17)	79.9% (2.30)	90.0% (1.51)
Ghana (2003)	39.5% (1.81)	39.4% (1.84)	63.2% (4.92)	69.2% (4.55)	39.7% (4.21)	58.5% (3.40)	94.9% (1.32)
Cambodia (2005)	34.8% (1.21)	33.8% (1.21)	73.8% (2.93)	66.4% (2.85)	48.7% (3.20)	82.4% (1.92)	89.6% (1.33)
Bangladesh (2004)	9.0% (0.80)	7.8% (0.76)	63.3% (3.81)	41.3% (3.02)	22.1% (2.64)	67.2% (2.62)	95.9% (0.91)
Tanzania (2004)	52.5% (1.29)	56.9% (1.33)	73.1% (3.16)	45.8% (2.91)	16.9% (2.42)	89.5% (1.52)	91.6% (1.26)
Zimbabwe (2005–2006)	67.5% (1.50)	69.0% (1.54)	41.9% (4.40)	15.2% (2.67)	14.3% (2.68)	75.3% (2.65)	87.6% (1.74)
Nepal (2006)	26.8% (1.49)	28.1% (1.44)	88.7% (3.23)	58.7% (4.12)	31.1% (3.50)	71.1% (3.02)	96.8% (1.00)
Uganda (2006)	39.5% (1.26)	36.9% (1.25)	83.7% (2.55)	65.1% (2.87)	33.9% (2.96)	78.2% (2.12)	90.1% (1.32)
Rwanda (2005)	63.7% (1.18)	65.5% (1.19)	94.4% (1.44)	92.6% (1.48)	79.4% (2.37)	64.0% (2.41)	95.9% (0.82)
Malawi (2004)	53.2% (1.05)	53.5% (1.06)	76.0% (2.38)	59.0% (2.46)	27.1% (2.32)	75.1% (1.75)	97.1% (0.59)
Ethiopia (2005)	66.4% (1.09)	67.5% (1.14)	78.5% (2.47)	64.6% (2.39)	51.2% (2.78)	50.2% (2.21)	91.7% (1.05)
Weighted total mean	38.1% (0.30)	38.3% (0.30)	69.7% (0.78)	52.4% (0.71)	30.7% (0.67)	65.6% (0.56)	91.4% (0.29)

SEM, standard error of the mean. *From WHO indicators for assessing infant and young child feeding (Working Group on Infant and Young Child Feeding Indicators 2007). †Most recent living breastfed children, including multiple births. ‡Demographic and Health Survey year. §Age group ranges represent child age through and including the last day of the second month.

Table 4. Mean prevalence [% (SEM)] of concordance with four solid food feeding indicators* for infants and young children† from 14 countries based on Demographic and Health Surveys, 2001–2006

Country (year)‡	Feeding frequency			Feeding diversity			Minimum acceptable diet			Iron-rich and iron-fortified foods including formula		
	Age 6–11 months§	Age 12–17 months§	Age 18–23 months§	Age 6–11 months§	Age 12–17 months§	Age 18–23 months§	Age 6–11 months§	Age 12–17 months§	Age 18–23 months§	Age 6–11 months§	Age 12–17 months§	Age 18–23 months§
India (2005–2006)	36.2% (0.71)	42.7% (0.73)	44.4% (0.74)	4.2% (0.30)	12.3% (0.49)	15.5% (0.54)	2.9% (0.25)	7.6% (0.39)	10.2% (0.45)	15.4% (0.54)	21.4% (0.61)	22.1% (0.62)
Zambia (2001–2002)	57.4% (1.95)	51.1% (1.94)	46.8% (1.97)	14.1% (1.37)	23.6% (1.65)	23.8% (1.68)	11.4% (1.25)	16.0% (1.42)	12.4% (1.30)	36.9% (1.90)	50.9% (1.95)	50.8% (2.02)
Nigeria (2003)	43.6% (1.99)	45.7% (2.09)	42.0% (2.39)	12.3% (1.31)	29.6% (1.91)	33.5% (2.29)	7.3% (1.04)	17.1% (1.58)	18.1% (1.87)	39.6% (1.97)	60.3% (2.07)	70.0% (2.28)
Kenya (2003)	58.1% (2.00)	55.5% (2.05)	51.5% (2.25)	17.2% (1.53)	25.0% (1.78)	25.5% (1.96)	12.0% (1.32)	15.9% (1.50)	14.9% (1.60)	23.6% (1.73)	29.9% (1.93)	30.8% (2.22)
Ghana (2003)	37.9% (2.43)	42.8% (2.46)	47.0% (2.80)	12.2% (1.64)	22.7% (2.08)	28.2% (2.52)	5.5% (1.14)	12.9% (1.67)	14.6% (1.98)	35.1% (2.40)	61.0% (2.45)	67.2% (2.69)
Cambodia (2005)	62.2% (1.73)	70.8% (1.61)	64.8% (1.74)	24.1% (1.52)	44.5% (1.76)	51.5% (1.82)	18.4% (1.38)	36.4% (1.71)	38.0% (1.76)	62.5% (1.73)	94.5% (0.81)	92.1% (0.98)
Bangladesh (2004)	56.0% (2.05)	70.9% (1.69)	83.7% (1.62)	19.8% (1.64)	53.6% (1.86)	67.5% (2.05)	16.1% (1.51)	42.8% (1.85)	58.7% (2.16)	40.2% (2.03)	75.7% (1.60)	86.8% (1.49)
Tanzania (2004)	45.3% (1.76)	48.7% (1.80)	41.0% (1.86)	12.8% (1.18)	17.4% (1.36)	18.3% (1.46)	7.1% (0.90)	10.8% (1.11)	7.9% (1.02)	33.9% (1.68)	44.2% (1.82)	44.6% (1.95)
Zimbabwe (2005–2006)	56.8% (2.24)	53.1% (2.22)	38.1% (2.43)	18.8% (1.77)	30.3% (2.04)	37.0% (2.42)	13.0% (1.52)	21.5% (1.83)	19.1% (1.97)	75.6% (1.96)	75.9% (1.93)	77.7% (2.13)
Nepal (2006)	70.1% (2.12)	84.3% (1.65)	84.5% (1.64)	24.0% (1.98)	50.1% (2.26)	47.7% (2.26)	22.7% (1.94)	45.9% (2.25)	45.9% (2.26)	15.4% (1.68)	25.5% (1.97)	28.4% (2.04)
Uganda (2006)	40.4% (1.79)	37.8% (1.76)	27.7% (1.65)	10.9% (1.14)	18.6% (1.41)	19.4% (1.46)	6.3% (0.89)	7.7% (0.97)	7.6% (0.98)	23.3% (1.55)	31.5% (1.70)	33.4% (1.76)
Rwanda (2005)	34.8% (1.68)	46.7% (1.72)	48.9% (1.82)	14.8% (1.26)	24.9% (1.49)	22.6% (1.52)	8.8% (1.00)	15.0% (1.23)	13.2% (1.23)	79.0% (1.71)	79.8% (1.57)	79.4% (1.75)
Malawi (2004)	49.4% (1.45)	46.3% (1.46)	45.1% (1.55)	17.6% (1.11)	32.1% (1.36)	34.8% (1.48)	10.0% (0.87)	16.7% (1.09)	18.4% (1.21)	28.7% (1.32)	43.1% (1.45)	45.5% (1.56)
Ethiopia (2005)	40.8% (1.64)	54.7% (1.59)	54.6% (1.88)	3.3% (0.60)	5.0% (0.70)	6.7% (0.94)	2.4% (0.51)	4.3% (0.65)	5.2% (0.84)	10.1% (1.01)	15.6% (1.16)	17.2% (1.43)
Weighted total mean	44.7% (0.43)	49.9% (0.42)	48.6% (0.45)	11.3% (0.27)	22.4% (0.35)	25.1% (0.39)	7.7% (0.23)	15.0% (0.30)	16.3% (0.33)	29.2% (0.39)	40.6% (0.42)	41.3% (0.45)

SEM, standard error of the mean. *From World Health Organization indicators for assessing infant and young child feeding (Working Group on Infant and Young Child Feeding Indicators 2007). †Most recent living breastfed children, including multiple births. ‡Demographic and Health Survey year. §Age group ranges represent child age through and including the last day of the second month.

Table 5. Economic status, growth measures and composite feeding index based on the World Health Organization (WHO) infant feeding indicators* for 14 countries, Demographic and Health Surveys (DHS), 2001–2006

World ranking by GNI per capita†	Country (year)‡	GNI ($US)†,§,††	% underweight overall¶ (rank)	% stunted overall¶ (rank)	Overall index** (rank)	Breastfeeding index**,†† (rank)	Solid foods index** (rank)
161	India (2005–2006)	820	33.3 (13)	41.7 (12)	30.2 (14)	47.4 (11)	22.3 (13)
172	Zambia (2001–2002)	630	22.1 (9)	43.9 (13)	41.7 (7)	51.6 (9)	37.1 (6)
173	Nigeria (2003)	620	24.6 (10)	37.8 (8)	35.7 (13)	33.6 (14)	36.7 (7)
175	Kenya (2003)	580	13.4 (2)	31.3 (3)	36.3 (12)	41.5 (12)	33.8 (10)
177	Ghana (2003)	510	18.3 (6)	25.3 (1)	41.7 (8)	57.7 (6)	34.3 (9)
180	Cambodia (2005)	490	21.5 (8)	32.0 (4)	57.3 (1)	57.8 (5)	57.1 (1)
182	Bangladesh (2004)	450	34.7 (14)	39.0 (9)	51.5 (3)	39.9 (13)	56.9 (2)
188	Tanzania (2004)	350	13.9 (3)	35.7 (7)	39.9 (9)	56.1 (7)	32.4 (11)
188	Zimbabwe (2005–2006)	340	11.7 (1)	34.2 (5)	46.7 (5)	49.3 (10)	45.6 (4)
192	Nepal (2006)	320	32.4 (12)	34.5 (6)	49.8 (4)	55.0 (8)	47.4 (3)
195	Uganda (2006)	300	19.7 (7)	30.5 (2)	36.4 (10)	58.2 (4)	26.4 (12)
199	Rwanda (2005)	250	17.7 (5)	41.0 (10)	53.9 (2)	81.9 (1)	40.9 (5)
201	Malawi (2004)	230	15.7 (4)	47.5 (14)	43.1 (6)	61.0 (3)	34.9 (8)
204	Ethiopia (2005)	170	26.7 (11)	41.5 (11)	36.3 (11)	61.0 (2)	20.8 (14)
	Total (average across all countries)	433	21.8%	41.7%	42.9%	54.4%	37.6%

*Working Group on Infant and Young Child Feeding Indicators (2007). †GNI = per capita gross national income; Source: World Bank Country Data and Statistics website, accessed May 2008 (http://data.worldbank.org/about/country-classifications). ‡Demographic and Health Survey year. §Source: World Bank Country Profiles, accessed May 2008 (http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/0,pagePK:180619~theSitePK:136917,00.html). ¶Percent of all children aged 0–23 months based on the WHO Standard. **The breastfeeding index is equal to the mean value of the breastfeeding indicators (initiation of breastfeeding, exclusive breastfeeding, currently breastfeeding at 12–14 months); the solid foods index is equal to the mean value of all of the solid food indicators (introduction of solid foods, dietary diversity, feeding frequency, minimum acceptable diet, consumption of iron-rich and iron-fortified foods). The overall index is the mean across all of the indicators (both breastfeeding and solid foods). ††$P < 0.01$, Spearman rank coalition.

6–11-month-olds, compliance with the feeding frequency indicator was highest in Nepal (70.1%) and lowest in Rwanda (34.8%). Among those aged 12–17.9 and 18–23 months, compliance was highest in Nepal and lowest in Uganda. In nine of the 14 countries, the rate of adherence to the feeding frequency indicator was lower for 18–23-month children than for those aged 12–17 months.

Minimum dietary diversity is defined as receiving foods from ≥4 food groups during the previous 24 h. Adherence with the dietary diversity guideline was much lower than adherence with the feeding frequency indicator. For infants aged 6–11 months, adherence rates ranged from 3.3% in Ethiopia to 24% in Cambodia and Nepal. The overall weighted mean for this age group was 11.3%. While there was some improvement among older children (the overall mean more than doubled from 11.3% to 25.1%), Bangladesh and Cambodia were the only countries in which more than half of 18–23-month children were in adherence with the feeding diversity guideline.

The low prevalence of food diversity was reflected in the low overall prevalence of children of all ages who achieved a minimum acceptable diet, which is a combination of the feeding frequency and dietary diversity indicators (6–11 months: 7.7%; 12–17 months: 15%; 18–23 months: 16.3%).

More children in all countries in all age groups met the guidelines for IRF. Among those aged 18–23 months, six countries achieved compliance of more than 60% for this indicator, although adherence was below 30% in three countries (Ethiopia, India, Nepal).

Table 5 presents the GNI for each country (World Bank 2008), composite indices (based on the weighted average across the relevant indicators) and relative ranks of country-based compliance with the WHO indicators. While country-level analyses have clear limitations, a significant negative correlation was found between the breastfeeding index and per capita GNI ($P < 0.01$), such that countries with lower per capita GNI tended to have higher compliance with the breastfeeding guidelines (initiation of breastfeeding, exclusive breastfeeding, breastfeeding at 12–15.9 months of age). The correlation between GNI and the solid food feeding indices was not significant ($P > 0.5$). The correlation between per capita GNI and stunting or underweight was not significant ($P > 0.05$).

Table 6 presents the results from the logistic models that we estimated to assess the association between the FI and underweight and stunting. While the models included all of the covariates described in the Methods section, Table 6 only reports the coefficients for the variables related to the FI, including the interaction terms between mother's education level and FI. The complete set of model results is available from the authors.

Among 0–5-month-old infants overall, there were no significant association between breastfeeding initiation or exclusive breastfeeding and stunting. The probability of being underweight was significantly lower for those who initiated breastfeeding within the first hour after birth ($P < 0.05$). Higher maternal education was significantly associated with a lower risk of both stunting and underweight among mothers who initiated breastfeeding in the first hour ($P < 0.05$ and $P < 0.01$, respectively).

Among children aged 12–15 months overall, those who were currently breastfeeding had a significantly higher rate of being underweight ($P < 0.001$). For underweight, a significant relationship was observed for the high-education group ($P < 0.01$), but not the low-education group.

For infants aged 6–8 months, consumption of solid foods was associated with significantly lower probabilities of both stunting and underweight ($P < 0.001$ for both outcomes). This relationship was observed for both the low- and high-education groups ($P < 0.001$ for both outcomes and both education groups).

While no relationship was found between feeding frequency and stunting, a significant association of feeding frequency and underweight was found ($P < 0.05$). There was no relationship between feeding frequency and either outcome measure in the version of the models that included feeding frequency and the maternal education interaction term.

Consuming a minimum acceptable diet was associated with a significantly lower overall probability of being underweight ($P < 0.01$), and with being stunted ($P < 0.01$). In the version of the models that interacted minimum acceptable diet with education, we found

Table 6. Association of World Health Organization (WHO) feeding indicators and growth outcomes: Stunting and underweight with relation to maternal education

WHO healthy feeding indicators	Stunting [Odds ratio (95% CI)]			Underweight [Odds ratio (95% CI)]		
	Maternal education level			Maternal education level		
	Low	High	Overall	Low	High	Overall
Breastfeeding						
Age 0–5 months						
Initiated breastfeeding in first hour	1.17 (0.90,1.52)	0.78*(0.62,0.98)	0.95 (0.79,1.13)	1.00 (0.76,1.32)	0.72**(0.58,0.89)	0.83*(0.70,0.98)
Exclusive breastfeeding	1.18 (0.93,1.51)	1.12 (0.90,1.38)	1.18 (1.00,1.39)	1.11 (0.87,1.41)	0.95 (0.78,1.15)	1.04 (0.89,1.21)
Continued breastfeeding through the first year						
Age 12–15 months						
Currently breastfeeding	1.14 (0.77,1.68)	1.13 (0.88,1.45)	1.11 (0.90,1.37)	1.56 (1.00,2.42)	1.54**(1.15,2.06)	1.52***(1.19,1.95)
Solid foods						
Age 6–8 months						
Any solids	0.55***(0.41,0.73)	0.45***(0.36,0.57)	0.50***(0.41,0.60)	0.49***(0.37,0.64)	0.53***(0.43,0.66)	0.52***(0.44,0.62)
Solid food feeding						
Age 6–23 months						
Model 1						
Minimum acceptable diet	0.93 (0.80,1.09)	0.83**(0.74,0.94)	0.87**(0.79,0.95)	0.89 (0.75,1.05)	0.88 (0.77,1.00)	0.85**(0.77,0.94)
Iron-fortified foods	0.87*(0.78,0.98)	0.73***(0.67,0.80)	0.78***(0.72,0.84)	0.86* (0.76,0.98)	0.75***(0.68,0.83)	0.79***(0.73,0.85)
Model 1a						
Feeding frequency	0.92 (0.83,1.03)	0.98 (0.90,1.07)	0.95 (0.89,1.01)	0.92 (0.82,1.02)	0.97 (0.89,1.07)	0.93*(0.87, 1.0)
Dietary diversity	1.01 (0.87,1.17)	0.69***(0.61,0.77)	0.79***(0.72,0.86)	0.90 (0.77,1.05)	0.74***(0.66,0.84)	0.78***(0.71,0.86)
Iron-fortified foods	0.86*(0.76,0.97)	0.78***(0.71,0.86)	0.82***(0.76,0.89)	0.87*(0.76,0.99)	0.81***(0.73,0.90)	0.83***(0.77,0.90)

CI, confidence interval. $^*P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$.

that a minimal acceptable diet was associated with a reduced risk of stunting among high maternal education group ($P < 0.01$). There was no significant relationship between minimum acceptable diet and underweight for either education subgroup.

Consumption of IFF was associated with a lower risk of both underweight and stunting ($P < 0.001$). A significant relationship was also observed separately for the low- and high-education groups ($P < 0.05$ or $P < 0.001$, respectively, for both measures).

Overall, dietary diversity was associated with a significantly lower risk of both stunting and underweight ($P < 0.001$ for both measures). For both outcomes, this relationship was significant for the high-education group for both outcome measures ($P < 0.001$), but was not significant for the low-education group.

Discussion

Similar to other reports, stunting prevalence progressively increased in all countries across the three age groups 6–11, 12–17 and 18–23 months, affecting almost 60% of children 18–23 months (Black *et al.* 2008; Victoria *et al.* 2008; Lutter *et al.* 2011).

Poverty, as measured by country level per capita GNI, was not correlated with underweight or stunting. Among these poor countries, only India had Blakely's minimal projected income of ≥$2/day for potential undernutrition reduction (Blakely *et al.* 2005); our data did not support that threshold as sufficient to obviate the prevalence of underweight or stunting.

In one of the countries included here (Cambodia), an earlier study showed that a within-country asset index *did* relate household wealth to growth (Marriott *et al.* 2010). It was not possible to use the DHS-generated asset index to measure relative wealth across countries in this study, because the index was not available for all 14 of the countries. In addition, the asset composition and construction of the index varied from country to country, so the index was not comparable across the countries. However, using the country-level GNI we did find that low country-level GNI was correlated with high scores on our composite breastfeeding index, suggesting that poverty need not impede compliance with this WHO FI.

The rates of initiation of breastfeeding within the first hour of birth and exclusive breastfeeding through 6 months were extremely variable, similar to other studies (Vesel *et al.* 2010). We found that early initiation of breastfeeding was significantly associated with reduction in risk of underweight, and higher maternal education was associated with reduced risk of both underweight and stunting among early breastfeeders. The absence of a significant association between early breastfeeding initiation and either outcome in the low education subgroups may suggest a need for improved education to realize the full benefits of early initiation of breastfeeding. Among these 14 countries, exclusive breastfeeding did not appear to be protective against later underweight or stunting. In contrast, meeting the complementary feeding guidance of solid foods at 6–8 months was highly associated with lowered risk of stunting and underweight. These results underscore that failure to introduce appropriate solids promptly in the second semester of infancy is critical to risk of later stunting and underweight. The steady increase in prevalence of stunting over the age groups in this study indicates sustained nutrition inadequacy, despite a high prevalence of continued breastfeeding in some countries.

The results in the current study suggest that of all the FIs, the timely introduction of solids is the most closely related to underweight and stunting. Because food type is not specified in this indicator, and likely is different across the countries, this result suggests that energy is the first limiting nutrient in the young child's diet. Other indicators for solid food feeding underscored a distinct lack of dietary diversity in children in all age groups. The specific types of food types that were not consumed varied by country, but most children regularly lacked vitamin A-rich foods, dairy products, and regular intake of fruits and vegetables.

These 14 countries had modest success in meeting the FI for intake of IRF (including IFF) among young children, with approximately 30–40% of children 6–23 months having been fed a source of iron in the previous 24 h. The prevalence of IRF intake is encouraging since iron deficiency anaemia is linked to approximately 134 000 deaths in children annually and regular intake of IRF has been reported to result in reduction of the prevalence of anaemia among young children from 10% to 40% in less than a year (World Food Programme & UNICEF 2006).

Modelling of the FI with underweight and stunting as outcomes indicated a relationship between the solid FI (diversity, IRF) and a lower probability of stunting. Compliance with all of the solid FI, with the exception of the feeding frequency FI, was associated with a lower probability of being underweight. These results suggest that WHO FIs that focus on feeding diversity and IRF should be emphasized more than feeding frequency and the composite index minimal acceptable diet.

Continued breastfeeding at 12–15 months was associated with a *higher probability* of underweight in the present study. Negative associations between prolonged breastfeeding and growth, or nutritional status, have been reported previously (Rao & Kanafe 1992; Grummer-Strawn 1993; Caulfield *et al*. 1996). Others have mentioned reverse causality as a possible explanation where the infants are breastfed longer for recovery (Caulfield *et al*. 1996); however, it seems unlikely that a single behavioural choice would operate commonly across the 14 countries studied here. It is possible that overreliance on breastfeeding has competed with dietary diversity (Caulfield *et al*. 1996; Horta *et al*. 2007; Cope & Alison 2008). Interestingly, the quality of the complementary diet but not continued breastfeeding was shown to correlate with lean tissue mass at 24 months in a sample of UK toddlers (Robinson *et al*. 2009). The data in this study and others underscore the need for additional longitudinal research to support recommendations for optimal breastfeeding duration (Dewey 1998, 2003; Dewey *et al*. 1999; Lartey *et al*. 2000; Fewtrell *et al*. 2007; Working Group on Infant and Young Child Feeding Indicators 2007; ESPGHAN Committee on Nutrition 2008).

Similar to other reports, this study found significant and somewhat complex statistical associations between higher maternal education level, feeding practices and growth outcomes (Caulfield *et al*. 1996; Armar-Klemesu *et al*. 2000; Ruel & Menon 2002; Limwattananon *et al*. 2010). Infants (0–5 months) of mothers with a higher educational attainment, who initiated breastfeeding within the first hour after birth, had a lower probability of stunting and underweight. With exception of the WHO age-based complementary FI food frequency, the majority of the other WHO age-based solid food FI showed a significant lower probability of both stunting and underweight with improved maternal education (stunting: introduce solids at 6–8 months, minimum acceptable diet, IRF, dietary diversity; underweight: introduce solids at 6–8 months, IRF, dietary diversity).

The limitations of DHS include reporting and recall bias, a problem common to other surveys, particularly for retrospective data relying on memory of past events (Peng *et al*. 1998; Ruel & Menon 2002). Another limitation is that the DHS is not conducted with the same periodicity in all countries. As a result, in our study while we used the most recent DHS data available for the 14 countries, the survey data collection period ranged from 2001 to 2006 across the countries. Identification of countries based on per capita GNI, instrument used, timing of the survey and availability of an English language version of the instrument limited the study to 14 countries that are not globally representative. In addition, while the same survey instrument was used across the countries, the DHS tailors the response variables to reflect the situation in each country; therefore, requiring some variable recoding for cross-country comparisons such as presented here. A DHS household-based asset index is available for most of the recent surveys; however, these indexes are constructed so that comparisons among countries are limited to disaggregated asset elements common to specific countries.

Improved feeding practices are key to reduction in underweight and stunting, and also reduction of diseases where underweight is linked as an underlying cause (Black *et al*. 2003). These results support a focus on early initiation of breastfeeding, timely introduction of solid foods, young child dietary diversity and maternal education as the most promising interventions to improve nutrition, and thereby reduce the disease burden and 7.7 million annual deaths globally among children less than 5 years of age.

Acknowledgements

We thank Janice Abbas for initial preparation of the manuscript and Laura Dotson and Viviane Enslein for assistance with final formatting and revisions of the manuscript. The authors are appreciative of the suggestions and comments of the anonymous reviewers which contributed important insight to the manuscript.

Source of funding

This project was funded by Pfizer Nutrition P.O. No. 4501241713/03 to Abt Associates, Inc.

Conflicts of interest

The authors declare that they have no conflicts of interest.

Contributions

All authors were involved in study design, analysis, and writing and editing of the manuscript. AW and LH were involved in the statistical design and SAS programming. BPM also oversaw the study.

References

Anonymous (2001) The optimal duration of exclusive breastfeeding: results of a WHO systematic review. *Indian Pediatrics* **38**, 565–567.

Arimond M. & Ruel M.T. (2002) Progress in developing an infant and child feeding index: an example using the Ethiopia demographic and health survey 2000. Discussion Paper – Food Consumption and Nutrition Division, International Food Policy Research Institute. International Food Policy Research Institute, Washington, USA.

Arimond M. & Ruel M.T. (2004) Dietary diversity is associated with child nutritional status: evidence from 11 demographic and health surveys. *The Journal of Nutrition* **134**, 2579–2585.

Armar-Klemesu M., Ruel M.T., Maxwell D.G., Levin C.E. & Morris S.S. (2000) Poor maternal schooling is the main constraint to good child care practices in Accra. *The Journal of Nutrition* **130**, 1597–1607.

Black R.E., Morris S.S. & Bryce J. (2003) Where and why are 10 million children dying every year? *Lancet* **361**, 2226–2234.

Black R.E., Allen L.H., Bhutta Z.A., Caulfield L.E., Deonis M., Ezzati M. *et al*. (2008) Maternal and child undernutrition: global and regional exposures and health consequences. *Lancet* **371**, 243–260.

Black R.E., Cousens S., Johnson H.L., Lawn J.E., Rudan I., Bassani D.G. *et al*. (2010) Global, regional, and national causes of child mortality in 2008: a systematic analysis. *Lancet* **375**, 1969–1987.

Blakely T., Hales S., Kieft C., Wilson N. & Woodward A. (2005) The global distribution of risk factors by poverty level. *Bulletin of the World Health Organization* **83**, 118–126.

Caulfield L.E., Bentley M.E. & Ahmed S. (1996) Is prolonged breastfeeding associated with malnutrition? Evidence from nineteen demographic and health surveys. *International Journal of Epidemiology* **25**, 693–703.

Cope M.B. & Alison D.B. (2008) Critical review of the World Health Organization's (WHO) 2007 report on 'evidence of the long-term effects of breastfeeding: systematic reviews and meta-analysis' with respect to obesity. *Obesity Reviews* **9**, 594–605.

Dewey K.G. (1998) Cross-cultural patterns of growth and nutritional status of breast-fed infants. *American Journal of Clinical Nutrition* **67**, 10–17.

Dewey K.G. (2003) *Guiding Principles for Complementary Feeding of the Breastfed Child*. Pan American Health Organization, WHO: Washington, DC, p. 37.

Dewey K.G. (2005) *Guiding Principles for Feeding Non-Breastfed Children 6–24 Months of Age*. World Health Organization: Geneva.

Dewey K.G., Cohen R.J., Brown K.H. & Rivera L. (1999) Age of introduction of complementary foods and growth of term, low-birth-weight, breast-fed infants: a randomized intervention study in Honduras. *American Journal of Clinical Nutrition* **69**, 679–686.

Dewey K.G., Cohen R.J., Rollins N.C. & Informal Working Group on Feeding of Nonbreastfed Children (2004) WHO technical background paper: feeding of nonbreastfed children from 6 to 24 months of age in developing countries. *Food and Nutrition Bulletin* **25**, 377–402.

ESPGHAN Committee on Nutrition (2008) Medical position paper: complementary feeding: a commentary by the ESPGHAN committee on nutrition. *Journal of Pediatric Gastroenterology and Nutrition* **46**, 99–110.

Fewtrell M.S., Morgan J.B., Duggan C., Gunnlaugsson G., Hibberd P.L., Lucas A. *et al*. (2007) Optimal duration of exclusive breastfeeding: what is the evidence to support current recommendations? *American Journal of Clinical Nutrition* **85**, 635S–638S.

Garza C. & De Onis M. (2004) Rationale for developing a new international growth reference. *Food and Nutrition Bulletin* **25**, S5–S14.

Gonzalez-Cossio T., Rivera-Dommarco J., Moreno-Macias H., Monterrubio E.A. & Sepulveda J. (2006) Poor compliance with appropriate feeding practices in children under 2 yr in Mexico. *The Journal of Nutrition* **136**, 2928–2933.

Grummer-Strawn L.M. (1993) Does prolonged breastfeeding impair child growth? A critical review. *Pediatrics* **91**, 766–771.

Hatt L.E. & Waters H.R. (2006) Determinants of child morbidity in Latin America: a pooled analysis of interactions between parental education and economic status. *Social Science and Medicine* **62**, 375–386.

Horta B., Bahl R., Martines J. & Victoria C. (2007) *Evidence of the Long-term Effects of Breastfeeding: Systematic Reviews and Meta-analysis*. World Health Organization Publication: Geneva.

Jones G., Steketee R.W., Black R.E., Bhutta Z.A. & Morris S.S. (2003) How many child deaths can we prevent this year? *Lancet* **362**, 65–71.

Lartey A., Manu A., Brown K.H., Peerson J.M. & Dewey K.G. (2000) Predictors of growth from 1 to 18 months among breast-fed Ghanaian infants. *European Journal of Clinical Nutrition* **54**, 41–49.

Limwattananon S., Tangcharoensathien V. & Prakongsai P. (2010) Equity in maternal and child health in Thailand. *Bulletin of the World Health Organization* **88**, 420–427.

Lutter C.K., Chaparro C.M. & Munoz S. (2011) Progress towards Millennium Development Goal 1 in Latin America and the Caribbean: the importance of the choice of indicator for undernutrition. *Bulletin of the World Health Organization* **89**, 22–30.

Marriott B.M., Campbell L., Hirsch E. & Wilson D. (2007) Preliminary data from Demographic and Health Surveys on infant feeding in 20 developing countries. *The Journal of Nutrition* **137**, 518S–523S.

Marriott B.P., White A.J., Hadden L., Davies J.C. & Wallingford J.C. (2010) How well are infant and young child World Health Organization (WHO) feeding indicators associated with growth outcomes? An example from Cambodia. *Maternal & Child Nutrition* **6**, 358–373.

Monteiro C.A., Benicio M.H.D., Conde W.L., Konno S., Lovadino A.L., Barros A.J.D. *et al*. (2010) Narrowing socioeconomic inequality in child stunting: the Brazilian experience, 1974–2007. *Bulletin of the World Health Organization* **88**, 305–311.

de Onis M., Garza C., Victora C.G., Onyango A.W., Frongillo E.A. & Martines J. (2004) The WHO Multicentre Growth Reference Study: planning, study design, and methodology. (The WHO multicentre growth reference study (MGRS): rational, planning, and implementation.). *Food and Nutrition Bulletin* **25**, S15–S26.

Peng Y.-K., Hight-Laukaran V., Peterson A.E. & Perez-Escamilla R. (1998) Maternal nutritional status is inversely associated with lactational amenorrhea in Sub-Saharan Africa: results from Demographic and Health Surveys II and III. *The Journal of Nutrition* **128**, 1672–1680.

Rajaratnam J.K., Marcus J.R., Flaxman A.D., Wang H., Levin-Rector A., Dwyer L. *et al*. (2010) Neonatal, postneonatal, childhood, and under-5 mortality for 187 countries, 1970–2010: a systematic analysis of progress towards Millennium Development Goal 4. *Lancet* **375**, 1988–2008.

Rao S. & Kanafe A.N. (1992) Prolonged breastfeeding and malnutrition among rural Indian children below 3 years of age. *European Journal of Clinical Nutrition* **46**, 187–195.

Robinson S.M., Marriott L.D., Crozier S.R., Harvey N., Gale C.R., Inskip H.M. *et al*. (2009) Variations in infant feeding practice are associated with body composition in childhood: a prospective cohort study. *The Journal of Clinical Endocrinology and Metabolism* **94**, 2799–2805.

Ruel M.T. & Menon P. (2002) Child feeding practices are associated with child nutritional status in Latin America: innovative uses of the demographic and health surveys. *The Journal of Nutrition* **132**, 1180–1187.

Rutstein S.O. & Rojas G. (2006) *Guide to DHS Statistics*. ORC Macro: Calverton, MD.

SAS Institute Inc (2004) *SAS/STAT9.1 Users Guide*. SAS Institute Inc.: Cary, NC.

UN (2000) Millennium development goals. http://www.un.org/millenniumgoals/.

UNICEF (2009) *The State of the World's Children: Special Edition: Celebrating 20 Years of the Convention on the Rights of the Child*. http://www.unicef.org/rightsite/sowc/pdfs/SOWC_Spec%20Ed_CRC_Main%20Report_EN_090409.pdf, 92.

Van Depoel E., Hosseinpoor A.R., Speybroeck N., Van Ourti T. & Vega J. (2008) Socioeconomic inequality in malnutrition in developing countries. *Bulletin of the World Health Organization* **86**, 282–291.

Vesel L., Bahl R., Martines J., Penny M., Bhandare N., Kirkwood B.R. & WHO Immunization-linked Vitamin A Supplementation Study Group (2010) Use of new World Health Organization child growth standards to assess how infant malnutrition relates to breastfeeding and mortality. *Bulletin of the World Health Organization* **88**, 39–48.

Victoria C.G., Adair L., Fall C., Hallal P.C., Martorell R., Richter L. *et al*. (2008) Maternal and child undernutrition: consequences for adult health and human capital. *Lancet* **371**, 340–357.

Victoria C.G., Wagstaff A., Armstrong Schellenberg J., Gwatkin D., Claeson M. & Hibicht J.-P. (2003) Applying an equity lens to child health and mortality: more of the same is not enough. *Lancet* **362**, 233–241.

WHO Multicentre Growth Reference Study Group (2006) *WHO Child Growth Standards Length/Height-for-age, Weight-for-age, Weight-for-length, Weight-for-height and*

Body Mass Index-for-age Methods and Development. World Health Organization: Geneva.

Working Group on Infant and Young Child Feeding Indicators (2007) Indicators for assessing infant and young child feeding. In: *WHO Consensus Meeting* (ed. B. Daelmans), p. 19. WHO: Washington, DC.

World Bank (2008) *Data and Statistics: Country Classifications*. World Bank: Geneva.

World Food Programme & UNICEF (2006) *Ending Childhood Hunger and Undernutrition Initiative: Revised Global Framework for Action*. UNICEF: New York.