The Impact of Timing of Introduction of Solids on Infant Body Mass Index

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Objectives To evaluate the associations between breastfeeding duration, age at solids introduction, and their interaction in relation to infant (age 9-15 months) above normal body mass index (BMI).

Study design Cross-sectional, population-based study with 3153 infants from Melbourne (2007-2011). Above normal BMI (*z* score > 2, equivalent to >97.7th percentile) defined using the World Health Organization standard.

Results Both longer duration of full and any (full or partial) breastfeeding were associated with lower odds of above normal BMI (eg, aOR, 0.37 [95% CI, 0.22-0.60] for full breastfeeding 4-5 months versus 0-1 months). Compared with introduction of solids at 5-6 months, both early and delayed introduction were associated with increased odds of above normal BMI (aOR for 4 months, 1.75 [95% CI, 1.10-2.80] and for ≥7 months, 2.64 [95% CI, 1.26-5.54] versus 6 months). Such associations differ by breastfeeding status at 4 months (interaction $P = .08$). Early introduction of solids was associated with increased odds of above normal BMI in both infants fully or partially breastfed for ≥4 months (aOR, 3.66; 95% CI, 1.41-9.51) and those breastfed for <4 months (aOR, 3.11; 95% CI, 1.39-6.97). Introduction of solids at ≥7 months was associated with increased odds of above normal BMI (aOR, 5.79; 95% CI, 1.91-17.49) among infants breastfed for <4 months only.

Conclusion Introduction of solids at 5-6 months, compared with either early or delayed introduction, is associated with decreased odds of above normal BMI at 1 year of age, regardless of infants' breastfeeding status at 4 months. These results may have implications for public health guidelines with regard to recommendations about the optimal timing of the introduction of solid foods in infancy. *(J Pediatr 2016;179:104-10).*

Childhood obesity is a serious public health problem and its prevalence has increased alarmingly over the past 3 decades.[1] Infancy is a critical window for obesity prevention as dietary, hormonal, and other stimuli can induce lifelong, often irreversible derangements in adiposity and metabolism through early life programming.[2] Furthermore, evidence suggests that infant overweight tracks into childhood,[3,4] and childhood obesity persists into adulthood,[5] leading to obesity-related morbidity and mortality. Infant feeding practices are modifiable and have been suggested to contribute to childhood obesity.[6,7] A better understanding of these factors is thus pivotal for the development of optimal obesity prevention strategies.[8]

Meta-analyses have concluded that breastfeeding, compared with formula feeding, is associated with a 7%-33% reduction in the risk of childhood obesity or overweight,[6,9,10] and there is a dose–response effect with longer duration of breastfeeding.[11] Although a randomized controlled trial of a breastfeeding promotion intervention did not prevent childhood obesity,[12,13] this may be due to that there were insufficient differences in breastfeeding rates between the intervention and control groups to demonstrate an effect, because initial breastfeeding was a trial entry criterion.[14]

The timing of the introduction of solid food into an infant's diet may also play a role in obesity prevention.[2] The World Health Organization recommends that infants be breastfed exclusively for the first 6 months of life, after which solids introduction should commence.[15] In contrast, allergy organizations suggest solids be introduced at 4-6 months to prevent allergy.[16-18] A recent systematic review concluded that there is some evidence that early introduction of solids (≤4 vs >4 months) may increase the risk of childhood overweight.[7] Only 3 studies included in this review collected data after the publication of current World Health Organization guidelines, so the review included few children whose introduction

BMI	Body mass index
SES	Socioeconomic status

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Funded by the Australian National Health and Medical Research Council (NHMRC), Ilhan Food Allergy Foundation, Anaphylaxi-Stop, and ANZ Trustees Medical Research & Technology, Victoria. C.S. and J.K. are supported by the NHMRC Early Career Public Health Fellowships. K.A., A-.L.P., M.W., and A.L. are supported by the NHMRC Research Fellowships. Murdoch Childrens Research Institute is supported by the Victorian Government's Operational Infrastructure Support Program. The authors declare no conflicts of interest.

http://dx.doi.org10.1016/j.jpeds.2016.08.064

to solids were delayed past 6 months. Furthermore, few studies have considered milk and solids feeding concurrently, even though formula-fed infants are generally introduced to solids earlier than breastfed infants.[19] In addition, one study found that an association between early introduction of solids and obesity is only evident among infants breastfed for <4 months, suggesting that breastfeeding status may modify the effect of age at introduction of solid foods on obesity risk.[20] More studies examining the full range of the age at introduction of solids (≤4 and >6 months) and its interplay with breast and formula feeding are clearly needed, particularly with regard to their impact on childhood obesity.[7,20]

In this study, we investigated the associations of breastfeeding duration, age at solids introduction, and their potential interaction with above normal body mass index (BMI) among 1-year-old infants participating in a large, population-based study.

Methods

The HealthNuts study is a cross-sectional population-based study that recruited 5276 infants at 1 year of age from council-run immunization sessions in metropolitan Melbourne, Australia, between September 2007 and August 2011. The study design and sample recruitment have been described previously.[21] In this study, we included 3153 participants with feeding information, weight and length measurements at age 9 to 15 months (1 year) (**Figure 1**; available at www.jpeds.com). Approval was obtained from the Victorian State Government Office for Children, the Department of Human Services, and the Royal Children's Hospital Human Research Ethics Committee. Parents or guardians provided informed consent.

Outcome Measure

The closest measurements of weight and length ± 3 months for 1 year of age were included and the date of measurements were provided by participant's guardian, usually the mother, who were carrying the participant's Victorian Child Health Record at the time of completing the questionnaire. BMI was calculated as weight divided by the square of supine length (kg/m^2).

We generated age- and sex-specific BMI *z* scores using the World Health Organization Child Growth standard classification, which describes the growth of healthy infants under optimal conditions.[22] Infant above normal BMI was defined as BMI *z* score of >2, which included infants classified as "overweight" (equivalent to >97.7th percentile) and "obese" (*z* score > 3, equivalent to >99.8th percentile). Normal (reference group) was defined as BMI *z* score ≤ 2 (≤97.7th percentile) and included those classified as "at risk of overweight," "normal," "wasted," and "severely wasted."

Infant Feeding Exposure Variables

We extracted information from the self-administered questionnaire on age breastfeeding was started (include colostrum in the first few days after birth), still breastfed (yes, no), age at stopping breastfeeding, age infant formula bottle feeding was started, age infant formula bottle feeding was stopped, age solid foods were first introduced, and age of change from formula to cow's milk. These questions were adapted from the Tasmania Infant Health Survey. In that cohort study, we found that health outcomes (eg, upper respiratory tract infection) related to breastfeeding were consistent with findings from prior studies.[23]

Using the international definition of the Interagency Group for Action on Breastfeeding, we defined full breastfeeding as breastfeeding with no other milk or solid food.[24] The duration of full breastfeeding, therefore, ended when either solid foods, or cow's milk, or formula feeding was initiated (whichever occurred first). We defined any breastfeeding as full or partial breastfeeding. Hence, the duration of any breastfeeding is the duration for which an infant is breastfed, regardless of any supplementary feeding of formula or solid food.

Duration of any (full or partial) breastfeeding and full breastfeeding were each divided into 4 categories (0-2, 3-5, 6-11, ≥12 months of age; 0-1, 2-3, 4-5, ≥6 months, respectively). Age at introduction of solids was divided into 5 categories (< 4, 4, 5, 6, and ≥7 months of age). These categorizations were based on previous studies and current infant feeding recommendations.[7,11,15,18] The majority of infants commenced solids at 5 and 6 months of age; therefore, both groups were used as the reference. We presented results mainly using solids introduction at 6 months as the reference.

Covariates

Information on the mother's country of birth (Asia, not Asia), maternal age at childbirth, maternal cigarette smoking during pregnancy (yes, no), gestational age, mode of delivery (vaginal, caesarean), birth weight, having any siblings (yes, no), and twin birth (yes, no) were derived from the questionnaire. We used the Australian census-based Socioeconomic Index for Areas disadvantage score to assess socioeconomic status (SES; 5 categories).[25]

Statistical Analyses

We used the Student *t* test and χ^2 test to compare characteristics between infants included and excluded from the study, and to compare included infants and their mothers according to infant BMI status. Using logistic regression models, we examined the association between feeding and infant above normal BMI. A range of potential confounders, including SES quintile, mother's country of birth, maternal cigarette smoking during pregnancy, any siblings, birth weight, and prematurity (gestation < 36 weeks) were selected a priori to be included in the multivariable model based on previous findings.[26-28] We also considered maternal age at childbirth, twin birth, and delivery mode in the model-building process, using a 10% change-in-estimate criterion for inclusion.

To test for interaction effects, we generated a binary variable based on evidence of interaction detected in previous studies: any (full or partial) breastfeeding for ≥4 months versus any breastfeeding for <4 months.[19,20] We used the likelihood ratio test to determine if there was an interaction between breastfeeding status and age at introduction of solid foods in relation to BMI. Because a previous report from the HealthNuts