Original Article

Breast vs. bottle: differences in the growth of Croatian infants

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Abstract

The aim of the paper was to compare the growth of rural Croatian infants with 2000 Centers for Disease Control and Prevention (CDC) growth standards and to evaluate the potential preventive influence of breastfeeding on the development of obesity in infancy. Two hundred three infant–mother pairs from Baranja, an Eastern region of Croatia, were enrolled into this study. Retrospective evaluation of infants' medical charts was used to obtain anthropometric data recorded at the birth, 1, 3, 6, 9 and 12 months of age. Infant feeding mode was self-reported by mothers. Breastfed infants gained the least weight of all observed groups. Up to 6 months of age, formula fed infants had the highest weight gain and after 6 months of age, mixed milk fed infants had the highest weight gain. At 12 months of age, 6.4% of all study infants and 7.6% of mixed milk fed infants were at risk of overweight, while the same risk for the group of breastfed infants was 4%. Most of the study infants achieved higher values of body mass and length than the child growth standards. Exclusively breastfed infants, in comparison with other study groups (formula fed infants, mixed milk fed infants and cow's milk fed infants), had lower weight-for-length z-scores during the first year, which suggests that breastfeeding may have a preventive impact on obesity development.

Keywords: infants, breastfeeding, formula feeding, growth, obesity.

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Introduction

Obesity is becoming one of the biggest public health problems of the 21st century (Rossner 2002). The basis for the development of overweight and obesity lies within genetic factors (Chagnon *et al.* 2000), but it is also undoubtedly associated with environmental factors (Strauss & Knight 1999). The incidence of obesity in Europe has tripled during the last two decades (World Health Organization 2007), and many studies have also indicated a large growth in the prevalence of obesity among European children (Rolland-Cachera *et al.* 2002). In Croatia, overweight

and obesity represent an important public health problem with about 11% of schoolchildren being overweight (Antonić-Degač *et al.* 2004).

The association between infant nutrition and obesity development has been widely debated. Obesity during the first 6 months of infancy has been found to be associated with obesity at 7 years of age (Stettler *et al.* 2002), while obesity in pre-schoolers has been associated with obesity in adolescence (Johannsson *et al.* 2006). The prevailing opinion is that exclusive breastfeeding during the first 6 months, combined with the appropriate introduction of complementary foods, has a protective effect on the

development of obesity (American Academy of Pediatrics 2005; Harder *et al.* 2005). The rate of breastfeeding in the Republic of Croatia, however, is low, with only 36.6% of mothers exclusively breastfeeding for longer than 3 months (Grgurić 1997).

Previous studies have indicated that infant formula feeding represents a risk factor for obesity during infancy (Grummer-Stawn & Mei 2004), childhood and adolescence (Sholters *et al.* 2007), and adulthood (Baird *et al.* 2005). Consequences of overweight and obesity in childhood include psychosocial difficulties and health problems such as diabetes type 2, hypertension, hyperlipidemia and hyperinsulinemia (Lucas & Feucht 2008).

The relationship between infant feeding mode and infant growth and weight gain among the Croatian rural population has not previously been investigated. The aim of this study was to investigate the influence of infant feeding mode on the growth of infants in Baranja. To achieve this objective, we evaluated differences in weight, length, weight and length gain, and *z*-scores among four groups of infants: breastfed, mixed milk fed, formula fed and cow's milk fed infants. Additionally, study infants were compared with 2000 Centers for Disease Control and Prevention (CDC) growth standards (Kuczmarski *et al.* 2002).

Subjects and methods

This study was carried out in a Community Health Centre in Beli Manastir and a paediatric service in Darda, both in Baranya. The study was performed as a part of a national project (as stated in the acknowledgements) that is in all its parts in compliance with all international and local laws, regulations and directions concerning protection of examinees. Additionally, the study was approved by the Ethics Committee of the Faculty of Food Technology.

Healthy, full-term (37–42 weeks), singleton infants weighing ≥ 2.5 kg at birth who scored more than 7 on Apgar evaluation ($n = 203$; 114 male and 89 female) from a rural part of Eastern Croatia and their mothers were enrolled in the study.

All data were collected by retrospective assessment of infants' medical charts. All anthropometric measurements were performed by trained medical staff according to the anthropometric standard procedures (WHO Expert Committee 1995). Babies were weighed naked on an electronic Sartorius scale (Sartorius AG, Goettingen, Germany) accurate to ± 5 g. Crown-heel length was recorded as an average of three measures using infantometer. Growth data were recorded at regular intervals (birth, 1, 3, 6, 9, 12 months) during visits to the health centre.

Information of infant feeding mode was based on a mother's self-report. Infants were divided into four groups according to feeding mode: infants exclusively breastfed until 6 months of age ($n = 50$), formula fed infants ($n = 47$), mixed milk fed infants ($n = 79$) and infants fed with cow's milk ($n = 27$). Mothers were interviewed by trained personnel to gather household demographics (description of socio-economic status), which included details of education, housing conditions, occupation, parity, family size and number of children.

Outcome measures and explanatory variables

The primary outcome measure of interest in this study was growth status from birth to 12 months computed from age- and sex-specific *z*-scores of infants fed via different feeding modes. Values of infant's weight and length were converted to weight-for-age, length-for-age and weight-for-length *z*-scores by using age- and sex-specific 2000 CDC reference values.

Key messages

- Compared with formula fed and mixed fed infants, exclusively breastfed infants in Croatia gained the least weight over a 12 month period.
- Exclusively breastfed infants had the lowest weight-for-length *z*-scores during the first year.
- At 12 months of age, breastfed infants had the lowest risk of being overweight.
- Breastfeeding may have a preventive impact on obesity development.

The z -score represents the distance in standard deviations (SD) units from the normative reference means for age and sex of the 2000 CDC standards (Kuczmarski *et al.* 2002). Two categorical variables were used to determine infants' risk for underweight or overweight. A composite *at-risk for underweight* variable was defined as weight-for-age, length-for-age and weight-for-length z -scores lower than -2 SD, and a composite *at-risk for overweight* variable was defined as weight-for-age, length-for-age and weight-for-length z -scores greater than 2 SD from median based on 2000 CDC standards (Kuczmarski *et al.* 2002).

Statistical analysis

Statistical analysis was conducted with Statistica 7.1 (StatSoft Inc., Tulsa, OK, USA). The acceptable level of statistical significance for all tests was $P < 0.05$.

Results

Demographic characteristics of infants and their mothers by feeding mode of infants are reported in Table 1. The rather low number (10/203, 5%) of mothers with college education can be explained with the fact that the study population was a rural population.

Table 2 shows the mean $\pm$ SD values of infant's anthropometric parameters (weight, length, head circumference) at different intervals. At birth, the mean weight and length for all infants were 3.41 ± 0.43 kg and 50.27 ± 2.04 cm, respectively. Considering weight gain of infants, we observed that breastfed infants gained less than other investigated groups, while formula fed infants gained most weight up to 6 months, and mixed milk fed infants gained most weight after 6 months.

The mean head circumferences were almost identical up to 6 months for all feeding groups of infants, but at 6 months, we found a significant difference between breastfed and mixed milk fed infants ($P < 0.01$) and at 9 months between breastfed and formula fed infants and mixed milk fed infants ($P < 0.05$).

Figures 1–3 show the changes in average group values of weight-for-age z -scores, length-for-age z -scores and weight-for-length z -scores over the 12 months period. The weight-for-age, length-for-age and weight-for-length z -score trend lines showed only a few gender differences across the observed period (data not shown).

The mean values of weight-for-age z -scores at birth were -0.30 – 0.13 . As shown in Fig. 1, at birth and after the first month, they were below the 2000 CDC median for all investigated groups except for the

Table 1. General characteristic of studied rural infants and their mothers by feeding mode

	Breastfeeding ($n = 50$)	Formula feeding ($n = 47$)	Mixed milk feeding* ($n = 79$)	Cow's milk feeding ($n = 27$)	All participants ($n = 203$)
Infant characteristics					
Gender			n (%)		
Male	23 (46)	31 (66)	44 (56)	16 (59)	114 (56)
Female	27 (54)	16 (34)	35 (44)	11 (41)	89 (44)
Maternal characteristics					
Mean number of children (n)	1.78	1.79	1.68	2.19	1.79
Number of delivery			n (%)		
1	26 (52)	21 (45)	37 (47)	10 (37)	94 (46)
2 and 3	21 (42)	24 (51)	38 (48)	15 (56)	98 (48)
>3	3 (6)	2 (4)	4 (5)	2 (7)	11 (5)
Education			n (%)		
Primary school	24 (48)	17 (36)	28 (35)	12 (44)	81 (40)
High school graduate	23 (46)	27 (57)	48 (61)	14 (52)	112 (55)
College graduate	3 (6)	3 (6)	3 (4)	1 (4)	10 (5)
Mother's first birth <21 y	25 (50)	19 (40)	27 (34)	9 (33)	80 (39)
Mother employed	18 (36)	21 (45)	32 (41)	10 (37)	81 (40)

*Infants were fed with both breast milk and formula.

Table 2. Average anthropometric parameters (mean $\pm$ SD) of the study infants at different intervals

	Breastfeeding (<i>n</i> = 50)	Formula feeding (<i>n</i> = 47)	Mixed milk feeding* (<i>n</i> = 79)	Cow's milk feeding (<i>n</i> = 27)	All participants (<i>n</i> = 203)
Birth					
Weight (kg)	3.31 $\pm$ 0.39	3.31 $\pm$ 0.37	3.52 $\pm$ 0.48	3.43 $\pm$ 0.37	3.41 $\pm$ 0.43
Length (cm)	49.64 $\pm$ 2.04	49.91 $\pm$ 1.84	50.78 $\pm$ 2.08	50.59 $\pm$ 1.89	50.27 $\pm$ 2.04
Head circumference (cm)	34.50 $\pm$ 1.51	34.68 $\pm$ 1.28	34.91 $\pm$ 1.52	34.70 $\pm$ 1.29	34.73 $\pm$ 1.36
1 month					
Weight (kg)	4.20 $\pm$ 0.55	4.24 $\pm$ 0.48	4.34 $\pm$ 0.52	4.26 $\pm$ 0.52	4.27 $\pm$ 0.52
Weight gain (kg)	0.89 $\pm$ 0.28	0.93 $\pm$ 0.38	0.82 $\pm$ 0.29	0.83 $\pm$ 0.31	0.87 $\pm$ 0.31
Length (cm)	52.95 $\pm$ 2.37	53.07 $\pm$ 1.98	53.80 $\pm$ 2.01	53.39 $\pm$ 1.98	53.37 $\pm$ 2.11
Head circumference (cm)	36.75 $\pm$ 1.28	36.61 $\pm$ 1.16	36.77 $\pm$ 1.32	36.67 $\pm$ 1.12	36.71 $\pm$ 1.24
3 months					
Weight (kg)	5.88 $\pm$ 0.68	6.04 $\pm$ 0.65	6.14 $\pm$ 0.65	6.09 $\pm$ 0.63	6.05 $\pm$ 0.66
Weight gain (kg)	2.57 $\pm$ 0.53	2.73 $\pm$ 0.58	2.62 $\pm$ 0.47	2.65 $\pm$ 0.45	2.64 $\pm$ 0.51
Length (cm)	59.60 $\pm$ 2.30	60.07 $\pm$ 2.42	60.65 $\pm$ 2.48	60.65 $\pm$ 2.32	60.26 $\pm$ 2.43
Head circumference (cm)	39.97 $\pm$ 1.28	39.95 $\pm$ 1.23	40.08 $\pm$ 1.31	40.09 $\pm$ 1.19	40.02 $\pm$ 1.26
6 months					
Weight (kg)	7.68 $\pm$ 0.74	7.94 $\pm$ 0.83	8.24 $\pm$ 0.74	8.09 $\pm$ 1.01	8.01 $\pm$ 0.83
Weight gain (kg)	4.37 $\pm$ 0.69	4.63 $\pm$ 0.76	4.71 $\pm$ 0.73	4.66 $\pm$ 0.89	4.60 $\pm$ 0.76
Length (cm)	66.74 $\pm$ 2.31	67.48 $\pm$ 2.40	68.42 $\pm$ 2.45	68.04 $\pm$ 2.82	67.74 $\pm$ 2.53
Head circumference (cm)	42.94 $\pm$ 1.38	43.31 $\pm$ 1.21	43.57 $\pm$ 1.26	43.35 $\pm$ 1.36	43.33 $\pm$ 1.31
9 months					
Weight (kg)	8.80 $\pm$ 0.88	9.13 $\pm$ 0.87	9.52 $\pm$ 0.80	9.33 $\pm$ 1.31	9.23 $\pm$ 0.95
Weight gain (kg)	5.30 $\pm$ 1.38	5.82 $\pm$ 0.82	6.00 $\pm$ 0.80	5.90 $\pm$ 1.18	5.77 $\pm$ 1.06
Length (cm)	70.51 $\pm$ 2.52	71.48 $\pm$ 2.24	72.57 $\pm$ 2.39	72.81 $\pm$ 2.70	71.84 $\pm$ 2.57
Head circumference (cm)	44.79 $\pm$ 1.37	45.38 $\pm$ 1.31	45.33 $\pm$ 1.35	45.24 $\pm$ 1.40	45.20 $\pm$ 1.36
12 months					
Weight (kg)	9.95 $\pm$ 0.87	10.42 $\pm$ 1.13	10.86 $\pm$ 0.92	10.57 $\pm$ 1.35	10.50 $\pm$ 1.08
Weight gain (kg)	6.64 $\pm$ 0.79	7.11 $\pm$ 1.08	7.34 $\pm$ 0.93	7.14 $\pm$ 1.26	7.09 $\pm$ 1.01
Length (cm)	75.14 $\pm$ 2.95	76.87 $\pm$ 2.51	76.87 $\pm$ 2.51	76.94 $\pm$ 3.61	76.25 $\pm$ 2.88

*Infants were fed with both breast milk and formula.

Fig. 1. Weight-for-age z-scores (WAZ) of the study infants grouped according to the feeding mode during the first year of life.

Fig. 2. Length-for-age z-scores (LAZ) of the study infants grouped according to the feeding mode during the first year of life.

Fig. 3. Weight-for-length z-scores (WLZ) of the study infants grouped according to the feeding mode during the first year of life.

group of mixed milk fed infants. After that, a continuous growth of the z-scores until 6 months was followed by fall in the ninth month, and again increased up to the 12th month where mean values for all observed groups were above the median based on the 2000 CDC standards. The infants who were fed by

mixed milk had highest z-score values, which were statistically higher at 3 months ($P < 0.05$), at 6, 9 and 12 months ($P < 0.001$) than the values of exclusively breastfed infants which were the lowest of all groups.

Length-for-age z-scores followed a similar pattern (Fig. 2), with baseline values at 0.0–0.42, until the first month when they rapidly decreased below the 2000 CDC medians for all observed groups of infants, then gradually increased until the sixth month. Breastfed infants had the lowest values of weight-for-age and length-for-age z-scores at all measured intervals.

As shown in Fig. 3, at birth, the mean weight-for-length z-scores were below the 2000 CDC median (–0.24 to 0.0) for all observed groups, and after 6 months of age values started to grow until 12 months when they were the highest for all feeding modes. A statistically significant difference ($P < 0.001$) was found between infants who were breastfed and those who were mixed milk fed at the age of 1 year (0.42 vs. 0.98).

We also tracked growth in terms of weight and length of individual infants over the 12-month period. Their weight-for-age, length-for-age and weight-for-length z-scores showed that, in general, infants born with lower z-scores had also lower values at the age of 12 months. Additionally, a statistically significant correlation was established between all observed z-scores (weight-for-age, length-for-age and weight-for-length) of infants between baseline values (at birth) and values by 12 months, respectively ($r = 0.33$, $P < 0.001$; $r = 0.44$, $P < 0.001$; $r = 0.14$, $P < 0.05$).

Discussion

This study evaluates the feeding mode and growth of infants in Baranja, Eastern Croatia, and is the first research of this type on the local infant population. Results of the study showed positive impact of breastfeeding on the growth of infants, as well as potential preventive impact on the infant obesity prevention.

Growth curves of all the groups of study participants were similar until the third month, but after that, differences in growth among feeding groups started to appear. The greatest differences were obtained between the exclusively breastfed and

mixed milk fed infant groups in the sixth month and beyond. A previously published study by Victora *et al.* (1998) has shown that exclusively breastfed infants grew more rapidly than the 2000 CDC references in weight for the first 6 months and length in the period from 3 to 6 months but appeared to falter thereafter. The similar pattern of more rapid growth than the 2000 CDC references in the period from 3 to 6 months, followed by relative decline afterwards, was found in our study.

We also observed that breastfed infants gained less weight during the first 3 months than other investigated groups. Unfortunately, it is not possible to conclude, at least not from this particular study, that the observed differences are the result only of feeding mode as many other factors can influence the nutrition status of infants at the same time. In cases when lack of weight gain or a loss of weight gain happens in a short time period, the child should be evaluated more thoroughly, and all factors which can influence nutrition status (birth measures, genetic factors, illness and family social problems) should be included into that evaluation. Formula fed infants had the highest weight gain up to 6 months of age, and after 6 months, the highest weight gain was in mixed milk fed infants, a finding similar to that shown in US infants (Hediger *et al.* 2000).

In comparison with other mode of feeding groups, exclusively breastfed infants had statistically lower weight-for-age *z*-scores in third, sixth and ninth month. These findings are in agreement with other studies that have also showed that exclusively breastfed infants show smaller weight gain than the infants who are not breastfed (Agostoni *et al.* 1999; Butte *et al.* 2000; Hediger *et al.* 2000; Kramer *et al.* 2004). In comparison, studies that have investigated infant growth in undeveloped African countries (Mamabolo *et al.* 2004) and among lower socio-economic immigrant groups (Neault *et al.* 2007) have showed that breastfed infants had higher weight gain than formula fed ones.

Our study also showed a statistically significant difference in head circumference at 6 months between exclusively breastfed and formula fed infants, and at 9 months between exclusively breastfed and mixed milk fed and formula fed infants ($P < 0.01$), in con-

trast to previous findings of Butte and Kramer (Butte *et al.* 2000; Kramer *et al.* 2004).

Despite paediatricians' advice to avoid cow's milk during infancy (because of its inadequacy), our study showed that some infants in this region were fed with cow's milk since birth. This could be explained by the fact that the study was conducted in a rural population that often breeds their own cattle. As expected, cow's milk fed infants had statistically higher weight-for-age and length-for-age *z*-scores than breastfed infants at 12 months. This is probably because infants who were cow's milk fed since birth will have consumed higher amounts of proteins (about 4 g/100 mL) than breastfed and formula fed infants. Most of the infant formulas in the Republic of Croatia contain 1.4–1.8 g of proteins per 100 mL. This supports the suggestion that protein intake is a determining factor of growth and obesity development during the infancy (Rolland-Cachera *et al.* 1995; Agostoni *et al.* 2005). Some studies have shown that prolonged and exclusive breastfeeding is correlated with lower long-term risk of obesity (Hediger *et al.* 2000; Harder *et al.* 2005; Sholters *et al.* 2007), while others report an unclear relationship between breastfeeding duration and obesity, but rather a major impact of family factors (nutritional habits, low socio-economic status, physical activity, mother's obesity) on obesity development (Bergmann *et al.* 2003). Our study has shown lower weight-for-length *z*-scores at the end of the first year in breastfed infants compared with formula fed and cow's milk fed infants.

It is important to consider that our study has some limitations. A short period of observation should be considered as a limitation of our study, as at least 3 years period is recommended for children growth monitoring (Dewey 2003). Therefore, this study will be continued through the further anthropometric parameters monitoring. Second, it is important to mention that the 2000 CDC Growth Charts used were originally developed for the United States. It is possible that some of the results would be slightly different if World Health Organization (WHO) Child Growth Standards were used. At the same time, it should be considered that the WHO standards demonstrate that healthy children from around the world who are raised in similar environments have very

similar growth patterns (WHO Multicentre Growth Reference Study Group & de Onis 2006). Third, although the study sample is big enough to get an insight into the situation in Eastern Croatia, it should be considered that this is a small study and the results cannot be generalized or taken as a representative for any other group.

In summary, this study resulted in two main conclusions. First, all study participants, regardless of feeding mode, achieved higher body weight and length as compared with the 2000 CDC growth chart median. Second, exclusively breastfed infants had lower weight-for-length *z*-scores during the first year than infants from other observed feeding mode groups, suggesting that breastfeeding has a potential preventive impact on obesity prevention.

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Conflicts of interest

No conflicts of interest have been declared.

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