Timing of Solid Food Introduction and Obesity: Hong Kong’s “Children of 1997” Birth Cohort

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KEY WORDS
solid food, infant feeding, obesity, China, cohort study

ABBREVIATIONS
SEP—socioeconomic position
SHS—secondhand smoke
WHO—World Health Organization

Ms Lin conceptualized the study, performed the literature review, conducted data analysis, interpreted findings, and drafted the manuscript; Dr Schooling conceptualized the study, designed and directed analytic strategy, interpreted findings, revised drafts of the manuscript, and supervised the study from conception to completion; Dr Lam initiated Hong Kong’s “Children of 1997” birth cohort; Drs Schooling and Leung resurrected the birth cohort; and all authors revised the manuscript critically for important intellectual content and approved the final version to be published.

www.pediatrics.org/cgi/doi/10.1542/peds.2012-2643
doi:10.1542/peds.2012-2643

Accepted for publication Jan 8, 2013

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PEDIATRICS (ISSN Numbers: Print, 0031-4005, Online, 1098-4275).
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FINANCIAL DISCLOSURE: The authors have indicated they have no financial relationships relevant to this article to disclose.

FUNDING: This work is a substudy of the “Children of 1997” birth cohort, which was initially supported by the Health Care and Promotion Fund, Health and Welfare Bureau, Government of the Hong Kong Special Administrative Region (SAR, HCPF grant 216109), and reestablished in 2005 funded by the Health and Health Services Research Fund (HHSRF grant 03040771), Government of the Hong Kong SAR. This substudy was funded by the Health and Health Services Research Fund (HHSRF grant 07080751), the Research Fund for the Control of Infectious Diseases in Hong Kong (RFID grant 04050172), the Government of the Hong Kong Special Administrative Region, and the University Research Committee Strategic Research Theme of Public Health, The University of Hong Kong.

WHAT’S KNOWN ON THIS SUBJECT: Some Western studies show early introduction of solid food is associated with subsequent obesity. However, introduction of solid food and obesity share social patterning, making these observations vulnerable to residual confounding.

WHAT THIS STUDY ADDS: In a non-Western developed setting, there was no clear association of the early introduction of solid food with childhood obesity. Studies in populations with a different confounding structure may be valuable in clarifying and reconciling potentially confounded epidemiologic associations.

BACKGROUND: Some observational studies in Western settings show that early introduction of solid food is associated with subsequent obesity. However, introduction of solid food and obesity share social patterning. We examined the association of the timing of the introduction of solid food with BMI and overweight (including obesity) into adolescence in a developed non-Western setting, in which childhood obesity is less clearly socially patterned.

METHODS: We used generalized estimating equation models to estimate the adjusted associations of the timing of the introduction of solid food (<3, 3–4, 5–6, 7–8, and >8 months) with BMI z score and overweight (including obesity) at different growth phases (infancy, childhood, and puberty) in 7809 children (88% follow-up) from a Chinese birth cohort, “Children of 1997.” We assessed if the associations varied with gender or breastfeeding. We used multiple imputation for missing exposure and confounders.

RESULTS: The introduction of solid food at <3 months of age was associated with lower family socioeconomic position (SEP) but was not clearly associated with BMI or overweight (including obesity) in infancy [mean difference in BMI z score: 0.01; 95% confidence interval (CI): −0.14 to 0.17], childhood (0.14; 95% CI: −0.11 to 0.40), or at puberty (0.22; 95% CI: −0.07 to 0.52), adjusted for SEP and infant and maternal characteristics.

CONCLUSIONS: In a non-Western developed setting, there was no clear association of the early introduction of solid food with childhood obesity. Together with the inconsistent evidence from studies in Western settings, this finding suggests that any observed associations might simply be residual confounding by SEP. PEDIATRICS 2013;131: e1459–e1467
Overweight and obesity are increasingly common. Overweight and obesity start early and tend to track into adulthood with detrimental long-term effects on physical and psychological well-being. The identification of modifiable risk factors for adiposity is urgently needed. Infancy may be a critical period when lifelong regulation of energy balance is programmed, with corresponding implications for the development of adiposity. Infant feeding practices, such as the timing of the introduction of solid food, are a potential risk factor for later adiposity. The American Academy of Pediatrics recommends no introduction of solid food earlier than the age of 4 to 6 months, with exclusive breastfeeding before that period. However, in some European countries, it is not uncommon for solid food to be introduced earlier, ie, by age 3 months (16%) or before the age of 4 months (51%). Some observational studies from Western settings have found early introduction of solid food was associated with weight gain in infancy. However, a small, short-term randomized controlled trial did not replicate this observation. Some Western observational studies found that early introduction of solid food was positively associated with later obesity, ie, in preschool children, especially in formula-fed infants, whereas other observational studies did not find any association until age 14 years. In Western settings, both the timing of the introduction of solid food and obesity are socially patterned, making observations in these settings open to residual confounding.

Given the equivocal evidence to date and the implications for policy, we triangulated the evidence by assessing these associations in a non-Western developed setting with a different social patterning of both the introduction of solid food and of childhood obesity. Moreover, most previous studies have only considered short-term outcomes. However, the main drivers of growth vary with growth phase (infant, childhood, and puberty), so the associations might differ by growth phase, which has not previously been considered. Early infancy is a key period of gender-specific hormonal activation ("mini-puberty") whose long-term consequences are unclear but might be expected to be gender-specific and evident only after the reawakening of this hormonal axis at puberty. Previous studies have not considered the effects of the timing of the introduction of solid food into puberty by gender. In a large, contemporary, population-representative Hong Kong Chinese birth cohort "Children of 1997," there is little social patterning of childhood obesity. We examined the association of the timing of the introduction of solid food with BMI and the presence of overweight (including obesity) into adolescence. To provide ethological insight we also examined the associations by growth phase and whether the associations varied with gender or breastfeeding status.

**METHODS**

**Source of Data**

The Hong Kong Children of 1997 birth cohort is a population-representative Chinese birth cohort (N = 8327) that covered 88.0% of all births from April 1, 1997, to May 31, 1997. The study was initially established to investigate the effect of secondhand smoke (SHS) exposure on infant health. Families were recruited at the first postnatal visit to any of the 49 Maternal and Child Health Centers in Hong Kong, which included socioeconomic position (SEP), birth weight, gestational age, parity, breastfeeding, and SHS exposure. Passive follow-up via record linkage was instituted in 2005 to obtain the following: weight and height from birth to age 5 years from the Maternal and Child Health Centers (96% success); (2) annual measurements of weight and height (age 6–7 years) from the Student Health Service, Department of Health, which provides free annual check-ups for all school students; and (3) death records from the Death Registry. Active follow-up via direct contact was instituted in 2007. A postal survey (survey I), including questions on the timing of the introduction of solid food was sent in July 2008, then re-sent a second and third time as necessary to nonrespondents over the following 9 months. With each wave of data collection, any missing baseline data were updated and any discrepancies between waves reconciled.

As shown in Supplemental Fig 4, of the original 8327 cohort members, as of August 31, 2011, 26 had permanently withdrawn from the study, leaving 8301 in our cohort. In 2008–2009, 7936 cohort members were potentially contactable for survey I, whereas 75 had migrated without trace, 278 were untraceable (probably migrated or dead), and 12 were known to be dead. Of these 7936, 3679 responded to survey I, of whom 97% provided the timing of the introduction of solid food.

Ethical approval was obtained from the University of Hong Kong–Hospital Authority Hong Kong West Cluster, Joint Institutional Review Board, and the Ethics Committee of the Department of...
Health, Government of the Hong Kong Special Administrative Region.

Exposure

The timing of the introduction of solid food was obtained from survey I by asking “When your child was a baby, how old were they when they first ate solid food?” with responses categorized as “before 3 months,” “3–4 months,” “5–6 months,” “7–8 months,” and “after 8 months”. We did not collect information about the type of solid food first introduced. It is common to first introduce rice cereal or wheat cereal in Hong Kong.

Outcomes

Adiposity during the 3 growth phases (ie, infancy (birth to <2 years), childhood (2 to <8 years), and puberty (8 to <14 years)) was proxied by all available routinely scheduled “well-baby/well-child” measurements of BMI at ages 3, 9, and 36 months and annually from ages 6 to 13 years. BMI measurements were considered as age- and gender-specific z scores (SDs) relative to the 2005 WHO growth standards for ages 0 to 5 years and the 2007 WHO growth standards for ages 5 to 19 years. For comparability with other studies we also considered overweight (including obesity) as an outcome in childhood and at puberty defined as a BMI for age and gender corresponding to an adult BMI ≥ 25 using the International Obesity Task Force cutoffs.

Potential Confounders

Infant characteristics such as gender, gestational age, birth weight z score, weight z score change from 0 to 3 months, and breastfeeding were identified as potential confounders because they may influence parents’ perception of their infant’s need for solid food and later growth. Because maternal characteristic and SEP might also be related to parents’ awareness of and compliance with feeding recommendations, we also adjusted for parity, mother’s age at birth, pre- and postnatal SHS exposure, mother’s birthplace, and family SEP (ie, highest parental education, the interaction of mother’s birthplace and highest parental education, parental occupation, household income per head at birth) as categorized in Table 1.

Missing Data

Among children with BMI z scores, 56.6% had missing data for the timing of the introduction of solid food. More than 90% had data on infant and maternal characteristics and information on family SEP. Multiple imputation is usually less biased than an available case analysis, because more assumptions are required for the validity of an available case analysis than for multiple imputation. We used multiple imputation to predict missing exposure information and confounders on the basis of a flexible additive regression model with predictive mean matching, incorporating data on the outcomes, exposure, confounders, and factors associated with “missingness” of the exposure or potentially associated with the timing of the introduction of solid food (mode of delivery, housing type at birth). We imputed missing values 50 times and verified that the distribution of the imputed data were similar to that of the observed data. No obvious problem with the imputation process was found. We analyzed the 50 complete data sets separately and summarized the results into single estimated β-coefficients (representing the mean difference in BMI z score) or odds ratios with confidence intervals adjusted for missing data uncertainty. As a sensitivity analysis we also performed an available case analysis, ie, pairwise deletion of observations with missing data. Statistical analyses were performed by using R, version 2.15.0 (R Development Core Team, Vienna, Austria).

Statistical Analysis

Generalized estimating equation models, which take into account correlations between measurements on the same child, were used to examine the adjusted associations of the timing of the introduction of solid food with overall BMI z score at each growth phase and with overweight (including obesity) in childhood and at puberty. We assessed whether the associations varied with gender or breastfeeding from the heterogeneity across strata and the significance of interaction terms, including interactions with other relevant confounders.

RESULTS

Of the remaining 8301 cohort members, 492 with unknown gestational age or premature birth (<37 weeks’ gestation) were excluded, because premature birth may result in different growth patterns, leaving 7809 term births included in the analysis. Of the 3571 children who had information on the timing of the introduction of solid food, 68 (2.0%) were introduced to solid food at <3 months, 750 (21.0%) at 3 to 4 months, 1580 (44.2%) at 5 to 6 months, 638 (17.8%) at 7 to 8 months, and 535 (15.0%) at >8 months of age (Fig 1). The percentage of overweight (including obesity) in childhood and at puberty are shown in Fig 2. The percentage of overweight (including obesity) in childhood and at puberty are shown in Fig 2. The percentage of overweight (including obesity) in childhood and at puberty are shown in Fig 2.
lower family SEP (parental education, occupation, household income at birth).

There was no indication that the association of the timing of the introduction of solid food with BMI z score or with overweight (including obesity) at any growth phase varied with gender (all \( P > .6 \)). For completeness, we present analysis adjusted for and stratified by gender. Estimates adjusted only for gender (data not shown) were similar to estimates adjusted for all potential confounders. Table 2 shows that the timing of the introduction of solid food was not associated with BMI z score or overweight (including obesity) at any growth phase, adjusted for gender, gestational age, birth weight z score, weight z score change from 0 to 3 months, breastfeeding, parity, mother’s age at birth, SHS exposure, mother’s birthplace, and family SEP. The timing of the introduction of solid food also had no clear association with BMI z score in gender-stratified analysis.
In the available case analysis, the introduction of solid food at 3 months was associated with higher BMI z-score in childhood and at puberty, particularly among boys (Appendix 1). Late introduction of solid food at ages 7 to 8 months was also associated with a higher BMI z-score in childhood and at puberty among boys. The timing of the introduction of solid food was not associated with overweight (including obesity).

**DISCUSSION**

In this large, population-representative birth cohort of Chinese children from a developed non-Western setting, the timing of the introduction of solid food was not clearly associated with BMI z score or overweight (including obesity) in infancy, childhood, or at puberty. We also found no evidence that the associations varied with gender or breastfeeding status.

In our population-representative birth cohort, height and weight were regularly measured by trained nurses, which enabled the consideration of short- and medium-term effects on adiposity. Nevertheless, our study has several limitations. First, information on the timing of the introduction of solid food was based on parental recall and could be subject to recall error. However, the low birth rate and small families in Hong Kong make the information more notable and easier to recall. Misclassification usually biases associations toward the null, for which our large sample compensates. Second, we imputed ~50% missing data for the timing of the introduction of solid food, because an available case analysis might be open to selection bias. Usually, estimates are less biased when using multiple imputation than when using an available case analysis.43 In the available case analysis, the U-shaped relation (Appendix 2) between the timing of solid food introduction and BMI z score in childhood and at puberty might suggest confounding or selection bias. Thus, we put more emphasis on the estimates from multiple imputation.

Our finding of no association of the timing of the introduction of solid food with BMI in infancy is consistent with a randomized trial9 and a reanalysis of combined data from 5 randomized trials.44 Large infant size has been identified as a reason for early introduction of solid food,16 making studies that did not adjust for size before the introduction of solid food6–8 open to reverse causality.

Our findings are also consistent with most previous observational studies,13–15,34,45,46 but not all.10–12 For example, a recent study from the United States found that the introduction of solid food before age 4 months was associated with a 6.3 odds ratio of obesity at age 3 years in formula-fed infants, although the authors did not explicitly test for differences by breastfeeding status. In addition, 46% of the participants, who tended to have lower SEP, were excluded due to loss to follow-up, making the results subject to selection bias.12 In Western settings, both the timing of the introduction of solid food and childhood obesity are associated with lower SEP16,17 and maternal smoking,47,48 making the association open to residual confounding.
In contrast, SEP is not clearly associated with childhood adiposity in our cohort.\textsuperscript{21} Our findings provided no strong evidence consistent with the hypothesis that exposures in infancy program metabolism and hence adiposity for life. However, we cannot rule out the possibility that, initially, solid food does not represent a qualitatively different exposure from continued breast- or formula-feeding, because it makes little difference to the overall nutrient content of the infant’s diet. Alternatively, the timing of the introduction of solid food may only have effects that become evident in late adolescence or adulthood. We cannot rule out the possibility that early introduction of solid food has a specific effect among boys that only becomes evident at puberty, given that infant diet may upregulate the gonadotrophic axis during “mini-puberty,” when boys have adolescent levels of testosterone and its metabolites.\textsuperscript{20} However, this possibility would need to be reassessed in a large sample with longer follow-up. From a public health perspective, the timing of the introduction of solid food does not appear to be a major contributor to the current burgeoning epidemic of obesity.

**CONCLUSIONS**

In this population-representative birth cohort from an understudied non-Western developed setting with little socioeconomic patterning of BMI, the timing of the introduction of solid food had little discernible effect on BMI or overweight (including obesity) into adolescence. Our findings should not detract from recommendations of no
introduction of solid food before age 4 months given other potential benefits. However, combating the epidemic of childhood obesity requires broader and multisectoral approaches.

**ACKNOWLEDGMENTS**

We thank colleagues at the Student Health Service and Family Health Service of the Department of Health for their assistance and collaboration. We also thank Dr Connie Hui for her assistance with the record linkage and the late Dr Connie O for coordinating the project and all the fieldwork for the initial study in 1997–1998.

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APPENDIX 1  Adjusted Association of the Timing of the Introduction of Solid Food With BMI $z$ Score or Overweight (Including Obesity) in “Children of 1997” Birth Cohort, Hong Kong, China (Available Case Analysis)

<table>
<thead>
<tr>
<th>Growth Phase and Timing of Solid Food Introduction</th>
<th>BMI $z$ Score</th>
<th>Overweight/Obesity: All</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All</td>
<td>Boys</td>
</tr>
<tr>
<td></td>
<td>$\beta^a$</td>
<td>95% CI</td>
</tr>
<tr>
<td><strong>Infancy (n = 2769)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;3 months</td>
<td>0.03</td>
<td>-0.14 to 0.20</td>
</tr>
<tr>
<td>3–4 months</td>
<td>-0.07*</td>
<td>-0.13 to -0.01*</td>
</tr>
<tr>
<td>5–6 months</td>
<td>Reference</td>
<td>Reference</td>
</tr>
<tr>
<td>7–8 months</td>
<td>-0.001</td>
<td>-0.06 to 0.08</td>
</tr>
<tr>
<td>&gt;8 months</td>
<td>0.04</td>
<td>-0.03 to 0.10</td>
</tr>
<tr>
<td><strong>Childhood (n = 2995)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;3 months</td>
<td>0.35*</td>
<td>0.12 to 0.57*</td>
</tr>
<tr>
<td>3–4 months</td>
<td>0.004</td>
<td>-0.09 to 0.09</td>
</tr>
<tr>
<td>5–6 months</td>
<td>Reference</td>
<td>Reference</td>
</tr>
<tr>
<td>7–8 months</td>
<td>0.08</td>
<td>-0.02 to 0.18</td>
</tr>
<tr>
<td>&gt;8 months</td>
<td>0.11*</td>
<td>0.003 to 0.22*</td>
</tr>
<tr>
<td><strong>Puberty (n = 3052)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;3 months</td>
<td>0.48*</td>
<td>0.23 to 0.76*</td>
</tr>
<tr>
<td>3–4 months</td>
<td>0.04</td>
<td>-0.07 to 0.15</td>
</tr>
<tr>
<td>5–6 months</td>
<td>Reference</td>
<td>Reference</td>
</tr>
<tr>
<td>7–8 months</td>
<td>0.10</td>
<td>-0.03 to 0.22</td>
</tr>
<tr>
<td>&gt;8 months</td>
<td>0.06</td>
<td>-0.06 to 0.19</td>
</tr>
</tbody>
</table>

*All* adjusted for gender. All models adjusted for gestational age, birth weight $z$ score, weight $z$ score change from 0 to 3 months, and breastfeeding (additionally adjusted for parity, mother's age at birth, SHS exposure, the interaction of mother's birthplace and parental education, occupation, and income did not change the results, but sample size decreased). *P < .05. CI, confidence interval; OR, odds ratio; —, Not available.

* $\beta$: Mean difference in $z$ score; a 1-unit change in BMI $z$ score is $\sim 1.6$ and 2.9 at the ages of 6.0 and 13.0 years, respectively.

APPENDIX 2

The adjusted association of the timing of the introduction of solid food with BMI $z$ score (available case analysis), “Children Of 1997” Birth Cohort, Hong Kong, China.
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Pediatrics 2013;131:e1459; originally published online April 8, 2013;
DOI: 10.1542/peds.2012-2643

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