International Journal of Obesity (2003) 27, 1523–1527
 0307-0565/03 $25.00
www.nature.com/ijo

PAPER

Relationship between growth and feeding in infancy and body mass index at the age of 6 years

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OBJECTIVE: To assess the relationship between size and growth measurements in infancy to body mass index (BMI) at 6 y.
DESIGN: A longitudinal observation study on randomly chosen infants' growth and consumption in infancy. Follow-up until the age of 6 y.
SUBJECTS: A total of 90 children who were born healthy and full-term.
MEASUREMENTS: Weight and height were measured at maternity wards and healthcare centers in Iceland throughout infancy and at 6 y. Food records were made every month during infancy. At 2, 4, 6, 9 and 12 months, food was weighed to calculate food and nutrient intake.
RESULTS: Weight gain from birth to 12 months as a ratio of birth weight was positively related to BMI at the age of 6 y in both genders ($B = 2.9 \pm 1.0$, $P = 0.008$, and $B = 2.0 \pm 0.9$, $P = 0.032$ for boys and girls, respectively). Boys in the highest quartile of protein intake (*E*%) at the age of 9–12 months had significantly higher BMI ($17.8 \pm 2.4\,kg/m^2$) at 6 y than the lowest ($15.6 \pm 1.0\,kg/m^2$, $P = 0.039$) and the second lowest ($15.3 \pm 0.8\,kg/m^2$, $P = 0.01$) quartile. Energy intake was not different between groups. Together, weight gain at 0–12 months and protein intake at 9–12 months explained 50% of the variance in BMI among 6-y-old boys.
CONCLUSION: Rapid growth during the first year of life is associated with increased BMI at the age of 6 y in both genders. In boys, high intake of protein in infancy could also contribute to childhood obesity.
International Journal of Obesity (2003) **27,** 1523–1527. doi:10.1038/sj.ijo.0802438

Keywords: infant; birth weight; growth; infant nutrition; nutrition; dietary proteins; body mass index; child

Introduction

The prevalence of overweight and obesity is increasing around the world, and is associated with large decreases in life expectancy and increases in early mortality.[1] Childhood obesity has been shown to be associated with adult obesity[2] and other unfavorable health outcomes in childhood as in adult life.[3–5]

Studies have shown breastfeeding to be protective against childhood and adult obesity,[6,7] and breastfeeding is associated with slower growth in the first year of life.[8–10] High birth weight is also related to slower growth in infancy.[8] In recent studies, childhood overweight is being related to rapid growth during the first 4 months of life,[11] the first year of life[12] and to catch-up growth from birth to 2 y.[13]

In 1995, Rolland-Cachera *et al*[14] suggested that high protein intake in early life increases the risk of obesity, and the hypothesis has been supported by one other study[15] and discussed by scientists.[16] Further studies are necessary to confirm these suggestions, but so far little attention has been paid to the risk associated with protein excess.[14] Studies where both data on growth and dietary intake in infancy are taken into consideration regarding childhood weight development are needed.

In Iceland, the mean birth weight is among the highest in the world,[8,17,18] Icelandic newborns are frequently breastfed, and the variation of protein intake in late infancy is high.[8] In the study on infant nutrition in Iceland,[8] food intake was measured monthly from birth to 12 months of age, using weighed food records covering 48 h at the ages of 2, 4, 6, 9 and 12 months. Weight and length were recorded throughout infancy. The children were followed up to 6 y of age, and their weight and height were measured to calculate body mass index (BMI). The data are more comprehensive than many other studies have had, and therefore this cohort gives a great opportunity to study thoroughly the effect of size at birth, and growth and intake during the first year of life on BMI at the age of 6 y.

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Received 26 February 2003 ; revised 13 May 2003 ; accepted 13 June 2003

Methods

Subjects

A total of 100 subjects were invited to participate in this nationwide longitudinal children study. They were participants in the Icelandic infant nutrition study of randomly chosen sample who fulfilled the criteria set for the present study, that is, complete data on infant size and growth parameters, along with complete information on nutrient intake throughout infancy. In all, 90 subjects agreed to participate. The original study sample has been described thoroughly before.[8] The mean weight and length at birth and at 12 months of the 90 participants in the present study are the same as for the 138 participants in the original Icelandic infant nutrition study.[8] Also the energy intake and intake of energy giving nutrients are identical.[19] Therefore, the sample in the present study is considered a random sample and representative for the Icelandic 6-y-olds.

The Local Ethical Committee at the Landspitali-University Hospital in Iceland and the Icelandic Data Protection Commission approved the study.

Growth

Information on the weight and length of the infants was used to evaluate body size at birth and throughout infancy, as well as growth during the first year of life. Birth information was gathered from the maternity wards involved in the study, and the participating families' health-care centers provided the measurements made during infancy and information on growth. Weight was measured to the nearest 0.1 kg and height to the nearest 0.5 cm at the age of 6 y in a clinical examination at Landspitali-University Hospital. The International Obesity Task Force cut of points for BMI[20] were used to assess the level of overweight and obesity at the age of 6 y.

Food records

Food records for the infants were made once a month from birth to the age of 12 months. The food records, which were completed by the infants' parents or caretakers, covered at least 24 h. Weighed food records covering 48 h at the ages of 2, 4, 6, 9 and 12 months were used to study the amount of food and nutrient intake in relation to BMI at the age of 6 y. All food ingested was weighed on accurate scales (PHILIPS HR 2385, Austria), and the infants were weighed before and after breastfeeding (Tanita 1581, Japan).

Calculation and statistical analysis

Weighed food records were analyzed on a Comp-Eat Nutrition System (Carlson Bengtson Consultants Ltd, London) with a database including nutrients in Icelandic food and special infant products. Statistical analyses were performed, using SPSS for Windows version 11.0 (SPSS Inc., Chicago, IL, USA). Mean and standard deviation were used to describe the data. Parameters used in the analysis were tested for normality by one-sample Kolmorgrov–Smirnov test. All parameters except for the protein intake (*E*%) at the age of 6 months were normally distributed. Univariate linear regression was used to assess relationships between size and growth variables and BMI at the age of 6 y. The relationship between energy giving nutrient intake in infancy and BMI at the age of 6 y was assessed by a multiple regression model including *E*% from fat, protein and carbohydrates and total energy intake at different ages in infancy. In the final regression model, independent predictor variables were included in a multiple regression analysis. When independent variables correleated with each other, the variables, which correlated strongest with BMI at the age of 6 y, were used in the regression model. One-way ANOVA and Bonferroni *post hoc* test was used to assess difference in BMI between quartiles of protein intake in infancy. *t*-Test was used to assess differences between two independent groups. The level of significance was taken as $P<0.05$.

Results

Of the 41 boys and 49 girls participating in the present study, seven boys (17%) and 11 girls (22. 4%) were overweight. One boy (2.4%) and three girls (6.1%) were obese. Table 1 shows the weight and length measurement at different ages.

Table 2 shows the results of univariate analysis of the relationship between size and growth measurements in infancy and BMI at the age of 6 y. Among boys, a univariate linear regression showed a 0.9 ± 0.3 kg/m^2 increase in BMI at the age of 6 y per each kg increase in weight at 12 months ($P=0.012$). Neither weight nor length or ponderal index at birth was related to BMI at the age of 6 y. In girls, no relationship was found between weight and length measurements in infancy and BMI at the age of 6 y.

Weight gained during the first 12 months of life was positively related to BMI at the age of 6 y in both genders (Table 2). Length growth from birth to 12 months was related to BMI at the age of 6 y in boys but not girls.

Table 3 shows the energy percentages (*E*%) of the energy giving nutrients throughout infancy. *E*% from proteins rises

Table 1 Body weight (kg) and length (cm) at different ages[a]

	Boys	*Girls*
At birth		
Weight	3.9 ± 0.4	3.7 ± 0.5[b]
Length	53 ± 2	52 ± 2[b]
At 12 months		
Weight	10.6 ± 1.0	9.6 ± 0.8[b]
Length	78 ± 2	76 ± 3[b]
At 6 y		
Weight	23.5 ± 3.2	22.6 ± 3.4
Length	120 ± 4	118 ± 5
BMI	16.4 ± 1.6	16.1 ± 2.0

[a]Values are mean $\pm$ s.d.
[b]Significantly different from boys, $P<0.05$.

Table 2 Univariate analysis of the relationship between size and growth measurements in infancy and BMI at the age of 6 y

	Boys		*Girls*	
	B ± *s.e.*[a]	P	B ± *s.e.*[a]	P
Birth weight (kg)	−0.9 ± 0.7	0.203	−0.7 ± 0.6	0.258
Birth length (cm)	−0.3 ± 0.1	0.081	−0.1 ± 0.2	0.416
Weight at 12 months (kg)	0.9 ± 0.3	0.012[b]	0.4 ± 0.4	0.322
Length at 12 months (cm)	0.1 ± 0.1	0.322	−0.02 ± 0.1	0.881
Absolute weight gain from birth to 12 months (kg)	1.1 ± 0.3	0.004[b]	0.6 ± 9.4	0.088
Weight gain from birth to 12 months as a ratio of birth weight	2.9 ± 1.0	0.008[b]	2.0 ± 0.9	0.032[b]
Length growth from birth to 12 months (cm)	0.4 ± 0.1	0.014[b]	0.1 ± 0.01	0.469

[a]Coefficients (*B*) in regression and standard error of the mean (s.e.).
[b]Statistically significant, $P<0.05$.

Table 3 Energy giving nutrient intake in infancy[a] (regression coefficients and *P*-values for the positive relationship between protein intake (*E*%) in infancy and BMI at the age of 6 y)

% of total energy	*Fat*	*Carbohydrates*	*Protein*	B ± *s.e.* (*P-values*)[a]
(a) Boys				
2 months	51 ± 2	41 ± 1	8 ± 1	1.2 ± 0.3 (0.003)
4 months	49 ± 4	43 ± 4	8 ± 2	0.3 ± 0.1 (0.027)
6 months	44 ± 6	47 ± 5	9 ± 2	NS
9 months	36 ± 6	49 ± 6	15 ± 4	0.2 ± 0.1 (<0.001)
12 months	36 ± 6	48 ± 7	16 ± 3	0.2 ± 0.1 (<0.001)
(b) Girls				
2 months	51 ± 1	41 ± 1	7 ± 1	
4 months	50 ± 3	42 ± 3	8 ± 1	
6 months	42 ± 7	49 ± 6	9 ± 2	
9 months	36 ± 7	48 ± 9	15 ± 4	
12 months	36 ± 7	47 ± 8	16 ± 4	

[a]Multivariate stepwise regression at each age between protein intake (*E*%) and BMI at the age of 6 y (total energy, *E*% from fat, *E*% from carbohydrates and *E*% from protein were included in the model at each age).The analysis showed no relationship between energy giving nutrients in infancy and BMI at the age of 6 y in girls.

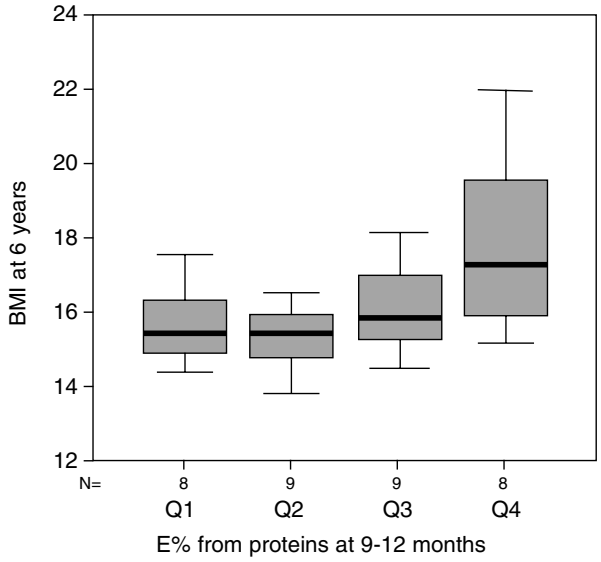

Figure 1 BMI of 6-y-old boys by quartiles (Q1 = lowest, Q4 = highest) of protein intake (*E*%) at the ages of 9 and 12 months. Energy intake was not different between groups.

from 9 to 15% from 6 to 9 months both in girls and boys. The corresponding figures presented as g protein/kg body weight are 1.8 to 3.3 and 1.7 to 3.7 g/kg for boys and girls, respectively. In boys, higher *E*% from protein at 2, 4, 9 and 12 months was associated with higher BMI at the age of 6 y. *E*% from protein was not normally distributed at the age of 6 months, which could explain the lack of significance at that age. The regression coefficients and *P*-values are shown in Table 3. Higher protein intake in infancy was not related to higher BMI in 6-y-old girls. For boys, the mean *E*% from protein at the ages of 9 and 12 months was divided into quartiles. Figure 1 shows a box plot of BMI in each quartile of protein intake (*E*%). *Post hoc* test showed that boys in the highest quartile of protein intake (*E*%) had significantly higher BMI ($17.8 \pm 2.4\,kg/m^2$) at the age of 6 y than the lowest ($15.6 \pm 1.0\,kg/m^2$, $P=0.039$) and the second ($15.3 \pm 0.8\,kg/m^2$, $P=0.01$) quartile. Total energy intake was not different between groups. An inverse relationship between duration of breastfeeding and BMI at 6 y was of borderline significance in boys ($B=-0.2\pm0.08$, adj. $R^2=0.07$, $P=0.064$), but not significant in girls.

Weight and growth variables related to BMI at the age of 6 y in the univariate regression analysis were interrelated. It was decided to include those variables correlating the strongest with BMI at 6 y (using Pearson's correlation). Protein intake (*E*%) at the age of 9–12 months, weight at the age of 12 months absolute weight gain from birth to 12 months were therefore included in a final regression model, as well as duration of breastfeeding as it was of borderline significance related to BMI. The analysis showed that protein intake at 9–12 months (*E*%) and the absolute weight change from 0 to 12 months were independently predicting BMI in 6-y-old boys ($B=0.3\pm0.1$, $P=0.004$, and $B=0.7\pm0.3$, $P=0.024$, respectively), explaining 50% of the variance in BMI in that model.

Discussion

The results of the present study showed that rapid growth during the first year of life is associated with higher BMI at the age of 6 y. The results also show an increased BMI of boys consuming a high protein diet (*E*%) in infancy. Around one-fifth of the 6-y-olds were overweight. The results of the present study demonstrate the importance of early prevention of childhood obesity.

The prevalence of child and adult obesity is increasing rapidly worldwide,[21] and Iceland is no exception.[22] As childhood obesity has been shown to be associated with adult obesity and other unfavorable health outcomes in childhood as in adult life,[2–5] prevention of childhood obesity is of high importance. In the present study, 17% of the boys and 22% of girls were overweight at the age of 6 y, using cutoff points for overweight from the International Obesity Task Force.[20] Although it is important to treat adult obesity to improve health and quality of life, prevention of childhood obesity should be a priority. The present study shows that this prevention should begin in the first months of life.

Recently, growth in infancy and in early childhood has been studied by other scientists in relation to childhood obesity. Rapid growth during the first 4 months of life is associated with being overweight at age 7 y.[11] Another study showed a greater BMI at the age of 5 y in children who showed a catch-up growth from birth to 2 y, and the results were unaffected by adjustment for breast or bottle feeding.[13] In the present study, rapid growth during the first 12 months of life was related to higher BMI at the age of 6 y in both genders. Slower growth during the first year of life has in the cohort studied not only been shown to be beneficial with regard to childhood obesity, slower growth in infancy has also been related to serum lipids[19] and better iron status at the age of 12 months.[23,24]

An inverse relationship between breastfeeding and growth from birth to 12 months has previously been described for this cohort by correlation coefficients.[8] Breastfeeding was related to slower growth during the first 12 months of life. Breastfed infants also consumed less protein in infancy (*E*%).[8] Duration of breastfeeding was of borderline significance being inversely related to BMI in 6-y-old boys in the present study. In a large study of 5- and 6-y-old children,[7] a consistent, protective and dose-dependent effect of breastfeeding on overweight and obesity was seen. Other studies have also seen this effect,[6] and several suggestions have been made about the mechanism behind the relationship,[7] but the cause is not known. The protein intake of breastfed infants is low, and when infant changes from a diet consisting only of breast milk to a diet based on family foods, the protein intake will increase markedly.[16] In the present study, the energy percentage from protein increased from 9 to 15% during a 3-month period from 6 to 9 months of age. The practice of introducing cow's milk in the latter half of the first year and the infrequent use of formula are part of the explanation for the high increase in protein intake in the Icelandic infant population.[8] It has been suggested that high protein intake in early life increases the risk of obesity, and the proposed mechanism is that a high protein intake stimulates secretion of insulin-like growth factor 1 (IGF-1) and thereby protein synthesis and cell proliferation.[14] The increased IGF-1 levels may then accelerate growth and increase muscle mass and adipose tissue.[16] In the present study, growth and protein intake in infancy (*E*%) were independently positively related to BMI at the age of 6 y in boys.

Most other studies on the relationship between growth or feeding in infancy and childhood obesity have not distinguished between boys and girls in the interpretation of their analysis.[11,13,14] The sex difference seen in the present study might be caused by the different growth patterns of girls and boys,[25] which could reflect the anabolic effects of early infancy sex hormone production in males[26,27] or could be due to endocrinologic differences.

Few years ago, when scientist were observing the slower growth of breastfed infants, their conclusion was that most certainly this slower growth would not have any adverse consequences and the findings should not advocate against breastfeeding during late infancy.[8,9] New analysis and data from the present study have now shown that this slow growth in infancy is beneficial. Duration of breastfeeding and low protein intake during the complimentary feeding period could be very important in the prevention of childhood obesity.

In conclusion, rapid growth during the first year of life is associated with increased BMI at the age of 6 y in both genders. In boys, high intake of protein in infancy could also contribute to childhood obesity.

Acknowledgements

The authors wish to thank Hildur Atladottir, nutritionist, for her valuable help in the data collection. This study was supported by a research grant to Inga Thorsdottir from The Icelandic Research Council, Research Fund of the University of Iceland, and to Ingibjörg Gunnarsdottir from the Fund for research training and graduate education.

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