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Effect of Breastfeeding Duration on Infant Growth Until 18 Months of Age: A National Birth Cohort Study

Sing-Chung Li¹, Shu-Chen Kuo², Ying-Ying Hsu³, Shio-Jean Lin⁴,
Pau-Chung Chen⁵, Yi-Chun Chen^{6*}

¹School of Nutrition and Health Sciences, Taipei Medical University, Taipei, Taiwan

²Department of Healthcare Management, Yuanpei University, Hsinchu, Taiwan

³School of Nutrition and Health Sciences, Taipei Medical University, Taipei, Taiwan

⁴Department of Pediatrics, National Cheng-Kung University Hospital, and College of Medicine,
National Cheng-Kung University, Tainan, Taiwan

⁵Institute of Occupational Medicine and Industrial Hygiene, National Taiwan University College of Public Health,
Taipei, Taiwan

⁶School of Nutrition and Health Sciences, Taipei Medical University, Taipei, Taiwan

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Background: Optimal nutrition during the 1st year of life is critical to infants' healthy growth and development, and breastfeeding is a key component. However, little is known about the effect of breastfeeding duration on infant growth in Taiwan.

Purpose: The aim of this study was to examine the effect of breastfeeding duration on infant growth.

Methods: This study was based on questionnaire interviews as part of the Taiwan Birth Cohort Study, which collected information on breastfeeding duration and infant growth among infants aged from 0 to 18 months. Participants were selected from Taiwan birth registry data for 2005, using multistage stratified random sampling. The sample population was 15,868 infants ranging in gestational age between 37 and 41 weeks, excluding those with birth defects or who were hospitalized after birth. The χ^2 test, analysis of variance and generalized estimating equations were used to analyze the effects of infant feeding patterns and other factors on infant growth.

Results: Breastfeeding duration had no significant effect on infant weight within the first 6 months, but after the 7th month, infants who had been breastfed for ≥ 6 months were lighter than infants who were not breastfed. Before 18 months of age, infants who had been breastfed for ≥ 6 months were slightly shorter than infants who had been breastfed for < 6 months. From the 7th month onward, breastfed infants were slightly shorter than formula-fed infants.

Conclusion: These results show that different infant feeding practices correspond to differences in infant growth from 0 to 18 months, and are consistent with the World Health Organization's new growth standards.

*Corresponding author. School of Nutrition and Health Sciences, Taipei Medical University, 250 Wu-Hsing Street, Taipei 11042, Taiwan.
E-mail: yichun@tmu.edu.tw

1. Introduction

Optimal nutrition during the 1st year of life is critical to infants' healthy growth and development. To promote the health of infants and children, the World Health Organization (WHO) recommends that infants be exclusively breastfed for the first 6 months of their life, and that they should continue to receive breast milk for the remainder of their 1st and 2nd years.¹

Breastfeeding is a key component of optimal infant nutrition and provides many important health benefits to both babies and mothers. Human milk contains just the right amount of fatty acids, lactose, water, and amino acids for human digestion, brain development, and growth.² It also contains many bioactive ingredients such as cytokines, nucleotides, hormones, and growth factors.³ Moreover, breastfeeding is associated with lower rates of infant morbidity.^{4,5}

Several studies have examined the effect of breastfeeding on infant growth.^{6–10} Breastfed infants show higher growth rates in their early life compared with formula-fed infants.¹⁰ Other studies have reported that the rate of weight gain in formula-fed infants is greater than that for breastfed infants during the first few months of growth.^{6–9} Thus the effect of breastfeeding on infant growth remains controversial, especially after the release in 2006 of new WHO standards for assessing the growth and development of children under 5 years old.¹¹ To the best of our knowledge, no studies have documented the effect of breastfeeding duration on infant growth in Taiwan. This study gathered data from the Taiwan Birth Cohort Study for that purpose.

2. Methods

2.1. Study population and sampling strategy

The Taiwan Birth Cohort Study, the first such study conducted in Taiwan, is a prospective longitudinal study. It used multistage stratified random sampling to obtain representative samples from national birth registry data for 2005. A total of 369 towns in Taiwan were classified into 12 strata according to administrative level (four strata) and total fertility rate (three strata). A random sample of 90 was selected from the 369 towns. Using the principle of probability proportionate to size, a total of 24,200 pairs of postpartum women and newborns were selected for the study from the 90 towns.¹²

2.2. Data collection

The first and second home interviews with the 24,200 postpartum women were conducted at 6 and 18 months after their deliveries using a structured questionnaire, during the period from June 2005 to December 2007. A total of 4028 cases were lost to follow-up because of

refusal to participate, home relocation, incorrect addresses, infant deaths, and other miscellaneous reasons. All study participants provided informed consent as approved by the Ethics Review Board of the College of Public Health, National Taiwan University. For the two rounds of interviews, a total of 21,248 and 20,172 women were interviewed, giving a completed interview rate of 87.8% and 83.4%, respectively. The total sample used in this research study was 15,868. Infants with birth defects or who were hospitalized because of illness were excluded from the study. Analysis was restricted to full-term healthy children (gestational ages between 37 and 41 weeks) because these factors influence children's growth.

2.3. Definition of breastfeeding exposure

Breastfeeding duration was assessed by questions on infant feeding patterns in questionnaires at 18 months. The breastfeeding duration was categorized as follows: never breastfed (only formula fed), breastfed for less than 6 months, and breastfed for 6 months or more.

2.4. Outcome measurements

Information on infant weight and height was obtained at birth, 1, 4, 6, 12 and 18 months. Weight and height measurements were obtained from parent-held child health records.

2.5. Definitions of confounders

Infant-related variables included birth order (grouped into one and two or more), sex, timing of the first introduction of complementary foods (≤ 6 months and > 6 months), and birth weight/height. The mothers were grouped by age: ≤ 25 years, 26–34 years, and ≥ 35 years. Their educational levels were stratified into university or above and high school or below. Household factors included urban city (categorized as urban, main street of a rural area, and rural area) and family income per month ($< \text{NT\$}50,000$, $\text{NT\$}50,000\text{--}99,000$, and $\geq \text{NT\$}100,000$).

2.6. Statistical analysis

The χ^2 test was performed to assess the difference in basic characteristics between breastfeeding duration groups. Analysis of variance and a Bonferroni test were used to examine infant growth among the three feeding groups. The Bonferroni test is a more conservative post-hoc method for avoiding the phenomenon of mass significance, since multiple comparisons were performed. The generalized estimating equation (GEE) was used to test the association between breastfeeding duration and infant growth, after adjusting for infant birth order, complementary feeding start time, sex, allergies, birth weight/height and infant age; maternal age, education, country

of origin and maternal height; family income and urban city. The GEE model is appropriate for longitudinal data with repeated individual measures (follow-up measurements of weight and height). The SAS-GENMOD procedure, a statistical procedure developed by the SAS Institute Inc. (Cary, NC, USA), was used in these analyses. Statistical analyses were performed using SPSS version 15.0 (SPSS Inc., Chicago, IL, USA) for Windows and SAS version 9.1 software (SAS Institute Inc.), with $p < 0.05$ regarded as statistically significant.

3. Results

3.1. Sociodemographic characteristics

The characteristics of different breastfeeding duration groups are summarized in Table 1. Approximately half of

the infants were first-born (51.6%) and 51.1% were male. Most infants were introduced to solid food before the age of 6 months (90.6%). Approximately 70% of mothers were aged 20–34 years, approximately 50% had a high school education or below, and 13.3% were foreign mothers. Most family incomes were under NT\$99,000 per month (88.9%) and 47.5% of subjects resided in urban areas (Table 1).

As shown in Table 1, the three groups had very different sociodemographic characteristics. The group who were breastfed for ≥ 6 months included more girls and they tended to be introduced to solid food after 6 months. Mothers who breastfed for ≥ 6 months were older, had a higher education and included more foreigners. The families of infants breastfed for ≥ 6 months had higher incomes, and tended to live in urban areas compared with the other two groups (52.7% vs. 47.3% and 40.2%) (Table 1). The mean $\pm$ standard deviation breastfeeding

Table 1 Demographic characteristics of different breastfeeding duration groups*

	Total	Breastfeeding duration			<i>p</i>
		Never breastfed	Breastfed < 6 mo	Breastfed ≥ 6 mo	
Number	15,686 (100.0)	2423 (15.3)	8716 (54.9)	3882 (24.5)	
Infant factors					
Parity					<0.001
First-born	7754 (51.6)	1096 (45.2)	4635 (53.2)	2023 (52.1)	
Not first-born	7267 (48.4)	1327 (54.8)	4081 (46.8)	1859 (47.9)	
Sex					0.001
Boy	7680 (51.1)	1215 (50.1)	4564 (52.4)	1901 (49.0)	
Girl	7341 (48.9)	1208 (49.9)	4152 (47.6)	1981 (51.0)	
Complementary feeding start time					<0.001
≤ 6 mo	13,600 (90.6)	2185 (90.2)	8048 (92.4)	3367 (86.8)	
> 6 mo	1415 (9.4)	238 (9.8)	665 (7.6)	512 (13.2)	
Maternal factors					
Age (yr)					<0.001
≤ 25	3285 (21.9)	651 (26.9)	1983 (22.8)	651 (16.8)	
26–34	10,150 (67.6)	1484 (61.2)	5910 (67.8)	2756 (71.0)	
≥ 35	1586 (10.6)	288 (11.9)	823 (9.4)	475 (12.2)	
Education					<0.001
$\leq$ High school	8058 (53.8)	1791 (74.1)	4619 (53.2)	1648 (42.5)	
$\geq$ University	6921 (46.2)	625 (25.9)	4070 (46.8)	2226 (57.5)	
Country of origin					<0.001
Taiwan	13,024 (86.7)	2073 (85.6)	7780 (89.3)	3171 (81.7)	
Foreign	1995 (13.3)	349 (14.4)	935 (10.7)	711 (18.3)	
Household factors					
Income (NT\$/mo)					<0.001
$< 50,000$	6168 (41.2)	1230 (51.0)	3342 (38.5)	1596 (41.2)	
50,000–99,000	7148 (47.7)	1052 (43.6)	4369 (50.3)	1727 (44.6)	
$\geq 100,000$	1657 (11.1)	131 (5.4)	979 (11.3)	547 (14.1)	
Urbanicity					<0.001
Urban	7127 (47.5)	973 (40.2)	4112 (47.3)	2042 (52.7)	
Main street	4170 (27.8)	705 (29.1)	2450 (28.2)	1015 (26.2)	
Rural	3699 (24.7)	742 (30.7)	2139 (24.6)	818 (21.1)	

*Data presented as *n* (%).

duration for the infants in the <6-month group was 1.8 ± 1.3 months, and $\geq 90\%$ of that group were breastfed for <4 months. The mean $\pm$ standard deviation breastfeeding duration for the infants in the ≥ 6 -month group was 11.8 ± 4.6 months, and $\geq 50\%$ of the group were breastfed for ≥ 12 months (data not shown in table).

3.2. Comparison of infants and children's growth among the different groups

The association between breastfeeding duration and infant weight at 6, 12 and 18 months is shown in Table 2. No significant difference was found among the three groups in infant weight at 6 months. At 12 and 18 months, however, the infants who had been breastfed for <6 months and the group that was never breastfed

were significantly heavier than the infants breastfed for ≥ 6 months ($p < 0.001$). These results were not affected by sex (Table 2). To illustrate how the mean weight data compare with the new WHO growth standards, the mean weights of different breastfeeding duration groups are shown in Figure 1. The mean weight of boys and girls in all breastfeeding duration groups was between the WHO-specified 50th and 85th percentiles.

The association between breastfeeding duration and infant height at 6, 12 and 18 months is shown in Table 3. At 6, 12 and 18 months, the infants breastfed for <6 months were slightly taller than the other groups. The results were similar according to sex (Table 3). To illustrate how the mean height data compared with the new WHO growth standards, the mean height of different breastfeeding duration groups is shown in Figure 2.

Table 2 Infant weight of different breastfeeding duration groups*

Breastfeeding duration	Weight (g)			<i>p</i>
	Never breastfed ^a	Breastfed <6 mo ^b	Breastfed ≥ 6 mo ^c	
6 mo				
Total	8111.8 $\pm$ 1025.6	8130.5 $\pm$ 975.0	8074.8 $\pm$ 956.3	0.112
Boy	8434.2 $\pm$ 1028.6	8439.2 $\pm$ 956.7	8410.5 $\pm$ 904.3	0.733
Girl	7798.0 $\pm$ 920.7	7789.1 $\pm$ 876.3	7746.4 $\pm$ 889.8	0.395
12 mo				
Total [†]	9697.7 $\pm$ 1110.9	9743.4 $\pm$ 1078.6	9523.6 $\pm$ 1061.7	<0.001
Boy [†]	10,078.3 $\pm$ 1065.9	10,065.3 $\pm$ 1060.7	9852.5 $\pm$ 1019.9	<0.001
Girl [†]	9331.5 $\pm$ 1027.7	9389.2 $\pm$ 983.0	9207.9 $\pm$ 1004.0	<0.001
18 mo				
Total [†]	11,167.5 $\pm$ 1318.5	11,186.0 $\pm$ 1286.7	10,972.0 $\pm$ 1282.2	<0.001
Boy [†]	11,506.2 $\pm$ 1293.9	11,507.3 $\pm$ 1275.1	11,295.9 $\pm$ 1320.1	<0.001
Girl [†]	10,827.4 $\pm$ 1255.0	10,827.6 $\pm$ 1202.4	10,657.5 $\pm$ 1161.6	0.001

*Data presented as mean $\pm$ standard deviation; [†]a > c, b > c.

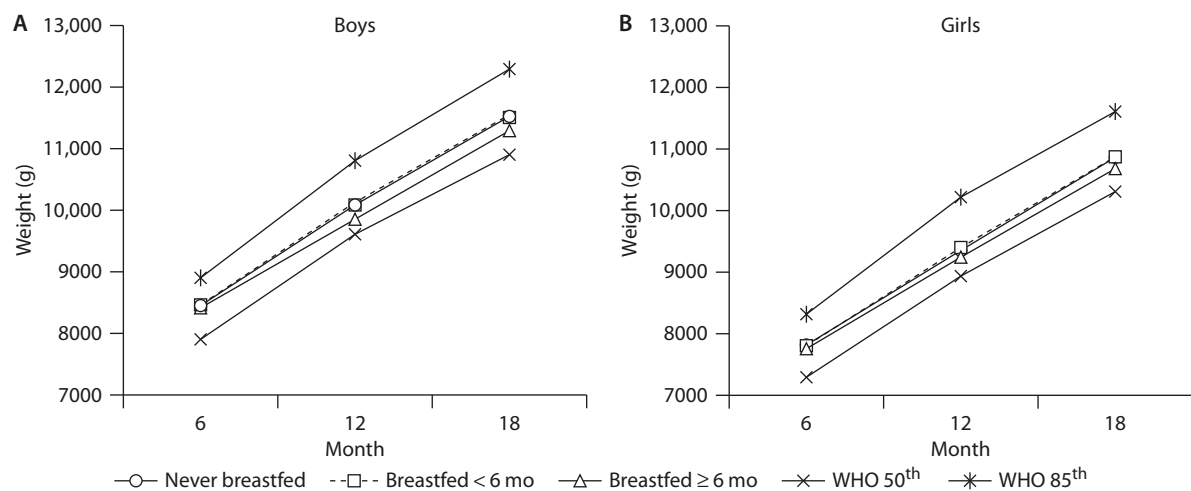


Figure 1 Mean weight of breastfeeding duration groups compared with the new World Health Organization (WHO) growth standards by sex.

Table 3 Infant height of different breastfeeding duration groups*

Breastfeeding duration	Height (cm)			<i>p</i>
	Never breastfed ^a	Breastfed < 6 mo ^b	Breastfed ≥ 6 mo ^c	
6 mo				
Total [†]	67.7 ± 3.2	68.0 ± 2.8	67.6 ± 2.9	< 0.001
Boy [‡]	68.7 ± 3.3	68.8 ± 2.8	68.5 ± 2.7	0.047
Girl [†]	66.8 ± 3.0	67.2 ± 2.6	66.7 ± 2.8	< 0.001
12 mo				
Total [†]	75.4 ± 2.9	75.7 ± 2.9	75.2 ± 3.0	< 0.001
Boy [‡]	76.3 ± 2.7	76.4 ± 2.8	76.0 ± 2.8	< 0.001
Girl [†]	74.5 ± 2.8	74.9 ± 2.8	74.4 ± 3.0	< 0.001
18 mo				
Total [‡]	81.8 ± 3.3	82.0 ± 3.3	81.7 ± 3.1	< 0.001
Boy [†]	82.6 ± 3.1	82.7 ± 3.2	82.3 ± 3.0	0.004
Girl	81.0 ± 3.3	81.3 ± 3.2	81.1 ± 3.1	0.038

*Data presented as mean ± standard deviation; [†]b > a, b > c; [‡]b > c.

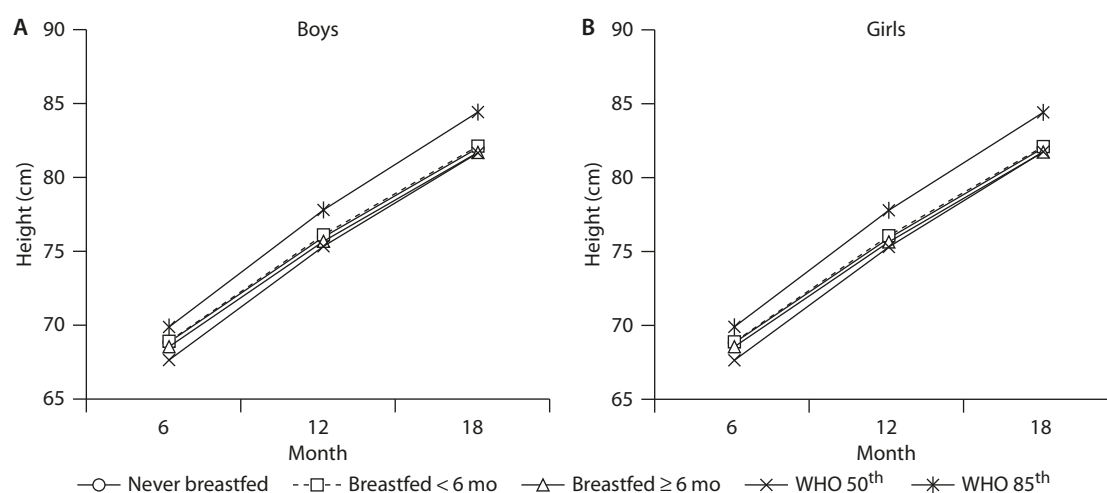


Figure 2 Mean height of breastfeeding duration groups compared with the new World Health Organization (WHO) growth standards by sex.

The mean height of boys and girls in the different breastfeeding duration groups was between WHO-specified 50th and 85th percentiles.

3.3. Effect of breastfeeding duration on infants' and children's growth

The effect of breastfeeding duration on infants' growth by the GEE model is shown in Table 4. After adjusting for infant birth order, complementary feeding start time, sex, birth weight, infant age; maternal age, education and country of origin; and family income and urbanicity, no significant difference was found among the three groups in infant weight up to 6 months. Compared with the other two groups, the infants breastfed for ≥ 6 months were significantly lighter and their weight relative to the other groups dropped after the 6th month compared with the other two groups ($p < 0.001$).

After adjusting for the other confounding factors, the group of infants breastfed for ≥ 6 months was slightly but significantly shorter than the group of infants breastfed for < 6 months after birth ($p < 0.001$). Similarly, from the 7th month onward, the group of infants breastfed for ≥ 6 months were slightly shorter than the group of infants who were never breastfed ($p < 0.001$).

4. Discussion

In the present study, we found that breastfeeding duration had no significant effect on infant weight within the first 6 months. However, after the 7th month, the group of infants breastfed for ≥ 6 months were lighter than the other two groups. Up to 18 months of age, infants who were breastfed for ≥ 6 months were slightly shorter than those who were breastfed for a shorter

Table 4 Generalized estimating equation model of growth of different breastfeeding duration groups

	Weight (g)*			Height (cm) [†]		
	β	SE	<i>p</i>	β	SE	<i>p</i>
0–18 mo						
Never breastfed	85.8	19.1	<0.001	0.2	0.1	<0.001
Breastfed <6 mo	102.6	13.5	<0.001	0.3	0.0	<0.001
Breastfed $\geq$ 6 mo	0.0			0.0		
0–6 mo						
Never breastfed	–3.4	17.5	0.846	0.1	0.1	0.063
Breastfed <6 mo	18.5	12.3	0.135	0.1	0.0	<0.001
Breastfed $\geq$ 6 mo	0.0			0.0		
7–12 mo						
Never breastfed	193.8	30.2	<0.001	0.5	0.1	<0.001
Breastfed <6 mo	198.7	21.4	<0.001	0.5	0.1	<0.001
Breastfed $\geq$ 6 mo	0.0			0.0		
13–18 mo						
Never breastfed	203.9	36.7	<0.001	0.3	0.1	<0.001
Breastfed <6 mo	204.8	26.2	<0.001	0.4	0.1	<0.001
Breastfed $\geq$ 6 mo	0.0			0.0		

*Model is adjusted for breastfeeding duration, complementary feeding start time, maternal factors (age, education, and country of origin), infant factors (age, parity, sex, and birth weight) and family factors (income and urban city); [†]model is adjusted for breastfeeding duration, complementary feeding start time, maternal factors (age, education, country of origin, and height), infant factors (age, parity, sex, and birth weight) and family factors (income and urban city). SE=standard error.

period. In addition, from the 7th month onward, infants who were breastfed for $\geq$ 6 months were slightly shorter than infants who were never breastfed. The difference in the infants' heights may be due to the large sample size of this study. These results are consistent with previous studies.^{6,7,9,13–15}

Since 1980, studies have consistently found that infants breastfed for $\geq$ 6 months tend to be lighter and shorter than infants breastfed for shorter periods. Hitchcock et al found that in healthy infants, those who were formula-fed and those breastfed for <6 months weighed more than infants breastfed for $\geq$ 6 months, and this divergence appeared at 3 months old to 12 months.⁶ Several observational studies have reported reduced weight and length gain in infants who receive prolonged breastfeeding.^{7,13,14} The Euro-Growth Study Group also found that breastfeeding duration was negatively correlated with incremental growth in length and weight at 12 and 24 months, but not at 36 months of age.⁹ Spyrides et al also confirmed differences in infant growth according to different breastfeeding practices starting from the 6th month of life.¹⁵

At least two possible mechanisms have been proposed to explain the association between breastfeeding and infant growth rates. One possible mechanism is the parental caring method. Bartok and Ventura showed that infants naturally regulate their energy intake, but their parents' behavior can override their appetite signals.¹⁶ During infancy, bottle feeding is usually conducted by parents according to a regular schedule, regardless of infants' signals of hunger and satiety. Mothers who are

breastfeeding may be more responsive to infants' signals with regard to the frequency and volume of feeding. Therefore, compared with bottle feeding, the act of breastfeeding may promote maternal feeding styles that are less controlling and more responsive to infant cues of hunger and satiety, thereby allowing infants greater self-regulation of energy intake while growing up. Compared with formula-fed infants, breastfed infants are unlikely to overfeed and, therefore, the risk of fatness is lower.¹⁷

Our study showed that the weight of infants breastfed for <6 months was greater than that of the $\geq$ 6-month group. Since breastfed infants are generally lighter, their mothers might be concerned that the lower weight gain could be due to breastfeeding, and thus switch to formula milk or start giving feeding supplements to their infants. This, in turn, might actually cause infants breastfed for less than 6 months to gain more weight. Previous studies have shown that inadequate infant growth is stressful for mothers and may lower mothers' self-efficacy.^{18,19} Mothers' self-efficacy is a very important predictor of breastfeeding duration.^{20–22}

The second possible mechanism that could explain the lower weight of infants breastfed more than 6 months is the metabolic consequences of ingesting breast milk and the biological activity of components of breast milk. The average protein intake of formula-fed infants is greater than that of breastfed infants during the first 6 months.²³ A higher intake of protein may result in higher levels of insulin and could lead to the development of adipose tissue and weight gain.²⁴ Rolland-Cachera et al suggested that a high-fat, low-protein diet,

such as exclusive breastfeeding, is adapted to the high energy demand for growth in early childhood.²⁵ A high-protein diet early in life could increase the risk of obesity and other pathologies later in life. After 1 year, breastfed infants are thinner than formula-fed infants.⁸ Several epidemiology studies have shown that infants breastfed for ≥ 6 months do not gain as much weight when growing up.^{26,27} Formula-fed infants tend to be easily overfed and to take in more protein. Breastfeeding duration is negatively related to the risk of childhood obesity.^{28–30}

However, some studies have found faster growth among infants breastfed for ≥ 6 months. In Brazil, researchers found that the growth rate of breastfed infants in terms of weight and height accelerates after 9 months of age.¹⁵ A study from Bangladesh also showed that the rate of growth in terms of weight and height of infants born in rural areas and breastfed for longer periods increases between birth and 2 years of age.³¹ These contrasting findings might be attributable to different public health environments. A higher prevalence of infant diarrhea may be the key reason for weight loss or limited weight gain in developing countries.^{32,33} Breastfeeding can prevent infections and lower the morbidity from diarrhea.^{34,35} Because Taiwan is a developed country with easy access to quality medical services and better hygiene conditions, the risk of diarrhea among formula-fed infants is low. Accordingly, we found that formula-fed infants are relatively heavier.

Despite the lower weight gain for infants breastfed for ≥ 6 months, it does not affect their long-term health. Dewey showed that under normal circumstances, the weight of continuously breastfed infants increases more slowly than infants who are not breastfed, but these breastfed infants are less likely to fall ill and also have better sensory development.⁸ There is no evidence of any functional advantage from the more rapid growth of formula-fed infants. Breast milk is the most appropriate food for infants, as it provides them with all the necessary nutrition needed for their growth.³⁶ Our results confirm the differences previously observed in infant growth between 6 and 18 months based on different feeding practices, and are consistent with the WHO's new growth standards.

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