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The introduction of solid food and growth in the first 2 y of life in formula-fed children: analysis of data from a European cohort study[1–5]

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ABSTRACT

Background: Early introduction of solid food has been suspected to induce excessive infant energy intake and weight gain.

Objective: The objective of this study was to test whether introduction of solid foods influences energy intake or growth.

Design: Healthy, formula-fed infants who were recruited in 5 European countries were eligible for study participation. Anthropometric measurements were taken at recruitment and at 3, 6, 12, and 24 mo. Time of introduction of solid foods and energy intake were determined by questionnaires and 3-d weighed food records at monthly intervals. Age at introduction of solid food was categorized into 4 groups: ≤13 wk, 14–17 wk, 18–21 wk, and ≥22 wk.

Results: Of 1090 recruited infants, 830 (76%) had data available for age at first introduction of solid food, and 671 (61%) completed the study until 24 mo of age. The median age at introduction of solid food was 19 wk. The time of introduction of solid foods was associated with country, sex, birth weight, parental education and marital status, and maternal smoking. Energy intake was higher in the first 8 mo of life in children with solid-food intake. Solid-food introduction did not predict anthropometric measures at 24 mo. Growth trajectories differed significantly: children with solid-food introduction in the first 12 wk experienced early catch-up growth, whereas those introduced to solid food at >22 wk of age grew more slowly and stayed on lower trajectories.

Conclusions: Solid foods do not simply replace infant formula but increase energy intake. Time of introduction of solid food has little influence on infant growth. This trial was registered at clinicaltrials.gov as NCT00338689. *Am J Clin Nutr* 2011;94(suppl):1785S–93S.

BACKGROUND

Determining the optimal time of solid food introduction in infancy remains controversial. Although expert recommendations unanimously recommend exclusive breastfeeding for at least the first 4 mo of life (1, 2), the practice differs: a large fraction of children in developed countries have already been introduced to solids before 4 mo of age (3–6).

The recommendation of the World Health Organization to not start complementary foods before 6 mo of age is based on a balance between the positive effects of breastfeeding, in particular the reduction of infectious disease risks in poor populations, and the nutritional requirements of the child (7). If the latter cannot be met adequately, growth faltering may be one of the consequences. However, one of the potential untoward effects of early introduction of solid food may be more rapid weight gain in infancy (8–10), which is associated with later obesity (11–13). Some authors stated that this might be specifically problematic in formula-fed children who carry a higher risk of overfeeding (14–17). Fewtrell et al (18) concluded in a recent review on the optimal duration of exclusive breastfeeding that the evidence to support recommendations for the introduction of solid food is especially scarce in formula-fed infants.

In breastfed children, infant demand is the main determinant of milk production (19); they generally regulate their energy intake at a lower level than do formula-fed children (20), and seem to self-regulate their intake when introduced to solids (21–25). Whether this also holds true for formula-fed children is less clear. Formula-fed children are known to grow more rapidly than

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breastfed children from about the third month in the first year of life (26, 27). Formula-fed children receive solids earlier than breastfed children (6, 28–31); hence, one might speculate that solids influence the growth pattern. Indeed, within the DARLING (Davis Area Research on Lactation in Infant Nutrition and Growth) study, growth differences between formula-fed and breastfed children disappeared after adjustment for the introduction of solid food and cow-milk intake (26). Wilson et al (32) also showed a weak positive association between early introduction of solid food and adiposity in later childhood, whereas Burdette et al (33) observed no association.

The objective of this study was to test the hypothesis that the timing of the introduction of solid food has no influence on the attained weight, length, or weight-for-length of formula-fed children at 24 mo of age, or on the growth trajectories of these children during the first 2 y of life.

METHODS

Study design

This study was based on a double-blind, randomized controlled trial that compared 2 groups of children fed cow-milk formula with either higher or lower protein content for the first year of life. A detailed description of the study has been published previously (6, 34). The study protocol was approved by the ethics committees of all study centers. Written informed parental consent was obtained for each infant.

Study population

Eligible for study participation were apparently healthy, singleton, term infants who were recruited shortly after birth between 1 October 2002 and 31 July 2004, from birth clinics in 8 urban areas of 5 countries (Belgium, Germany, Italy, Poland, and Spain). Infants had to be exclusively fed study formula by the end of the eighth week of life. Children up to the age of 8 mo were excluded afterward if fed non–study formula or breastfed for >10% of feedings.

Of the original 1090 formula-fed children included in the study, 687 (63%) completed the study until 24 mo of age, 338 children from the lower-protein formula group and 349 children from the higher-protein formula group, without differential loss between both groups (34). Two hundred twenty-nine children were lost to follow-up (ie, parental refusal, loss of contact), and 5 children were excluded for illness/medication and 169 for lack of compliance (ie, they switched to a non–study formula). Up to the ages of 3, 6, 12, and 24 mo of age, 933, 785, 767, and 687 children, respectively, were followed. Some 249 (23%) of the 1090 children were exclusively formula-fed from birth, and all others switched from breastfeeding to formula feeding within the first 8 wk of life.

Age at the study entry visit with baseline anthropometric measurements was 16 d (interquartile range, 25th–75th percentile: 2–29 d). Information on the course of pregnancy, medical history, lifestyle and behavior choices, socioeconomic background, and mother's prepregnancy weight was obtained from standardized parent interviews at the baseline visit.

At 3, 6, and 9 mo, parents were asked about the current type of feeding and the week of introduction of solids. Infant food intakes were recorded by prospective 3-d weighed food records at monthly intervals from the ages of 1 to 9 mo, and additionally at ages 12, 18, and 24 mo. A detailed description of procedures has been published elsewhere (6). All 3530 food items used and documented in the protocols in the first year of life were categorized into food groups by one dietitian (SS). As solids we defined any food categorized as beef, cereal, bread, egg, fish, fruit, meat, milk or milk products (other than formulae), nuts or seeds, potatoes, poultry, pulses, sausages, soy or soy products, and vegetables. The week of introduction of solid food was defined by the first food protocol with a documented solid. In the case of missing food protocol data, the age of introduction of solid food was defined according to the week given in the questionnaire. In the case of no introduction of solid food and censoring (exclusion or loss to follow-up), the child was considered not to have had solids up to the week of either the last available questionnaire or food protocol. For descriptive and analytic purposes the time of introduction of solid food was categorized into 4 groups: ≤13 wk (<3 mo), 14–17 wk (3–3.9 mo), 18–21 wk (4–4.9 mo), and ≥22 wk (≥5 mo).

Both randomized formula groups with lower and higher protein content were combined into one group for all analyses, because we did not expect any influence of protein intake on the start of solid foods. Length and weight-for-length at 24 mo were chosen as the main outcomes, because weight gain until 24 mo of age was judged to be the strongest predictor of later obesity (35). Anthropometric measures were expressed as *z* scores relative to the growth standards of the World Health Organization for exclusively breastfed children (36). This approach makes the data more comparable with other studies, standardizes for sex, and takes into account the true age at the measurement. *Z* scores were calculated with the use of World Health Organization programs (http://www.who.int/childgrowth/software/en/). Means (±SD) or medians (interquartile range) were used as appropriate. Pearson's chi-square test and Fisher's exact test were used for statistical comparison of categorical data, and Student's *t* test for normally distributed continuous data. Linear regression analysis was applied to test the effect of type of feeding on *z* scores at 24 mo for weight, length, weight-for-length, and body mass index (BMI; in kg/m^2), with adjustment for the respective baseline values as recommended (37) and for potential confounders. We considered formula group, sex, country, mother's and father's education, birth order of the child, and mother's BMI, smoking status, age, and partnership status (married, single) as potential confounders. If there was a considerable change in the effect size of solid introduction or its CI, we judged the factor to be a confounder.

We also applied multilevel linear growth models and piecewise-linear-random-coefficient models as described by Singer and Willett (38) and Fitzmaurice et al (39) to model growth differences between the different groups of solid-food introduction with the use of all available measurements from baseline to 24 mo. Both models account for the correlated data structure because of the repeated measurements, and use the exact age of measurement. The piecewise-linear-random-coefficient model was chosen to analyze the age-dependent effect of the introduction of solid food on the anthropometric outcome. The idea of the model is to split the time into fixed segments with different slopes in each segment, in contrast to the usual multilevel linear growth model, which uses one slope over the whole analysis time.

The choice of the time segments (0–3 mo, 3–6 mo, 6–12 mo, and 12–24 mo) for this model was based on the measurement points as planned per protocol. Data management and statistical analyses were carried out with the software packages SAS 9.2 (SAS Institute Inc, Cary, NC) and Stata 9.2 (StataCorp LP, College Station, TX).

RESULTS

Sample characteristics and introduction of solid food

Of the 687 children still participating in the study at 24 mo, 681 (99%) had at least one food protocol, and 476 (69%) had filled in all 6 food protocols from the second to seventh months of life. The age of solid-food introduction and all anthropometric measurements from baseline to 24 mo of age were available for 671 children (98%). For 830 children, the time of solid-food introduction was known.

The median age at solid-food introduction was 19 (interquartile range: 17–21) wk. About 7% of the children were introduced to solid food before the end of the third month of life (≤13 wk) (**Table 1**). By age 6 mo, 97% of all children had been introduced to solids.

The timing of the introduction of solid food was significantly associated with the study country; sex of the child; nationality, marital status, and educational level of the parents; smoking behavior of the mother; BMI of the mother; and birth weight (Table 1). Boys were introduced to solids earlier; 40% of the boys had been introduced to solids by 17 wk of age compared with 31% of the girls. Birth weight in early introducers (≤13 wk) and in the group of late introducers (≥22 wk) was ≈116 g (95% CI: 21, 210 g) and 78 g (95% CI: 18, 138 g), respectively, lighter at birth compared with those introduced to solids between 18 and 21 wk.

Country, birth order, and anthropometric measures at birth and at study inclusion were significantly associated with weight or length at 24 mo, whereas smoking during pregnancy, parental education, and mother's BMI were not (*see* Table S1 under "Supplemental data" in the online issue).

Introduction of solid food and growth

The time of solid-food introduction was not significantly associated with anthropometric measures at 24 mo in unadjusted analysis. However, after adjustment for the respective anthropometric baseline value and country, *z* scores differed significantly for weight (P = 0.027) and length (P = 0.049), without showing a linear effect in the sense of a time- (dose-) response relation (**Table 2**). Adjustment for other potential confounders did not change the effect size or strength considerably. Children introduced to solids at ≤13 wk of age and those with introduction between 18 and 21 wk grew faster and were heavier than other children introduced to solids in between or later.

There was a significant difference in growth pattern over the first 24 mo of life between the 4 groups of solid-food introduction for weight-for-age (P = 0.005) and BMI-for-age (P = 0.011) but not for weight-for-length (P = 0.084) or length-for-age (P = 0.127) (**Figure 1**). The observed difference was mainly attributable to the different pattern of the early (≤13 wk) and late (≥22 wk) introducers. Whereas early introducers "caught up" growth between baseline and 6 mo and transiently attained a higher BMI-for-age/weight-for-length at 6 mo than all other children, the late introducers had less weight and length gain between baseline and 3 mo and continued at a lower weight-for-age trajectory than all other children until 24 mo of age.

Introduction of solid food and energy intake

By the third month of life, the energy intake from solids was ≈11% in those children introduced to solids in the first 13 wk of life; this proportion increased to about one-third at 6 mo and to about two-thirds at 12 mo of age (**Table 3**). From 8 mo of age onwards, the proportion of energy from solids was about equal in all solid-food introduction groups. The difference in the proportion of energy from solids between the solid-food introduction groups was at a maximum at 5 mo, when the early-introducer group received at a median 26%, and the late-introducer group 0%, of energy from solids.

Over all time points during the first 8 mo there was a more or less ordered decrease in energy intake from the early-introducer to the late-introducer group (all $P \leq 0.003$). This observed decrease was not attenuated when country was taken into account as a potential confounder. The difference was observed despite the fact that the median energy intake from solids was, for instance, in the first 2 mo of life 0% in all solid-food introduction groups. From age 12 mo, energy intake no longer differed between solid-food introduction groups.

A comparison of those children eating solids with those being exclusively formula fed in a given month showed that energy intake was higher in each of the first 8 mo of life in those eating solids (**Figure 2**). The observed difference varied between 25 kcal/d (95% CI: −67, 17 kcal/d) at 2 mo of age and 148 kcal/d (95% CI: 18, 278 kcal/d) at 8 mo of age.

DISCUSSION

In this prospective cohort study we had the opportunity to relate detailed information about the effects of solid-food introduction on growth parameters during the first 2 y of life. The main findings were that early solid introducers (≤13 wk) were lighter at birth compared with those who were introduced to solids in the third and fourth months of life. In the following months, these children caught up growth and were transiently (at 6 mo of age) even heavier than all other children. In contrast, the group of late introducers (≥22 wk) had a less pronounced growth until 3 mo of age and continued at a lower growth trajectory than all other children. However, at 24 mo of age there were no reasonable differences in attained weight, length, weight-for-length, or BMI due to the time of introduction of solid food. Energy intake was positively associated with earlier solid-food introduction. Solids did not simply replace formula feeds but also added additional energy to the diet during the introduction period.

Birth weight and time of introduction of solid food

Several other studies have analyzed the influence of birth weight on the introduction of solid food, or growth before the introduction of solid food. Results are heterogeneous, with a balance between those studies that concluded that infants given solids early were smaller (26, 29, 40, 41) or heavier (5, 28, 42–44) before solids were started. In our population, the results were also not straightforward. Whereas growth between baseline (median 16 d of age) and 3 mo of age was not associated with solid-food introduction, birth weight was: early introducers were indeed lighter at birth. However, late introducers, here especially girls, were also lighter than those introduced to solids between 3 and 5 mo of age. Thus, one could speculate that early and late solid introducers are different "phenotypes": parents of infants light at birth might be induced to introduce solids earlier to achieve better weight gain; another group of parents might introduce solids later to girls, especially to those slimmer at birth. It is also possible that infants born small provide other signals to which parents react.

Time of introduction of solid food and growth during the first 2 y of life

The observed associations between the time of introduction of solid food and growth were weak. The growth pattern of infants

TABLE 1
Characteristics of 830 formula-fed children and time of introduction of solid food

	Introduction of solid food					
	≤13 wk	14–17 wk	18–21 wk	≥22 wk	Total	*P* value[1]
	n (%)				*n (%)*	
Country						<0.001
Germany	8 (6)	42 (31)	39 (29)	46 (34)	135 (16)	
Belgium	18 (19)	28 (29)	26 (27)	24 (25)	96 (12)	
Italy	6 (3)	51 (26)	97 (49)	46 (23)	200 (24)	
Poland	8 (5)	53 (34)	82 (52)	15 (9)	158 (19)	
Spain	19 (8)	63 (26)	98 (41)	61 (25)	241 (29)	
Total	59 (7)	237 (29)	342 (41)	192 (23)	830 (100)	
Sex						0.033
Male	38 (9)	129 (31)	158 (38)	94 (22)	419 (50)	
Female	21 (5)	108 (26)	184 (45)	98 (24)	411 (50)	
Both parents foreigners						0.036
Yes	1 (3)	13 (42)	6 (19)	11 (35)	31 (4)	
No	58 (7)	224 (28)	335 (42)	181 (23)	798 (96)	
Mother married						0.027
Yes	34 (6)	167 (28)	258 (43)	143 (24)	602 (73)	
No	25 (11)	70 (31)	83 (37)	49 (22)	227 (27)	
Single mother						0.510
Yes	3 (6)	19 (38)	18 (36)	10 (20)	50 (6)	
No	56 (7)	218 (28)	323 (41)	182 (23)	779 (94)	
Mother's educational level						0.025
None/low	20 (8)	89 (35)	88 (35)	55 (22)	252 (30)	
Middle	33 (8)	117 (27)	184 (42)	103 (24)	437 (53)	
High	5 (4)	31 (22)	69 (50)	34 (24)	139 (17)	
Father's educational level						0.031
None/low	19 (7)	96 (36)	103 (38)	50 (19)	268 (33)	
Middle	30 (7)	104 (25)	185 (44)	103 (24)	422 (52)	
High	9 (7)	30 (24)	49 (40)	36 (29)	124 (15)	
Smoking beyond 12 wk of gestation						0.004
Yes	27 (12)	70 (31)	82 (36)	46 (20)	225 (27)	
No	32 (5)	166 (28)	258 (43)	145 (24)	601 (73)	
Birth order						0.298
First child	29 (6)	128 (28)	209 (45)	95 (21)	461 (56)	
Second child	20 (7)	84 (31)	100 (37)	69 (25)	273 (33)	
Third child	7 (10)	19 (26)	27 (38)	19 (26)	72 (9)	
>Third child	2 (10)	5 (24)	6 (29)	8 (38)	21 (3)	
BMI of mother						0.048
Normal	42 (8)	151 (28)	233 (42)	123 (22)	549 (68)	
Overweight	5 (3)	61 (34)	71 (40)	41 (23)	178 (22)	
Obese	10 (13)	18 (24)	28 (37)	20 (26)	76 (9)	
Birth weight						0.024
≤3000 g	15 (8)	46 (24)	73 (38)	58 (30)	192 (23)	
>3000–3500 g	36 (9)	124 (30)	166 (40)	87 (21)	413 (50)	
>3500 g	8 (4)	67 (30)	103 (46)	47 (21)	225 (27)	
z Score change in weight-for-length baseline to 3 mo						0.521
<−0.5	20 (6)	95 (27)	157 (45)	75 (22)	347 (43)	
−0.5–1	32 (8)	115 (29)	156 (39)	93 (23)	396 (49)	
>1	4 (6)	25 (35)	26 (36)	17 (24)	72 (9)	

[1] Chi-square test.

TABLE 2
Anthropometric measures at age 24 mo and time of introduction of solid food in 671 formula-fed children[1]

	Introduction of solid food				
	≤13 wk	14–17 wk	18–21 wk	≥22 wk	*P* value[2]
Weight					
kg	12.6 ± 1.5	12.4 ± 1.5	12.7 ± 1.3	12.3 ± 1.4	
kg/30 d[3]	0.38 ± 0.06	0.36 ± 0.06	0.37 ± 0.05	0.36 ± 0.05	
z score	0.40 ± 1.01	0.31 ± 0.98	0.53 ± 0.82	0.23 ± 0.91	0.027
Length					
cm	88.0 ± 3.1	87.9 ± 3.2	88.4 ± 3.2	87.9 ± 3.0	
cm/30 d[3]	1.53 ± 0.16	1.49 ± 0.14	1.52 ± 0.12	1.51 ± 0.12	
z score	0.14 ± 1.09	0.18 ± 1.01	0.39 ± 0.97	0.18 ± 0.93	0.049
BMI					
kg/cm[3]	16.4 ± 1.2	16.2 ± 1.3	16.3 ± 1.2	16.0 ± 1.3	
z score	0.45 ± 0.91	0.26 ± 0.95	0.40 ± 0.88	0.14 ± 0.96	0.220
Weight-for-length					
z score	0.40 ± 0.92	0.23 ± 0.94	0.38 ± 0.85	0.11 ± 0.93	0.127

[1] All values are means ± SDs.
[2] Derived from linear regression with adjustment for respective anthropometric baseline measurement and country.
[3] Growth velocity from baseline measurement.

with late solid-food introduction (≥22 wk) was more similar to that of exclusively breastfed children than to all groups of earlier solid-food introduction, after 6 mo of age. In agreement with our study, several other observational studies have reported transient effects on weight gain during the first year of life (8–10, 42, 45). In contrast, other observational studies (31, 40, 46–48) and 2 randomized controlled trials (22, 23) did not see any effect on early growth. However, these randomized trials had little power to detect differences (both included ≈150 children). Most of these studies also included (in contrast to our study) mixed populations of breastfed and formula-fed infants. In the 1970s and 1980s, when formula feeding was highly prevalent and early solid-food introduction was common in some Western countries, some others suggested that infantile overfeeding due to early solid-food introduction and excessive early growth might be especially problematic in formula-fed children (14–17). The results of all studies together suggest that there may be a small effect of time of solid-food introduction on early growth, but this effect seems to be only transient.

Because more rapid weight gain during the first 2 y of life is associated with later obesity (11–13), even transient effects might translate into a higher risk of later obesity. A very recent study concluded that early introduction of complementary feeding may lead to more adult overweight (44). The effect of the introduction

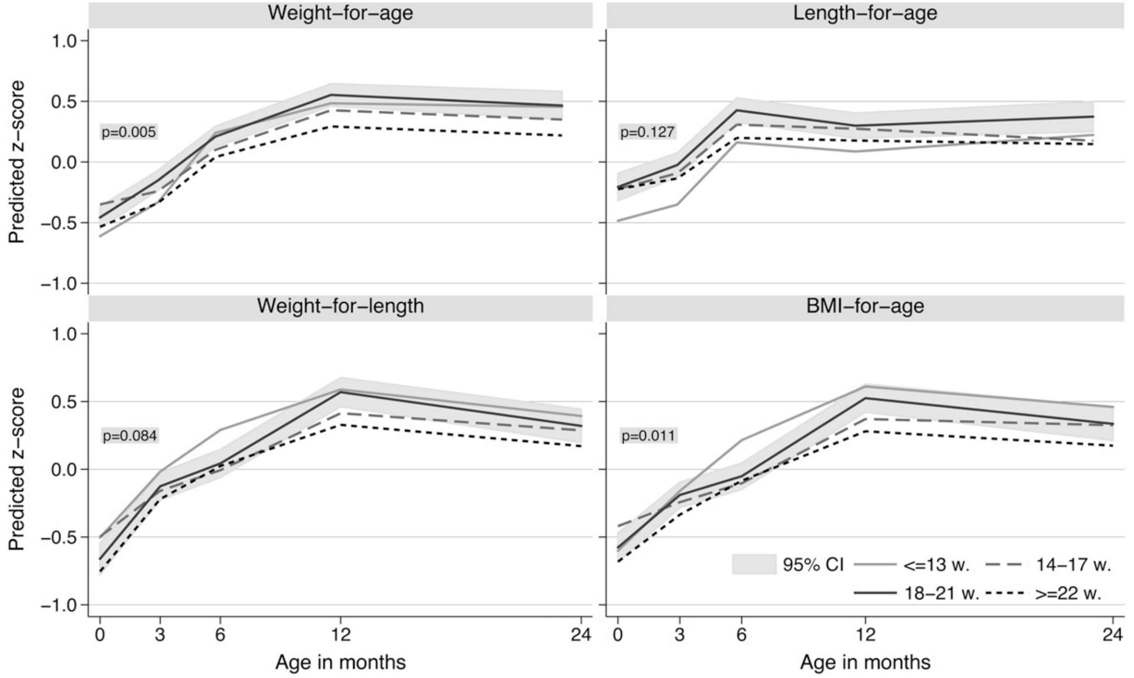

FIGURE 1. Predicted mean growth trajectories of 828 children followed over the first 2 y of life by time of introduction of solid food, with *P* values for overall growth difference (adjusted by country) and 95% CIs of the children introduced to solids between 18 and 21 wk of age. Growth on a predicted *z* score of 0 would imply growth at the 50% percentile of the World Health Organization Multicenter Growth Reference Study (36) of exclusively breastfed children.

TABLE 3
Week of introduction of solid food, caloric intake, and proportion of caloric intake from solids per month

	Introduction of solid food				
	≤13 wk	14–17 wk	18–21 wk	≥22 wk	*P* value[1]
Month 1					
n	45	165	207	109	
kcal/d	557 ± 94[2]	506 ± 97	523 ± 90	496 ± 113	0.003
Percentage of energy from solids	0 (0, 0)[3]	0 (0, 0)	0 (0, 0)	0 (0, 0)	
Month 2					
n	53	226	312	154	
kcal/d	587 ± 107	555 ± 95	562 ± 91	544 ± 105	0.029
Percentage of energy from solids	0 (0, 3)	0 (0, 0)	0 (0, 0)	0 (0, 0)	
Month 3					
n	45	243	318	156	
kcal/d	653 ± 116	580 ± 102	583 ± 96	575 ± 99	<0.001
Percentage of energy from solids	7 (3, 12)	0 (0, 0)	0 (0, 0)	0 (0, 0)	
Month 4					
n	44	232	321	152	
kcal/d	670 ± 115	632 ± 101	612 ± 93	614 ± 95	<0.001
Percentage of energy from solids	11 (5, 21)	10 (4, 16)	0 (0, 0)	0 (0, 0)	
Month 5					
n	49	218	323	152	
kcal/d	712 ± 123	677 ± 115	660 ± 100	636 ± 102	<0.001
Percentage of energy from solids	26 (14, 35)	22 (13, 33)	15 (8, 24)	0 (0, 0)	
Month 6					
n	44	212	305	153	
kcal/d	771 ± 137	719 ± 138	703 ± 116	668 ± 116	<0.001
Percentage of energy from solids	38 (22, 51)	33 (21, 46)	30 (19, 41)	21 (8, 30)	
Month 7					
n	39	197	283	142	
kcal/d	792 ± 149	754 ± 132	757 ± 137	718 ± 130	0.003
Percentage of energy from solids	45 (36, 56)	47 (34, 58)	48 (34, 60)	43 (26, 53)	
Month 8					
n	38	194	268	137	
kcal/d	831 ± 135	798 ± 137	801 ± 154	750 ± 144	<0.001
Percentage of energy from solids	49 (40, 59)	51 (38, 64)	54 (39, 65)	52 (41, 60)	
Month 9					
n	36	197	263	130	
kcal/d	793 ± 148	836 ± 162	826 ± 156	778 ± 173	0.004
Percentage of energy from solids	51 (44, 57)	56 (43, 67)	56 (44, 66)	55 (46, 63)	
Month 12					
n	34	188	267	125	
kcal/d	920 ± 178	887 ± 171	881 ± 168	852 ± 165	0.195
Percentage of energy from solids	64 (53, 76)	67 (57, 81)	66 (56, 77)	66 (57, 76)	
Month 24					
n	24	152	211	93	
kcal/d	1084 ± 196	1122 ± 225	1108 ± 241	1098 ± 253	0.515

[1] Kruskal-Wallis test.
[2] Mean ± SD (all such values).
[3] Median; 25th, 75th percentile in parentheses (all such values).

of solid food was seen at the age of 42 y, despite the fact that there was no effect of solid-food introduction on weight in infancy within the same population. Wilson et al (32) made a similar observation in 7-y-old subjects, whereas Burdette et al (33) did not find any effect of the time of solid-food introduction on BMI at 5 y of age. Thus, the evidence of long-term effects of early solid-food introduction is still inconclusive.

Introduction of solid food and energy intake

If there are transient effects of the time of introduction of solid food on growth, these are most likely explained by higher energy intakes earlier in life. However, energy intake from solids is limited during the first 6 mo of life. In our population the median proportion of energy intake from solids until 4 mo of age was 0%, and ≈28% at 6 mo of age. Thus, any differential effects on growth by solid food intake are expected to be only weak. Nevertheless, early introducers grew somewhat faster between 3 and 6 mo, had a higher energy intake than did groups with later solid-food introduction, and were somewhat heavier at 24 mo despite the fact that they were lighter at birth.

In contrast to the notion that breastfed children self-regulate their intake when introduced to solids (22, 25, 49), we noticed in

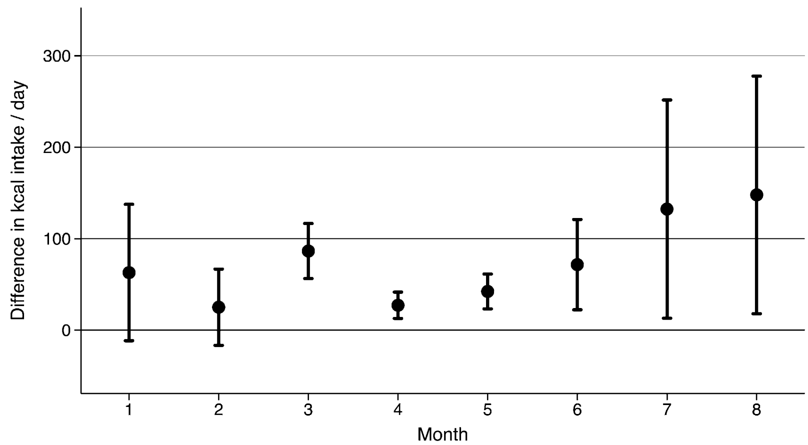

FIGURE 2. Differences (±95% CI) in energy intake between children with and without solid intakes by month. Values above zero indicate more energy intake in those infants consuming solids in the respective month. From the ninth month of age onward all children had been introduced to solids. Numbers of children for months 1–8, respectively, are as follows (solid food/no solid food): 7/592, 22/783, 45/766, 276/494, 609/153, 703/26, 666/5, and 642/5.

our population of formula-fed children a considerably higher energy intake in those introduced to solids during the first 8 mo of life. These observations support the potential role of early solid-food introduction on growth. The widening energy intake gap toward the end of the solid-food introduction period between those introduced to solids and those not introduced might indicate either that formula-fed children who are adapted to spoon feeding might have an excessive energy intake, or that there are potential nutritional deficiencies due to late solid-food introduction even in formula-fed children.

It was interesting to note that the energy intake by group, of solid-food introduction, was not concurrent with the intake of energy by solids (eg, the energy intake in the early introducers was always higher and in the late introducers always lower during the first 8 mo of life than in all other groups, irrespective of the proportion of energy from solids in the respective month). This might indicate that those children introduced early to solids have higher energy needs. Under this perception parents might be more inclined to introduce their children to solids earlier. We assume chance to be less likely an explanation for this finding, which was quite constant over the first 8 mo of life.

Strengths and limitations

Data on anthropometric measures and on consumed food products during the first 2 y of life were collected prospectively with a high standardization, which minimized measurement error and recall bias concerning the time of introduction of solid food. Because of the availability of monthly documentation of food intakes, the dynamics of the introduction of solid food on energy intake could be depicted clearly without relying on a single, one-time measurement. The study had enough power to detect a difference of 0.6 SD at 24 mo in any anthropometric measurement between the early introducers and those who were introduced to solids between weeks 18 and 21. The power to detect differences in growth pattern increased considerably, because we used longitudinal growth models that took into account all measurements during the first 2 y of life.

The study dealt only with the influence of the timing of the introduction of solid food. However, one might speculate that the quality of introduced solids is more influential than the timing. In the primary analysis of the presented study, with the use of the original randomization, we showed that children who were fed a higher-protein formula attained a greater weight at 24 mo than children on a lower-protein diet (34). Likewise, Rzehak et al (50) showed transient differences in growth between children fed a casein- or a whey-based formula, and Gunther et al (51) associated higher animal, especially dairy, protein intake at 12 mo with an unfavorable body composition at 7 y of age. Thus, the type of foods given might have a stronger influence than the timing of their introduction.

Conclusions

The interplay between energy intake, solid-food introduction, and growth is complex. The time of solid-food introduction is influenced by culture, perinatal factors such as birth weight, socioeconomic factors, and the potential energy expenditure of the children. Introduction of solid food seems to have little influence on early growth but adds additional energy to the diet of formula-fed children. This supports the recommendation that solids should not be introduced before 4 mo of age.

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