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ORIGINAL COMMUNICATION

Relations between high ponderal index at birth, feeding practices and body mass index in infancy

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Objective: We compared feeding practices between infants of high ponderal index (PI) at birth (PI above the 90th percentile) and normal PI at birth (PI between 10th and 90th percentiles), and examined how birth size and infant feeding practices were related to body mass index (BMI) at 12 months.
Design: In a cohort of 3000 infants invited to participate in a national Norwegian dietary survey, 1825 participated both at 6 and 12 months of age, and the present study included those born full term and with a PI (weight/length^3) at birth $\geq$10th percentile ($n=1441$). Data on feeding practices were collected by food-frequency questionnaires, and anthropometrical data were measured by health-care personnel.
Results: A lower proportion of infants born with high PI were exclusively breastfed for at least 4 months compared with infants born with normal PI (37 and 47%, respectively; $P=0.03$). Earlier introduction of solid foods and higher consumption of some foods were also observed among infants of high PI. In a multivariate analysis, adjusted mean BMI (kg/m^2) at 12 months was higher for infants of high PI at birth than for infants of normal PI (17.6 and 17.0, respectively; $P<0.001$) and higher for infants exclusively breastfed <3 months than for infants exclusively breastfed ≥ 3 months (17.5 and 17.2, respectively; $P=0.001$).
Conclusions: High PI at birth was associated with a shorter duration of exclusive breastfeeding. Furthermore, high PI at birth and short-term exclusive breastfeeding were both associated with higher BMI at 12 months.
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Introduction

The proportion of babies weighing 4000 g or more at birth in Norway has increased from 17. 9% in 1990 to 21.1% in 2002 (Medical Birth Registry of Norway, 2004). A similar trend has also been described in other Nordic countries (Meeuwisse & Olausson, 1998). The increase in birth weight observed in Norway coincides with an increase in body mass index (BMI) and obesity among Norwegian women of childbearing ages (Jacobsen *et al*, 2001).

Several studies have found a positive association between birth weight and BMI or overweight/obesity in childhood and young adulthood (Martorell *et al*, 2001; Rogers *et al*, 2003). A positive association between ponderal index

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(PI; weight/length^3), as a measure of relative weight at birth, and later BMI has also been reported (Pietiläinen *et al*, 2001). Furthermore, early dietary habits have been related to later BMI and obesity, and studies suggest that breastfeeding may reduce the risk of childhood obesity (Dewey, 2003), while consumption of sugar-sweetened drinks in childhood may increase the risk (Ludwig *et al*, 2001). BMI in infancy has been positively associated with BMI later in childhood (Fuentes *et al*, 2003). Studies in infancy on relations between birth size, feeding practices and BMI are sparse. In particular, infants born with high PI (indicating overweight at birth) may be exposed to feeding practices that are different from those of infants born with normal PI. However, we are not aware of any previous studies with special focus on the possible relations between birth size and infant feeding practices. Considering the worldwide epidemic of obesity (World Health Organization, 2003), increased knowledge of early feeding practices and other factors that, already from infancy on, may be related to BMI and obesity is important.

Based on data from a large national infant dietary survey, we compared feeding practices during the first year of life between infants of high and normal PI at birth, and examined how birth size and infant feeding practices were related to BMI at 12 months of age.

Subjects and methods

Subjects and design

A national dietary survey included all 3000 infants born in Norway during a 3-week period from April 27 until May 17, 1998, of mothers born in Norway or another Scandinavian country. The infants' mothers/parents were invited to participate at two occasions, when their children were 6 and 12 months of age. They first received a semiquantitative food-frequency questionnaire (SFFQ) by mail about 2 weeks before the infants turned 6 months, and then another food-frequency questionnaire about 2 weeks before the infants turned 12 months old. Parents were asked to fill in the questionnaires as closely to the child's 6-month and 1-y birthday as possible, and to bring the questionnaires to the regular 6- and 12-months check-ups at the child health clinics to obtain data on weight and length. Parents were then asked to return the completed questionnaires in pre paid envelopes. A total of 2383 (80%) and 1934 infants (66%) participated at 6 and 12 months, respectively.

The Regional Ethics Committee for Medical Research approved the study, and written informed consent was obtained from the parents. Statistics Norway was responsible for data collection. More detailed descriptions of the sample and design have been presented previously (Lande *et al*, 2003, 2004).

Semiquantitative food-frequency questionnaires

Two SFFQs were designed to describe feeding practices at 6 and 12 months of age, respectively, and also feeding practices from birth up to 12 months of age. Parents were asked to describe habitual feeding practices at 6 and 12 months and to keep in mind their child's diet over the past 14 days when filling in the questionnaires. The 6-month SFFQ included questions on frequency of use of about 40 food and drink items. For infant formula/cow's milk and commercial infant porridge, categories for amounts and photos of portion sizes were also included. The 12-month SFFQ included questions on frequency of use and amount of about 140 food and drink items. A booklet with photos of portions sizes was provided to report amounts. When no photo was available for a food item, household units were used (eg, slices, pieces and spoonfuls). The SFFQs also provided information on the mother's and father's educational levels, gestational age of infant at birth, number of children the mother had and maternal employment status. Information on maternal smoking status in pregnancy and when the child was 6 months old was reported in the 6-month SFFQ. More detailed descriptions of the SFFQs and results from the validation of the 12-month SFFQ have been presented elsewhere (Andersen *et al*, 2003; Lande *et al*, 2003, 2004). In summary, the validation study found that the SFFQ gave acceptable estimates for average intakes of foods, drinks and nutrient densities, while most of the absolute intakes of nutrients were overestimated. The capability of the SFFQ to rank infants according to intakes of nutrients, foods and drinks was moderate, but at the same levels as others has observed with SFFQs (Andersen *et al*, 2003).

Intakes of foods, drinks, energy and nutrients were computed using a food database and a software system developed at the Department of Nutrition, University of Oslo. The food database is based mainly on the official Norwegian food composition table (Statens ernæringsråd and Statens næringsmiddeltilsyn, 1995), and is continuously supplemented with data on new food items and nutrients. The use of cod liver oil and other vitamin/mineral supplements was included in nutrient calculations. Breast-milk intake was not quantified. At 6 months, as mostly frequencies and not amounts of foods and drinks were assessed, mainly proportions of consumers of various foods and drinks were computed, and energy and nutrient intakes could not be calculated at this age.

Breastfeeding classification

In the SFFQs, we asked whether and how often the child received breast milk at 6 and 12 months. Data on breastfeeding from birth up to 6 months and from 7 months up to 12 months were obtained via retrospective questions about the age at which breastfeeding was stopped. We asked specifically at what age the child started receiving infant formula/other milk, other liquids (water not included) and when the child received solid or semisolid foods for the first time. The classifications of exclusive breastfeeding and breastfeeding in this paper are based on WHO (1999) definitions. However, for exclusive breastfeeding water

intake was allowed. The term breastfeeding included all infants who received breast milk, both those exclusively breastfed and those given complementary foods in addition to breast milk.

Length and weight measurements

In Norway, health-care personnel measure infant length and weight routinely at hospitals at birth and at child health clinics at 6 and 12 months of age. Health-care personnel at the child health clinics were asked to assure weight and length measurements of the participating children at the 6- and 12-month check-ups, to fill in these data in the SFFQs, and also to fill in data on birth weight and length given on the children's health cards. Weights were reported in grams and lengths to the nearest centimetre. Measurements were carried out according to general methods used at the hospitals and child health clinics in Norway.

The following weight-for-length ratios were calculated, PI (kg/m^3) at birth and BMI (kg/m^2) at 6 and 12 months of age.

Other data collected

Statistics Norway provided data from the Central Population Register on infant gender, maternal age, marital status, degree of urbanisation and geographical region.

Study sample

The 1825 infants who participated both at 6 and 12 months of age formed the basis for this study. We included only full-term infants (born after 37 completed weeks of gestation, $n=1616$) who had a PI at birth $\geq$10th percentile for the full-term infants. The infants were classified as high PI at birth if PI for the full-term infants was above the 90th percentile and as normal PI at birth if PI was between 10th and 90th percentiles. These two groups comprised the study sample of 1441 infants. The classification was performed separately for boys and girls. Thus, the high PI and normal PI groups included equal proportions of boys and girls.

Statistical analyses

Intakes of foods and drinks are presented as means, medians and the 25th and 75th percentiles. Anthropometrical data are presented as means with standard deviations (s.d.s). Comparisons between infants of high PI and normal PI were performed by the Mann–Whitney *U*-test for food intakes, by the Student's *t*-test for anthropometrical data, breastfeeding frequency and intakes of energy and nutrients, and by a χ^2 test for use of complementary foods at 6 months, breastfeeding duration, introduction of infant formula, exclusive breastfeeding and introduction of solid foods. The analyses of the two latter feeding practices were supplemented with logistic regression analyses, with adjustment for maternal and infant characteristics and demographic variables.

Multiple linear regression analysis was applied to study associations between birth size, infant feeding practices and BMI at 12 months. The results are presented as crude and adjusted means with 95% confidence intervals (CIs). Potential interaction effects were assessed. We used both univariate analyses (with a lax criterion of $P<0.10$) and evidence from the literature to decide which variables to include in the multivariate analysis. The final model included only significant variables ($P<0.05$). Statistical significance was tested by the likelihood ratio test, and tests for trends across categories were performed by treating the categories as continuous variables. The regression analysis included birth size (high and normal PI as described earlier), duration of breastfeeding (<6, 6–11 and $\geq$12 months), exclusive breastfeeding (two different categorizations: <4 and $\geq$4 months; <3 and $\geq$3 months), introduction of solid foods (<4, 4–5 and >5 months) and breastfeeding frequencies at 6 and 12 months (times/24 h). For feeding practices at 6 months, intakes of commercial infant porridge and infant formula and proportion of consumers of different foods and drinks (listed in Table 2) were analysed. For feeding practices at 12 months, intakes of selected foods and drinks (listed in Table 3) and intakes of energy and nutrients (fat, protein, carbohydrates, saturated fatty acids, monounsaturated fatty acids, polyunsaturated fatty acids, added sugar and fibre) from foods and drinks other than breast milk were analysed. The analysis also included the mother's and the father's educational levels ($\leq$10, 11–12 and $\geq$13 years), maternal age (<25, 25–34 and $\geq$35 years), maternal employment status when the child was 12 months old (not working, working part-time and working full-time), marital status (married, cohabitant and not married/cohabitant), degree of urbanisation (<2000, 2000–19 999, 20 000–99 999 and $\geq$100 000 inhabitants) and geographic region (Capital and surroundings, East region, South, West, Middle and North region). Finally, the analysis included first-born status of the child (yes or no) and maternal smoking (yes or no) in pregnancy or when the child was 6 months old.

All *P*-values were two-sided, and a 5% level of significance was used. All statistical analyses were performed with SPSS (version 11.0; SPSS Inc., Chicago).

Results

Characteristics of the final study sample ($n=1441$) and their mothers are presented in Table 1. No significant differences were found between infants of high PI at birth ($n=158$) and normal PI at birth ($n=1283$) regarding maternal age, education or smoking. A significantly lower proportion of infants born with high PI were a first-born child (30 and 39%, respectively). Infants born with high PI had a mean PI (kg/m^3) at birth of 33.4 (s.d. = 2.4) and infants born with normal PI had a PI of 28.3 (s.d. = 1.6).

Table 1 Selected characteristics[a] for infants born with normal ponderal index (PI) and infants born with high PI[b]

Characteristic	Normal PI (n = 1283)	High PI (n = 158)	Total (n = 1441)
Mothers			
Age (y)			
<25	160 (12)	16 (10)	176 (12)
25–34	910 (71)	108 (68)	1018 (71)
≥35	213 (17)	34 (22)	247 (17)
Education (y)[c]			
≤10	123 (10)	12 (8)	135 (10)
11–12	506 (41)	62 (40)	568 (41)
≥13	616 (49)	80 (52)	696 (50)
Smoking in pregnancy[c]	306 (24)	38 (24)	344 (24)
Smoking when the child was 6 months old[c]	310 (24)	35 (22)	345 (24)
Infants			
First-born child[c]	505 (39)	47 (30)[d]	552 (38)
Boys	683 (53)	84 (53)	767 (53)
Birth weight (g)	3747 (451)	4180 (509)[e]	3795 (477)
Birth weight ≥4000 g	351 (27)	102 (65)[f]	453 (31)
Birth length (cm)	50.9 (1.9)	50.0 (2.0)[e]	50.8 (2.0)

[a]Number (%) for categorical variables and mean (s.d.) for continuous variables.
[b]Normal PI (weight/length^3; kg/m^3) at birth is defined as PI between the 10th and 90th percentiles; that is, $25.2 \leq PI \leq 31.3$ for boys and $25.2 \leq PI \leq 31.8$ for girls. High PI at birth is defined as PI above the 90th percentile.
[c]Education: $n = 1399$; smoking in pregnancy: $n = 1436$; smoking when the child was 6 months old: $n = 1439$; and first-born child: $n = 1436$.
[d]Significant difference between the birth-size groups (χ^2 test), $P = 0.02$.
[e]Significant difference between the birth-size groups (Student's *t*-test), $P < 0.001$.
[f]Significant difference between the birth-size groups (χ^2 test), $P < 0.001$.

Table 2 Comparison of exclusive breastfeeding, breastfeeding duration, introduction of infant formula, time for introduction of solid foods and use of complementary foods at 6 months of age among infants born with normal ponderal index (PI) and infants born with high PI[a], $n = 1441$

Feeding practice	Normal PI (n = 1283) (%)	High PI (n = 158) (%)	P[b]
Exclusive breastfeeding ≥4 months	47	37	0.03
Breastfeeding duration (months)			
<6	16	18	
6–11	47	49	
≥12	37	33	0.56
Introduction of infant formula ≤4 months of age	24	24	0.94
Time for introduction of solid foods (age in months)			
≤4	20	27	
4–5	58	60	
>5	22	13	0.02
Daily or weekly use of complementary foods at 6 months of age			
Vegetables/potatoes	39	34	0.24
Meat with vegetables/ potatoes	42	52	0.02
Fish with vegetables/ potatoes	3	3	0.71
Fruit and berries	53	57	0.38
Yoghurt	7	13	0.02
Commercial baby drink/ sugar-sweetened squash	27	36	0.01
Juice	1	2	0.69
Water	42	45	0.45

[a]Normal PI (weight/length^3) at birth is defined as PI between the 10th and 90th percentiles. High PI at birth is defined as PI above the 90th percentile.
[b]χ^2 test.

High PI at birth and infant-feeding practices

A significantly lower proportion of infants born with high PI were exclusively breastfed for 4 months or longer compared with infants born with normal PI (37 and 47%, respectively) (Table 2). Infants of high PI at birth were introduced to solid foods significantly earlier than infants of normal PI, whereas no significant differences were found for introduction of infant formula or breastfeeding duration. Furthermore, among breastfed infants, we found no significant differences in breastfeeding frequencies (times/24 h) at 6 and 12 months of age between infants of high and normal PI at birth ($P = 0.25$ and 0.42, respectively, data not shown). In addition, we performed multivariate logistic regression analyses of exclusive breastfeeding for 4 months or longer and early introduction of solid foods (before 4 months). These two variables were significantly associated with birth size also after adjustment for demographic variables, maternal characteristics (eg, maternal age, education and smoking) and infant gender (data not shown) that previously were found to be associated with exclusive breastfeeding and time for introduction of solid foods among 6-month-old infants (Lande *et al*, 2003).

Significantly higher proportions of infants born with high PI compared with infants born with normal PI were consumers of meat with vegetables/potatoes, yoghurt and commercial baby drink/sweetened squash at 6 months of age (Table 2). Furthermore, infants born with high PI had significantly higher daily intakes of commercial infant porridge at 6 months and of meat/meat products at 12 months than infants born with normal PI, and there was a weak indication of a higher intake of sugar-sweetened drinks at 12 months among those born with high PI ($P = 0.09$) (Table 3).

When comparing intakes of energy, macro- and micronutrients at 12 months of age (from foods and drinks other than breast milk), no significant differences between infants of high and normal PI at birth were found ($0.06 \leq P \leq 0.99$, data not shown).

Table 3 Comparison of intakes of foods and drinks (g/day) at 6 and 12 months of age among infants born with normal ponderal index (PI) and infants born with high PI[a], $n = 1441$

	Normal PI (n = *1283)*		*High PI* (n = *158)*	
	Mean	*Median (25th–75th percentiles)*	*Mean*	*Median (25th–75th percentiles)*
6 months of age				
Commercial infant porridge	164	129 (50–229)	206	175 (100–300)[b]
Infant formula as a drink	147	0 (0–120)	159	0 (0–94)
12 months of age				
Commercial infant porridge	226	200 (43–400)	214	200 (25–300)
Bread	61	53 (30–82)	65	59 (32–89)
Vegetables and potatoes[c]	97	77 (39–127)	103	85 (37–137)
Meat/meat products[d]	30	26 (15–41)	36	31 (18–46)[e]
Com. infant dinner with meat[d,f]	94	56 (0–126)	99	84 (0–126)
Fish/fish products	10	7 (1–14)	12	9 (1–16)
Com. infant dinner with fish[f]	12	0 (0–0)	12	0 (0–0)
Fruit and berries[g]	88	73 (39–117)	89	73 (40–117)
Yoghurt	62	36 (9–89)	60	36 (9–111)
Margarine and butter (as spreads)	12	10 (5–16)	12	10 (5–16)
Infant formula as a drink	102	0 (0–51)	95	0 (0–45)
Cow's milk as a drink	193	120 (0–360)	217	180 (17–360)
Juice	22	0 (0–17)	22	0 (0–17)
Commercial baby drinks	13	0 (0–0)	13	0 (0–0)
Sugar-sweetened drinks[h]	78	34 (0–120)	92	34 (0–120)
Water	194	180 (60–300)	175	120 (43–240)

[a]Normal PI (weight/length^3) at birth is defined as PI between the 10th and 90th percentiles. High PI at birth is defined as PI above the 90th percentile.
[b]Significant difference between the birth-size groups (Mann–Whitney *U*-test): $P<0.01$.
[c]Vegetables and potatoes in commercial infant food with meat or with fish are not included.
[d]Liver and liver products are included.
[e]Significant difference between the birth-size groups (Mann–Whitney *U*-test): $P=0.02$.
[f]Vegetables and potatoes are included in commercial infant dinner with meat or with fish.
[g]Jam is not included.
[h]Include squash, nectar and soft drinks.

High PI at birth and weight, length and BMI at 6 and 12 months

Infants of high PI at birth had significantly higher BMIs both at 6 and 12 months of age than infants of normal PI (Table 4). They also had higher weights at 6 and 12 months than infants born with normal PI, though significant differences were observed only for girls. No significant differences were seen in length between the two birth-size groups at 6 and 12 months, except for a lower length in the high PI group at 12 months for boys. The difference in mean weight between the birth-size groups was smaller at 6 and 12 months than at birth (eg, for boys the difference was 453 g at birth, 195 g at 6 months and 211 g at 12 months).

Birth size and feeding practices in relation to BMI at 12 months

Birth size, gender, exclusive breastfeeding, duration of breastfeeding, time for introduction of solid foods, breastfeeding frequency at 6 months, intakes of infant formula at 6 months, margarine and butter (as spreads) at 12 months and cow's milk at 12 months were significantly associated with BMI at 12 months in the univariate analyses ($P \leq 0.02$). In addition, indications of associations with BMI at 12 months were found for use of potatoes/vegetables and water at 6 months, as well as for degree of urbanisation and paternal education ($0.07 \leq P \leq 0.09$).

In the multiple linear regression analysis, only birth size, exclusive breastfeeding, margarine/butter intake (as spreads) at 12 months and gender were significantly associated with BMI at 12 months. Adjusted mean BMI was higher for infants of high PI at birth than for infants of normal PI at birth and higher for those exclusively breastfed for less than 3 months than for those exclusively breastfed for 3 months or longer (Table 5). Moreover, boys had higher BMI than girls ($P<0.001$, data not shown). A significant association with BMI was found for margarine/butter intake (in quartiles) ($P<0.01$), but no significant linear trend was found ($P_{\text{trend}}=0.08$), and the results for the other variables in the model did not change when margarine/butter was excluded from the model (data not shown). No significant interaction was found between any pairs of the variables included in the final model ($P \geq 0.32$). Additional adjustment for sociodemographic variables, maternal smoking and first-born status did not change the results in Table 5 (data not shown).

Breastfeeding and exclusive breastfeeding are related variables. If breastfeeding duration was included instead of exclusive breastfeeding in the multivariate model, a

Table 4 Comparison of weight, length, ponderal index (PI) at birth and weight, length and body mass index (BMI) at 6 and 12 months of age[a] among infants born with normal PI and infants born with high PI[b], $n=1400$[c]

	Boys			Girls		
	Normal PI (n = 658)	High PI (n = 81)	P[d]	Normal PI (n = 588)	High PI (n = 73)	P[d]
Birth						
Weight (g)	3824 (448)	4277 (511)	<0.001	3659 (444)	4067 (483)	<0.001
Length (cm)	51.3 (1.9)	50.5 (1.6)	<0.001	50.5 (1.9)	49.4 (2.3)	<0.001
PI (kg/m^3)	28.2 (1.6)	33.2 (1.9)	<0.001	28.4 (1.7)	33.7 (2.9)	<0.001
6 months of age						
Weight (g)	8523 (915)	8718 (970)	0.07	7796 (919)	8042 (849)	0.03
Length (cm)	69.8 (2.3)	69.4 (2.4)	0.16	67.6 (2.3)	67.2 (2.1)	0.17
BMI (kg/m^2)	17.5 (1.4)	18.1 (1.6)	<0.001	17.0 (1.7)	17.8 (1.6)	<0.001
12 months of age						
Weight (g)	10396 (1091)	10607 (1286)	0.16	9596 (1016)	9861 (972)	0.04
Length (cm)	77.7 (2.5)	77.0 (2.7)	0.02	75.8 (2.5)	75.4 (2.5)	0.26
BMI (kg/m^2)	17.2 (1.4)	17.8 (1.6)	0.001	16.7 (1.4)	17.3 (1.4)	<0.001

[a]Mean (s.d.).
[b]Normal PI (weight/length^3) at birth is defined as PI between the 10th and 90th percentiles. High PI at birth is defined as PI above the 90th percentile.
[c]Only infants with data on weight and length both at 6 and 12 months were included.
[d]Student's *t*-test.

Table 5 Birth size and exclusive breastfeeding in relation to body mass index (BMI) at 12 months of age, $n=1412$

	BMI (kg/m^2) at 12 months	
Variables	Crude means (95% CI)	Adjusted means (95% CI)[a]
Birth size[b]		
Normal PI	17.0 (16.9–17.0)	17.0 (16.9–17.1)
High PI	17.6 (17.4–17.8)	17.6 (17.4–17.9)
P	<0.001	<0.001
Exclusive breastfeeding (months)		
≥3	16.9 (16.8–17.0)	17.2 (17.1–17.3)
<3	17.3 (17.1–17.4)	17.5 (17.3–17.6)
P	<0.001	0.001

[a]Adjusted for gender, margarine/butter intake (as spreads) at 12 months and the other variable in the table.
[b]Normal ponderal index (PI; weight/length^3) at birth is defined as PI between the 10th and 90th percentiles. High PI at birth is defined as PI above the 90th percentile.

significant linear trend of increasing BMI at 12 months was found with decreasing breastfeeding duration ($P_{trend}<0.01$). The adjusted means (95% CI) were 17.1 (17.0–17.3), 17.3 (17.2–17.4) and 17.5 (17.3–17.7) for breastfeeding durations of ≥12 months, 6–11 months and <6 months, respectively.

Discussion

Our main findings were the significant differences in exclusive breastfeeding, time for introduction of solid foods and use of some foods and drinks between infants of high and normal PI at birth. Furthermore, in a multivariate analysis, we found that both high PI at birth and short-term exclusive breastfeeding were associated with higher BMI at 12 months.

Important strengths of the present study are the longitudinal cohort design, the population-based sample and the relatively large number of participants. We collected detailed data on infant feeding practices from birth to 12 months, including data on exclusive breastfeeding. Furthermore, it is a strength that weight and length were measured by healthcare personnel, although we cannot exclude that measurement procedures may have varied somewhat between clinics. In addition, we had data on several sociodemographic variables and infant and maternal factors, which are considered important in a multivariate analysis of BMI. It is a limitation that we did not have information on maternal BMI as this variable has been found to be associated with birth weight (Baeten *et al*, 2001), infant obesity (Galtier-Dereure *et al*, 2000) and breastfeeding (Rasmussen *et al*, 2001). However, studies have found that the relation between birth weight and BMI or obesity in childhood was independent of maternal and paternal BMI (Rogers *et al*, 2003). Moreover, a study found a relation between breastfeeding and overweight in childhood also after adjustment for prepregnancy maternal BMI (Grummer-Strawn & Mei, 2004). When comparing the background data of those born full term with a PI ≥10th percentile ($n=1808$) in the 6-month survey with those included in the present study, there were no indications of differences regarding maternal age, education, smoking, first-born child, infant gender, birth weight, length or PI. More detailed discussions of the samples and methods of the national dietary survey have been presented earlier (Lande *et al*, 2003, 2004).

This is, to our knowledge, the first time a detailed comparison of feeding practices between infants of high

and normal PI at birth is presented. We found that infants of high PI were exclusively breastfed for a shorter time period than infants of normal PI, and they were introduced earlier to solid foods, whereas no significant difference was found for introduction of infant formula. This might indicate that parents of infants born with high PI may expect or experience that their child needs complementary feeding as solid foods at an earlier age than infants born with normal PI. No significant differences were found for breastfeeding duration or breastfeeding frequencies. At 6 months of age, we found significantly higher consumption of some foods and drinks, such as commercial infant porridge, meat and commercial baby drink/sweetened squash among those born with high PI, and these dietary differences may in part reflect that infants of high PI had a shorter duration of exclusive breastfeeding and an earlier introduction of solid foods than infants of normal PI. At 12 months of age, the only significant dietary difference observed between the two birth-size groups was a higher intake of meat and meat products among those born with high PI. The relatively few differences in food and drink consumption that were found between infants of high and normal PI may reflect that a majority of Norwegian infants are fed in accordance with feeding recommendations (Lande *et al*, 2003). A remaining question is whether there are relations between birth size and dietary habits after the first year of life, when family diet becomes dominant.

In the present study, infants born with high PI had significantly higher BMI at 6 months than those born with normal PI, and this difference remained to 12 months of age. The difference in mean weight between the birth-size groups was largest at birth; however, the weight differences seen at 6 and 12 months of age were comparable. When comparing our data with Norwegian national reference data (Knudtzon *et al*, 1988), we find that the mean weights of infants born with high PI were at the 90th percentile of the national reference data at birth, at the 75th percentile at 6 months, and between the 50th and the 75th percentiles at 12 months. These results are in accordance with findings from earlier (Davies, 1980; Kramer *et al*, 1985) and more recent studies (Hediger *et al*, 1998) showing that, despite a relative slowing of growth rates, especially during the first 6 months, infants born large tend to remain larger than normal-sized through infancy and early childhood.

We found that birth size, exclusive breastfeeding, breastfeeding duration and a few other feeding practices were significantly associated with BMI at 12 months in univariate analyses. In the multivariate analysis, high PI at birth was associated with higher BMI at 12 months than normal PI at birth, and exclusive breastfeeding for less than 3 months was associated with higher BMI than exclusive breastfeeding for at least 3 months. Moreover, being male was associated with a higher BMI at 12 months than being female. In addition, a significant association with BMI was found for intake of margarine/butter as spreads at 12 months. However, as no significant trend for margarine/butter intake (in quartiles) was found, the interpretation of this finding is difficult. Adjustment for sociodemographic factors, maternal smoking and first-born status in the final model did not change the results. We are not aware of any directly comparable studies applying multivariate analysis of BMI in infancy and including comparable variables on infant feeding and birth size. However, Kramer *et al* (1985) found that birth weight, duration of exclusive breastfeeding and gender were significantly associated with BMI at 12 months. Fuentes *et al* (2003) analysed BMI at 6 months and found an indication of a positive association with birth weight ($P=0.057$), a significant association with gender and no significant association with parental education and family history of obesity, whereas variables on infant feeding were not included. Tanaka *et al* (2001) showed that birth weight and weight gain during the first months of life were significantly and positively associated with BMI at 3 y. They did not find associations with BMI at 3 y for early feeding method (breastfed, formulafed or mixedfed at 1 months), or for gender, birth order, parental age or smoking during pregnancy. He *et al* (2000) found that high birth weight (≥ 4 kg) and eating speed were the risk factors for obesity in children aged 0.1–2.9 y, while child and parental physical activity did not show any strong association with childhood obesity.

Our results support studies suggesting that exclusive breastfeeding and breastfeeding are related to BMI. We found that both exclusive breastfeeding and breastfeeding duration were associated with BMI at 12 months. But because exclusive breastfeeding and breastfeeding are related variables, they were not included in the same regression model. Several studies have documented slower growth in breastfed compared with formulafed or non-breastfed infants (Dewey *et al*, 1992; Dewey, 1998; Nielsen *et al*, 1998; Atladottir & Thorsdottir, 2000; Ong *et al*, 2002). For example, Nielsen *et al* (1998) reported that when controlling for birth weight and mid-parental height, infants breastfed for ≥ 7 months had a slower weight gain during the 5–10 months age period compared with infants breastfed for a shorter period. Some infant growth studies have included BMI or other measures of overweight/obesity, and breastfed infants have been found to be leaner than formulafed infants at 1 y of age (Dewey *et al*, 1993); however, relations between breastfeeding and obesity have been studied more extensively after the period of infancy. Two recent reviews suggest a protective effect of breastfeeding against childhood overweight and obesity (Dewey, 2003; Swinburn *et al*, 2004), and these are supported by three recent studies (Bergmann *et al*, 2003; Thorsdottir *et al*, 2003; Grummer-Strawn & Mei, 2004). For example, Bergmann *et al* (2003) observed that breastfeeding for at least 3 months lowered the risk for overweight and obesity at 6 y. In contrast, Li *et al* (2003) found no significant associations between breastfeeding duration and BMI or obesity in children aged 4–18 y. In the review by Dewey (2003), eight of the 11 examined studies showed a lower risk of overweight in children who had been breastfed. The three studies that did not find a significant association lacked information on

the exclusivity of breastfeeding, whereas seven of the eight positive studies had this information. Different definitions of breastfeeding and lack of data on exclusive breastfeeding might explain some of the inconsistent results observed in studies on breastfeeding and obesity (Dewey, 2003).

In conclusion, we found that infants of high PI at birth were exclusively breastfed for a shorter time period than infants of normal PI at birth. Earlier introduction of solid foods and higher consumption of some foods were also observed among infants born with high PI. Furthermore, high PI at birth and short-term exclusive breastfeeding were both associated with higher BMI at 12 months. The present study supports the importance of exclusive breastfeeding and breastfeeding.

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