Breastfeeding at 6 months of age had a positive impact on overweight and obesity in Japanese adolescents at 15 years of age

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Short title: Breastfeeding and adolescent obesity in Japan

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Abstract

Aim: A number of studies have indicated the potential benefits that breastfeeding has on reducing childhood obesity, but few studies have evaluated the effect on adolescent obesity. We examined the association between breastfeeding and overweight or obesity at 15 years of age using data from a large nationwide longitudinal study launched by the Japanese Government in 2001.

Methods: We analysed data for 26,164 participants with known infant feeding practices at 6 months of age, namely the duration of breastfeeding or formula feeding. Overweight or obesity at 15 years of age were calculated based on the subject's self-reported height and weight. Multinomial logistic regression analysis adjusted the data for child factors, namely sex, siblings, birth weight and physical activity clubs and the maternal factors of age, educational attainment and smoking status.

Results: Formula feeding was associated with an increased risk of overweight or obesity at 15 years of age. The adjusted odds ratios (95% confidence intervals) were 0.99 (0.89–1.09) for partial breastfeeding and 1.23 (1.02–1.48) for formula feeding, when exclusive breastfeeding was the reference category.

Conclusion: Breastfeeding during infancy had potential benefits for overweight or obesity among 15-year-old adolescents. Our results provide further evidence of the importance of breastfeeding.

Keywords

Adolescents; Breastfeeding; Epidemiology; Long-term effects; Obesity

Key Notes

- Few studies have evaluated the potential benefits of breastfeeding on overweight and obesity in adolescents.
- This Japanese study analysed data for 26,164 participants with known infant feeding practices at 6 months of age and checked their weight status at 15 years of age.
- Children who were formula fed were nearly a quarter more likely to be overweight or obese in adolescence than children who were exclusively or partially breastfed.

Introduction

There has been a marked worldwide increase in childhood and adolescent obesity [1, 2] and a number of studies have reported associations with adverse long-term health outcomes during adulthood. These have included the increased risks of type 2 diabetes, cardiovascular disease and cancer.[3-5]

Breastfeeding has many health benefits for children, such as protecting them against infectious diseases and immune disorders.[6, 7] In addition, a number of studies have indicated the potential benefits that breastfeeding has in reducing childhood and adolescent obesity.[8-13] This may be partly due to the components of breast milk, such as appetite and satiety hormones like leptin, ghrelin and adiponectin. In addition, the feeding methods that parents chose shaped their children's future eating habits.[8, 14-17] Indeed, our previous study showed that breastfeeding during infancy reduced the prevalence of obesity at 7 and 8 years of age.[9] Although many studies have evaluated the links between breastfeeding and child and adolescent obesity, the age ranges targeted by these studies were wide. Obesity during adolescence has been more closely linked with obesity in adulthood than childhood obesity, because the growth curve tends to becomes less steep after 15 years of age, especially in girls.[18, 19] This means that we need studies on the potential benefits of breastfeeding for adolescent obesity, especially after 15 years of age.

The aim of this study was to examine the association between breastfeeding status at 6 months of age and overweight or obesity at 15 years of age, using data from a large, nationwide, longitudinal study in Japan.

Methods

Study participants

The Longitudinal Survey of Babies in the 21st Century is a nationwide cohort

study that has been conducted by the Japanese Ministry of Health, Labour and Welfare since 2001. The aim of the study is to collect the basic information that is required to counteract declining birth rates. The first questionnaire was sent to all families living in Japan who had a baby, or babies, between 10-17 January or 10-17 July 2001. They were sent when the infants were 6 months of age. Of the 53,575 questionnaires that were posted to families, 47,015 (88%) were returned. Follow-up questionnaires were sent each year after that, to collect information on the children's health, growth, developmental status and child-rearing environments. These were initially just completed by the parents or guardians, but the children were included as they got older and the contents of the questionnaire were changed to reflect their age. Each participant was linked to their birth record in the Japanese Vital Statistics System, which includes data such as sex, gestational weeks at birth, singleton or multiple birth, parity and maternal age at delivery.[20]

We restricted participants to children born after 37 weeks of gestation and singleton births, because infants born preterm, and or as part of multiple births, were more likely to be formula fed.[19] This mean that 2,906 ineligible children were excluded and 44,109 participants remained (Figure 1).

Infant feeding practices

We used breastfeeding status at age 6 months as an indicator of infant feeding practices and the first survey included questions on breastfeeding and formula feeding practices. The three breastfeeding options were: breastfed, only fed colostrum or never breastfed. The formula feeding options were formula fed or never formula fed. By combining the responses, we categorised the infant feeding practices as: exclusive breastfeeding, partial breastfeeding and formula feeding. Just feeding colostrum was placed in the never breastfed category.

We also carried out a detailed analysis of three categories, based on the duration of partial breastfeeding: 1-2 months, 3-5 months and 6 months. This comprised 43,383 participants, as we did not have information on the feeding practices of 726 children at 6 months of age (Figure 1).

Overweight and obesity status

We determined whether the subjects were overweight or obese at 15 years of age, based on their self-reported height and weight in the 15th survey, which was carried out in 2016. After we calculated the body mass index (BMI), we divided the participants into four BMI categories using the age-specific and sex-specific BMI cut-off values proposed by the International Obesity Task Force.[21, 22] These were: underweight (<5th percentile), normal (5th–84th percentile), overweight (85th–94th percentile) and obesity (≥95th percentile). We then used the categories of overweight and obesity as the main outcomes of interest. We analysed 26,164 participants, because 17,219 children did not respond to the 15th survey and provide their height and weight information (Figure 1).

Statistical analysis

We initially compared the baseline characteristics of the children according to the infant feeding practice categories: exclusive breastfeeding, partial breastfeeding and formula feeding. To evaluate the impact of the participants who did not continue to take part in the study (Figure 1), we compared their baseline characteristics with those with did respond to the 15th survey.

We conducted a multinomial logistic regression analysis to evaluate the associations between infant feeding practices and BMI categories at 15 years of age, using exclusive breastfeeding as the reference category. We excluded participants in the

underweight BMI category from the regression analysis because the main aim of the study was to assess the association between breastfeeding and overweight or obesity. We compared the participants in the normal weight versus overweight and normal weight versus obesity BMI categories, using the normal weight category as the baseline. We first estimated crude odds ratios (ORs) and their 95% confidence intervals (CIs) (Model 1). We then constructed models that were adjusted for child factors (Model 2) and both child and maternal factors (Model 3).

The child factors included male or female sex, parity (first born or not), normal or low birth weight (<2500g or ≥2500g) and whether they engaged in physical activity at a club. The maternal factors included maternal age at delivery (<20, 20–25, 25–30, 30–35 or ≥35 years), whether they smoked or not and maternal educational attainment, namely university or higher, junior college or vocational or high school or less. Information on sex, birth weight, parity and maternal age at delivery were obtained from birth records. Information on whether the children participated in physical activity was obtained from the 15th survey. Information on maternal smoking status was obtained from the first survey and information on maternal educational attainment was obtained from the second survey when the child was 18 months of age. These potential confounders were selected based on previous studies and prior knowledge regarding associations between breastfeeding and obesity.[23-26] Some missing data for adjustment factors were handled by 10 imputations, using predictive mean matching.[27]

We incorporated breastfeeding duration into the analysis. We also conducted a sex-stratified analysis.

We calculated the BMI z-score of the participants using the lambda-mu-sigma method, with reference to BMI standards for a representative Japanese paediatric population.[28] Then we performed multiple linear regression analyses, using the category of

exclusive breastfeeding as a reference, to estimate the β-coefficients with their 95% CIs.

We also carried out sensitivity analyses and independently adjusted the data for several further potential confounders in addition to the adjusted variables in Model 3. These were annual household income quartiles, whether or not the children ate breakfast and whether or not they snacked and whether their bedtime was before or after midnight. Annual household income was obtained from the 15th survey and used as a surrogate for socioeconomic status. We felt that breakfast, snacking and bedtime were relevant parameters related to the children's lifestyle and also obtained this information from the 15th survey.

All the statistical analyses were conducted using Stata SE version 17 (StataCorp LP, Texas, USA). The study was approved by the Institutional Review Board at Okayama University Graduate School of Medicine, Dentistry and Pharmaceutical Sciences (number 1506-073).

Results

The baseline characteristics of the 43,383 participants, stratified by their breastfeeding status at 6 months of age, are shown in Table 1: 9,537 (22.0%) were exclusively breastfed, 31,249 were partially breastfed (72.0%) and 2,597 (6.0%) received formula. The exclusively breastfed children tended to have more siblings than other children. Formula-fed children tended to be less physically active at 15 years of age and had mothers who smoked and had lower educational attainment. The children who did not respond to the 15th survey tended to have been formula fed and had mothers who smoked and had lower educational attainment (Table S1). The baseline characteristics of the participants stratified by their BMI categories are shown in Table S2. The mothers of obese children tended to be smokers and to have lower levels of education.

Table S3 shows a cross-tabulation between breastfeeding status and BMI categories, namely underweight, normal, overweight and obesity, at 15 years of age. Formula-fed children had higher proportions of overweight (12.3%) and obesity (7.7%) than other children.

The results of the multinomial logistic regression analysis of overweight or obesity at 15 years of age are shown in Table 2. Formula feeding was associated with increased risks of overweight and obesity compared with exclusive breastfeeding in Model 1. Adjusting the data for potential confounders attenuated the associations, particularly for obesity. Indeed, the ORs (95% CIs) for overweight were 1.01 (0.92–1.12) for partial breastfeeding and 1.33 (1.11–1.60) for formula feeding, compared with exclusive breastfeeding in Model 1. However, they changed to 0.99 (0.89–1.09) and 1.23 (1.02–1.48) after the adjustments in Model 3, respectively. The results are also shown in Figure 2. No clear dose-response patterns were observed when the duration of breastfeeding was considered,.

When we used the BMI z-scores as outcomes, we did not observe elevated β-coefficients in the formula feeding category than the exclusive breastfeeding category (Table 3).

The results of the sex-stratified analysis are shown in Table S4. The prevalence of obesity was higher in boys (22.4%) than girls (17.7%), although formula feeding tended to be a risk for overweight or obesity in both sexes.

In the sensitivity analyses, independent adjustments for each potential confounder, namely household income, breakfast, snacking and bedtime, in addition to the adjusted variables in Model 3, did not substantially change the OR estimates (Table S5).

Discussion

This study demonstrated the association between breastfeeding at 6 months of age and overweight or obesity at 15 years of age, using data from a large Japanese nationwide longitudinal study. We found that formula feeding was associated with an elevated risk of overweight in adolescents, compared with exclusive breastfeeding. However, a dose-response relationship between the duration of breastfeeding and the risk of overweight or obesity was not apparent and the BMI z-scores did not differ among the breastfeeding categories.

The present findings were consistent with other studies that examined the associations between breastfeeding and adolescents with overweight and obesity. For example, a study in the United States found that breastfeeding for at least 7 months was associated with a decreased risk of obesity at 9–14 years of age, compared with breastfeeding for 3 months or less.[10] A study from Australia on children aged 9–16 years found that breastfeeding for more than 6 months was associated with decreased risks of overweight and obesity compared with never breastfeeding.[11] In addition, a cross-sectional survey on children aged 11–14 years from East Germany found a protective effect of breastfeeding, with a dose-response relationship for obesity, but not for overweight. [29] In contrast, a study from the United Kingdom showed that breastfeeding for more than 6 months was associated with obesity at 14 years of age, compared with breastfeeding for less than 6 months in crude models, but not in adjusted models.[12] The present findings support previous evidence that breastfeeding was associated with a decreased risk of overweight. These results are supported by the fact that out study had a large number of participants and we used detailed classifications for breastfeeding. Furthermore, a restricted analysis of overweight or obesity in children up to age 15 is interesting, because the growth curve is generally less steep during this period. Despite this, further studies are warranted to address some of the conflicting results in previous studies. We previously demonstrated that

breastfeeding was associated with a decreased risk of overweight at 7 and 8 years of age using the same dataset[9] and the present study extended that follow-up period. It will also be important to evaluate such long-term benefits of breastfeeding in future studies.

Two mechanisms may explain the association between breastfeeding and the reduced risk of overweight or obesity: self-regulation and nutrient content. When it comes to self-regulation, breastfed children may have more discretion over the amount of milk they consume than those who are fed with infant formula. For example, the timing and amount of formula feeding are planned by the parents and bottle-fed infants tend to completely consume the formula provided.[8, 14] The second mechanism may be related to the biochemical components of breast milk. Breast milk contains several hormones that are involved in appetite control, such as leptin, adiponectin and ghrelin, and these may reduce over-eating.[15] In addition, breast milk contains high levels of lipids that can help the body to burn fat.[16] As indicated by a previous study, which showed that excess accumulation of adipose tissue during childhood was associated with adolescent obesity,[17] childhood overweight or obesity may persist into adolescence. These mechanisms may explain the potential benefits of breastfeeding on adolescent overweight or obesity.

The reasons why we did not observe a dose-response relationship between duration of breastfeeding and the risk of overweight or obesity are unclear. However, providing any quantity of breast milk, rather than formula, may be helpful in preventing overweight.[8-13] Because we did not have information on breastfeeding after 6 months of age, misclassification may have attenuated the effect estimates for longer durations of breastfeeding in partially or exclusively breastfed infants. In addition, the BMI z-scores did not differ among the breastfeeding categories. This indicates that the relationship between breastfeeding and overweight or obesity may not be adequately evaluated by the mean BMI values, while cut-off values with certain percentiles may adequately reflect the relationship.

The main strength of the present study was its use of longitudinal data from a nationwide cohort study in Japan. Although the response rates to the questionnaires decreased over time, we were still able to test our hypothesis with a large sample. We were also able to adjust for the socioeconomic status of the parents. Maternal education and maternal smoking status[30] were important confounders for the association between feeding practices and overweight or obesity. This was reflected by the attenuation of the ORs in Model 3.

Our study had some limitations. First, some of the participants who had previously taken part did not respond to the 15th survey, which may have introduced selection bias. The non-responders tended to be formula fed and have lower socioeconomic status and both of these factors may have increased their risk of overweight or obesity compared to the participants included in the analysis. This bias would have underestimated the effect estimates. Second, we were concerned about exposure misclassification. We collected information on breastfeeding practices when the infants were around 6 months of age and had no way of knowing if they continued to receive it after this point. Moreover, we did not have information on breast milk delivery, either direct or bottle-fed, and liquid administration in a hospital or clinic. Therefore, the potential risk of overweight or obesity with formula feeding was not discussed in this study, but further research is needed to determine this. Third, there were concerns about whether the outcome variables were misclassified, because the information on the adolescents' height and weight was self-reported. Finally, residual confounding by unmeasured familial factors was possible. For example, no information was available on parental BMI,[26] which may have confounded our findings. Indeed, maternal BMI can predict the basic dietary patterns of children in later life. Moreover, we did not have information on variables related to delivery, such as Caesarean sections, or variables related to children's dietary habits, such as the introduction

of solid foods. However, we adjusted for potential confounders in the primary and sensitivity analyses, including lifestyle factors, and the results did not change substantially.

Conclusion

We found that breastfeeding at 6 months of age had potential benefits, as adolescents were less likely to be overweight or obese than formula fed infants when they reached 15 years of age. Given the accumulating evidence regarding the beneficial advantages of breastfeeding on children's health, breastfeeding should continue to be recommended. Our findings support this recommendation, by providing evidence on the potential benefits that it has on adolescent health. Further studies are warranted to examine any associations between breastfeeding during infancy and overweight or obesity in adults.

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Conflict of interest

The authors have no conflict of interests to disclose.

Abbreviations

BMI: body mass index

CI: confidence interval

OR: odds ratio

SD: standard deviation

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Table 1. Demographic characteristics of the 43,383 children who were included in the study, stratified by breastfeeding status

	Exclusive breastfeeding (n=9,537)	Partial breastfeeding (n=31,249)	Formula feeding (n=2,597)	p value[a]
Children's characteristics				
Sex, n (%)[b]				
Boys	4,808 (50.4)	16,179 (51.8)	1,386 (53.4)	0.011
Girls	4,729 (49.6)	15,070 (48.2)	1,211 (46.6)	
Parity, n (%)[b]				
0	3,885 (40.7)	16,321 (52.2)	1,267 (48.8)	<0.001
> 1	5,652 (59.3)	14,928 (47.8)	1,330 (51.2)	
Birth weight, n (%)[b]				
<2500	337 (3.5)	1,659 (5.3)	186 (7.2)	<0.001
>2500	9,200 (96.5)	29,590 (94.7)	2,411 (92.8)	
Physical club activity[c], n (%)[d]				
No	2,141 (33.7)	6,805 (35.7)	573 (41.1)	<0.001
Yes	4,219 (66.3)	12,235 (64.3)	820 (58.9)	
Parental characteristics				
Mean maternal age at delivery, years (SD)[b]	30.2 (4.1)	29.8 (4.5)	29.9 (5.0)	<0.001
Maternal smoking status[c], n (%)[e]				
Non-smoker	8,687 (91.4)	25,162 (81.0)	1,774 (69.1)	<0.001
Smoker	813 (8.6)	5,916 (19.0)	792 (30.9)	
Maternal education[c], n (%)[f]				
University or higher	1,588 (17.5)	3,883 (13.4)	144 (6.2)	<0.001
Junior college	4,117 (45.4)	11, 877 (41.0)	721 (30.9)	
Less than, or equal, to high school	3,364 (37.1)	13,229 (45.6)	1,472 (63.0)	

SD, standard deviation.

[a]Differences between the breastfeeding statuses were evaluated by the chi-square test or analysis of variance.

[b]Obtained from birth records.

[c]The number of missing children was 16,590 for physical activity at clubs, 239 for maternal smoking status and 2,988 for maternal educational attainment.

[d]Obtained from the 15th survey (age 15 years).

[e]Obtained from the first survey (age 6 months).

[f]Obtained from the second survey (age 18 months).

Table 2. Associations between infant feeding practices at 6 months of age and overweight or obesity at 15 years of age

	Cases/Total Number(%)	Model 1: Crude (n=25,117)		Model 2[a] (n=25,117)		Model 3[b] (n=25,117)	
		OR	(95% Cl)	OR	(95% Cl)	OR	(95% Cl)
Overweight[c]							
Breastfeeding status							
Exclusive breastfeeding	612/5,980 (10.2)		1 (ref)		1 (ref)		1 (ref)
Partial breastfeeding	1,839/17,837 (10.3)	1.01	(0.92-1.12)	1.02	(0.93-1.13)	0.99	(0.89-1.09)
Formula feeding	167/1,300 (12.9)	1.33	(1.11-1.60)	1.34	(1.12-1.61)	1.23	(1.02-1.48)
Breastfeeding duration							
Exclusive breastfeeding at 6 months of age	612/5,980 (10.2)		1 (ref)		1 (ref)		1 (ref)
Partial breastfeeding, breastfeeding duration							
1–2 months	459/4,295 (10.7)	1.06	(0.93-1.21)	1.07	(0.94-1.21)	0.99	(0.87-1.13)
3–5 months	486/4,842 (10.0)	0.98	(0.86-1.11)	0.98	(0.87-1.12)	0.94	(0.83-1.07)
6 months	894/8,700 (10.3)	1.01	(0.91-1.13)	1.02	(0.91-1.14)	1.01	(0.90-1.13)
Formula feeding	167/1,300 (12.9)	1.33	(1.11-1.60)	1.34	(1.12-1.61)	1.23	(1.02-1.48)
Obesity[c]							
Breastfeeding status							
Exclusive breastfeeding	345/5,980 (5.8)		1 (ref)		1 (ref)		1 (ref)
Partial breastfeeding	1,119/1,7837 (6.3)	1.09	(0.97-1.24)	1.08	(0.95-1.22)	1.00	(0.88-1.14)
Formula feeding	104/1,300 (8.0)	1.47	(1.17-1.85)	1.39	(1.10-1.75)	1.16	(0.91-1.46)
Breastfeeding duration							
Exclusive breastfeeding at 6 months of age	345/5,980 (5.8)		1 (ref)		1 (ref)		1 (ref)
Partial breastfeeding, breastfeeding duration							
1–2 months	284/4,295 (6.6)	1.16	(0.99-1.37)	1.14	(0.97-1.34)	0.98	(0.83-1.16)
3–5 months	288/4,842 (6.0)	1.03	(0.88-1.21)	1.01	(0.86-1.19)	0.93	(0.79-1.10)
6 months	547/8,700 (6.3)	1.10	(0.95-1.26)	1.08	(0.94-1.24)	1.05	(0.91-1.21)
Formula feeding	104/1,300 (8.0)	1.47	(1.17-1.85)	1.39	(1.10-1.75)	1.15	(0.91-1.46)

CI, confidence interval; OR, odds ratio; ref, reference category.

ORs were calculated using a multinomial logistic regression analysis after excluding participants in the underweight category.

[a]Adjusted for child factors (sex, parity, birth weight and physical club activity). Complete-case estimates are shown.

[b]Adjusted for child factors and maternal factors (maternal age at delivery, maternal educational attainment and maternal smoking status). Multiple imputation estimates are shown.

[c]Overweight was defined as BMI =85th–94th percentile and obesity was defined as BMI ≥95th percentile.

Table 3. Associations between infant feeding practices and BMI z-scores[a] at 15 years of age

	Total Number	Mean (SD)	Model 1: Crude		Model 2[b]		Model 3[c]	
			β	(95% Cl)	β	(95% Cl)	β	(95% Cl)
Breastfeeding status								
Exclusive breastfeeding	5,980	-0.3 (0.9)		1 (ref)		1 (ref)		1 (ref)
Partial breastfeeding	17,837	-0.3 (1.0)	-0.01	(-0.04 to 0.02)	-0.01	(-0.03 to 0.02)	-0.03	(-0.05 to 0.00)
Formula feeding	1,300	-0.3 (1.1)	0.04	(-0.02 to 0.09)	0.04	(-0.01 to 0.10)	-0.01	(-0.07 to 0.05)
Breastfeeding duration								
Exclusive breastfeeding at 6 months of age	5,980	-0.3 (0.9)		1 (ref)		1 (ref)		1 (ref)
Partial breastfeeding, breastfeeding duration								
1–2 months	4,295	-0.3 (1.0)	0.00	(-0.04 to 0.04)	0.01	(-0.03 to 0.04)	-0.04	(-0.08 to 0.00)
3–5 months	4,842	-0.4 (1.0)	-0.05	(-0.08 to -0.01)	-0.04	(-0.08 to -0.01)	-0.07	(-0.10 to -0.03)
6 months	8,700	-0.3 (0.9)	0.00	(-0.03 to 0.03)	0.00	(-0.03 to 0.04)	0.00	(-0.03 to 0.03)
Formula feeding	1,300	-0.3 (1.1)	0.04	(-0.02 to 0.09)	0.04	(-0.01 to 0.10)	-0.01	(-0.07 to 0.04)

BMI, body mass index; CI, confidence interval; OR, odds ratio; ref, reference category.

β-coefficients were estimated using multiple linear regression analysis.

[a]BMI z-scores were calculated using the lambda-mu-sigma method with reference to BMI standards for a representative Japanese paediatric population.

[b]Adjusted for child factors (sex, parity, birth weight and physical activity at club). Complete case estimates are shown.

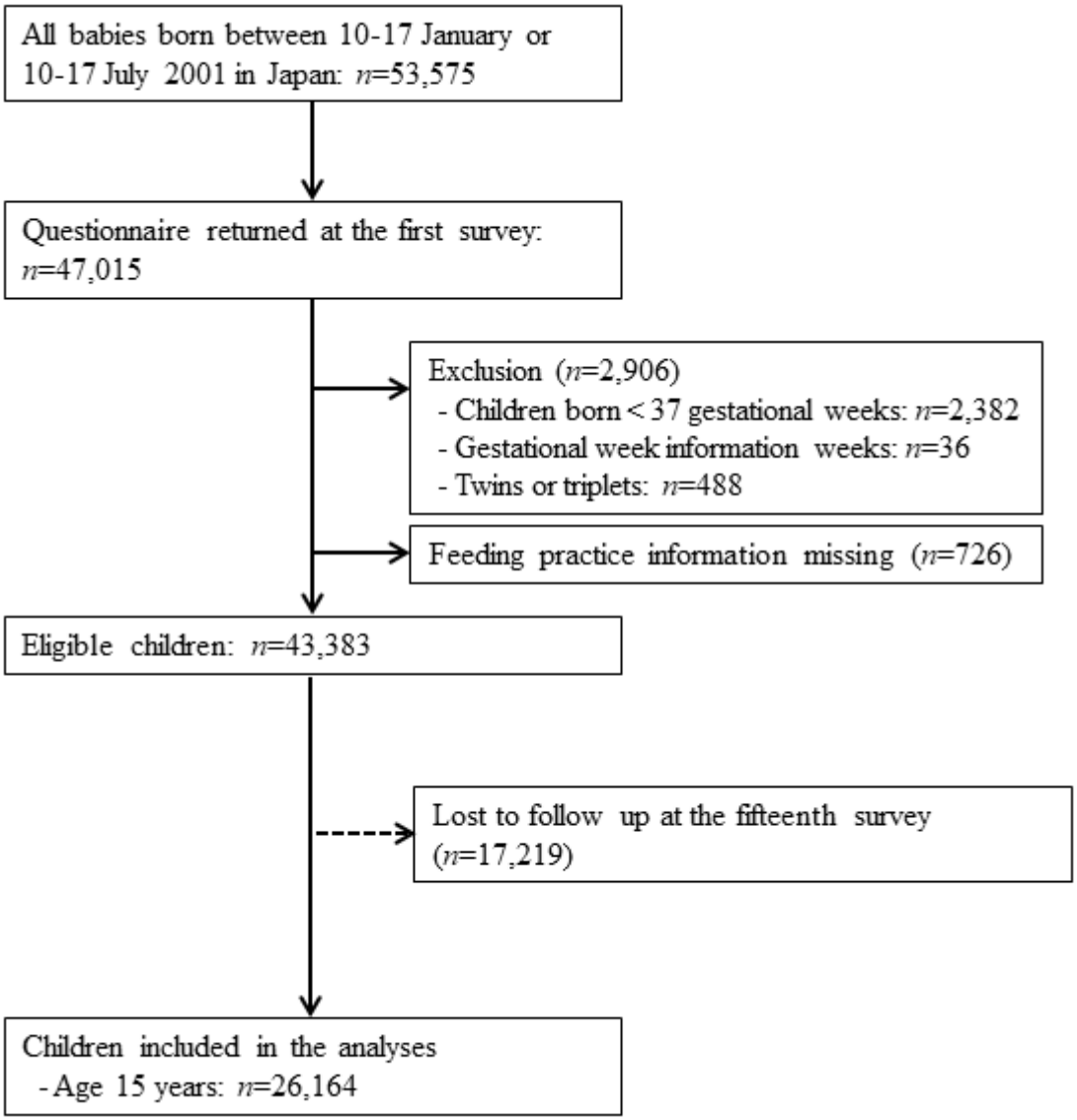
[c]Adjusted for child factors and maternal factors (maternal age at delivery, maternal educational attainment and maternal smoking status). Multiple imputation estimates are shown.

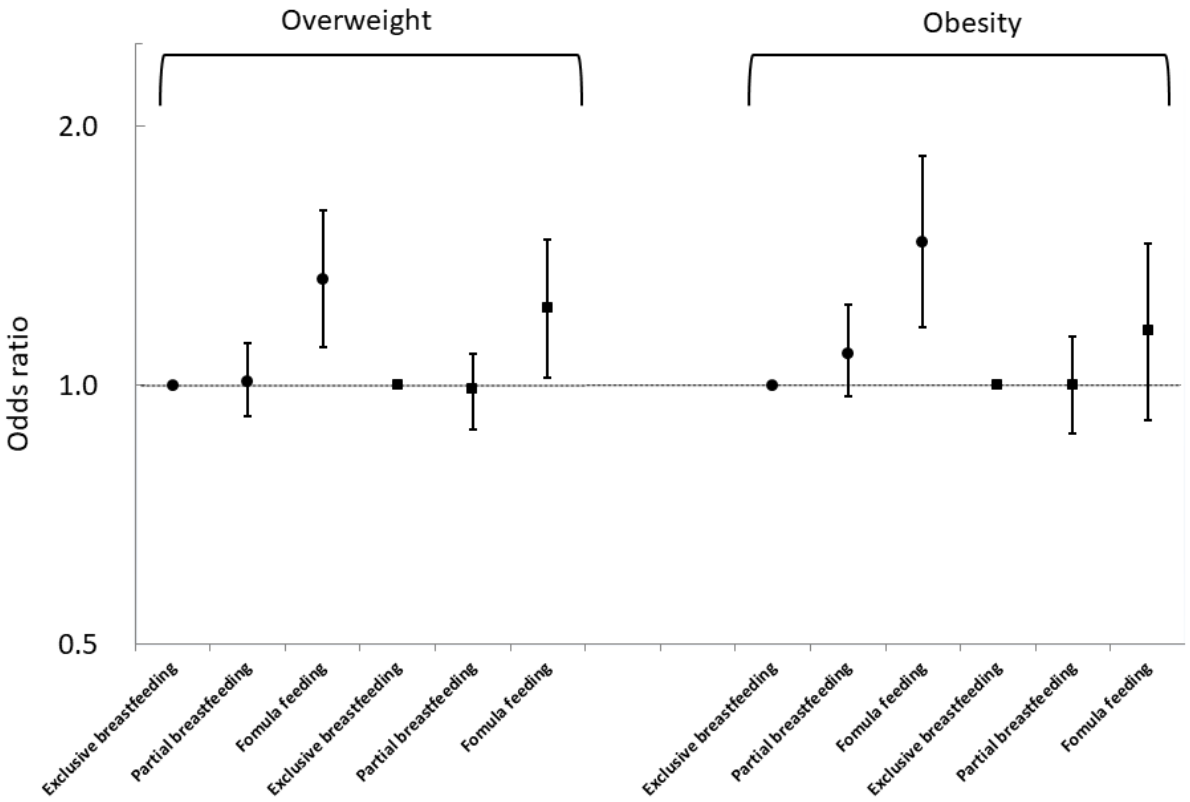
Figure legends

Figure 1. Flowchart of the study participants.

Figure 2. Associations between infant feeding practices at 6 months of age and overweight or obesity at 15 years of age.

Odds ratios are plotted on a log scale with their 95% confidence intervals. The odds ratios from crude models are shown in circles and those from adjusted models are shown in squares.


All babies born between 10-17 January or 10-17 July 2001 in Japan: n=53,575
Questionnaire returned at the first survey: n=47,015
Exclusion (n=2,906)
- Children born < 37 gestational weeks: n=2,382
- Gestational week information weeks: n=36
- Twins or triplets: n=488
Feeding practice information missing (n=726)
Eligible children: n=43,383
Lost to follow up at the fifteenth survey (n=17,219)
Children included in the analyses
- Age 15 years: n=26,164


Overweight
Obesity
2.0
1.0
0.5
Odds ratio
Exclusive breastfeeding
Partial breastfeeding
Fomula feeding
Exclusive breastfeeding
Partial breastfeeding
Fomula feeding
Exclusive breastfeeding
Partial breastfeeding
Fomula feeding
Exclusive breastfeeding
Partial breastfeeding
Fomula feeding

Supplemental Material

Table S1. Demographic characteristics of the children included in the analyses and the children without response to the 15th survey (n=43,383).

Table S2. Demographic characteristics of the eligible children stratified by BMI categories (n=26,164).

Table S3. Distribution of the BMI categories stratified by breastfeeding statuses (n=26,164).

Table S4. Associations between infant feeding practices and overweight or obesity at 15 years of age stratified by sex.

Table S5. Sensitivity analyses of the associations between infant feeding practices and overweight or obesity at 15 years of age.

Table S1. Demographic characteristics of the children included in the analyses and the children without response to the 15th survey (n=43,383)

	Total (N=43,383)	Included in the analyses (N=26,164)	Without response to the 15th survey (N=17,219)	p value[a]
Characteristics of children				
Sex, n (%)[b]				
Boys	22,373 (51.6)	13,350 (51.0)	9,023 (52.4)	0.005
Girls	21,010 (48.4)	12,814 (49.0)	8,196 (47.6)	
Parity, n (%)[b]				
0	21,473 (49.5)	12,887 (49.3)	8,586 (49.9)	0.215
> 1	21,910 (50.5)	13,277 (50.8)	8,633 (50.1)	
Birth weight, n (%)[b]				
<2500	2,182 (5.0)	1,305 (5.0)	877 (5.1)	0.623
>2500	41,201 (95.0)	24,859 (95.0)	16,342 (94.9)	
Breastfeeding status, n (%)[c]				
Exclusive breastfeeding	9,537 (22.0)	6,207 (23.7)	3,330 (19.3)	<0.001
Partial breastfeeding	31,249 (72.0)	18,597 (71.1)	12,652 (73.5)	
Formula feeding	2,597 (6.0)	1,360 (5.2)	1,237 (7.2)	
Parental characteristics				
Mean maternal age at delivery, years (SD)[b]	29.9 (4.5)	30.5 (4.2)	29 (4.7)	<0.001
Maternal smoking status, n (%)[c]				
Non-smoker	35,623 (82.6)	22,908 (87.9)	12,715 (74.4)	<0.001
Smoker	7,521 (17.4)	3,148 (12.1)	4,373 (25.6)	
Maternal educational attainment, n (%)[d]				
University or higher	5,615 (13.9)	4,177 (16.2)	1,438 (9.9)	<0.001
Junior college	16,715 (41.4)	11,372 (44.1)	5,343 (36.6)	
Less than or equal to high school	18,065 (44.7)	10,243 (39.7)	7,822 (53.6)	

SD, standard deviation.

[a]Differences between the children included in the analyses and the children without response to the 15th survey were evaluated by the chi-square test or analysis of variance.

[b]Obtained from birth records.

[c]Obtained from the first survey (age 6 months).

[d]Obtained from the second survey (age 18 months).

Table S2. Demographic characteristics of the eligible children stratified by BMI categories[a] (n=26,164)

	Underweight (N=1,047)	Normal (N=20,931)	Overweight (N=2,618)	Obesity (N=1,568)	p value[b]
Characteristics of children					
Sex, n (%)[c]					
Boys	645 (61.6)	10,578 (50.5)	1,231 (47.0)	896 (57.1)	<0.001
Girls	402 (38.4)	10,353 (49.5)	1,387 (53.0)	672 (42.9)	
Parity, n (%)[c]					
0	549 (52.4)	10,274 (49.1)	1,261 (48.2)	803 (51.2)	0.044
> 1	498 (47.6)	10,657 (50.9)	1,357 (51.8)	765 (48.8)	
Birth weight, n (%)[c]					
<2500	966 (92.3)	19,879 (95.0)	2,512 (96.0)	1,502 (95.8)	<0.001
>2500	81 (7.7)	1,052 (5.0)	106 (4.1)	66 (4.2)	
Physical club activity, n (%)[d]					
No	477 (45.6)	7,039 (33.6)	953 (36.4)	732 (46.7)	<0.001
Yes	570 (54.4)	13,892 (66.4)	1,665 (63.6)	836 (53.3)	
Parental characteristics					
Mean maternal age at delivery, years (SD)[c]	30.7 (4.2)	30.5 (4.2)	30.6 (4.3)	30.7 (4.6)	0.062
Maternal smoking status, n (%)[e]					
Non-smoker	945 (90.7)	18,435 (88.4)	2,227 (85.6)	1,301 (83.5)	<0.001
Smoker	97 (9.3)	2,417 (11.6)	376 (14.4)	258 (16.6)	
Maternal educational attainment, n (%)[f]					
University or higher	166 (16.1)	3,443 (16.7)	374 (14.5)	194 (12.6)	<0.001
Junior college	471 (45.6)	9,229 (44.7)	1,077 (41.9)	595 (38.6)	
Less than or equal to high school	395 (38.3)	7,974 (38.6)	1,121 (43.6)	753 (48.8)	

BMI, body mass index; SD, standard deviation.

[a]BMI categories were based on the age- and sex-specific BMI cutoff values for children proposed by the International Obesity Task Force.

[b]Differences between the BMI categories were evaluated by the chi-square test or analysis of variance.

[c]Obtained from birth records.

[d]Obtained from the 15th survey (age 15 years).

[e]Obtained from the first survey (age 6 months).

[f]Obtained from the second survey (age 18 months).

Table S3. Distribution of the BMI categories stratified by breastfeeding statuses (n=26,164)

	Exclusive breastfeeding (N=6,207)	Partial breastfeeding (N=18,597)	Formula feeding (N=1,360)
BMI category[a]			
Underweight	227 (3.7)	760 (4.1)	60 (4.4)
Normal	5,023 (80.9)	14,879 (80.0)	1,029 (75.7)
Overweight	612 (9.9)	1,839 (9.9)	167 (12.3)
Obesity	345 (5.6)	1,119 (6.0)	104 (7.7)

BMI, body mass index.

[a]BMI categories were based on the age- and sex-specific BMI cutoff values for children proposed by the International Obesity Task Force.

Table S4. Associations between infant feeding practices and overweight or obesity at 15 years of age stratified by sex

		Model 1: Crude (n=25,117)		Model 2[a] (n=25,117)		Model 3[b] (n=25,117)	
	Cases/Total Number (%)	OR	(95% Cl)	OR	(95% Cl)	OR	(95% Cl)
Overweight[c]							
Boy Breastfeeding status							
Exclusive breastfeeding	279/2,990 (9.3)		1 (ref)		1 (ref)		1 (ref)
Partial breastfeeding	872/9,041 (9.6)	1.05	(0.91-1.21)	1.05	(0.91-1.21)	1.02	(0.88-1.18)
Formula feeding	80/674 (11.9)	1.35	(1.04-1.77)	1.34	(1.03-1.75)	1.25	(0.95-1.64)
Girl Breastfeeding status							
Exclusive breastfeeding	333/2,990 (11.1)		1 (ref)		1 (ref)		1 (ref)
Partial breastfeeding	967/8,796 (11.0)	0.99	(0.86-1.13)	1.00	(0.88-1.15)	0.96	(0.84-1.10)
Formula feeding	87/626 (13.9)	1.32	(1.02-1.70)	1.34	(1.04-1.73)	1.21	(0.93-1.57)
Obesity[c]							
Boy Breastfeeding status							
Exclusive breastfeeding	188/2,990 (6.3)		1 (ref)		1 (ref)		1 (ref)
Partial breastfeeding	648/9,041 (7.2)	1.16	(0.98-1.37)	1.13	(0.96-1.35)	1.08	(0.91-1.28)
Formula feeding	60/674 (8.9)	1.51	(1.11-2.05)	1.40	(1.03-1.91)	1.21	(0.89-1.66)
Girl Breastfeeding status							
Exclusive breastfeeding	157/2,990 (5.3)		1 (ref)		1 (ref)		1 (ref)
Partial breastfeeding	471/8,796 (5.4)	1.02	(0.85-1.23)	1.01	(0.84-1.22)	0.91	(0.76-1.11)
Formula feeding	44/626 (7.0)	1.42	(1.00-2.00)	1.37	(0.97-1.95)	1.10	(0.77-1.56)

CI, confidence interval; OR, odds ratio; ref, reference category.

ORs were calculated using a multinomial logistic regression analysis after excluding participants in the underweight category.

[a]Adjusted for child factors (parity, birth weight and physical activity at club). Complete-case estimates are shown.

[b]Adjusted for child factors and maternal factors (maternal age at delivery, maternal educational attainment and maternal smoking status). Multiple imputation estimates are shown.

[c]Overweight was defined as BMI =85th–94th percentile, and obesity was defined as BMI ≥95th percentile.

Table S5. Sensitivity analyses of the associations between infant feeding practices and overweight or obesity at 15 years of age

	Model 3[a] (n=25,117)		Model 3[a] plus parental income[b] (n=11,018)[c]		Model 3[a] plus breakfast[b] (n=25,117)		Model 3[a] plus snack[b] (n=25,117)		Model 3[a] plus bedtime[b] (n=25,117)	
	OR	(95% Cl)	OR	(95% Cl)	OR	(95% Cl)	OR	(95% Cl)	OR	(95% Cl)
Overweight[d]										
Breastfeeding status										
Exclusive breastfeeding	1 (ref)		1 (ref)		1 (ref)		1 (ref)		1 (ref)	
Partial breastfeeding	0.99	(0.89-1.09)	1.01	(0.87-1.17)	0.99	(0.89-1.09)	0.99	(0.89-1.09)	0.99	(0.89-1.09)
Formula feeding	1.23	(1.02-1.48)	1.19	(0.88-1.61)	1.22	(1.02-1.48)	1.23	(1.02-1.48)	1.23	(1.02-1.48)
Obesity[d]										
Breastfeeding status										
Exclusive breastfeeding	1 (ref)		1 (ref)		1 (ref)		1 (ref)		1 (ref)	
Partial breastfeeding	1.00	(0.88-1.14)	1.03	(0.85-1.25)	1.00	(0.88-1.14)	1.00	(0.88-1.14)	1.00	(0.88-1.14)
Formula feeding	1.16	(0.91-1.46)	1.07	(0.73-1.57)	1.15	(0.91-1.46)	1.16	(0.91-1.46)	1.16	(0.91-1.46)

CI, confidence interval; OR, odds ratio; ref, reference category.

ORs were calculated using a multinomial logistic regression analysis after excluding participants in the underweight category.

[a]Adjusted for child factors (sex, parity, birth weight and physical activity at club) and maternal factors (maternal age at delivery, maternal educational attainment and maternal smoking status).

[b]Further adjusted for each variable in Model 3.

[c]Because more than half of the participants lacked information on parental income, we excluded participants with missing data and conducted the analyses on those with complete information only, rather than performing multiple imputation. The other analyses were conducted by multiple imputation.

[d]Overweight was defined as BMI =85th–94th percentile, and obesity was defined as BMI ≥95th percentile.