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Research Article

The association between complementary feeding practice and linear growth faltering among Cambodian children: an analysis of the 2014 Cambodia Demographic and Health Survey

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Background

Inappropriate complementary feeding is a factor contributing to linear growth faltering in early childhood. We aimed to assess complementary feeding practice and investigate its association with linear growth faltering among children aged 6 to 23 months among children aged 6-23 months in Cambodia.

Methods

This study is a secondary data analysis of the 2014 Cambodia Demographic and Health Survey (CDHS). Multivariable linear regression analysis was used to investigate associations between complementary feeding practice and linear growth faltering as length-for-age z-scores (LAZ), adjusted for all covariates.

Results

This study included 1381 children aged 6 to 23 months. The prevalence of age-appropriate complementary feeding practice was low in Cambodia. Only 23% of the children met all three criteria of minimum dietary diversity, minimum meal frequency, and age-appropriate breastfeeding. Approximately 30% of children aged 6 to 11 months met the minimum dietary diversity requirements and less than 40% of children aged 18 to 23 months were provided breastfeeding after the introduction of complementary food. This study found that there is no relationship between food diversity and feeding frequency and child linear growth. However, the provision of both complementary food and breast milk was independently and negatively associated with linear growth (β-Coefficient=-0.38, 95% confidence interval, CI=-0.60, -0.16). Positive effects on child linear growth, after controlling for all covariates, included the richer (β-Coefficient=0.36, 95% CI=0.07, 0.66) and richest (β-Coefficient=0.50, 95% CI=0.20, 0.79) quintiles of households, as well as appropriate water treatment before drinking (β-Coefficient=0.22, 95% CI=0.05, 0.40).

Conclusions

Most Cambodian young children aged 6 to 23 months received inappropriate complementary feeding. This study suggests that from the time of conception there is a necessity to improve maternal and child nutrition educational intervention for mothers, including feeding and hygiene practices.

Optimal growth and development in early childhood is important for child health. Linear growth faltering describes an abnormally lower rate of growth in length compared with the potential growth according to age.[1] As a

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short-term consequence, there is an increased risk of mortality and morbidity in childhood; and as long-term consequences, negative influences occur in cognitive development, future productivity, and health conditions.[2] Linear growth faltering leads to the development of stunting; which is defined as a length-for-age z-score (LAZ) of less than minus 2, and is an important child health indicator.[3] In Cambodia, child linear growth faltering is a critical public health issue, and roughly 25% of children aged 0 to 2 years are reported as stunted.[4]

Linear growth faltering develops in early childhood, predominantly from six months until two years of age, which is the same period as complementary feeding. WHO and UNICEF recommend exclusive breastfeeding from birth to 6 months of age; and thereafter until two years of age the introduction of complementary foods in addition to breastfeeding, in accordance with an increase in nutrient and energy requirements.[5]

Inappropriate complementary feeding practice is a primary impact on the development of linear growth faltering.[6-8] However, appropriate complementary feeding practice is rarely observed in low- and middle-income countries.[9] The poor quality complementary feeding practices of low dietary diversity and insufficient frequency of meals respectively lead to a deficiency of micronutrients and protein intake, and inadequate amount of calorie intake. Weaning earlier than recommended is also likely to result in energy and nutritional deficiencies, as well as reducing the opportunity to receive passive immunity from the mother.[10]

Inappropriate complementary feeding has been considered to be a key factor contributing to suboptimal child linear growth in Cambodia.[11,12] The most recent Cambodia Demographic and Health Survey (CDHS) report in 2014 described inappropriate complementary feeding practices, such as poor food diversity and early weaning. However, the effect of age-appropriate complementary feeding practice on childhood linear growth is yet to be fully explored using the 2014 CDHS data; in particular, food diversity and appropriate meal frequency in complementary feeding, and continued breastfeeding. Therefore, this study aimed to: (i) assess complementary feeding practice of children according to age in months, and (ii) investigate the association between age-appropriate complementary feeding practice and linear growth faltering among children aged 6 to 23 months using 2014 CDHS data.

METHODS

DATA

The Demographic and Health Surveys (DHS) are cross-sectional, nationally representative household surveys. This study used the most recent DHS available data in Cambodia in 2014. The questionnaire included data on household and individual characteristics, feeding practice, and nutritional status of mothers and children, including anthropometric measurements. The Cambodia DHS (CDHS) 2014 used a two-stage stratified sampling method, with enumeration areas (EAs) as the primary sampling unit, and households as a secondary stage. From the full list of EAs according to the Cambodia General Population Census (updated in 2012), 28,455 were selected for the 2014 DHS. Of these, 4245 EAs were designated as urban and 24,210 as rural, with a total size of 15,825 households interviewed.[13]

POPULATION

As part of the DHS survey design, diet diversity data were collected from the youngest children born to mothers 15 to 49 years old and living with the mother at the time of survey. In the CDHS 2014 meeting inclusion criteria, a random sample of two-thirds of children were selected for inclusion in the child anthropometry module.[13] We therefore restricted the study population of this analysis to the youngest children in each household aged 6 to 23 months who lived with their mother and had their anthropometry measurements taken in the CDHS 2014.

VARIABLES

OUTCOME VARIABLES

The primary outcome was the length-for-age z-score (LAZ); which is a measure of linear growth faltering among young children and assessed using a z-score calculated by age, sex, and length for each child according to the WHO child growth standards.[3] Lengths of children aged less than 23 months were measured with the laying down position using a SECA measuring board in the CHDS 2014.

EXPOSURE VARIABLES

Age-appropriate complementary feeding practice was the primary exposure in this study. It was generated as a composite variable of minimum dietary diversity, minimum meal frequency, and age-appropriate breastfeeding using three WHO infant and young child feeding (IYCF) indicators.[14] It was assessed as appropriate if children aligned with the definitions of all three indicators: minimum dietary diversity, minimum meal frequency, and age-appropriate breastfeeding. These three IYCF indicators were determined according to the following definitions:

MINIMUM DIETARY DIVERSITY

Minimum dietary diversity is assessed according to the consumption of food items categorised into seven food groups; including, “grains, roots, and tubers”, “legumes and nuts”, “dairy products (milk, yoghurt, cheese)”, “flesh foods (meat, fish, poultry, and liver/organ meats)”, “eggs”, “vitamin-A rich fruits and vegetables”, and “other fruits and vegetables”. Children who received at least 4 of the above 7 food groups were defined as meeting dietary diversity.[14]

MINIMUM MEAL FREQUENCY

Breastfed children are considered to be meeting a minimum meal frequency if they receive solid, semisolid, or soft foods at least twice a day for infants aged 6 to 8 months, and at least three times a day for children aged 9 to 23 months. Non-breastfed children aged 6 to 23 months are considered

to be fed with a minimum meal frequency if they receive solid, semisolid, or soft foods at least four times a day.[14]

AGE-APPROPRIATE BREASTFEEDING

Age-appropriate breastfeeding is attained if children aged 6 to 23 are provided breast milk plus solid, semi-solid, or soft foods during the previous day.[14]

The information on the specific liquid and foods group provided to the child and its frequency during 24 hours of the day before the survey and current breastfeeding practice were used to define the variables.

COVARIATES

Potential risk factors for linear growth faltering related to child, mother, and household were used as covariates in this analysis; such as age, sex, birth weight, type of birth, and recent illness history (acute respiratory infection (ARI), fever, diarrhoea) of the child; educational background and body mass index of the mother; and wealth index and place of residence of the household. These factors were identified from the UNICEF conceptual framework for maternal and child undernutrition and the previous literature and available to be generated using the dataset of CDHS 2014.[13, 15-17]

OTHER VARIABLES RELATED TO COMPLEMENTARY FEEDING PRACTICE

PRELACTEAL FEEDING PRACTICE

Prelacteal feeding practice is defined as providing any liquid before breastfeeding to an infant during the first 3 days after birth. Mothers were interviewed about their experience of the most recent childbirth if it was in 2009 or later. They were asked if they provided anything to drink other than breast milk to the child in the survey.

BOTTLE FEEDING OF CHILDREN

Bottle feeding is assessed if children are fed using a bottle with a nipple during the previous day. In the DHS interview, the mother was asked if they gave their child anything to drink using a bottle with a nipple during the previous day or the last night.

HYGIENE PRACTICES RELATED TO COMPLEMENTARY FEEDING

DRINKING WATER SOURCE AND ITS TREATMENT BEFORE DRINKING WITHIN THE HOUSEHOLD

Drinking water status was assessed as improved or unimproved according to core questions on drinking water source and sanitation for household surveys.[18] In the DHS, the responder was asked about the primary source of drinking water for household members during the dry and rainy season, and treatments performed before drinking to make the water safer.

HANDWASHING FACILITY

A handwashing facility was categorised as basic if there was observed in the household a handwashing facility with available water and soap, detergents, or other cleaning agents.[19] In the DHS, the responder was asked to show the place where household members most often washed their hands.

ANALYSIS

Statistical analysis was carried out using Stata software version Stata/MP 17.0 (StataCorp LLC, College Station, TX, USA). Survey sampling weights were used for all analyses to adjust for disproportionate sampling and nonresponse. The interest of our study was to assess the complementary feeding practice according to age in months and to investigate the association between age-appropriate complementary feeding and IYCF indicators and linear growth among Cambodian children aged 6 to 23 months. A binary variable was created to classify complementary feeding practices according to WHO IYCF indicators[14]; and descriptive analysis was performed to assess child feeding practice by age groups, 6 to 11, 12 to 17 and 18 to 23 months. Univariable linear regression analysis was applied to examine the association between child feeding practice and other explanatory variables and length for age z-score. A multivariable linear regression was carried out to investigate the independent association between each complementary feeding practice variable and length for age z-score, adjusted by all covariate variables. Sub-categorical analyses according to children aged 6 to 11, 12 to 17, and 18 to 23 months were carried out to investigate the association between complementary feeding practice and linear growth in each age group.

RESULTS

A total of 1404 children met the inclusion criteria; specifically, being the youngest child in the household and between the ages of 6 to 23 months, living with their mother, and anthropometry measurements in the CDHS in 2014. Of these, 23 children with invalid LAZ (LAZ<-6, or LAZ>6 was treated as invalid data in the DHS) were excluded; leaving 1381 children included in the current analysis. **Table 1** describes the basic characteristics of the children, mothers, and household. The mean (SD) of LAZ among Cambodian children aged 6 to 23 months was -1.2 (1.4). There was a decreasing trend in the mean LAZ with an increase in age in months; which was -0.72, -1.4, and -1.5 in the age group of 6 to 11, 12 to 17, and 18 to 23 months, respectively (**Table 1** and **Figure 1**).

Seven hundred eighteen participants were male (52%), and 83 (6.5%) children were born at weights less than 2500 g. More than 80% of the households used an improved water source for drinking, and approximately 60% of the households used appropriate treatment methods for water before drinking. Of the households, 65% had a basic handwashing facility on the premises. The mean body mass in-

Table 1. Basic characteristics of participants and households of this study (N=1,381).

Variables	6 to 23 months (N=1,381)			6 to 11 months (n=450)			12 to 17 months (n=463)			18 to 23 months (n=468)		
	n	(%)	(95%CI)	n	(%)	(95%CI)	n	(%)	(95%CI)	n	(%)	(95%CI)
Sex of the child (male)	718	(52.0)	(48.3, 55.6)	215	(47.9)	(41.9, 53.9)	278	(60.1)	(53.9, 66.0)	224	(47.9)	(42.4, 53.5)
Low birth weight * (less than 2500 g)	83	(6.5)	(5.0, 8.4)	28	(6.5)	(4.0, 10.3)	22	(5.2)	(3.2, 8.4)	33	(7.7)	(5.2, 11.3)
Type of birth (twin)	13	(1.0)	(0.5, 2.0)	9	(2.0)	(0.8, 5.0)	2	(0.3)	(0.0, 2.3)	3	(0.7)	(0.2, 2.6)
Prelacteal feeding *, †	346	(25.6)	(22.8, 28.7)	117	(26.7)	(21.4, 32.6)	125	(27.5)	(22.7, 33.0)	103	(22.8)	(18.3, 28.0)
Bottle feeding of children†	469	(33.9)	(30.8, 37.2)	177	(39.3)	(33.4, 45.5)	145	(31.4)	(26.0, 37.3)	147	(31.3)	(26.6, 36.5)
Improved water source for drinking *, †	1148	(83.2)	(79.9, 86)	382	(84.9)	(79.4, 89.2)	375	(81.0)	(75.6, 85.5)	391	(83.7)	(78.4, 87.8)
Appropriate treatment for drinking water†	825	(59.7)	(55.5, 63.8)	261	(57.9)	(51.1, 64.4)	275	(59.3)	(52.5, 65.8)	290	(61.8)	(55.9, 67.4)
Basic handwashing facility in household†	897	(64.9)	(61.0, 68.7)	285	(63.4)	(57.1, 69.3)	319	(69.0)	(62.6, 74.7)	292	(62.4)	(56.3, 68.1)
Wealth index Poorest	346	(25)	(21.5, 28.9)	93	(20.7)	(15.5, 27.0)	127	(27.5)	(21.8, 33.9)	126	(26.8)	(21.8, 32.5)
Poorer	273	(19.8)	(17.1, 22.8)	89	(19.8)	(15.7, 24.6)	98	(21.2)	(17.1, 26.0)	86	(18.4)	(14.4, 23.1)
Middle	264	(19.1)	(16.4, 22.2)	85	(18.9)	(14.6, 24.1)	93	(20.1)	(15.1, 26.2)	86	(18.3)	(14.3, 23.2)
Richer	247	(17.9)	(15.1, 21.0)	85	(18.8)	(14.5, 24.1)	73	(15.8)	(11.6, 21.3)	89	(18.9)	(14.7, 23.9)
Richest	252	(18.2)	(15.6, 21.2)	98	(21.8)	(17.4, 27.1)	71	(15.4)	(11.6, 20.2)	82	(17.6)	(14.1, 21.7)
Place of residence (rural)	1193	(86.4)	(84.5, 88)	384	(85.4)	(81.8, 88.3)	408	(88.0)	(84.8, 90.6)	401	(85.7)	(82.5, 88.4)
Mother's BMI status * <18.5	215	(15.6)	(13.3, 18.4)	61	(13.5)	(9.7, 18.3)	86	(18.6)	(14.5, 23.5)	69	(14.8)	(11.3, 19.1)
18.5-24.9	952	(69.2)	(65.9, 72.2)	327	(72.7)	(67, 77.8)	303	(65.4)	(59.8, 70.6)	322	(69.5)	(64.4, 74.1)
≥25	209	(15.2)	(12.7, 18.2)	62	(13.8)	(9.9, 19.0)	74	(15.9)	(11.5, 21.7)	73	(15.8)	(12.3, 20.0)
Mother's BMI *, mean (SD)	21.7	(3.4)	(21.4, 22.0)	21.6	(3.2)	(21.2, 22.0)	21.7	(3.7)	(21.0, 22.3)	21.7	(3. 4)	(21.3, 22.1)
Mother's education No education	166	(12)	(9.9, 14.4)	47	(10.4)	(7.4, 14.5)	64	(13.8)	(10.2, 18.4)	55	(11.7)	(8.4, 16.0)
Primary	768	(55.6)	(52.1, 59.1)	260	(57.8)	(52.4, 63.1)	266	(57.4)	(50.8, 63.8)	242	(51.7)	(46.3, 57.1)
Secondary or higher	447	(32.4)	(29.1, 35.8)	143	(31.7)	(26.7, 37.3)	133	(28.8)	(23.6, 34.6)	171	(36.5)	(31.4, 42.0)
Length for age z-score, mean (SD)	-1.2	(1.4)	(-1.29, -1.11)	-0.72	(1.4)	(-0.9, -0.6)	-1.4	(1.2)	(-1.5, -1.3)	-1.5	(1.3)	(-1.46, 1.32)
Illness history of ARI (last 2weekes)	103	(7.5)	(5.8, 9.5)	28	(6.3)	(3.5, 11.2)	36	(7.7)	(5.3, 11.1)	39	(8.3)	(5.5, 12.3)
Illness history of fever (last 2weekes)	494	(35.8)	(32.7, 38.9)	165	(36.7)	(31.0, 42.9)	174	(37.6)	(31.8, 43.8)	154	(33.0)	(27.8, 38.5)
Illness history of diarrhoea (last 2weekes)	270	(19.6)	(16.8, 22.7)	97	(21.5)	(16.3, 27.9)	77	(16.7)	(12.9, 21.4)	96	(20.5)	(16.4, 25.3)

SD: standard deviation, CI: confidential interval, BMI: body mass index, ARI: acute respiratory infection

*Missing data: 6 to 23 months: Low birth weight (n=99)/ Prelacteal feeding (n=33)/ Improved water source for drinking (n=1)/ Mother's BMI (n=4), 6 to 11 months: Low birth weight (n=19), Prelacteal feeding (n=9), 12 to 17 months: low birth weight (n=37), 18-23 month: Low birth weight (n=44), Prelacteal feeding (n=16), Improved water source for drinking(n=1), Mother's BMI (n=4).

†Prelacteal feeding: provision of any liquid before breastfeeding to an infant during the first 3 days after birth; Bottle feeding of children: children were fed using a bottle with a nipple during the previous day of the survey; Improved water source for drinking: household used an improved water source for drinking, assessed according to core questions on drinking water source and sanitation for household surveys[18]; Appropriate treatment for drinking water: household used appropriate methods (boiling, adding bleach/chlorine, use of water filter, or solar disinfection) to treat the water before drinking[18]; Basic handwashing facility in household: there is a place for handwashing soap, detergents, or other cleaning agents.[19]

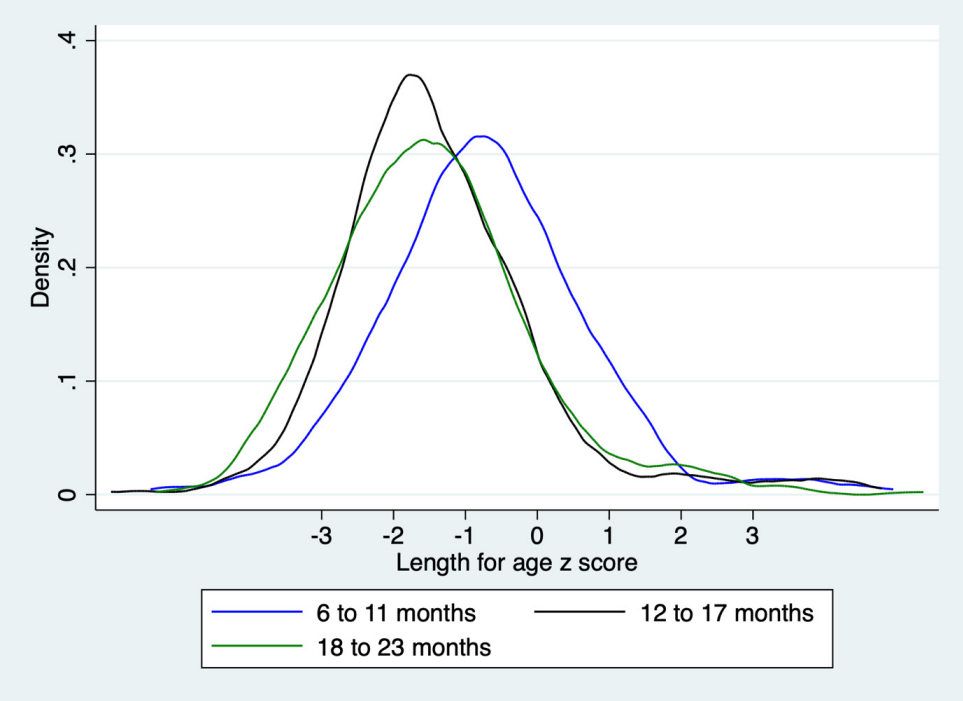

Figure 1. Distribution of length for age z-score (LAZ) by age group (n=1,381).

dex (BMI) of the mothers in this study was 21.7, and 69% were categorised as having a normal BMI (18.5 ⩽BMI<25).

Table 2 shows a complementary feeding practice assessed by the IYCF indicator of minimum dietary diversity, minimum meal frequency, and age-appropriate breastfeeding. Twenty-three percent of all the children had an age-appropriate complementary feeding practice. Although 72% of children aged 6 to 23 months met the criteria of minimum meal frequency, less than half (48%) of the children complied with the minimum dietary diversity. The dietary diversity was the lowest in the youngest age group, 6 to 11 months, and highest in the oldest age group, 18 to 23 months. Approximately 80% of children aged 6 to 17 months met the criteria of age-appropriate breastfeeding for their age group, versus 39% of children aged 18 to 23 months.

Table 3 describes the associations between the exposure variables and child linear growth assessed using univariable linear regression. There was no association between complementary feeding practice and LAZ among children aged 6 to 23 months. In the subset analysis by age group, children who were provided breast milk with complementary foods had significantly lower LAZ in the age group of 6 to 11 months (β-Coefficient=-0.42, 95% confidence interval, CI=-0.79, -0.04) and 18 to 23 months (β-Coefficient=-0.39, 95% CI=-0.70, -0.09), when compared to their counterparts who, by and large, received complementary food only without breast milk. The distribution of LAZ by indicators of complementary feeding practice except for age-appropriate breastfeeding described a similar shape (Figure 2, Panels A-D). There were differences in the distribution of LAZ by age-appropriate breastfeeding practice. The peak of the LAZ distribution among the children with age-appropriate breastfeeding was lower than those with age-inappropriate breastfeeding; and it was the most clearly observed at 18 months or older (Figure 2, Panel D). An increase in age in months (β-Coefficient=-0.07, 95% CI=-0.08, -0.05), and living in a rural area (β-Coefficient=-0.37, 95% CI=-0.59, -0.16) were associated with lower LAZ. Significant association with higher LAZ included bottle feeding (β-Coefficient=0.21, 95% CI=0.04, 0.37), using an improved water source (β-Coefficient=0.25, 95% CI=0.02, 0.47), using appropriate water treatment methods for drinking (β-Coefficient=0.23, 95% CI=0.06, 0.39), and being within the richer (β-Coefficient=0.49, 95% CI=0.22, 0.77) or richest (β-Coefficient=0.74, 95% CI=0.49, 1.00) quintiles of households (Table 3).

In multivariable analysis (Table 4), an increase in age (β-Coefficient=-0.08, 95% CI=-0.10, -0.06) and age-appropriate breastfeeding (β-Coefficient=-0.38, 95% CI=-0.60, -0.16) were independently associated with decreased LAZ for children aged 6 to 23 months. The richer (β-Coefficient=0.36, 95% CI=0.07, 0.66) and richest (β-Coefficient=0.50, 95% CI=0.20, 0.79) quintiles of a household, and using an appropriate treatment for drinking water (β-Coefficient=0.22, 95% CI=0.05, 0.40) such as using chlorine and water filter, were associated with increased LAZ after controlling for all covariates. In the subset analysis by age group, there was an independent association between age-appropriate breastfeeding and a decrease in LAZ among older children aged 18 to 23 months but not in other younger groups. While there was no association between dietary diversity and child growth, a child provided four or less food groups of foods generally had lower LAZ compared to a child provided five or more food groups (**Figure S1** in the **Online Supplementary Document**).

Table 2. Complementary feeding practice by age group (N=1,381).

Feeding practice	6 to 23 months (N=1,381)		6 to 11 months (n=450)		12 to 17 months (n=463)		18 to 23 months (n=468)	
	n (%)	(95%CI)	n (%)	(95%CI)	n (%)	(95%CI)	n (%)	(95%CI)
Age-appropriate complementary feeding practice*	319 (23.1)	(20.0, 26.4)	90 (20.0)	(15.7, 25.2)	145 (31.4)	(25.8, 37.5)	83 (17.8)	(13.8, 22.6)
Minimum meal frequency*	1000 (72.4)	(68.8, 75.8)	326 (72.6)	(66.2, 78.1)	355 (76.6)	(71.3, 81.2)	319 (68.1)	(62.3, 73.4)
Minimum dietary diversity*	659 (47.7)	(43.9, 51.5)	130 (28.8)	(23.8, 34.3)	234 (50.6)	(44.1, 57)	295 (63.0)	(57.6, 68.1)
Age-appropriate breastfeeding*	923 (66.8)	(63.4, 70.1)	366 (81.4)	(76.6, 85.4)	376 (81.1)	(76.3, 85.2)	181 (38.7)	(33.0, 44.7)

CI: confidential interval

*Age-appropriate complementary feeding practice: children who aligned with all of the definitions of minimum dietary diversity, minimum meal frequency, and age-appropriate breastfeeding are assessed as appropriate; Minimum meal frequency: breastfed children who received solid, semisolid, or soft foods at least twice a day for 6 to 8 age in months, and at least three times a day for 9 to 23 age in months, and at least four times a day for non-breastfed children aged 6 to 23 months are defined as meeting a minimum meal frequency[14]; Minimum dietary diversity: children who received at least 4 of the 7 food groups ("grains, roots, and tubers", "legumes and nuts", "dairy products (milk, yoghurt, cheese)", "flesh foods (meat, fish, poultry, and liver/organ meats)", "eggs", "vitamin-A rich fruits and vegetables", and "other fruits and vegetables") were defined as meeting dietary diversity[14]; Age-appropriate breastfeeding: children aged 6 to 23 who were provided breast milk in addition to solid, semi-solid, or soft foods during the previous day were defined as appropriate.[14]

Table 3. Association between length for age z score and explanatory variables in univariable analysis (N=1,381).

Variables	6 to 23 months (N=1,381)		6 to 11 months (n=450)		12 to 17 months (n=463)		18 to 23 months (n=468)	
	β-Coefficient	(95%CI)	β-Coefficient	(95%CI)	β-Coefficient	(95%CI)	β-Coefficient	(95%CI)
Sex (male)	-0.16	(-0.32, 0.003)	-0.23	(-0.55, 0.08)	-0.13	(-0.4, 0.14)	-0.01	(-0.28, 0.26)
Age in month	-0.07‡	(-0.08, -0.05)	-0.14†	(-0.22, -0.05)	-0.07	(-0.15, 0.01)	-0.08	(-0.17, 0.01)
Minimum dietary diversity (yes) ‖	-0.02	(-0.19, 0.15)	0.20	(-0.14, 0.53)	0.06	(-0.20, 0.33)	0.27	(-0.05, 0.59)
Minimum meal frequency (yes) ‖	0.18	(-0.01, 0.36)	0.10	(-0.23, 0.44)	0.17	(-0.14, 0.47)	0.23	(-0.05, 0.51)
Age-appropriate breastfeeding (appropriate) ‖	-0.14	(-0.33, 0.05)	-0.42*	(-0.79, -0.04)	-0.31	(-0.63, 0.02)	-0.39*	(-0.70, -0.09)
Age-appropriate complementary feeding practice (appropriate) ‖	0.004	(-0.20, 0.21)	0.10	(-0.22, 0.43)	0.09	(-0.22, 0.40)	-0.11	(-0.50, 0.29)
Pre-lacteal feeding practice§, ‖	0.17	(-0.02, 0.36)	0.24	(-0.1, 0.57)	0.12	(-0.16, 0.4)	0.11	(-0.24, 0.45)
Bottle feeding of children ‖	0.21*	(0.04, 0.37)	0.12	(-0.19, 0.43)	0.16	(-0.12, 0.44)	0.17	(-0.12, 0.46)
Illness history of ARI (last 2weekes)	-0.13	(-0.41, 0.15)	-0.58	(-1.16, -0.01)	-0.23	(-0.55, 0.09)	0.41	(-0.06, 0.88)
Illness history of fever (last 2weekes)	-0.07	(-0.25, 0.11)	-0.25	(-0.58, 0.09)	-0.14	(-0.41, 0.12)	0.15	(-0.17, 0.46)
Illness history of diarrhoea (last 2weekes)	-0.10	(-0.35, 0.14)	-0.28	(-0.73, 0.16)	-0.24	(-0.55, 0.08)	0.11	(-0.33, 0.55)
Low birth weight (less than 2500 g) §	-0.33	(-0.72, 0.05)	-0.91†	(-1.51, -0.31)	0.52	(-0.35, 1.39)	-0.43	(-0.94, 0.09)
Mother's education No education	Ref.		Ref.		Ref.		Ref.	
Primary	-0.02	(-0.30, 0.25)	-0.08	(-0.52, 0.35)	0.01	(-0.42, 0.44)	-0.12	(-0.61, 0.36)
Secondary or higher	0.21	(-0.07, 0.50)	0.07	(-0.37, 0.52)	0.05	(-0.39, 0.49)	0.41	(-0.09, 0.90)
Mother's BMI§	0.03*	(0.01, 0.05)	0.04	(-0.01, 0.09)	0.03*	(0.01, 0.06)	0.02	(-0.01, 0.06)
Place of residence (rural)	-0.37†	(-0.59, -0.16)	-0.19	(-0.52, 0.15)	-0.34*	(-0.62, -0.05)	-0.53*	(-0.91, -0.16)
Basic handwashing facility in household ‖	0.19	(-0.01, 0.39)	0.12	(-0.19, 0.44)	0.22	(-0.08, 0.53)	0.26	(-0.05, 0.56)
Improved water source for drinking§ ‖	0.25*	(0.02, 0.47)	0.39	(-0.07, 0.85)	0.15	(-0.21, 0.50)	0.15	(-0.25, 0.54)
Appropriate treatment for drinking water ‖	0.23†	(0.06, 0.39)	0.19	(-0.12, 0.50)	0.25	(-0.01, 0.51)	0.29	(-0.02, 0.60)
Wealth quintile Poorest	Ref.		Ref.		Ref.		Ref.	
Poorer	0.12	(-0.14, 0.38)	0.07	(-0.38, 0.52)	0.29	(-0.09, 0.68)	-0.15	(-0.53, 0.24)
Middle	0.26	(-0.01, 0.54)	0.47	(-0.04, 0.98)	0.06	(-0.30, 0.41)	0.18	(-0.24, 0.6)
Richer	0.49‡	(0.22, 0.77)	0.37	(-0.07, 0.81)	0.49*	(0.02, 0.95)	0.49*	(0.06, 0.92)
Richest	0.74‡	(0.49, 1.00)	0.69‡	(0.31, 1.08)	0.46*	(0.06, 0.87)	0.82‡	(0.38, 1.26)

SD: standard deviation, CI: confidential interval, BMI: body mass index, ARI: acute respiratory infection

*P<0.05, † P<0.01, ‡ P<0.001

§ Missing data: 6 to 23 months: Prelacteal feeding (n=33)/ Low birth weight (n=99)/ Mother's BMI (n=4)/ Improved water source for drinking (n=1), 6 to 11 months: Prelacteal feeding (n=9)/ Low birth weight (n=19), 12 to 17 months: low birth weight (n=37), 18-23 month: Prelacteal feeding (n=16)/ Low birth weight (n=44)/ Mother's BMI (n=4)/ Improved water source for drinking(n=1)

|| Minimum dietary diversity: children who received at least 4 of the 7 food groups ("grains, roots, and tubers", "legumes and nuts", "dairy products (milk, yoghurt, cheese)", "flesh foods (meat, fish, poultry, and liver/organ meats)", "eggs", "vitamin-A rich fruits and vegetables", and "other fruits and vegetables") were defined as meeting dietary diversity[14]; Minimum meal frequency: breastfed children who received solid, semisolid, or soft foods at least twice a day for 6 to 8 age in months, and at least three times a day for 9 to 23 age in months, and at least four times a day for non-breastfed children aged 6 to 23 months are defined as meeting a minimum meal frequency[14]; Age-appropriate breastfeeding: children aged 6 to 23 who were provided breast milk in addition to solid, semi-solid, or soft foods during the previous day were defined as appropriate[14]; Age-appropriate complementary feeding practice: children who aligned with all the definitions of minimum dietary diversity, minimum meal frequency, and age-appropriate breastfeeding are assessed as appropriate; Prelacteal feeding: provision of any liquid before breastfeeding to an infant during the first 3 days after birth; Bottle feeding of children: children were fed using a bottle with a nipple during the previous day of the survey; Basic handwashing facility in household: there is a place for handwashing soap, detergents, or other cleaning agents[19]; Improved water source for drinking: household used an improved water source for drinking, assessed according to core questions on drinking water source and sanitation for household surveys[18]; Appropriate treatment for drinking water: household used appropriate methods (boiling, adding bleach/chlorine, use of water filter, or solar disinfection) to treat the water before drinking.[18]

Table 4. Association between length for age z score and explanatory variables in multivariable analysis (N=1,246).

Variables	6 to 23 months (N=1,246)		6 to 11 months (n=421)		11 to 17 months (n=419)		17 to 23 months (n= 406)	
	β-Coefficient	95%CI	β-Coefficient	95%CI	β-Coefficient	95%CI	β-Coefficient	95%CI
Sex (male)	-0.11	(-0.28, 0.06)	-0.2	(-0.49, 0.08)	-0.08	(-0.37, 0.20)	-0.05	(-0.33, 0.24)
Age in month	-0.08‡	(-0.10, -0.06)	-0.13†	(-0.22, -0.04)	-0.09*	(-0.17, -0.01)	-0.12†	(-0.21, -0.03)
Minimum dietary diversity (yes) §	0.04	(-0.15, 0.24)	0.14	(-0.22, 0.51)	-0.02	(-0.29, 0.26)	0.06	(-0.28, 0.39)
Minimum meal frequency (yes) §	0.09	(-0.1, 0.28)	0.001	(-0.40, 0.40)	0.11	(-0.19, 0.40)	0.17	(-0.14, 0.48)
Age-appropriate breastfeeding (appropriate) §	-0.38†	(-0.60, -0.16)	-0.20	(-0.64, 0.23)	-0.31	(-0.67, 0.04)	-0.41*	(-0.74, -0.09)
Pre-lacteal feeding practice§	0.03	(-0.16, 0.22)	0.22	(-0.12, 0.56)	-0.04	(-0.33, 0.25)	-0.06	(-0.39, 0.26)
Bottle feeding of children§	-0.08	(-0.26, 0.11)	0.02	(-0.32, 0.37)	-0.03	(-0.33, 0.27)	-0.1	(-0.41, 0.2)
Illness history of ARI (last 2 weeks)	-0.03	(-0.35, 0.29)	-0.30	(-0.81, 0.20)	-0.26	(-0.64, 0.13)	0.30	(-0.24, 0.84)
Illness history of fever (last 2 weeks)	-0.08	(-0.26, 0.1)	-0.22	(-0.53, 0.09)	-0.15	(-0.46, 0.17)	0.11	(-0.22, 0.43)
Illness history of diarrhoea (last 2 weeks)	0.01	(-0.22, 0.25)	-0.13	(-0.54, 0.29)	-0.08	(-0.40, 0.24)	0.11	(-0.33, 0.56)
Low birth weight (less than 2500 g)	-0.30	(-0.70, 0.10)	-0.80†	(-1.40, -0.21)	0.40	(-0.58, 1.39)	-0.39	(-0.85, 0.08)
Mother's education No education	Ref.		Ref.		Ref.		Ref.	
Primary	-0.22	(-0.52, 0.08)	-0.36	(-0.85, 0.12)	-0.18	(-0.70, 0.34)	-0.29	(-0.81, 0.22)
Secondary or higher	-0.13	(-0.45, 0.19)	-0.41	(-0.92, 0.11)	-0.29	(-0.82, 0.24)	0.09	(-0.45, 0.62)
Mother's BMI	0.02	(-0.002, 0.05)	0.02	(-0.03, 0.07)	0.03	(0.0001, 0.06)	0.0012	(-0.04, 0.04)
Place of residence (rural)	0.08	(-0.14, 0.30)	0.21	(-0.19, 0.61)	-0.09	(-0.56, 0.37)	0.04	(-0.43, 0.51)
Basic handwashing facility in household§	-0.05	(-0.24, 0.14)	-0.02	(-0.36, 0.32)	0.03	(-0.31, 0.37)	-0.11	(-0.41, 0.18)
Improved water source for drinking§	0.04	(-0.21, 0.29)	0.18	(-0.25, 0.62)	0.22	(-0.16, 0.59)	-0.25	(-0.72, 0.21)
Appropriate treatment for drinking water§	0.22*	(0.05, 0.40)	0.19	(-0.12, 0.50)	0.18	(-0.09, 0.44)	0.25	(-0.05, 0.54)
Wealth quintile Poorest	Ref.		Ref.		Ref.		Ref.	
Poorer	-0.02	(-0.27, 0.22)	-0.10	(-0.56, 0.37)	0.21	(-0.23, 0.64)	-0.3	(-0.69, 0.09)
Middle	0.05	(-0.22, 0.32)	0.26	(-0.32, 0.83)	-0.07	(-0.43, 0.28)	-0.18	(-0.63, 0.27)
Richer	0.36*	(0.07, 0.66)	0.20	(-0.34, 0.73)	0.28	(-0.17, 0.72)	0.40*	(0.003, 0.80)
Richest	0.50†	(0.20, 0.79)	0.55*	(0.03, 1.08)	0.22	(-0.35, 0.78)	0.54	(-0.02, 1.10)

SD: standard deviation, CI: confidential interval, BMI: body mass index, ARI: acute respiratory infection

*P<0.05, † P<0.01, ‡ P<0.001

§Minimum dietary diversity: children who received at least 4 of the 7 food groups ("grains, roots, and tubers", "legumes and nuts", "dairy products (milk, yoghurt, cheese)", "flesh foods (meat, fish, poultry, and liver/organ meats)", "eggs", "vitamin-A rich fruits and vegetables", and "other fruits and vegetables") were defined as meeting dietary diversity[14]; Minimum meal frequency: breastfed children who received solid, semisolid, or soft foods at least twice a day for 6 to 8 age in months, and at least three times a day for 9 to 23 age in months, and at least four times a day for non-breastfed children aged 6 to 23 months are defined as meeting a minimum meal frequency[14]; Age-appropriate breastfeeding: children aged 6 to 23 who are provided breast milk in addition to solid, semi-solid, or soft foods during the previous day were defined as appropriate[14]; Prelacteal feeding: provision of any liquid before breastfeeding to an infant during the first 3 days after birth; Bottle feeding of children: children were fed using a bottle with a nipple during the previous day of the survey; Basic handwashing facility in household: there is a place for handwashing soap, detergents, or other cleaning agents[19]; Improved water source for drinking: household used an improved water source for drinking, assessed according to core questions on drinking water source and sanitation for household surveys[18]; Appropriate treatment for drinking water: household used appropriate methods (boiling, adding bleach/chlorine, use of water filter, or solar disinfection) to treat the water before drinking.[18]

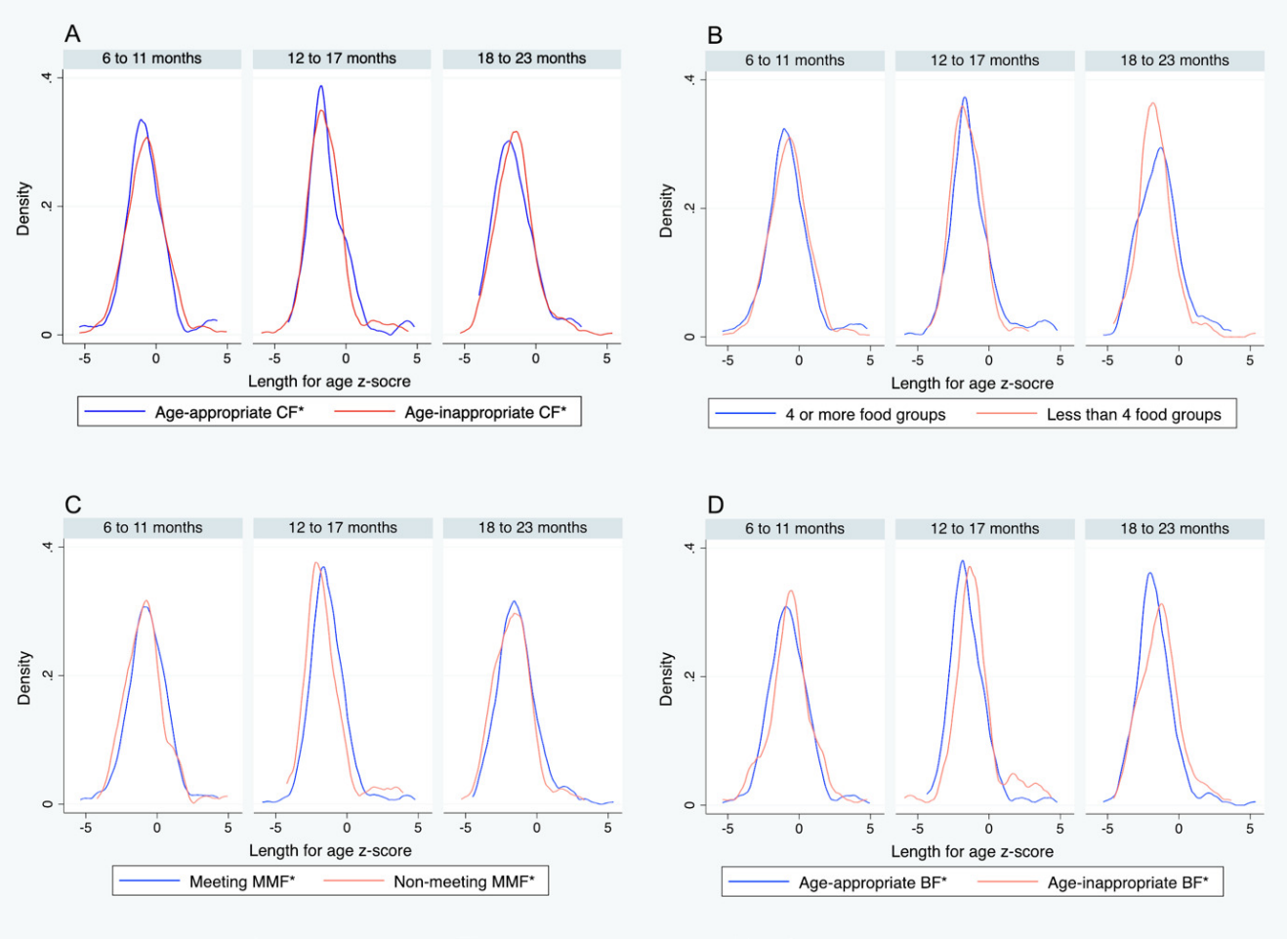

Figure 2. Distribution of length for age z-score (LAZ) by feeding practice (n=1,381).

Panel A. Age-appropriate complementary feeding practice.
*CF: complementary feeding practice, Age-appropriate complementary feeding practice: children aligned with all of the definitions of minimum dietary diversity, minimum meal frequency, and age-appropriate breastfeeding.
Panel B. Minimum dietary diversity.*
* Minimum dietary diversity: children who received at least 4 of the 7 food groups ("grains, roots, and tubers", "legumes and nuts", "dairy products (milk, yoghurt, cheese)", "flesh foods (meat, fish, poultry, and liver/organ meats)", "eggs", "vitamin-A rich fruits and vegetables", and "other fruits and vegetables") were defined as meeting dietary diversity.[14]
Panel C. Minimum meal frequency.*
* MMF: minimum meal frequency, Minimum meal frequency: breastfed children who received solid, semisolid, or soft foods at least twice a day for 6 to 8 age in months, and at least three times a day for 9 to 23 age in months, and at least four times a day for non-breastfed children aged 6 to 23 months are defined as meeting a minimum meal frequency.[14]
Panel D. Age-appropriate breastfeeding* practice.
* BF: breastfeeding, Age-appropriate breastfeeding: children aged 6 to 23 who were provided breast milk in addition to solid, semi-solid, or soft foods during the previous day.[14]

DISCUSSION

This study is a secondary data analysis using data from the Cambodia Demographic and Health Surveys in 2014 to assess the effect of complementary feeding practice on linear growth faltering among children aged 6 to 23 months. Low prevalence was observed in Cambodia for an age-appropriate complementary feeding practice among children aged 6 to 23 months. Roughly 30% of children did not receive the minimum meal frequency. For children aged 6 to 11 months, less than 30% met the minimum diet diversity requirements. Minimum diet diversity increased for children aged 12 to 17 months (51%) and 18 to 23 months (63%); although the continuation of breastfeeding among older children aged 18 to 23 months dropped to below 40%.

This study found no evidence to support that either food diversity or feeding frequency affects a child's linear growth. The provision of both complementary food and breast milk, however, appeared to pose a negative effect on linear growth, compared to children who received complimentary food and no breast milk. The effect was particularly pertinent in children aged 18 to 23 months compared to their younger counterparts aged 6 to 17 months.

COMPLEMENTARY FEEDING PRACTICE ACCORDING TO AGE GROUP

In this population most children did not receive appropriate complementary feeding according to age. The low dietary diversity in the younger age group and the low prevalence of continued breastfeeding in the older age group may contribute to the inadequacy of complementary feeding practices. A similar trend to findings in this study – that the lowest dietary diversity was at 6 to 11 months and low prevalence of breastfeeding at 24 months - was ob-

served in the 2010 Cambodia Demographic Health Survey and other studies from five countries in middle-east and northern Africa, and Cambodia.[20-22]

In Cambodia, mothers provide to children a simple rice porridge or with small amounts of vegetables, fish, or meat as a typical complementary meal.[23] Cambodian mothers believe that the rice porridge is a suitable and preferable meal for their children, which may result in children being fed limited kinds of food.[23] The low household economic, and maternal educational status, and limited access to health services were also reported as factors associated with lower dietary diversity.[21] Continued breastfeeding after the introduction of complementary foods is important to provide the required calorie intake, protein, and micronutrients needed for the optimal growth of children. However, weaning is often observed earlier than the WHO/UNICEF recommended age of two years old, particularly among children with appropriate nutrition status.[24,25]

THE EFFECT OF COMPLEMENTARY FEEDING PRACTICE ON THE CHILD'S GROWTH

This study suggests that the continuation of breastfeeding in complementary feeding periods negatively affects child linear growth, while there is no effect posed by dietary diversity and meal frequency on the linear growth. Although inadequate complementary feeding practice has been recognised as a major determinants of child nutrition and growth,[6-8] the association between the quality of complementary feeding practice, such as feeding diversity and frequency, and child linear growth has been reported to vary across the context.[12,26-28] A review study, which analysed the relationship IYCF indicators and child linear growth using data from 8 countries in sub-Saharan Africa, Caribbean, and Asia regions, including Cambodia, showed the association between them in Bangladesh, India, and Zambia, but not in other countries.[27] However, improving the quality of complementary feeding is important for children to meet the nutrient requirements for optimal growth.[7,28] One possible reason why the association between food diversity and meal frequency and child linear growth was not shown in this analysis is an insufficient quantity of intake, which was not measured as an IYCF indicator. In Cambodia, rice porridge is commonly provided to a child as a complementary food and every day children usually consume rice; some vegetables; and animal source products including egg, fish, or pork.[23,29] However, providing the typical complementary meal, rice porridge, often contains only a limited portion size of ingredients; which is insufficient to complement all of the required nutrients.[23,29] Improving the quality of rice porridge should be considered to meet the sufficient amount of nutrients by taking homemade rice porridge as a complementary meal.[23]

The adverse effect of breastfeeding over 12 months of age on linear growth has been reported,[30-34] while the benefits of continued breastfeeding are widely evident.[6,10] Continued breastfeeding, even after the introduction of complementary foods, can supply essential nutrients and calories, which cannot be taken from complementary foods only.[5] The association between continued breastfeeding and lower LAZ in this study can be considered the reverse causality of the result similar to the literature. These studies conclude this association as the mothers of undernourished children tend more to continue breastfeeding compared to mothers of healthier children; although continued breastfeeding beyond 12 months of age in itself does not cause undernutrition.[25,33] A study examining the impact of prolonged breastfeeding on child growth in Peruvian children aged 12 to 15 months reported that mothers of children with a poor health condition, such as frequent illness episodes, poor dietary intake and nutritional status, tended to wean later compared to mothers of healthy children.[24] Continued breastfeeding to a child with a poor health status can be considered as a maternal response, since mothers perceive that breastfeeding is a good nutrition practice.[25] In particular, families with low economic status and poor access to health services are likely to continue breastfeeding longer as a substitute for providing the necessary foods and care for the unhealthy condition of their child.[25] While mothers understand the importance of breastfeeding, they might have excessive expectations about the benefits of breastfeeding. It indicates the necessity of specific education to the mothers on the benefit of breastfeeding according to age in months. Another possible explanation for the adverse effect of continued breastfeeding on child growth is that the quality of breast milk from mothers with poor nutritional status can be inadequate. The breast milk composition is affected by maternal nutritional status, such as BMI and micronutrient status.[35,36] A mother whose child is undernourished may have a poor nutritional status the same as their child. Even though that mother may try to provide breast milk to the child to supply the essential nutrients, it might be less than the requirements for the child's optimal growth. Maternal nutrition, including dietary habits, affects both the quality of breast milk and the diversity of complementary foods provided to the child.[37] In Cambodia, nutrition counselling and the encouragement of taking a variety of foods in antenatal or postnatal care is recommended. The strengthening of nutrition education through antenatal and postnatal care can improve the nutritional status of mothers and lead to better feeding practices and nutrition for children.

This study suggests that hygiene practices related to complementary feeding improve the linear growth of children in complementary feeding periods.[38,39] Children in the complementary feeding periods have more opportunities to be exposed to an unhygienic environment through feeding than exclusively or predominantly breastfed children. In particular, unclean water can be a cause of diarrhoea or infection. Even if it does not cause diarrhoea or infection, chronic exposure to an unhygienic environment, such as unclean water can cause chronic inflammation of the intestinal tract leading to malabsorption, called "environmental enteric dysfunction"; which contributes to development of linear growth faltering.[40,41]

LIMITATIONS

There are several limitations to this study. Firstly, in this study it is not possible to determine the causality due to

the secondary data analysis using cross-sectional data from CDHS 2014. In addition, while this is the most recent available dataset, it has been a relatively long time since the survey. Therefore, it may be possible that the current situation has changed over the years. Finally, this study uses only three indicators among eight core and seven optional IYCF indicators - dietary diversity, meal frequency, and age-appropriate breastfeeding - to evaluate age-appropriate complementary feeding practices. In addition, this study does not assess the quantity and quality of foods provided to the children. Therefore, it may not be possible to capture the full impact of complementary feeding practice on child growth. However, IYCF indicators have been commonly used for child feeding assessment in low- and middle-income countries, including previously in Cambodia.[13] Therefore, it enables us to compare complementary feeding practices between years and countries.

CONCLUSIONS

Most children do not have appropriate complementary feeding behaviours; such as lower dietary diversity in the 6 to 11 months age group and earlier weaning at 18 to 23 months. This study found an association between continued breastfeeding and linear growth faltering. However, it may be the reverse causality of the result because of caregivers' over-expectation of the benefit of breastfeeding to children with poor nutritional status. It suggests that there is a need for comprehensive interventions to support mothers to stay well-nourished, feed their children appropriately with a combination of breast milk and complementary food, and appropriate hygiene to ensure child nutrition and healthy growth for children.

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ETHICS STATEMENT

The DHS program obtained ethical approval from institutional review boards at Inner City Fund (ICF) International Inc. and the National Ethics Committee for Health Research (NEHRC) in Cambodia. Before each interview was conducted, every participant was informed that participation in the survey was fully voluntary, the respondent could refuse to answer any question, they could withdraw their participation from the survey at any time, and the collected information in this survey is strictly confidential. For each survey, respondents were asked to provide written informed consent prior to the survey. Parents or guardians were asked to provide the written consent for participation of their child or adolescent in the survey (https://dhsprogram.com/Methodology/Protecting-the-Privacy-of-DHS-Survey-Respondents.cfm). This study was a secondary analysis of data without identifiable information of each individual participant in the CDHS 2014; and therefore, ethical approval from Nagasaki University is not required. This study complied with the 'Ethical Guidelines for Medical and Biological Research Involving Human Subjects' jointly issued from the Ministry of Education, Culture, Sports, Science and Technology, the Ministry of Health, Labor and Welfare, and the Ministry of Economy, Trade and Industry in 2022 in Japan.

DATA AVAILABILITY

The CDHS dataset is available for research purposes from the MEASURE DHS website (https://www.dhsprogram.com/data/available-datasets.cfm) after registration.

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AUTHORSHIP CONTRIBUTIONS

AM & MM conceived the study, AM & KW designed the study protocol, and AM & KW carried out the data curation and analysis. AM drafted the manuscript. All authors contributed to the critical revision of the manuscript and approved the final version. AM is a guarantor of the paper.

DISCLOSURE OF INTEREST

The authors completed the ICMJE Disclosure of Interest Form (available upon request from the corresponding author) and disclose no relevant interests.

ADDITIONAL MATERIAL

Table S1. Association between length for age z score and age-appropriate complementary feeding practice in multivariable analysis.

Figure S1. Predicted Length for age Z score by the number of food groups adjusted by all covariate from multivariable regression model among children aged 6-23 months.

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SUPPLEMENTARY MATERIALS

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