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Early macronutrient intake and overweight at five years of age

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OBJECTIVE: To examine the influence of the macronutrient intake in early life on the development of overweight in children.
DESIGN AND SUBJECTS: An ongoing longitudinal study including 147 randomized healthy children followed up from birth.
MEASUREMENTS: Anthropometric parameters were measured at birth, 1 and 5 y of age. Dietary habits at the age of 1 and 5 were assessed by age-adjusted food-frequency questionnaires and 24 h recalls. Parents' body mass index (BMI) was also recorded.
RESULTS: Parental overweight was observed for 51% children. The prevalence of overweight at the age of 5 y was higher in children with than without parental overweight (37.3% *vs* 8.3%, $P<0.0001$). Five-year old overweight children had a higher percentage intake of proteins at the age of 1 y than non overweight children (22% *vs* 20%, $P=0.024$) and lower intake of carbohydrates (44% *vs* 47%, $P=0.031$). Multiple logistic analysis confirmed that protein intake at 1 y of age was associated with overweight at 5 y ($P=0.05$). In children born from overweight mothers, prevalence of overweight at the age of 5 y tended to be higher in bottle-fed than in breast-fed ones (62.5% *vs* 23.3%, $P=0.08$).
CONCLUSION: Parental overweight is a major risk factor for childhood overweight in the first years of life, but an early high protein intake may also influence the development of adiposity.
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Keywords: macronutrient intake; body mass index; childhood obesity

Introduction

The widespread interest on the causes of childhood obesity is raised by its increasing prevalence in Western countries and the recognized association with adult obesity and related disorders.[1–3] Preventive efforts have been aimed at identifying early markers influencing the development of obesity in children.[4] In particular, high-fat and high-sugar, low-carbohydrate diets have been associated with the development of childhood adiposity,[5] but the role of overeating is definitely unclear.[6] Investigations assessing the role of energy and macronutrient (protein, fat, carbohydrate) intake in the development of adiposity in children have given controversial results.[7–9] At the same time several reports have underlined the relevance of genetic factors in the development of childhood obesity.[10–13] The distinction between genetic and environmental factors is difficult. Moreover, among environmental factors, it is relevant to distinguish between dietary habits *when* obesity is established and dietary habits *before* the onset of obesity, suggesting possible cause–effect relationships.

The aim of the present study was to examine the influences of the early intake of macronutrients on the development of overweight in healthy children.

Subjects and methods

Recruitment was made of 171 babies randomly selected (1 out of 4) from all live births ($n=684$) that occurred at our maternity ward during the second semester of 1991. Inclusion criteria were: weight at birth ≥ 2500 g, gestational age 37–42 weeks inclusive, singleton birth, no neonatal disease or congenital malformation and Caucasian parents. Exclusion criteria were: at least one parent with debilitating infections, dysmetabolic and/or degenerative diseases, parental drug consumption. In all, 164 (95.9%) infants (80 females, 84 males) satisfied the eligibility criteria and were included into this prospective study providing anthropometric and nutritional examinations at birth and age 1, 5, 8 and 12 y.

The trial was approved by the Institutional Ethical Committee. When infants entered their 9th month of age families were contacted. A pediatrician described the trial and informed consent was obtained from parents.

The analysis includes current information from the assessements at birth, 1 and 5 y of age, when the growth parameters were measured and the dietary habits evaluated. When children were 1 y old, mothers

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were further interviewed about infants' feeding practice in the previous period, and both parents had weight and height measured.

Among breast-fed infants (84.3%), mean (s.d.) of total duration of breastfeeding was 4.1 (3.6) months, while the mean (s.d.) duration of full (exclusive or predominant) breastfeeding was 2.7 (2.6) months. In the whole population the first solid foods were introduced between 4 and 6 months of age, according to the present dietary recommendations.[14]

Anthropometric measurements on children and parents were performed at our department by two experienced pediatricians according to a standardized procedure. In particular, for each anthropometric parameter three measurements were taken and the mean value was then considered for the analysis. The coefficient of variation of the measurements ranged from 0.7% to 1.3% (observer 1) and from 0.8% to 1.3% (observer 2). This comparable degree of interobserver measurement variation was deemed to yield reliable anthropometric data.

At birth and the age of 1 y, the body weight of the infants was measured by an electronic Sartorius scale accurate to ± 5 g, and crown–heel length was measured on a portable measuring board to the nearest 0.1 cm. At the age of 5 y children had weight measured by an electronic scale accurate to ± 0.1 kg and height measured to the nearest 0.5 cm with a Harpenden stadiometer. The same procedure was used to evaluate parental anthropometry. Body mass index (BMI) was calculated from the ratio of weight to (height)^2. A child was defined to be overweight if her/his BMI was over the 90th centile of the age- and sex-adjusted Rolland–Cachera curves.[15] Parental BMI, evaluated when children were 1 y old, was used in the statistical calculations. A parent was defined overweight if her/his BMI (kg/m^2) was greater than 25.[16] Parental overweight occurred when at least one parent was overweight.

The dietary habits of children were determined by a well-trained and experienced dietitian on the basis of age-adjusted Food Frequency Questionnaires made up of 116 items and designed according to Block.[17] The mothers were interviewed for approximately 50 min and each meal was analyzed to find out which food was eaten and how often. Usual portion sizes were estimated using household measures, the weight of purchase (eg pasta) or unit (eg fruit juice). A 24 h recall was further conducted at the end of the interview to standardize the usual serving size. Quantification and analysis of the energy intake and nutrient composition were performed with an *ad hoc* PC software program developed at our department and based on the Food and Nutrient Data Base issued by the National Institute of Nutrition.[18] The sample size had been determined assuming in our area an expected prevalence of overweight (defined according to the Rolland–Cachera curves)[15] in 5–6 y-old children of 12.5%,[19] in order to include at age 5 y at least 20 overweight children.

Statistical analysis

Descriptive results are given as mean (s.d.) or percentage. The odds ratio (OR) and 95% confidence interval (CI) were calculated when appropriate. Student's *t* test and the non-parametric Wilcoxon and Mann–Whitney tests were used to compare between-groups differences of continuous variables. The chi-square test and the Fisher's exact test were used to compare discrete variables. Multiple logistic analysis was carried out to estimate the independent contribution of macronutrient intake at the age of 1 y on overweight at the age of 5 y. Factors associated with a $P<0.05$ at univariate analysis were analyzed by multiple logistic regression and adjusted on potential confounding variables (infant's gender, weight and length at birth and 1 y of age, parental age). All values of P less than 0.05 were considered to indicate statistical significance (two-tailed test). The SPSS package version 7.5 for Windows (SPSS Inc., Chicago, IL, USA) was used for the statistical analysis.

Results

Follow-up data at the age of 5 y were available in 147 (89.6%) children, 67 females and 80 males. Figure 1 indicates the longitudinal changes in BMI of children during the examination period. The prevalence of overweight increased from 10.9% at 1 y of age to 23.1% at 5 y ($P<0.001$). There was no significant difference in the prevalence between boys and girls, both at the age of 1 y (8.7% *vs* 13%, $P=0.62$) and 5 y (20.0% *vs* 26.9%, $P=0.32$). Parents' age was not associated with the overweight in children at any time (minimum $P=0.44$).

Tables 1 and 2 show the relationship of overweight at the age of 5 y to anthropometric parameters and the dietary intake at the age of 1 y, respectively.

No significant correlation was found between the children's BMI at the age of 1 y and parental BMI

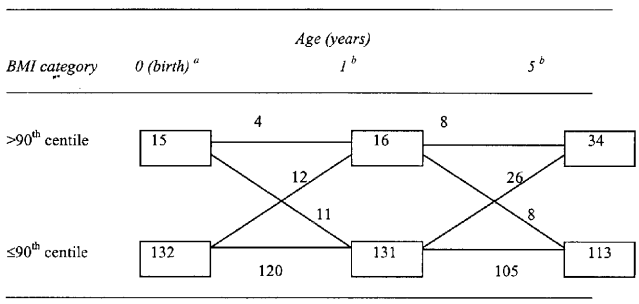

Figure 1 Longitudinal variation in BMI of children. Horizontal lines: no change in BMI category between age groups; ascending lines: BMI category increased; descending lines: BMI category decreased. Numbers indicate the number of children. Difference statistically significant from 1 to 5 years of age ($P<0.001$, Wilcoxon matched pairs signed-ranks test). [a]Sex-adjusted 90th centile calculated from the sample (females 15.4 kg/m^2, males 15.8 kg/m^2); [b]Age- and sex-adjusted 90th centile according to curves from Rolland-Cachera *et al.*[15]

(minimum $P = 0.10$). Children's BMI at 5 y of age positively correlated with BMI at 1 y ($r = 0.46$, $P < 0.0001$), father's BMI ($r = 0.35$, $P < 0.0001$) and mother's BMI ($r = 0.21$, $P = 0.01$). Overweight at 5 y was more likely in children with ($n = 75$) than without ($n = 72$) parental overweight (37.3% *vs* 8.3%; OR = 6.55, 95% CI = 2.51–17.10). It appears from Table 2 that children overweight at 5 y ingested at 1 y a significantly higher percentage of energy as proteins and a lower percentage as carbohydrates than non-overweight children. Fat intake was comparable and slightly lower than 35% in both groups.

At the age of 5 y no significant difference was found between overweight and non-overweight children for any dietary nutrient (Table 3). In both groups, there was a significant drastic reduction of the protein intake from 1 to 5 y of age ($P < 0.0001$) and an increase of the carbohydrate intake ($P < 0.0001$). Significance of the reduction of the fat intake was less marked ($P = 0.01$ in non-overweight children, $P = 0.06$ in overweight children). Moreover, in non-overweight children a significant correlation was found between intakes of carbohydrates ($r = 0.23$, $P = 0.02$) and fats ($r = 0.19$, $P = 0.05$) as percentages of energy at 1 and 5 y of age.

Table 4 shows the relationship between parental overweight and the dietary intakes of children at the age of 1 y. No statistically significant association was found.

The multiple logistic regression identified parental BMI as the most relevant factor associated with overweight at 5 y of age (father's BMI, $P = 0.003$; mother's BMI, $P = 0.05$). Among macronutrients, only protein intake as a percentage of energy at 1 y was associated with overweight at 5 y ($P = 0.05$). Similar results were obtained when parental overweight instead of parental BMI entered the logistic model (parental overweight, $P = 0.0002$; protein percentage, $P = 0.07$).

Another logistic analysis was performed on the subsample of 131 children who were not overweight at the age of 1 y. In this group the adjusted association of the

Table 1 Comparison of anthropometric parameters of infants at birth and 1 y, and parents, as a function of children's BMI at the age of 5 y. Values are mean (s.d.)

	BMI at age 5 y		
Characteristic	*≤90th centile (n = 113)*	*>90th centile (n = 34)*	*P*
Infant birth weight (g)	3274 (460)	3451 (508)	0.053
birth length (cm)	49.2 (1.0)	49.5 (1.3)	0.185
birth BMI (kg/m^2)	13.4 (1.4)	14 (1.6)	0.051
Infant weight at 1 y (kg)	9.7 (1.0)	10.5 (1.0)	<0.0001*
height at 1 y (cm)	77.8 (2.7)	76.7 (3.0)	0.843
BMI at 1 y (kg/m^2)	16.5 (1.5)	17.8 (1.4)	<0.0001*
Maternal weight (kg)	59.6 (8.9)	65.7 (14.7)	0.020*
height (cm)	159 (21)	157 (27)	0.745
BMI (kg/m^2)	22.9 (3.5)	25.1 (5.4)	0.032*
Paternal weight (kg)	74.4 (9.3)	79.2 (10.3)	0.008*
height (cm)	168 (32)	175 (8)	0.218
BMI (kg/m^2)	24.5 (2.5)	26.5 (3.0)	<0.0001*
Midparental BMI	23.7 (2.5)	25.8 (2.9)	<0.0001*

* = statistical significance.

Table 2 Comparison of energy and nutrient intake in children at the age of 1 y, as a function of children's BMI at the age of 5 y. Values are mean (s.d.)

	BMI at age 5 y		
Characteristic	*≤90th centile (n = 113)*	*>90th centile (n = 34)*	*P*
Daily energy			
total (kJ)	3545.5 (1201)	3440.9 (1000)	0.663
(kcal)	847 (287)	822 (239)	0.663
per kg body weight (kJ/kg)	364.2 (125.6)	330.7 (96.3)	0.149
(kcal/kg)	87 (30)	79 (23)	0.149
Nutrient (energy %)			
proteins	20 (3)	22 (5)	0.024*
carbohydrates	47 (7)	44 (8)	0.031*
fats:	33 (5)	34 (4)	0.728
saturated	15 (3)	15 (3)	0.788
monounsaturated	10 (2)	11 (2)	0.161
polyunsaturated	6 (1)	6 (1)	0.595

* = statistical significance.

Table 3 Comparison of energy and nutrient intake in children at the age of 5 y, as a function of children's BMI at the age of 5 y. Values are mean (s.d.)

	BMI at age 5 y		
Characteristic	*≤90th centile (n = 113)*	*>90th centile (n = 34)*	*P*
Daily energy			
total (kJ)	9193.0 (2067)	9676.4 (2519)	0.077
(kcal)	2196 (494)	2312 (602)	0.077
per kg body weight			
(kJ/kg)	489.6 (104.6)	431.0 (113.0)	0.218
(kcal/kg)	117 (25)	103 (27)	0.218
Nutrient (energy %)			
proteins	15 (2)	15 (2)	0.530
carbohydrates	53 (5)	53 (4)	0.218
fats:	32 (4)	32 (4)	0.917
saturated	12 (2)	12 (2)	0.907
monounsaturated	11 (1)	12 (1)	0.401
polyunsaturated	4 (1)	4 (1)	0.529

* = statistical significance.

Table 4 Comparison of energy and nutrient intake at the age of 1 y, as a function of parental overweight. Values are mean (s.d.)

	Parental overweight		
Characteristic	*Yes (n = 75)*	*No (n = 72)*	*P*
Daily energy			
total (kJ)	3516.2 (1146.9)	3524.6 (1167.8)	0.955
(kcal)	840 (274)	842 (279)	0.955
Per kg body weight			
(kJ/kg)	364.2 (117.2)	351.6 (125.5)	0.490
(kcal/kg)	87 (28)	84 (30)	0.490
Nutrient (energy %)			
proteins	20 (4)	21 (4)	0.479
carbohydrates	47 (8)	46 (7)	0.487
fats:	33 (5)	33 (5)	0.622
saturated	15 (3)	15 (3)	0.571
monounsaturated	10 (2)	10 (2)	0.945
polyunsaturated	6 (1)	6 (1)	0.648

protein intake as a percentage of energy at 1 y with overweight at 5 y was more marked (parental overweight, $P = 0.0004$; percentage protein, $P = 0.03$).

Finally, an analysis was carried out to assess whether the type of feeding at birth might be associated with overweight at the age of 5 y. When the sample was analyzed as a whole, overweight at 5 y of age occurred in 21.8% of 124 breast-fed children, and in 30.4% of 23 bottle-fed children ($P = 0.52$). The difference was remarkably greater in the group of 38 children born from overweight mothers (23.3% *vs* 62.5%) and approached statistical significance ($P = 0.08$). In this group the risk of being overweight at 5 y of age for bottle-fed children ($n = 8$), when compared to breast-fed children ($n = 30$), was 2.68. Among the breast-fed children, duration of full breast-feeding (mean ± s.d.) tended to be longer in children who were not overweight at 5 y (2.9 ± 2.6 months) than in overweight ones (2.2 ± 2.7 months), although the difference was not significant ($P = 0.358$). In breast-fed children overweight at 5 y and born from overweight mothers, duration of full breast-feeding was even shorter (1.4 ± 1.8 months).

Discussion

Dietz has stated that 'Although obesity-associated morbidities occur more frequently in adults, significant consequences of obesity as well as the antecedents of adult disease occur in obese children and adolescents'.[20] To design effective preventive interventions any possible relationship between genetic and environmental factors should be investigated. Few prospective studies have examined the mutual role of environmental and genetic factors on childhood obesity.[21,22] Dietary habits may be the most relevant environmental factor possibly influencing the early development of obesity. In particular, interest has been focused on the dietary habits during the early periods of life, including the milk-feeding period and the transition from the milk to an omnivorous diet.[23]

In the present prospective study we have investigated the association of overweight at 5 y of age with macronutrient intake at 1 y and parental overweight.

It may be pointed out that in our sample prevalence of parental overweight was very high (51%). Although the reasons for this high value are open to speculation, the present findings are consistent with previous results.[24,25] Indeed, the Italian Household Multipurpose Survey[24] estimated in the general adult population an overall prevalence of overweight (BMI ≥ 25) of 31.6%, and in particular a value of 44.7% and 54.5% in middle-aged women and men, respectively.

Prevalence of overweight in children was 10.9% at the age of 1 y and increased to 23.1% at 5 y. The quite high prevalence at 5 y of age may be partially explained on the basis of the high prevalence of parental overweight and the high protein intake at the age of 1 y. Indeed, in agreement with the literature,[26] we have found a strong association between children's and parental overweight. Moreover, the average protein intake at 1 y was about 20% of the energy intake, a value similar to that found in a previous study performed in our area,[27] but remarkably higher than the 10–12% level indicated by the Italian Recommended Dietary Allowances[28] and also than the median value of 15% estimated in the Copenhagen Cohort study.[29]

Such a high protein intake at 1 y might be surprising and needs further investigation. Therefore some caution has to be paid in extending conclusions to other general populations. However, the role of the early protein intake in the development of later obesity may be further emphasized by our observations on infants not overweight at 1 y of age and is also supported by other authors.[30] Rolland–Cachera and colleagues found that protein intake at the age of 2 y is associated with the pattern of fatness development at 8 y. They hypothesized that a high protein intake could trigger adipocyte multiplication (normally starting at 8 y, but starting at an even earlier age in the obese[31]) by stimulating the production of insulin-like growth factors.[32] Based on early experience, Rolland–Cachera proposed another interesting model using GH and IGF1 concentration to explain adiposity variation.[33]

Our data also suggest a positive role of breast-feeding in the prevention of the development of overweight, especially in infants born to overweight mothers. This hypothesis is supported by a recent cross-sectional study performed among children aged 5–6 y.[34] The authors of this survey have found that breast-feeding had a significant protective role in preventing early obesity development. Furthermore, the Darling Study suggested that the low protein content of human milk, as compared to formula, may account for breast-fed infants being thinner than bottle-fed infants in the first 2 y of life.[35]

The dietary pattern of children may be influenced by child-feeding practices too. It has been suggested that eating environments may differ between families with and without overweight parents.[36] Our data did not highlight significant associations of parental overweight with any macronutrient intake at the age of 1 y.

More longitudinal studies are needed to clarify the independent role of the genetic background and the early dietary patterns on the development of overweight in childhood. Anyway, the high rate of overweight at the age of 5 y, besides confirming the increasing prevalence of overweight in Western areas,[37] also emphasizes the need to promote effective preventive programs.

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