

Randomized controlled trial of 4 compared with 6 mo of exclusive breastfeeding in Iceland: differences in breast-milk intake by stable-isotope probe¹⁻³

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ABSTRACT

Background: The WHO recommends exclusive breastfeeding (EBF) for 6 mo after birth. However, the time at which breast milk ceases to provide adequate energy and nutrition, requiring the introduction of complementary foods, remains unclear. Most studies that investigated this issue were observational and potentially confounded by variability in social circumstances or infant growth.

Objective: We hypothesized that EBF infants would consume more breast milk at age 6 mo than infants receiving breast milk and complementary foods.

Design: We measured anthropometric outcomes, body composition, and breast-milk intake at age 6 mo in infants who were randomly assigned at age 4 mo either to 6-mo EBF or to the introduction of complementary foods with continued breastfeeding. We recruited 119 infants from health centers in Reykjavik and neighboring municipalities in Iceland. In 100 infants who completed the protocol (50/group), breast-milk intake was measured by using stable isotopes, and complementary food intakes were weighed over 3 d in the complementary feeding (CF) group.

Results: Breast-milk intake was 83 g/d (95% CI: 19, 148 g/d) greater in EBF (mean \pm SD: 901 \pm 158 g/d) than in CF (818 \pm 166 g/d) infants and was equivalent to 56 kcal/d; CF infants obtained 63 \pm 52 kcal/d from complementary foods. Estimated total energy intakes were similar (EBF: 560 \pm 98 kcal/d; CF: 571 \pm 97 kcal/d). Secondary outcomes (anthropometric outcomes, body composition) did not differ significantly between groups.

Conclusions: On a group basis, EBF to age 6 mo did not compromise infant growth or body composition, and energy intake at age 6 mo was comparable to that in CF infants whose energy intake was not constrained by maternal breast-milk output. *Am J Clin Nutr* 2012;96:73-9.

INTRODUCTION

Since 2001 the WHO has recommended exclusive breastfeeding (EBF) for the first 6 mo of life in all populations (1). These recommendations were officially adopted by the governments of some but not all industrialized populations, including the United Kingdom in 2003 (2, 3). In the developing world, where the benefits of EBF to reduce diarrheal disease are paramount, the recommendations have been widely adopted.

Despite widespread official endorsement, the scientific basis of the recommendations has been questioned, attributable in part to limited evidence on when EBF ceases to provide adequate energy

and nutrition, and hence when complementary foods should be introduced alongside breast milk. According to published data on breast milk (intake, energy content) and infant energy requirements, average intakes would fail to meet energy requirements in the average 6-mo-old infant (4), although this approach relied on various assumptions about breast-milk energy content. However, insufficient relevant evidence is available, particularly in EBF infants. The appropriate time for introducing complementary foods therefore remains uncertain.

A major limitation is the scarcity of data from randomized trials (5, 6). Mothers who breastfeed their infants at all differ from those who do not breastfeed, and those who undertake 6 mo EBF differ from those who breastfeed for shorter periods (7-11). Fewer than 1% of UK mothers were practicing EBF up to age 6 mo in 2005 (12), and those who did were highly educated and well financially supported during this period (13). Reported phenotypic differences between EBF and non-EBF infants might arise either from different nutritional intakes or from differences in parental or socioeconomic circumstances. Two randomized trials of 4 compared with 6 mo of EBF were conducted in Honduras, where low birth weight is common (14, 15). In each trial, breast-milk intake was greater in the 6-mo EBF group, but anthropometric outcomes did not differ between groups. Equivalent data from populations with larger body size during infancy are lacking.

The effect of introducing complementary foods is also controversial, as such foods, which are variable, may add to or replace

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breast milk in the infant diet (16). In observational studies, infants receiving complementary foods earlier in infancy may also have systematically different initial growth patterns or other characteristics than those receiving complementary foods later in infancy (11). We conducted a randomized trial to evaluate the effect of timing of introduction of complementary foods on infants whose mothers practiced EBF for the first 4 mo. The study was conducted in Iceland, where EBF rates at age 6 mo were 12% (17). Mothers who agreed to participate were randomly assigned either to continue EBF for 6 mo (EBF group) or to introduce complementary foods alongside breast milk at age 4 mo [complementary feeding (CF) group]. The primary hypothesis was that breast-milk intake at 6 mo would be greater in EBF than in CF infants. Secondary hypotheses were that complementary food intake would differ between groups, whereas anthropometric outcomes and body composition would not.

SUBJECTS AND METHODS

Recruitment for the study was undertaken from November 2007 to November 2009, with ethical permission granted by the National Bioethical Committee in Iceland and the Massachusetts General Hospital Institutional Review Board. Data collection was approved by the Data Protection Authority in Iceland. Mothers provided written informed consent to participate.

Recruitment

Mothers were recruited from 7 health centers in the Reykjavik Capital Area and neighboring municipalities in Iceland. Mothers were informed about the study when their infant was ~2 mo old and were given study handouts if the infant was still exclusively breastfeeding at 3 mo of age. If the infant was still exclusively breastfeeding at 4 mo and the mother was interested in the study, they were invited to participate. Mothers and infants attended a screening visit and, after providing informed consent, were evaluated for the following eligibility criteria:

Infants: singleton birth, gestational age ≥ 37 wk, healthy (ie, absence of congenital abnormalities or chronic health issues likely to affect growth, development, or iron status), and exclusively breastfeeding at the time of assessment

Mothers: willing to be randomly assigned either to continue to breastfeed exclusively until infant age of 6 mo or to introduce complementary foods alongside breast milk at infant age of 4 mo

The operational definition of EBF was breastfeeding with no additional liquid or solid foods other than vitamins and medications (18, 19), although up to a maximum of 10 feedings of formula or water during the first 6 mo were allowed because of practicalities of EBF. Newborn infants are at times given formula or sugar water at birth and may be given extra fluids after returning home. Eligible infant-mother pairs were randomly assigned to the 2 feeding groups. Vitamin D supplementation was provided to both groups. Mothers in both groups received counseling from nurses who were lactation specialists (International Board Certified Lactation Consultants). Specifically, EBF mothers were advised to exclusively breastfeed for 6 mo and CF mothers were advised to introduce complementary foods within 7 d of being randomly assigned. During the 2-mo study

period, mothers were encouraged to contact the research staff at the Unit for Nutrition Research (Reykjavik, Iceland) and a specialist at the health care centers if they had any questions or concerns.

Background information

Baseline data on maternal age and education (categorized here dichotomously as with/without university education), parity, and mode of delivery were collected on eligible mother-infant pairs.

Anthropometric measurements

Data on body weight and length and head circumference were abstracted from the infants' charts at birth, and the infants were measured again at 4 and 6 mo by using Seca 757 scales and a Seca model 207 infantometer (Vogel & Halke) and flexible non-stretching tape. BMI was calculated as weight divided by length squared. All data were converted to *z*-scores by using current WHO reference data (20). Maternal weight was also measured at 6 mo (Seca 761 scales; Vogel & Halke).

Dietary assessment

A 3-d weighed food record was obtained when the infant was aged 157 ± 7 d to estimate the intake of complementary foods in the CF group. Parents were advised to keep records for 3 consecutive days and to weigh and record all complementary foods given over this period by using electronic scales accurate to 1 g (Philips model HR 2385). Data on diet were collected during the 4–6-mo study period to determine the date of introduction of the first new food item in both groups. Detailed weighed measurements were not made in the EBF group, but diary records were obtained in all subjects in case complementary foods were initiated in the EBF group before measuring breast-milk intake. Energy intakes were calculated from complementary foods by using nutrient calculation software (ICEFOOD, version 2002; Public Health Institute of Iceland) (21), with added information about infant foods.

Isotope measurements

Breast-milk intake was determined by the deuterium dose-to-the-mother method (22, 23). Briefly, each mother received orally ~10 g deuterium oxide ($^2\text{H}_2\text{O}$) diluted in ~50 g drinking water. The dose consumed was determined accurately to 0.01 g. Pre-dose urine samples were obtained from mothers and infants. Additional urine samples were collected from the mothers on days 1, 4, and 14 and from the infants on days 1, 3, 4, 13, and 14. A second isotope dose (0.05 g deuterium/kg body weight) was given orally to the infants on day 14 to calculate total body water; further infant urine samples were collected 5 h after the dose and on day 16.

Infant urine samples were obtained by placing an absorbent cotton pad in the diaper, which was checked every 30 min for wetness. The time of urination was taken as the midpoint between the last time it was dry and the time it was wet. Urine was transferred to 2-mL cryogenic tubes and stored at -20°C . Urine and dose samples were transported frozen to the United Kingdom for isotope-ratio mass spectrometry (Delta XP; Thermo

Fisher Scientific). Samples were analyzed in duplicate (precision 1.4 delta units) by using the equilibration method.

Modeling

Total body water was calculated by using the back-extrapolation method in both mothers and infants (24). Dilution spaces were assumed to overestimate body water by a factor of 1.044 (25). Breast-milk intake was calculated by fitting the isotopic (tracer) data to a model for water (tracee) turnover in the mothers and infants, and the transfer of milk from mother to infant, on the basis of equations and assumptions described previously (22, 23). A “solver” function in Excel (Microsoft) was used to minimize the sum of squares of differences between observed and fitted values for maternal and infant data combined.

Statistical analyses

The sample size calculations were based on the primary hypothesis that EBF infants would have higher breast-milk intakes than CF infants. Fifty mother-infant pairs per group allowed us to detect differences of ≥ 75 g/d with 80% power and 5% significance, which is equivalent to ~ 0.6 SD (23). Recruitment continued until 100 mother-infant pairs completed the study. Independent *t* tests and chi-square tests were used to compare results between groups. Regression analysis, with a dummy variable for feeding group, was used to test group differences in breast milk with adjustment for confounding variables. Exploratory analyses were used to identify factors associated with EBF mothers introducing any non-breast-milk foods during the period

of breast-milk measurement. The index of potential harm assessed was growth status.

Randomization

With the use of specially designed software (www.randomization.com), permuted blocks of 2 and 4 with the sequence presented in random order were used to generate assignments, which were accessed by using a password-protected Web-based application after eligibility criteria were confirmed. Assignments were generated by one person who was not involved in any other aspect of the study. After randomization, one mother who was randomly assigned to the CF group was incorrectly instructed to the EBF group. We performed the primary analyses with this mother included in the EBF group ($n = 50$ EBF, 50 CF) but have reported outcomes for the baseline analyses with this subject in the CF group ($n = 49$ EBF, 51 CF). Nurses who collected data on complementary food intakes and anthropometric outcomes were not blinded to participant group status, but all mass spectrometric analyses and isotopic modeling were blinded.

RESULTS

A total of 119 mother-infant pairs were recruited, of whom 100 completed the trial protocol (Figure 1). Among the 10 CF mothers who did not complete the study, either their infants were not given, or did not accept, complementary foods or the mothers stopped breastfeeding or did not complete the study. Seven EBF infants were given complementary foods after 6 mo, whereas 2 EBF mothers did not complete the study. The primary

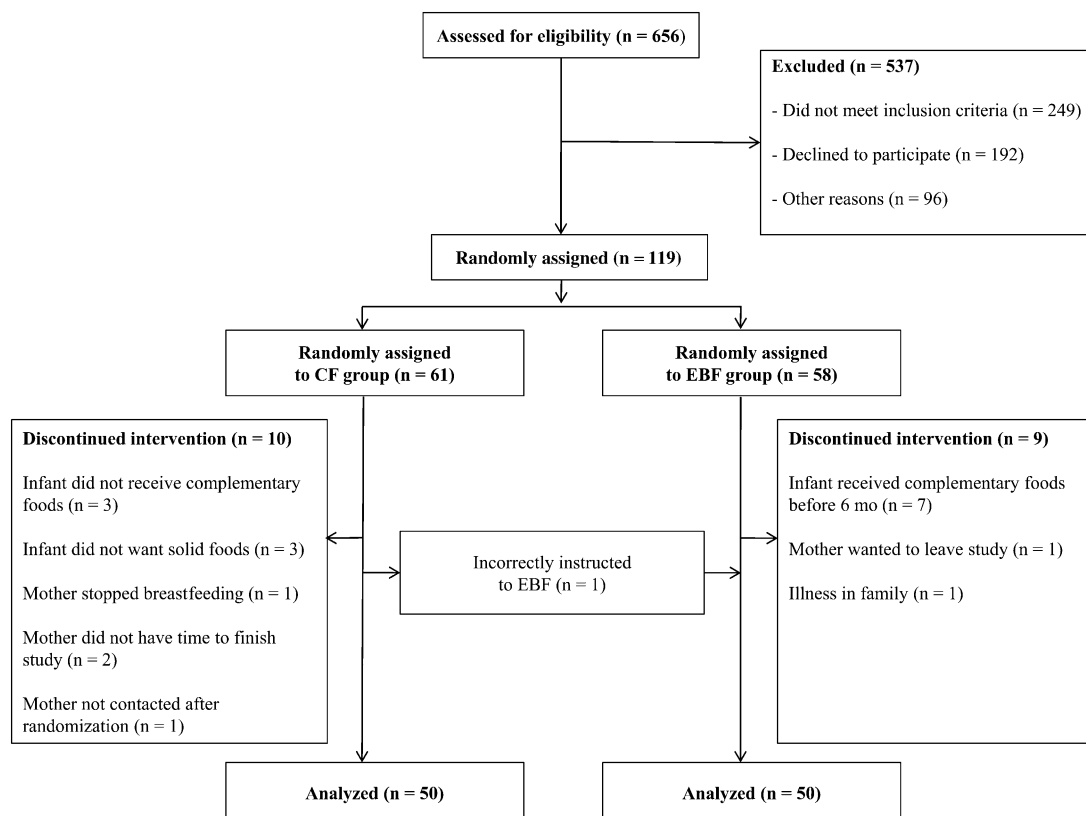


FIGURE 1. Profile of the recruitment process. CF, complementary feeding; EBF, exclusive breastfeeding.

outcome (milk intake) was not measured in the infants whose mothers did not comply with the protocol.

Data on maternal and infant characteristics at birth or at the time of randomization are provided in **Table 1**. There were few differences between completers and noncompleters; however, noncompleting infants were 0.9 cm (95% CI: -0.1, 1.9 cm) longer at 4 mo, which was significant when expressed in *z*-scores (0.42; 95% CI: 0.01, 0.82; *P* = 0.04). Noncompleters were also more likely to be primiparous (dropouts: 10 of 19, 52.6%; completers: 27 of 100, 27%; *P* = 0.027). Within the EBF group, noncompleting infants did not differ in 4-mo anthropometric outcomes compared with completing infants. Within the EBF group, noncompleting mothers were younger than completing mothers (mean \pm SD: 25.0 \pm 3.4 compared with 30.9 \pm 5.1 y; NS) and were significantly more likely to be primiparous (*n* = 6 of 8 compared with *n* = 10 of 50, *P* < 0.001).

The mother-infant pairs in the 2 groups who completed the trial are also compared in Table 1. There were no differences in maternal characteristics or in infant anthropometric outcomes, except that a smaller proportion of the EBF infants were delivered vaginally (46% compared with 36%, *P* = 0.03), and there was a borderline-significant trend for fewer primiparous mothers in the EBF group (*P* = 0.057).

Infant anthropometric outcomes and breast-milk intake at age 6 mo are shown in **Table 2**. Although one mother was instructed to join the wrong group, all mothers in the final analysis successfully followed the isotope protocol for breast-milk intake. Relative to WHO reference values, the sample had significantly greater anthropometric outcome *z*-scores in both groups from birth to age 6 mo. However, there were no significant differences between groups in anthropometric outcomes (**Figure 2**) or in lean or fat mass by deuterium dilution.

Mean (\pm SD) breast-milk intake in the EBF group was 901 \pm 158 g/d, which was higher than the WHO reference values of 854 \pm 24 g/d (Δ = 47 g/d; 95% CI: 2, 92 g/d; *P* = 0.04). The CF group consumed 818 \pm 166 g breast milk/d, which was not significantly different from the WHO reference values (Δ = -36; 95% CI: -83, 11 g/d). The EBF group therefore consumed 83 g/d (95% CI: 19, 148 g/d) more breast milk than did the CF group (*P* = 0.012). Regression analysis showed that, holding constant for primiparity and mode of delivery, the EBF group still consumed significantly more breast milk (Δ = 83 g/d; 95% CI: 18, 154 g/d). None of the findings for growth, body composition, or breast-milk intake (Δ = 76; 95% CI: 11, 141 g/d) changed if the analysis was conducted for the 2 groups as originally randomized (ie, 51 CF compared with 49 EBF infants).

The average daily intake of complementary foods among CF infants was 92.2 g and included 43% water given as a drink or as part of foods prepared by the parents, such as porridge. The remaining foods included 17% infant formula, 16% fruit purée, 12% fruit/vegetables, 9% infant cereal (dry mass), and small amounts of other foods. Mean (\pm SD) daily energy intake was 63.4 \pm 52.3 kcal, which is equivalent to 265.4 \pm 219 kJ, of which 49% was attributable to infant cereals, 12% to fruit/vegetables, 18% to infant formula, 13% to fruit purée, 3% to oils or butter, 1% to infant vitamin or cod liver oil, and 4% to other foods.

During the 2-wk period of isotope measurement, a small proportion of mothers in the EBF group gave their infants either water (*n* = 4; 8% of the group), sugar water (*n* = 1; 2%), formula milk (*n* = 3; 6%), or rice porridge (*n* = 2; 4%). In total, 6 mothers (12%) gave their infants some energy-containing fluids or foods other than breast milk. In most cases, however, the amounts were

TABLE 1

Baseline characteristics of subjects who completed the study compared with dropouts and of the 2 groups of mothers and infants¹

	Completing (<i>n</i> = 100)	Noncompleting (<i>n</i> = 19)	<i>P</i>	CF group (<i>n</i> = 51)	EBF group (<i>n</i> = 49)	<i>P</i>
Maternal data						
University education (<i>n</i>)	54	11	0.76 ²	31	24	0.23 ²
Primiparous (<i>n</i>)	27	10	0.027 ²	18	9	0.057 ²
Multiparous (<i>n</i>)	73	9		33	40	
Vaginal delivery (<i>n</i>)	83	89	0.48 ²	46	36	0.02 ²
Weight (kg)	—	—	—	73.0 \pm 15.5	71.3 \pm 12.4	0.5
Age (y)	30.2 \pm 4.8 ³	28.1 \pm 6.9	0.22	29.7 \pm 4.4	30.7 \pm 5.1	0.2
Infant data						
Male (<i>n</i>)	46	9	0.9 ²	25	21	0.5 ²
Age at enrollment (d)	123.0 \pm 3.3	122.0 \pm 3.9	0.77	123.0 \pm 3.4	123.0 \pm 3.2	0.95
Gestational age (d)	280.9 \pm 8.3	278.6 \pm 11.5	0.29	279.6 \pm 8.8	277.9 \pm 8.1	0.3
Birth weight (kg)	3.71 \pm 0.48	3.67 \pm 0.37	0.75	3.70 \pm 0.44	3.71 \pm 0.52	0.9
Birth weight <i>z</i> -score ⁴	0.83 \pm 0.94	0.77 \pm 0.65	0.77	0.82 ⁵ \pm 0.89	0.83 ⁵ \pm 1.00	0.9
Weight at age 4 mo (kg)	7.0 \pm 0.9	7.0 \pm 0.6	1.00	7.05 \pm 1.00	6.99 \pm 0.81	0.9
Weight <i>z</i> -score ⁴	0.33 \pm 0.95	0.37 \pm 0.57	0.89	0.34 ⁵ \pm 1.05	0.33 ⁵ \pm 0.83	0.9
Length at age 4 mo (cm)	64.4 \pm 2.1	65.1 \pm 1.8	0.13	64.3 \pm 2.3	64.5 \pm 1.9	0.7
Length <i>z</i> -score ⁴	0.65 \pm 0.86	1.07 \pm 0.59	0.04	0.58 ⁵ \pm 0.91	0.72 ⁵ \pm 0.80	0.4

¹ All comparisons were made by independent *t* test except where indicated otherwise. CF, complementary feeding; EBF, exclusive breastfeeding.

² Chi-square test.

³ Mean \pm SD (all such values).

⁴ Calculated by using WHO reference data (18).

⁵ Significantly different from WHO mean values, *P* < 0.05.

TABLE 2Age, size, body composition, and breast-milk intake of the infants at age 6 mo¹

	CF group (n = 50)	EBF group (n = 50)	Difference between groups ²	P
Age (d)	186.7 ± 7.1 ³	187.3 ± 6.6	0.6 (−3.3, 2.2) ⁴	0.6
Weight (kg)	7.96 ± 1.06	8.01 ± 1.04	0.05 (−0.47, 0.37)	0.8
Weight z-score	0.28 ± 1.08	0.36 ⁵ ± 0.99	−0.08 (−0.49, 0.33)	0.7
Length z-score	0.60 ⁵ ± 0.92	0.77 ⁵ ± 0.84	0.17 (−0.52, 0.18)	0.3
BMI z-score	−0.08 ± 1.14	−0.10 ± 1.04	−0.03 (−0.41, 0.46)	0.9
Head circumference z-score	0.94 ⁵ ± 0.77	1.02 ⁵ ± 0.89	0.07 (−0.26, 0.40)	0.6
Lean mass (kg) ^{6,7}	5.13 ± 0.92	4.96 ± 1.18	−0.17 (−0.28, 0.62)	0.4
Fat mass (kg) ^{6,7}	2.71 ± 0.96	3.04 ± 1.12	0.33 (−0.77, 0.11)	0.14
Breast-milk intake ⁶ (g/d)	818 ± 166	901 ± 158	83 (19, 148)	0.012

¹ CF, complementary feeding; EBF, exclusive breastfeeding.² Differences between groups tested by independent *t* test³ Mean ± SD (all such values).⁴ Mean; 95% CI in parentheses (all such values).⁵ Significantly different from WHO mean values by paired *t* test, *P* < 0.05.⁶ Determined by using isotope measurements.⁷ *n* = 43 and 46 for CF and EBF groups, respectively.

very small, occurred on one day only, and contained very little energy. Because the isotope method estimates deuterium transfer from the mother, these extra fluids do not compromise the accuracy of breast-milk intake values. Only 2 mothers gave their infants any significant quantity of energy other than breast milk during the isotope study period: one fed her infant 200 mL of infant formula on one day only, whereas one mother provided 4–5 spoons of rice porridge almost daily. Breast-milk intake of the 6 infants who received any extra calories was marginally (26 g/d; 95% CI: −166, 113 g/d) higher than that in the remaining 44 EBF infants (mean ± SD intakes: 924 ± 192 compared with 898 ± 155 g/d), suggesting they were hungrier, but the difference was not significant. If these 6 infants were excluded, the remaining 44 EBF infants still consumed significantly more breast milk than did the 50 CF group infants (Δ = 80 g/d; 95% CI: 13, 146 g/d; *P* = 0.018).

DISCUSSION

Our trial, which, to our knowledge, is the first of its kind in a population with average growth rates consistent with current WHO reference data throughout infancy, showed that infants of mothers randomly assigned to 6 mo of EBF showed satisfactory growth and had average breast-milk intakes slightly above WHO reference values (26). Infants randomly assigned to complementary foods at age 4 mo consumed significantly less breast milk at age 6 mo. Our approach allowed experimental disentangling of the effect of introducing complementary foods on breast-milk intake from the effects of baseline maternal or infant factors that may affect both infant diet and growth. Our findings were similar to those of 2 trials in Honduras, a population with a high frequency of low-birth-weight infants, where breast-milk intake at age 6 mo was greater in EBF than in CF infants, although growth rates were similar (14, 15).

The comparison of intakes of breast milk and complementary foods between groups of infants, whose behavior or social circumstances may drive the pattern of weaning, has long been a challenge. Measurement of breast-milk intake is also challenging, because intakes are “invisible” and cannot be readily

studied using approaches common in other age groups. Techniques adapted for infants, such as test-weighing, may intrude on the normal behavior of mothers and/or infants and hence bias the results (27). Despite the enormous emphasis placed on the value of breastfeeding for short- and long-term health, objective data on breast-milk intakes remain sparse, although a review of objective isotope data from 12 countries was recently published (28). A third challenge is that rates of EBF at age 6 mo are typically <15% in industrialized populations [Canada, 13.8%; United States, 11.3%; Sweden, 10.1%; Norway, 7% (29–32)] and only ~1% in the United Kingdom (12).

We addressed these challenges in a randomized trial in Iceland by using an established isotope method to obtain objective data on breast-milk intake. In a national cohort in 1995–1997, rates of EBF in Iceland were 88% at 1 mo, 69% at 3 mo, and 46% at 4 mo (33), whereas in a 2005–2007 cohort, rates were higher (34).

Previous data on our research question are sparse. In a review of observational data from 8 developed country populations, the mean (±SD) breast-milk intake in 93 EBF infants at age 6 mo was 854 ± 118 g/d, although individual population averages ranged from 800 ± 120 to 925 ± 112 g/d (26). There is concern

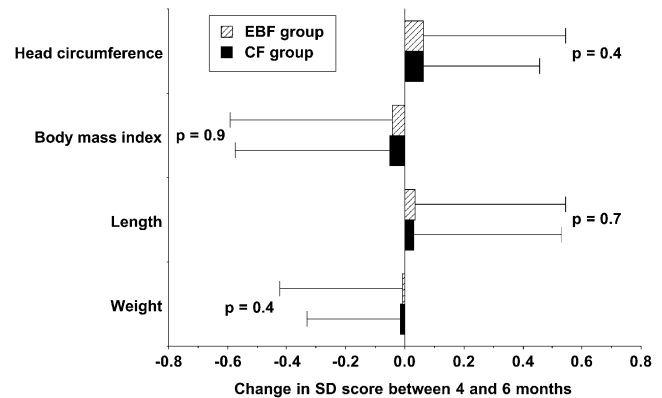


FIGURE 2. Changes in anthropometric z-scores between ages 4 and 6 mo in EBF and CF groups. The average changes did not differ between groups (all *P* values were >0.4). Error bars represent SD. CF, complementary feeding; EBF, exclusive breastfeeding.

regarding the utility of these test-weighting values from highly selected populations as a reference. Randomized trials enable these concerns to be addressed. Data from 2 randomized trials from Honduras indicated no adverse effect of 6 mo of EBF on growth (14, 15), but whether this applies to populations with larger infant sizes requires confirmation.

The mothers in our trial showed a high degree of compliance with the protocol. The majority (88%) of completing EBF mothers reported giving no energy-containing food to their infants up to the end of the isotope measurement, and of those who provided such foods, only 2 did so in any significant quantity. The exclusion of these infants did not affect our findings. However, another 7 EBF infants were dropped from the study because they were given complementary foods; hence, the total EBF compliance rate was 77%. For CF infants, the compliance rate was 82%. Because the primary outcomes were not measured in those not complying with the full protocol, our analysis was restricted to the 100 infants with isotopic data.

We calculated energy consumption with the assumption that the metabolizable energy content of breast milk at age 6 mo is 62.1 kcal/100 g (4). Current WHO guidelines for energy requirements in breastfed infants at age 6 mo are 78 kcal · kg⁻¹ · d⁻¹ (35), which in this study would equate to 625 kcal/d for the average EBF infant in this study. The EBF infants received 560 ± 98.2 kcal/d, which is equivalent to 90.1% of the recommendation. The CF group received 508 ± 103 kcal/d from breast milk plus 63 ± 53.2 kcal/d from complementary foods, totaling 571 ± 97 kcal/d, which is equivalent to 92.7% of the recommendation. Our data therefore show an apparent inconsistency, in that the infants appear to meet WHO recommendations for breast-milk intake but not energy intake. This may be because the WHO recommendations were calculated from total energy expenditure data in predominantly, not exclusively, breastfed infants. Introducing formula milk or cow milk into the diet increases infant energy expenditure (35, 36); hence, the value of 78 kcal · kg⁻¹ · d⁻¹ may be an overestimate of actual energy requirements in EBF infants. It is also possible that the energy content of breast milk in our population is >62.1 kcal/100g, and this merits further research.

The similar estimated energy intakes of the 2 groups indicate that complementary foods acted primarily to replace breast milk. Given the similarity between groups in body weight throughout the trial and in body composition and estimated energy intake at age 6 mo, we assume that infant appetite was the key factor driving energy intake.

There was no indication of energy inadequacy in the EBF infants. Anthropometric outcome *z*-scores were consistently above zero; although this partly reflects the infants' large size at birth, which is typical in the Icelandic population (37), *z*-scores at ages 4 and 6 mo in the 2 groups were very similar, as was lean mass at age 6 mo, giving no indication of faltering in the EBF group. However, each group also showed variability, and we were unable to determine whether those infants within each group who grew less between birth and 6 mo had insufficient breast-milk intakes earlier in infancy.

We have highlighted the fact that previously published evidence on breast-milk intakes did not support the proposition that the average infant could satisfy his or her energy requirements at age 6 mo from breast milk alone (4, 38). This suggestion was not intended to undermine breastfeeding but rather to promote further research into this important issue. Mothers themselves commonly

cite concern that their breast milk has become insufficient as a source of nutrition for their infant as a reason for introducing formula-milk or complementary foods (39, 40); hence, evidence on the breast-milk intakes of EBF infants will help encourage mothers to breastfeed. In the present study, we have shown that the large majority (77%) of a sample of mothers practicing EBF at 4 mo successfully continued EBF to 6 mo, with their infants showing adequate growth. Another longitudinal study, in Glasgow, showed that EBF mothers recruited from breastfeeding support groups increased breast-milk output between 4 and 6 mo (41). Thus, both of these studies rebut our challenge and suggest that EBF successfully meets energy requirements, but further work will be required to determine whether all mothers in this and other populations could achieve this outcome.

The strengths of our study include its randomized design and the use of an objective method for measuring breast-milk intake. Conducting the study in Iceland represents both a strength, because EBF is sufficiently common there for a randomized trial to be feasible, and a limitation, because the cold environment and high birth weight are not typical of most European populations, which reduces generalizability. The 2 feeding groups differed at baseline in the mode of delivery and maternal parity; however, these differences were relatively minor and did not account for our main findings regarding breast-milk or complementary food intakes. We were not able to test whether those who dropped out of the study were those with lower breast milk intakes—ie, potentially a self-selected group. Finally, our study was designed to evaluate growth and energy intake and not other issues such as development of dietary preferences, mineral status, or effects on health such as diarrhea and allergy.

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The responsibilities of the authors were as follows:—GG, AL, MSF, REK, PLH, JCKW, and IT: designed the study; OHJ: was responsible for the nutritional and isotope data collection; SE: was responsible for the mass spectrometric analyses; and JCKW: undertook the isotope calculations and, after extensive discussions among the study team, conducted the statistical analysis and wrote the first draft of the manuscript. All authors critically revised the manuscript and had full access to all of the data in this study and take complete responsibility for the integrity of the data and the accuracy of the data analysis. The study sponsors had no role in study design; in the collection, analysis, and interpretation of data; in the writing of the report; or in the decision to submit the manuscript for publication. None of the authors declared a conflict of interest.

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