Original Article
PEDIATRIC OBESITY

Obesity

Age at Introduction of Solid Food and Obesity Throughout the Life Course

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Objective: This study aimed to examine the association between age at solid food (SF) introduction and obesity throughout the life course.

Methods: Among 31,816 mother–nurse daughter dyads in the Nurses' Mothers' Cohort Study and the Nurses' Health Study II, information was collected on age at SF introduction, body somatotype at ages 5 and 10, and Body Mass Index at age 18 and in adulthood. Odds ratios (ORs) and 95% confidence intervals (95% CIs) for obesity throughout life were estimated using logistic regression models with adjustment for parental and nurse daughter covariates.

Results: Nurse daughters introduced to SF at ≥ 9 months versus 6 to 9 months had marginally higher age-adjusted (OR: 1.21; 95% CI: 1.01, 1.47) and covariate-adjusted (OR: 1.22; 95% CI: 1.01, 1.47) odds of obesity at age 5. Age at SF introduction was not related to obesity at ages 10 and 18 or in adulthood.

Conclusions: Late age at SF introduction was marginally associated with obesity at age 5, but this association did not persist throughout the life course.

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Introduction

Obesity, a global epidemic and leading public health challenge, affects 9.4% of children aged 2 to 5 years, 17.4% of children aged 6 to 11 years, 20.6% of adolescents aged 12 to 19 years, and 37.7% of adults in the United States (1,2). Obesity may track throughout the life course (3) and is associated with a myriad of conditions, including cardiovascular disease, type 2 diabetes, metabolic syndrome, joint problems, reduced life expectancy, and poorer psychological state (4). Obesity is a multifaceted disorder with an interplay among genetic, dietary, and hormonal factors contributing to its development early in life (5). As such, exposures during infancy may program metabolic health later in life, and prevention efforts could begin early.

Drawing on the hypothesis that early life exposures may determine later health and disease, age at introduction of solid food (SF) may be an early modifiable risk factor for obesity. The American Academy of Pediatrics currently recommends exclusive breastfeeding for about 6 months, followed by complementary feeding with continued breastfeeding until 1 year and beyond as mutually desired by the mother and infant (6). However, approximately 40% of mothers in the United States do not comply with these recommendations and introduce SF to their infants earlier than 4 months of age, whereas 7% introduce SF at or after 6 months of age (7). Therefore, it is important to determine whether age at SF introduction is associated with obesity across the life course in a cohort of mother–offspring dyads.

Studies evaluating the association between age at SF introduction and obesity have inconsistent results. Research has shown higher odds of increased weight for age in infancy (8) and childhood overweight and obesity (9,10) with earlier SF introduction, whereas other studies have demonstrated null associations in childhood and adolescence (11,12). Results from one study indicated the association between early SF introduction and childhood obesity existed only among formula-fed infants (13). Other research has suggested that delayed introduction of SF beyond 6 months may in fact increase the risk of childhood obesity (14,15). Several of these studies have been limited by their relatively small sample sizes and an inability to adjust for multiple confounding

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variables or track results into adolescence or adulthood. Therefore, our aim was to evaluate the association between age at introduction of SF and obesity at different stages of the life course using a large ambidirectional cohort study with exposure and outcome data from two independent sources and adjustment for potential confounders.

Methods

Study population

The Nurses' Health Study (NHS) II (https://www.nurseshealthstudy.org/) is a prospective cohort study of 116,430 female registered nurses aged 25 to 42 years in 1989 (baseline) and followed biennially. At baseline, nurses self-reported their medical and reproductive history and health behaviors. Updates on lifestyle, diet, and clinical data were provided every 2 years with a 90% response rate for each 2-year interval. The Nurses' Mothers' Cohort Study includes the mothers of the nurses in the NHS I and NHS II who retrospectively reported early life exposures of their nurse daughter. In 2000, a total of 52,155 questionnaires were mailed to mothers of nurses who were willing to participate along with a prepaid return envelope. Approximately 77% of the mailed questionnaires were completed and returned ($n=39{,}904$) to the Channing Laboratory, Brigham and Women's Hospital, Boston, Massachusetts (16). Maternal and nurse daughter data were linked to obtain exposure and outcomes for the nurse, forming an ambidirectional cohort study design. Analyses were restricted to participants in the NHS II whose mothers completed and returned the Nurses' Mothers' Cohort Study questionnaire ($n=35{,}830$). Nurses who were adopted or had an unknown adoption status ($n=1{,}895$); twins ($n=561$); and missing exposure ($n=562$) and outcome ($n=996$) data were excluded from the analyses, yielding a final sample size of 31,816 mother–nurse daughter dyads. The study protocol was approved by the institutional review boards of the National Cancer Institute, Bethesda, Maryland, and the Brigham and Women's Hospital and Harvard School of Public Health, Boston, Massachusetts.

Age at SF introduction

The age at which SF was introduced to the nurse daughters was ascertained via the Nurses' Mothers' Cohort Study questionnaire. Mothers were asked to recall the following: "At what age did you start feeding this daughter SF?" Response categories were "before 3 months of age," "3 to 6 months of age," "6 to 9 months of age," or "9 months of age or older." Age at SF introduction at 6 to 9 months was chosen as the referent category based on current recommendations for age at SF introduction (17,18).

Ascertainment of obesity

To assess childhood obesity, nurses were asked to recall their body somatotype at different stages of their life (ages 5 and 10) on the 1989 baseline questionnaire using a nine-level pictogram with body somatotypes/shapes ranging from 1 being the leanest to 9 being the most overweight (19). Given the limited number of nurses reporting somatotypes on the higher end and in accordance with prior research utilizing this scale, a somatotype of 5 or greater was defined as having "above healthy weight" or obesity (20,21).

Evidence supporting use of the same somatotypes as indicators of obesity was demonstrated in earlier research. In follow-up of the longitudinal Third Harvard Growth Study, the correlation among females aged 71 to 76 years who recalled somatotype at age 5 and their body mass index (BMI) based on weight and height directly measured at age 5 was 0.60 (22). For age 10, the correlation between the somatotypes and measured BMI was 0.65. In a study by Must et al., the Pearson correlation coefficient between BMI percentile at menarche and recalled body somatotype at menarche was 0.61 (23). Predictive validity was demonstrated by the positive association between increasing childhood somatotype and type 2 diabetes among nurses (21).

Weight at age 18 and weight and height in 1989 (ages 25 to 42 years/adulthood) were self-reported on the NHS II 1989 baseline questionnaire. Weight at age 18 and height in 1989 were used to assess BMI at age 18; weight and height in 1989 were used to assess BMI in adulthood (24). The National Heart, Lung, and Blood Institute classification of BMI was followed with underweight (<18.5 kg/m^2), normal weight (18.5 to 24.9 kg/m^2), overweight (25.0 to 29.9 kg/m^2), and obesity (≥ 30.0 kg/m^2) (25). In a study of 140 NHS I participants, the Pearson correlation coefficient between self-reported weight and the average weight measured by two trained technicians following adjustment for age and within-person variability was 0.97 (26). Moreover, records of physical examinations conducted on 118 NHS II participants upon entry to college or nursing school were compared with self-reported weight at age 18 and current height. The correlation coefficients between measured weight and height from records and recalled weight and reported current height were 0.87 and 0.94, respectively (27). Therefore, there appears to be high validity of recalled weight and self-reported height in this cohort.

Statistical analyses

The sample was characterized using frequencies, percentages, measures of central tendency (mean ± standard deviation), and graphical analyses, and data are presented by somatotype at age 5. χ^2 tests were computed to evaluate differences in participant characteristics between somatotypes. Trends in age at SF introduction were assessed via cross tabulations with covariates. Binomial logistic regression models were applied to estimate the odds ratios (ORs) and 95% confidence intervals (95% CIs) of obesity at ages 5 and 10 (somatotype ≥ 5 compared with < 5) and at age 18 and in adulthood (BMI ≥ 30 compared with < 30) by age at SF introduction adjusted for age of nurses at baseline. This was done to account for potential recall bias due to the age range of the nurses at the time of questionnaire return. Models at age 5 were then adjusted for the following parental and nurse daughter potential predictors of obesity (chosen *a priori*): maternal and paternal education (<12, 12, 13 to 15, ≥ 16 years), maternal prepregnancy BMI and paternal BMI at nurse's birth (12 to < 18.5, 18.5 to < 25, 25 to < 30, ≥ 30), maternal gestational weight gain (< 10, 10 to 14, 15 to 19, 20 to 29, 30 to 40, > 40 lb), maternal smoking during pregnancy (nonsmoker, quit during pregnancy, smoked 1 to 14 cigarettes per day, smoked ≥ 15 cigarettes per day), maternal activity during pregnancy (highly active, somewhat active, mostly inactive/inactive), maternal gestational diabetes (yes, no), family history of diabetes (yes, no), maternal age at nurse's birth (< 20, 20 to 24, 25 to 29, 30 to 34, 35 to 39, ≥ 40 years), home ownership at nurse's birth (yes, no), nurse's birth weight (< 5.5, 5.5 to 6.8, 6.9 to 8.7, 8.8 to 9.9, ≥ 10 lb), nurse's gestational age (32 to 36, 37 to 39, 40 to 42, ≥ 43 weeks), nurse's birth cohort (1946 to 1949, 1950 to 1954, 1955 to 1959, 1960 to 1964), nurse's breastfeeding duration (not breastfed or < 1 week, < 3 months, 3 to 5 months, 6 to 8 months, 9 to 11 months, ≥ 12 months), type of SF first introduced to nurses (cereals, fruits, vegetables, and breads/crackers/cookies), nurse's physical activity at ages 3 to 5 years (highly active, active, mostly inactive/inactive), and nurse's daily screen time at ages 3 to 5 years (none, 0.5 to 1, 2, 3, ≥4 hours). At age 10, nurse's physical activity at ages 5 to 10 years (highly active, active, mostly inactive/inactive) and nurse's daily screen time at ages 5 to 10 years (none, 0.5 to 1, 2, 3, ≥ 4 hours) were also added as potential covariates. At age 18, age 5 and 10 covariates and nurse's age at menarche (<12, 12, 13, 14, > 14 years), activity during high school (never, 1 to 3, 4 to 6, 7 to 9, 10 to 12 mo/y), and cigarettes smoked at < 15 and 15 to 19 years (never, 1 to 14 cigarettes per day, ≥ 15 cigarettes per day) were added as potential confounders. In adulthood, nurse's age at menarche, smoking status (never, past, 1 to 14 cigarettes per day, ≥ 15 cigarettes per day), and activity level during the past year in 1989 (<3, 3 to 8, 9 to 17, 18 to 26, 27 to 41 and ≥ 42 metabolic equivalents per week) were included as potential covariates in addition to age 5 and 10 covariates. Missing indicators were used for participants with missing covariate information.

Secondary analyses of obesity at age 18 and in adulthood were conducted using BMI as a continuous variable in a linear regression model adjusted for the aforementioned covariates. Interactions between age at SF introduction and birth year, breastfeeding duration, infant feeding status (breastfed to 9 months vs. never breastfed), and content of the bottle (canned evaporated milk, soy-based infant formula, or commercial infant formula) in relation to obesity at ages 5, 10, and 18 in adulthood were also tested by entering both variables and an interaction term between them in logistic regression models. Last, binomial logistic regression models were considered by infant feeding status to assess differences in the association between age at SF introduction and obesity among nurses breastfed to 9 months versus those not breastfed (i.e., formula fed). All analyses were completed using SAS 9.4 (SAS Institute Inc., Cary, North Carolina).

Results

Parental and nurse daughter characteristics (n = 31,816) are presented in Table 1 by somatotype at age 5; 22%, 33%, 25%, 13%, and 6% of nurses classified themselves into somatotypes 1 through ≥ 5 at age 5, respectively. The highest percentage of mothers had 12 years of education, a prepregnancy BMI between 18.5 and < 25, and weight gain of 20 to 29 lb during pregnancy, and most were nonsmokers and were active during pregnancy. The average maternal age at nurses' birth was 26.3 ± 4.9 years. Likewise, the highest percentage of nurses' fathers had a normal BMI and had 12 years of education at nurses' birth. Fifty-two percent of nurses' parents did not own homes at nurses' birth. The average birth weight for nurses was 6.8 ± 1.1 lb with a mean gestational age of 39.8 ± 2.6 weeks. Roughly 34% of nurses were born from 1955 to 1959, 41% were breastfed, 92% had cereal as a first food, 64% were active at ages 3 to 5 years, and 70% had 0.5 to 2 hours of screen time daily at ages 3 to 5 years. Maternal age and education at nurses' birth, prepregnancy BMI, gestational weight gain, and activity during pregnancy; family history of diabetes; paternal education and BMI at nurses' birth; nurses' birth weight, gestational age, birth year, breastfeeding duration, type of SF first consumed, and physical activity and screen time at ages 3 to 5 years differed significantly by nurses' somatotype at age 5 (P < 0.05).

The distribution of age at SF introduction was similar across somatotypes and BMI categories. Approximately 29% of mothers reported introducing SF at < 3 months of age, 45% at 3 to 6 months, 19% at 6 to 9 months, and 7% at ≥ 9 months across somatotypes 1 to ≥ 5 at age 5 (Figure 1). A decreasing trend in late age at SF introduction (≥ 9 months) was seen across increasing categories of gestational age, birth year, and maternal education at nurses' birth; a higher percentage of nurses born prematurely (32 to < 36 weeks), born between 1946 and 1949, and with mothers who had < 12 years education were introduced to SF later. These trends did not appear for other covariates (data not shown).

In the age-adjusted binomial logistic regression analysis, nurse daughters who were fed SF at ≥ 9 months had higher odds of somatotype ≥ 5 at age 5 (OR: 1.21; 95% CI: 1.01, 1.47), compared with those introduced to SF at 6 to 9 months (Table 2). This association remained significant after adjustment for parental and nurse daughter characteristics (OR: 1.22; 95% CI: 1.01, 1.47). In the covariate-adjusted model, higher maternal prepregnancy BMI and paternal BMI at nurses' birth (≥25 kg/m^2), maternal gestational weight gain of 10 to 14 and 30 to 40 lb, maternal smoking during pregnancy (1 to 15+ cigarettes per day); nurses' birth weight (≥ 6.9 lb), inactivity between ages 3 to 5 years, and daily screen time between ages 3 to 5 years (≥ 3 h/d) were all independently associated with higher odds of obesity at age 5 (Supporting Information Table S1).

At ages 10 and 18 in adulthood, no significant associations between age at SF introduction and the odds of obesity were seen in age-adjusted and covariate-adjusted models (Table 2). Similar null results were demonstrated in the covariate-adjusted model when BMI was considered as a continuous variable at age 18. SF introduction at ≥ 9 months versus 6 to 9 months was associated with a higher BMI in adulthood (β = 0.23; 95% CI: 0.02, 0.45; P for trend = 0.17) (data not shown).

There was no effect of an interaction between age at SF introduction and birth year, breastfeeding duration, infant feeding status, or content of the bottle on the odds of obesity across all age groups. Further, when the associations between age at SF introduction and obesity were analyzed in separate models for nurses breastfed up to 9 months and then for nurses who were never breastfed, associations were null except for higher odds of obesity at age 5 (OR: 1.44; 95% CI: 1.04, 1.99) and in adulthood (OR: 1.40; 95% CI: 1.06, 1.83) with introduction of SF at ≥ 9 months versus 6 to 9 months among breastfed nurses after adjustment for parental and nurse covariates (data not shown).

Discussion

In this large cohort of mother–nurse daughter dyads from the Nurse's Mothers Cohort study linked to the NHS II, we report that late age at SF introduction was marginally associated with obesity at age 5, but this effect did not persist throughout the life course. These results, taken together with our previous work demonstrating a borderline association between exclusive breastfeeding for > 6 months and reduced risk of somatotype ≥ 5 at age 5 but no association later in life (16), suggest that infant feeding practices were not strongly associated with obesity risk during the nurses' birth cohorts and their life course.

Although several studies between 1990 and 2014 have reported an effect of early age at SF introduction on higher odds of obesity at 10 years (9), BMI at 2 years (10), BMI z scores at 3 years (13), weight for age at 1 year (8), and infant weight gain from birth to 1 year (28), two systematic reviews have indicated no clear association between age at SF introduction and obesity, suggesting that further research is needed to inform guidelines on age at SF introduction (29,30). Of note, several studies in the reviews compared early introduction (< 3 months) with introduction at > 3 to 5 months, excluding children who were introduced to SF even later and who may be experiencing different outcomes accordingly. Only one study utilizing the Copenhagen Perinatal Cohort assessed the long-term effect of age at SF introduction on overweight at age 42,

TABLE 1 Demographic and lifestyle characteristics of nurse daughters and their parents by daughter's somatotype at age 5 (*n* = 31,816)

	Somatotype 1 (*n* = 7,061), %	Somatotype 2 (*n* = 10,475), %	Somatotype 3 (*n* = 8,073), %	Somatotype 4 (*n* = 4,187), %	Somatotype ≥ 5 (*n* = 2,020), %
Maternal education at nurse's birth (y)*					
< 12	16.2	12.5	12.0	13.4	14.8
12	53.2	50.1	48.2	49.3	50.0
13 to 15	22.4	26.6	27.7	26.3	25.8
≥ 16	8.2	10.9	12.2	11.0	9.5
Maternal prepregnancy BMI (kg/m^2)*					
12 to < 18.5	13.4	11.1	8.4	6.7	6.4
18.5 to < 25	81.3	83.2	84.5	84.2	82.3
25 to < 30	4.6	4.9	6.3	8.0	9.7
≥ 30	0.8	0.7	0.8	1.1	1.6
Maternal gestational weight gain (lb)*					
< 10	3.7	3.8	3.2	3.4	3.8
10 to 14	12.1	11.0	10.9	11.0	11.8
15 to 19	21.5	21.5	21.1	19.2	18.3
20 to 29	41.9	42.8	42.6	41.6	40.0
30 to 40	15.8	16.3	17.2	18.5	20.1
> 40	5.1	4.6	5.1	6.3	6.2
Maternal smoking during pregnancy[a]					
Nonsmoker	75.6	76.0	75.5	74.2	72.5
Quit during pregnancy	4.2	3.9	4.1	4.0	4.3
1 to 14 cigarettes per day	12.5	12.0	12.7	13.1	14.4
≥ 15 cigarettes per day	7.8	8.2	7.7	8.6	8.9
Maternal activity during pregnancy*					
Highly active	27.0	27.1	27.4	25.7	23.9
Active	64.5	63.9	64.3	66.2	67.0
Mostly inactive/inactive	8.5	9.1	8.3	8.1	9.1
Maternal gestational diabetes (yes)	0.5	0.3	0.5	0.6	0.4
Family history of diabetes (yes)*	25.0	22.5	23.5	25.0	26.0
Maternal age at nurse's birth (y)*					
< 20	5.5	5.1	4.9	4.8	4.9
20 to 24	37.5	35.5	35.3	33.8	34.0
25 to 29	34.8	36.0	35.9	36.3	35.7
30 to 34	15.5	16.4	17.2	18.2	17.8
35 to 39	5.6	6.0	5.6	5.9	6.2
≥ 40	1.2	1.0	1.0	1.1	1.4
Paternal education at nurse's birth (y)*					
< 12	21.3	17.0	16.5	19.4	22.4
12	40.2	38.3	38.1	36.7	40.6
13 to 15	19.9	20.3	20.3	20.6	17.7
≥ 16	18.7	24.4	25.1	23.3	19.4
Paternal BMI at nurse's birth (kg/m^2)					
12 to < 18.5	2.3	1.6	1.3	1.3	1.3
18.5 to < 25	76.9	75.6	72.1	70.4	66.8
25 to < 30	19.3	21.0	24.4	26.1	29.1
≥ 30	1.6	1.8	2.2	2.3	2.8
Home ownership at nurse's birth (yes)	46.2	48.5	47.8	47.8	48.0

	Somatotype 1 (*n* = 7,061), %	Somatotype 2 (*n* = 10,475), %	Somatotype 3 (*n* = 8,073), %	Somatotype 4 (*n* = 4,187), %	Somatotype ≥ 5 (*n* = 2,020), %
Birth weight (lb)*					
< 5.5	15.9	13.4	11.2	11.8	12.1
5.5 to 6.8	28.5	26.5	23.7	20.4	20.4
6.9 to 8.7	51.8	55.6	59.1	59.6	58.6
8.8 to 9.9	3.2	3.8	5.2	7.0	7.2
≥ 10	0.6	0.7	0.8	1.4	1.8
Gestational age (weeks)[b,*]					
32 to 36	5.5	4.0	3.5	4.2	3.8
37 to 39	47.7	48.3	46.3	43.8	45.4
40 to 42	36.7	36.7	39.0	39.9	38.5
≥ 43	10.2	11.0	11.3	12.1	12.4
Birth year*					
1946 to 1949	16.1	12.8	13.6	13.2	15.5
1950 to 1954	30.5	29.4	32.1	33.9	32.8
1955 to 1959	33.0	35.1	34.3	34.5	33.9
1960 to 1964	20.4	22.8	19.9	18.3	17.8
Breastfeeding duration (mo)*					
Not breastfed or < 1 week	60.9	58.9	56.5	57.8	61.0
< 3	18.7	19.4	19.9	20.1	19.0
3 to 5	9.7	10.5	11.4	9.8	10.0
6 to 8	5.9	6.4	7.2	7.2	5.4
9 to 11	3.4	3.4	3.9	3.8	3.6
≥ 12	1.5	1.4	1.3	1.3	1.0
Type of solid food first introduced to nurse*					
Cereal	90.2	92.2	92.2	91.9	91.6
Vegetables	3.6	2.6	2.5	2.2	2.8
Fruits	4.1	3.5	3.5	3.9	3.6
Breads, crackers, or cookies	2.1	1.7	1.8	1.9	2.0
Nurse's physical activity at ages 3 to 5 y*					
Highly active	37.1	34.1	31.6	29.1	26.8
Active	59.8	63.1	65.1	66.1	66.1
Mostly inactive + inactive	3.1	2.7	3.3	4.9	7.2
Nurse's screen time at ages 3 to 5 y (h)*					
None	22.7	19.8	21.6	21.5	21.1
0.5 to 1	42.4	45.8	44.8	44.4	41.0
2	25.0	25.2	24.4	24.2	25.4
3	7.8	7.0	6.9	7.2	9.6
≥ 4	2.1	2.1	1.7	2.0	3.0

[a]2% missing.
[b]42% missing or do not recall.
*Significantly different between somatotype categories ($P < 0.05$).

indicating lower odds of overweight in adulthood with increasing age (in months) at introduction of meats, firm food, and vegetables (31).

Our marginal association between late age at SF introduction and obesity at age 5 is in accord with other studies (13-15,32). Specifically, in a small sample ($n = 54$) of children enrolled in a prospective cohort study within 1 week of birth, delaying SF introduction to later than 5 months was related to higher BMI at 3 and 6 years of age (32). In a cross-sectional, population-based study (2007 to 2011), both early (4 months) and late (≥ 7 months) introduction of SF increased the odds of BMI > 97.7th percentile at ages 9 to 15 months with ORs of 1.75 and of 2.64, respectively (14). Papoutsou et al. also demonstrated a 38% higher odds of childhood overweight/obesity (ages 2 to 9 years) among exclusively breastfed infants with introduction of SF at ≥ 7 months of age using cross-sectional data from eight European countries (2007 to 2008) (15).

The null associations between age at SF introduction and obesity at ages 10 and 18 and in adulthood have been demonstrated at different

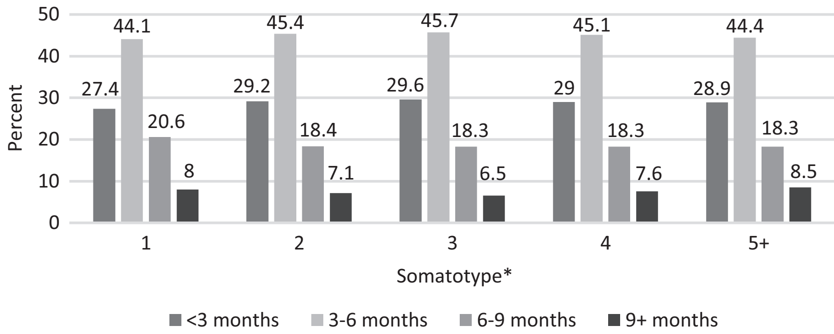

Figure 1 Somatotype at age 5 by age at solid food introduction. *Somatotypes denote "body shapes" on the nine-level Stunkard somatotype pictogram with somatotype 1 defined as being lean and somatotype 5+ defined as having obesity.

TABLE 2 ORs and 95% CIs for obesity at ages 5, 10, and 18 and in adulthood by age at solid food introduction

Age at solid food introduction (mo)	Obesity (*n*)	Age-adjusted OR	Covariate-adjusted OR[a]
Somatotype ≥ 5 at age 5			
< 3	583	1.06 (0.93, 1.22)	1.08 (0.94, 1.24)
3 to 6	896	1.02 (0.90, 1.16)	1.04 (0.92, 1.19)
6 to 9	370	Reference	Reference
≥ 9	171	1.21 (1.01, 1.47)	1.22 (1.01, 1.47)
P for trend		0.19	0.21
Somatotype ≥ 5 at age 10			
< 3	1,013	0.94 (0.85, 1.05)	0.97 (0.87, 1.08)
3 to 6	1,585	0.92 (0.84, 1.02)	0.95 (0.86, 1.05)
6 to 9	717	Reference	Reference
≥ 9	279	1.01 (0.87, 1.17)	1.01 (0.87, 1.18)
P for trend		0.30	0.68
BMI ≥ 30 kg/m^2 at age 18			
< 3	183	0.80 (0.64, 1.01)	0.85 (0.67, 1.07)
3 to 6	320	0.93 (0.76, 1.14)	1.02 (0.83, 1.26)
6 to 9	141	Reference	Reference
≥ 9	57	1.05 (0.77, 1.43)	0.99 (0.72, 1.37)
P for trend		0.17	0.28
BMI ≥ 30 kg/m^2 in adulthood			
< 3	859	1.01 (0.91, 1.13)	0.99 (0.88, 1.11)
3 to 6	1,334	0.95 (0.85, 1.05)	0.98 (0.88, 1.09)
6 to 9	602	Reference	Reference
≥ 9	254	1.11 (0.95, 1.29)	1.09 (0.92, 1.28)
P for trend		0.13	0.62

[a]Adjusted for: Age 5: maternal education, prepregnancy BMI, gestational weight gain during pregnancy, smoking during pregnancy, activity during pregnancy, gestational diabetes, and age at nurse's birth; family history of diabetes; paternal education and BMI at nurse's birth; home ownership at nurse's birth; nurse's birth weight, gestational age, birth year, breastfeeding duration, type of solid food first introduced, physical activity, and screen time at ages 3 to 5 years; and age at questionnaire return (1989). Age 10: age 5 covariates and nurse's physical activity and screen time at ages 5 to 10 years. Age 18: Age 10 covariates and age at menarche, activity during high school, and cigarettes smoked at < 15 years and 15 to 19 years of age. Adulthood: Age 10 covariates and age at menarche, activity level in 1989, and smoking status in 1989.

ages in previous studies (11,12,31,33). It is possible that 10 and 18 years of age are proximal to puberty and that the complexity of factors influencing obesity in puberty and then later in life may mask the effect of a single early indicator such as age at SF introduction.

Some studies have showed that the association between age at SF introduction and obesity may be influenced by infant feeding status, with adverse effects mostly seen among formula-fed infants or those breastfed for short durations (<4 months) (13,14). In a trial of exclusively formula-fed infants introduced to SF at different ages (i.e., starting from 3 vs. 6 months), differences in energy intake between early (3 months) and late (6 months) introduction did not appear, as energy from formula feeds was displaced by SF (34). This may explain why age at SF introduction did not influence obesity risk among nurses who were formula fed in our study.

Inconsistency and difficulty in interpreting results across studies may stem from discrepancies in study design, sample sizes, confounders, age at which outcomes were assessed, tools to report or measure data, and the definition of and cutoffs for exposures and outcomes. The definition of and cutoffs for exposures are important within this study context, as the response category ranges for our exposure variable are not concordant with current recommendations for SF introduction at around 6 months of age. Introduction of SF at 6 to 9 months may mean introduction anywhere between 24 and 36 weeks of age. The biological implications could be different over these 3 months, and grouping them together may alter our findings. Further, although mothers were asked to report when they first introduced SF to their nurse daughter, the questionnaire did not define "age at SF introduction." This could have been perceived as the age at "first taste" of any food other than breastmilk or formula or the age at which any food or liquid other than breastmilk or formula was introduced and was consistently given to infants. These definitions are vague in the literature with discrepancies across major health organizations (35). Such ambiguity in definitions may lead to under- or overestimation of the magnitude of the exposure depending on maternal perception, and it ultimately sends mixed messages to mothers regarding the optimal age for SF introduction.

Nurses in our study were born from 1946 through 1964; therefore, our results have a historical context. Knowledge about recommendations by physicians at the time are vaguer than the messages delivered to mothers today, although limited evidence indicates that mothers tended to introduce SF as early as 2 to 4 months of age during the birth years of the nurses (36). In addition, 92% of mothers reported introducing cereal as a first food, which limits our ability to directly assess the association between age of introduction of SF and obesity by types of SF. It is therefore difficult to disentangle the effect of age at SF introduction from the effect of the content of the diet consumed early in life.

The mechanism behind the observed borderline higher odds of obesity at age 5 with delayed introduction of SF at or beyond 9 months is uncertain. There appears to be a vulnerable window when delayed SF introduction, particularly at later months (e.g., ≥ 9 months), is associated with conditions other than childhood obesity, including pediatric acute lymphoblastic leukemia (37), feeding problems, and reduced consumption of food groups such as fruit and vegetables (38). Given that introduction of SF, particularly protein and fiber, enhances microbial diversity, later introduction of solids may delay development of normal and healthy gut microbiota and have a negative impact on risk of disease later in life (39). It is unclear why mothers waited until 9 months of age to introduce SF to their infants. Our cross tabulations between age at SF introduction and gestational age, birth year, and maternal education indicated a decreasing trend in the proportion of nurses fed SF at or after 9 months with increasing categories of these variables.

Strengths of our study include the use of two well-characterized cohorts with large sample sizes. Our exposure and outcome data were obtained from two independent sources (mothers and nurse daughters, respectively), and although the exposure data were retrospectively collected, the overall prospective nature of the study allows for a temporal relation between age at SF introduction and childhood obesity.

Despite the plethora of confounders that were adjusted in our models of obesity, there is still the possibility that residual confounding may occur. We recognize that energy intake is an important contributor to obesity. Although we do not have information on energy intake at ages 5 and 10, we adjusted for type of SF first introduced to infants—predominantly cereal, an energy-dense food. No information on energy intake at age 18 was collected and adulthood dietary intake was not collected until the 1991 follow-up questionnaire and thus was also not included as a covariate in our sample. Generalizability of the results to other races/ethnicities and men is not permitted, given that 97% of the nurses are Caucasian white women. Although maternal and nurses' reporting of the exposure and outcomes respectively may be subject to recall bias, research in numerous countries has indicated that mothers are able to reliably recall infant feeding data in the short (40) and long term (41,42), and recall of body somatotype has been previously validated as discussed in *Methods* (22,23,43). Aside from the potential recall bias associated with the outcome, there is also a possibility of misclassification of nurses into body somatotypes that may not look different.

Obesity involves an interaction of factors in prenatal and early postnatal life, with potential tracking in adulthood. Results from our study may add insight to the role of age at SF introduction on early life and later adiposity but also confirm well-known and emerging prenatal and early postnatal risk factors for the condition (Supporting Information Table S1), which are consistent with other research (10,44,45). The magnitude of the effect of late age at SF introduction on childhood obesity is relatively small compared with the effect of high maternal prepregnancy BMI and paternal BMI at birth, maternal smoking during pregnancy, and high birth weight. This suggests that infant feeding practices may be important for healthy growth and development, but prime modifiable factors appear earlier with maternal and paternal BMI and maternal smoking during pregnancy to reduce population obesity rates. Interventions might consider incorporating a holistic host of modifiable risk factors, with a focus on exposures that are likely to have the largest effects on curbing obesity rates across the life course. Further research is needed to replicate our results in a cohort born more recently in time than the nurses, with more clear definitions of and discrete cutoffs for age at SF introduction.

Conclusion

In conclusion, our data suggest that late age at SF introduction only slightly influenced women's odds of having obesity in childhood, with no effects extending throughout life. Additional research is needed to replicate these results in more recent birth cohorts and to assess the dynamic influence of age at SF introduction and early life diet on the obesity epidemic.**O**

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