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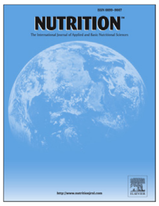

Applied nutritional investigation

Weight following birth and childhood dietary intake: A prospective cohort study

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ABSTRACT

Objectives: Unhealthy childhood dietary habits track through life and are independent and modifiable risk factors for disease. Therefore, it is essential to understand the factors involved. We aimed to evaluate the associations of birthweight (BW) and newborn weight change (NWC) during the first 96 h of life and childhood longitudinal weight trajectories with dietary intake at age 4.

Methods: As part of the Generation XXI birth cohort (G21), children were recruited in 2005 and 2006 at all public units providing obstetrical and neonatal care in Porto, Portugal. Information was collected by face-to-face interview and abstracted from clinical records. At age 4, weight measurements recorded from birth to current age were abstracted and weight trajectories estimated. Food frequency questionnaires were applied, and three dietary patterns (DPs) were identified: “Energy-dense food (EDF)+Dairy,” “Lower in Healthy Food,” and “Healthier.” Logistic regression models were used to compute the odds ratio (OR) and 95% confidence intervals (CIs) (OR [95% CI]) in a sample of 775 children.

Results: Children with higher BW were less frequently in the “EDF+Dairy” DP (0.94 [0.89–0.98] per 100 g increase in BW). Children with higher NWC had lower odds of eating fruit $\geq$3/d (0.93 [0.87–0.99] per 1% increase in NWC). Children with higher weight during childhood had higher odds of belonging to the “EDF+Dairy” DP (1.90 [1.04–3.47]) and lower odds of eating vegetable soup $\geq$2/d (0.56 [0.34–0.91]). Children showing catch-up grow in the first year of life had higher odds of eating dairy products $\geq$3/d (3.76 [1.31–10.80]).

Conclusions: The way that children grow during childhood played a major role on dietary intake at age 4.

Introduction

The prevention of adverse lifestyles such as unhealthy dietary habits in early childhood has become increasingly important, mainly due to the increasing prevalence of overweight among preschool children [1]. Moreover, unhealthy dietary habits track into later ages and are also considered independent and modifiable risk factors for cardiovascular disease and type 2 diabetes [2]. Therefore, it is essential to understand the determinants of childhood dietary habits.

Previous studies have suggested that a period of inadequate nutrition and growth can “program” an individual’s food preferences later in life [3–8]. A classic example of this so-called “programming” is the preference for fatty foods later in life in children whose mothers were exposed to the Dutch famine

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during pregnancy [6]. In a more recent study, poor fetal growth was positively correlated with hedonic response to a sweet solution in the first day of life [3]. Even in young adults, intrauterine growth restriction was associated with preference for carbohydrates over protein in regular diets [4]. However, programming is not limited to gestation; evidence shows that it extends from the periconception period throughout the postnatal period, adding to the importance of studying growth in a longitudinal way [9].

In addition to programming appetite, early inadequate nutrition and growth can affect childhood dietary habits by influencing parental beliefs and feeding practices [10]. In addition, it may cause problems in feeding, such as swallowing, vomiting, refusal to eat, or neophobia [11,12], and eating disorders such as anorexia and bulimia nervosa [13].

Although the relation between fetal growth and dietary habits has been addressed previously [3–8], to the best of our knowledge, there have been no studies of the impact of growth during early postnatal life on later dietary intake. The use of longitudinal weight trajectories to evaluate this association is also novel.

Therefore, we aimed to evaluate the association of birth weight (BW), newborn weight change (NWC), and childhood weight trajectories with dietary intake at age 4, including specific food groups and items, and *a posteriori*-defined dietary patterns (DPs).

Material and methods

Participants

Participants were recruited to the Generation XXI (G21) birth cohort [14] between April 2005 and August 2006, during the hospital stay, from all five public units providing obstetrical and neonatal care in the metropolitan area of Porto, Portugal. A total of 8647 newborns were recruited to G21. At age 4, the total cohort was invited to a reevaluation.

For this study, we only used data from children recruited since November 2005 because only since that date was a second weight measurement performed in the newborns. Since then, 5034 newborns were recruited to G21, of which 4449 were full-term singletons without congenital anomaly. Of those 4449, a subsample of 1806 newborns had a second weight measurement performed by trained examiners, constituting the eligible sample for our study. Of the 1806 newborns, 471 had missing information at the time of measurement, 28 were measured after 96 h of life, and 19 were considered outliers (1st/3rd quartile ± 3 times the interquartile range: those with weight loss higher than 0.50% of BW per hour [$n = 15$] and those with weight gain higher than 0.19% of BW per hour [$n = 4$]) [15]. Of the remaining 1288, 152 were lost to follow-up at age 4; 257 were interviewed by telephone, therefore lacking information on food frequency questionnaire (FFQ); three had food allergy or intolerance; one had celiac disease; eight had incomplete data on the FFQ; and 92 had missing information on weight trajectories. The final sample comprised 775 children. Figure 1 shows the study flow chart of participants.

Participants ($n = 775$) and eligible nonparticipants ($n = 1031$) were compared, and the statistically significant differences were that participants had higher mean maternal education (11.2 versus 10.5 y, $P = 0.002$) and age at delivery (29.6 versus 28.3 y, $P < 0.001$) and lower proportion of tobacco smoke during third trimester (11.9% versus 16.3%, $P = 0.010$).

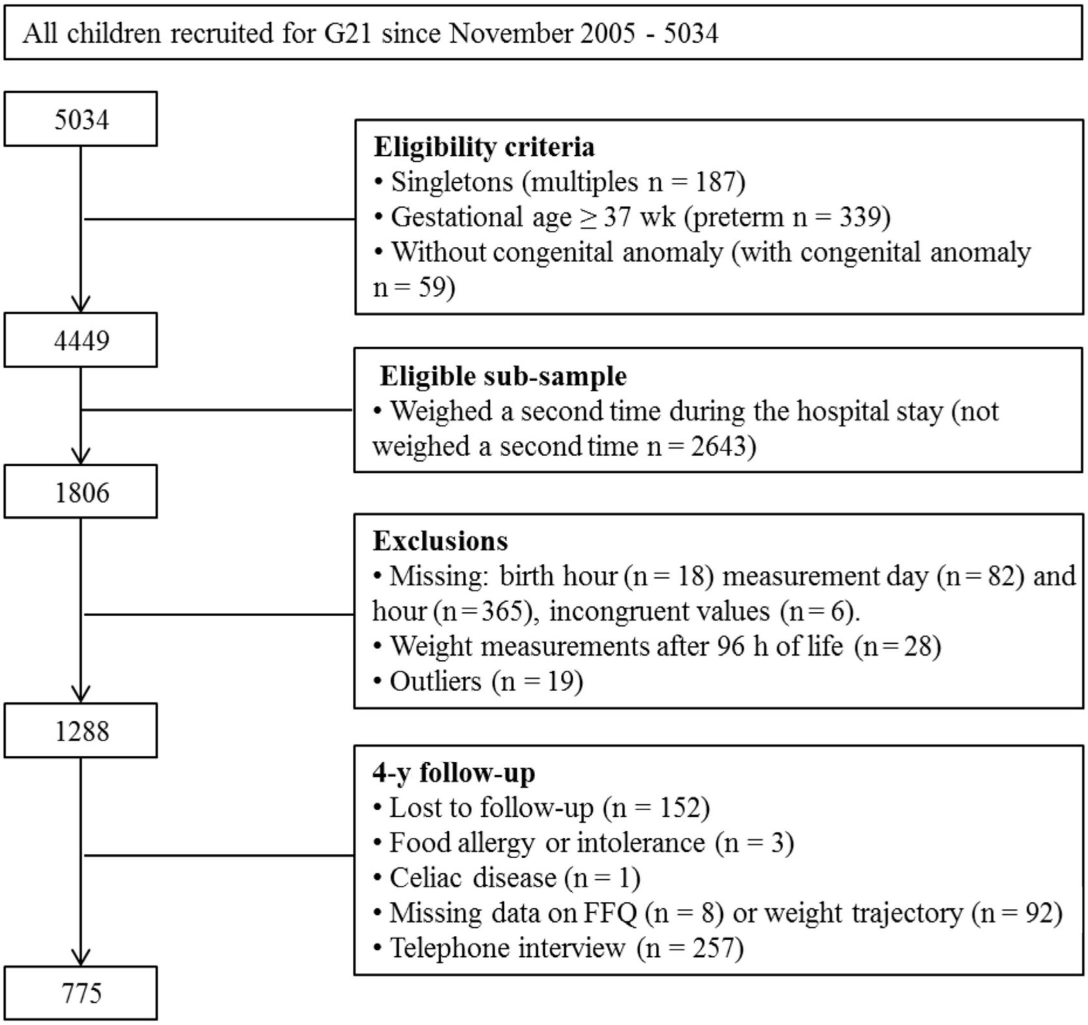

Fig. 1. Study flow chart of participants.

Baseline evaluation: BW and NWC

All newborns were weighed at birth and, since November 2005, whenever possible, newborns had a second weight measurement performed. This second newborn weight measurement was performed to the nearest 1 g by our trained examiners during the hospital stay independently of routine procedures and the date and time of measurement were registered. Of the 1288 newborns with valid data on first and second weight measurements, 215 (16.7%) were measured the second time before 24 h of life, 566 (43.9%) between 24 and 48 h of life, 388 (30.1%) between 48 and 72 h of life, and 119 (9.2%) after 72 h of life. Because newborns were weighed at different ages (in h), we calculated the NWC using the formula NWC % = ([weight–BW]/BW) × 100, where the weight used for each newborn was the estimated weight at 52.3 h of life because it was the mean nadir time [16]. Also at birth, information was collected by a face-to-face interview using structured questionnaires 24 to 72 h after delivery. Data on delivery and newborn characteristics, including BW, were abstracted from clinical records.

Four-year follow-up evaluation

At age 4, the total cohort was invited to a reevaluation occurring between April 2009 and July 2011 at our department, including face-to-face interviews and physical examinations. Whenever the child could not attend the face-to-face interview, a short telephone interview was conducted, which did not include the FFQ, so they were not included in this specific study.

As part of the standard child care in Portugal, health professionals perform anthropometric measurements of the child and record it in a child health book at every medical visit; however, no regular periods for these visits are established by the Portuguese Health Authorities. At the G21 follow-up evaluation, when the children were 4 y old, mothers were asked to bring their child health book to abstract data on the child's weight measurements from birth to current age. This information was used to estimate weight trajectories.

Children's usual dietary intake was evaluated through a previously used 35-item FFQ assessing usual food consumption in the previous 6 mo. Nine response options were available (≥4 times/d, 2–3 times/d, once/d, 5–6 times/wk, 2–4 times/wk, once/wk, 1–3 times/mo, <1 time/mo, and never). These frequencies were converted into daily frequencies (e.g., once/wk was converted into 1/7 d = 0.14 times/d) [17].

To evaluate the frequency of specific food items or groups, three FFQ items (vegetable soup, fruit, and fish) and four food groups (dairy: whole, semiskimmed, and skimmed milk and sugared and nonsugared yogurt; vegetables on a plate: raw and cooked vegetables on a plate; sugar-sweetened beverages: sweetened beverages, carbonated or not; and sweets and fast food: candies, cakes, cookies, sugar, and fast food) were considered. We distinguished vegetables on a plate from vegetable soup because in Portugal, it is an established idea among parents that children must eat vegetable soup twice a day and therefore a common practice. This practice is reflected in the proportion of children who adopt this food habit (see Table 1; 76.9% of our sample ate vegetable soup 2 times a day). Conversely, vegetables on a plate are not as common as soup because parents do not think that this food habit is as important (see Table 1; only 45.3% of our sample ate vegetables on a plate at least once per day). Although the groups were similar in their nutritional composition, parents' beliefs and feeding practices regarding each one were different, so they were analyzed separately.

Regarding food groups, we added the daily frequencies of the composite food items and then divided into two categories with different cut points (dairy: ≥3 times/d; vegetables on a plate: ≥ once/d; sugar-sweetened beverages: ≥ once/d; and sweets and fast food: ≥ once/d). Regarding vegetable soup, fruit, and fish, we used a FFQ response option as a cutoff (vegetable soup: ≥2 times/d; fruit: ≥2 times/d; fish: ≥5 times/wk).

All phases of the study complied with the Ethical Principles for Medical Research Involving Human Subjects expressed in the Declaration of Helsinki [18]. The study was approved by the University of Porto Medical School/S. João Hospital Centre Ethics Committee and a signed informed consent according to Helsinki principles was required for all participants.

Statistical analysis

For estimating weight trajectories, all data available from the whole G21 cohort were used. Of the 5282 children whose parents brought the child health book to the 4-y follow-up evaluation, those who had <5 measurements ($n = 45$) were excluded. Therefore, data from 5237 children were included in this analysis. These children provided for the estimation of the weight trajectories, 86 428 weight records, with a median of 16 records (25th–75th percentile: 13–19) per child. Several polynomial models were tested to estimate weight trajectories. Individual patterns of weight trajectories were measured by the intercept, slope, quadratic, and cubic random terms estimated by a mixed model. Normal mixture modeling for model-based clustering was used to identify patterns in the weight trajectories. The most appropriate models were considered those allowing for the most homogeneous grouping of individual patterns of growth selected among those with the lowest Bayesian information criterion (BIC). Four weight trajectories were defined:, the "normal weight gain" trajectory that comprised most children, the "persistent weight gain" trajectory that included children who always had higher weight than the average, the "weight gain during childhood" trajectory characterized by a continuous weight gain, and the "weight gain during infancy" trajectory that included children who were born with low BW and gained weight essentially during infancy, showing a catch-up growth in the first year of life (Fig. 2). Table 1 shows the distribution of our 775 included children across the four weight trajectories. Children were similarly distributed across the weight trajectories in the sample of 775 ("normal weight gain," 65.4%; "persistent weight gain," 12.3%; "weight gain during childhood," 16.1%; "weight gain during infancy," 6.2%) and 5237 ("normal weight gain," 62.4%; "persistent weight gain," 11.7%; "weight gain during childhood," 16.1%; "weight gain during infancy," 9.7%).

Considering the discrete nature of FFQ items and their asymmetrical distribution, children's DPs were identified by latent class analysis in a previous work [19]. This method focuses on relationships among individuals (i.e., a person-centered approach) rather than relationships among variables and describes how the probabilities of a set of observed categorical variables (e.g., FFQ's items) vary across groups of individuals (distinguishing clusters of individuals homogeneous with groups) to find the smallest number of latent classes (e.g., DPs) by adding classes stepwise until the model fits the data well [20]. Probabilities of choosing each item response conditionally on class membership can be interpreted based on item profiles in each class [21]. The number of DPs was defined using BIC. Seventeen food items/groups were considered and categorized into lower (first quintile), intermediate (second to fourth quintiles combined), and higher (fifth quintile) frequency of intake. Children were assigned to each pattern according to the highest probability of class membership and profiles of probabilities in each item category, conditionally on pattern membership, were used to interpret DPs. Three DPs were identified: "Energy-dense food (EDF)+Dairy," characterized by higher consumption of EDF, dairy, processed meat, bread, and butter; "Lower in Healthy Food," characterized by lower consumption of fruit, vegetables, fish, white meat and eggs, bread and butter, and with intermediate EDF consumption; and "Healthier," characterized by higher consumption of fruit, vegetables, and fish and lower consumption of processed meat and EDF. Table 1 shows the distribution of the 775 included children across the three DPs.

Crude and adjusted odds ratios (ORs) and 95% confidence intervals (95% CI) were computed using logistic regression models (analysis performed using SPSS version 21.0). Final models were adjusted for maternal education, age, and parity.

Table 1
Characteristics of the study sample at baseline and 4-y follow-up

$n = 775$	Baseline	4-y follow-up
Maternal characteristics		
Education, y, mean (SD)	11.2 (4.2)	–
Age at delivery, y, mean (SD)	29.6 (5.3)	–
Parity, *n* (%)		
Multipara	328 (42.3)	–
Primipara	447 (57.7)	–
Weight measurements		
BW, g, mean (SD)	3255 (437)	–
NWC, %, mean (SD)	−6.8 (2.4)	–
Weight trajectory, *n* (%)		
"Normal weight gain"	–	507 (65.4)
"Persistent weight gain"	–	95 (12.3)
"Weight gain during childhood"	–	125 (16.1)
"Weight gain during infancy"	–	48 (6.2)
Food patterns, *n* (%)		
Healthier	–	301 (38.8)
EDF+dairy	–	167 (21.5)
Lower in healthy food	–	307 (39.6)
Food groups, *n* (%)		
Dairy ≥3/d	–	604 (77.9)
Vegetable soup ≥2/d	–	596 (76.9)
Vegetables on plate ≥1/d	–	351 (45.3)
Fruit ≥2/d	–	467 (60.3)
Fish ≥5/wk	–	239 (30.8)
Sugar-sweetened beverages ≥1/d	–	316 (40.8)
Sweets and fast food ≥1/d	–	626 (80.8)

EDF, energy-dense food; SD, standard deviation

Results

In this sample of 775 full-term singletons (50.3% male), mean BW was 3255 g (SD 437 g) and mean NWC was −6.8% (SD 2.4%).

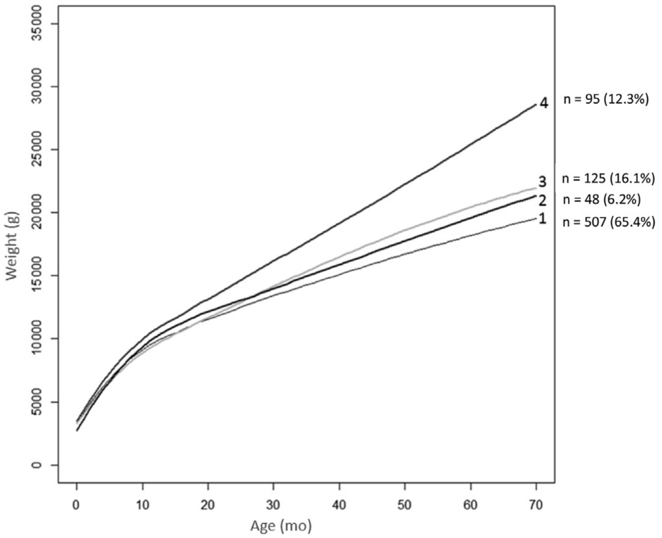

Fig. 2. Weight trajectories: normal weight gain (1), weight gain during infancy (2), weight gain during childhood (3), and persistent weight gain (4).

Regarding weight trajectories, 507 (65.4%) children were classified in the trajectory “normal weight gain,” 95 (12.3%) in the “persistent weight gain,” 125 (16.1%) in the “weight gain during childhood,” and 48 (6.2%) in the “weight gain during infancy” (Table 1).

At age 4, 604 (77.9%) children consumed dairy products ≥3 times/d, 596 (76.9%) consumed vegetable soup ≥2 times/d, 351 (45.3%) consumed vegetables on a plate ≥1 time/d, 467 (60.3%) consumed fruit ≥2 times/d, 239 (30.8%) consumed fish ≥5 times/wk, 316 (40.8%) consumed sugar-sweetened beverages ≥1 time/d, and 706 (91.1%) consumed sweets and fast food ≥1 time/d (Table 1). The “EDF+Dairy” DP comprised 167 children (21.5%), the “Lower in Healthy Food” DP 307 children (39.6%), and the “Healthier” DP 301 children (38.8%) (Table 1).

Table 2 shows the OR and respective 95% CIs for the associations of BW, NWC, weight trajectories, and some selected maternal characteristics with food items/groups consumption at age 4. BW was not associated with the consumption of the studied food items/groups. For each 1% increase in NWC (i.e., lower weight loss), there was a 7% lower odds of consuming fruit ≥2 times/d (OR = 0.93; 95% CI 0.87–0.99). Regarding childhood weight trajectories, children who were in the “persistent weight gain” trajectory had a 44% lower odds of consuming vegetable soup ≥2 times/d (OR = 0.56; 95% CI 0.34–0.91) and children who were in the “weight gain during infancy” trajectory had almost 4 times the odds of consuming dairy products ≥3 times/d than children in the “normal weight gain” trajectory (OR = 3.76; 95% CI 1.31–10.80).

Table 3 shows the OR and respective 95% CIs for the associations of BW, NWC, weight trajectories, and some selected maternal characteristics with DPs at age 4. For each 100-g increase in BW, there was a 6% decrease in the odds of being in the “EDF+Dairy” DP (OR = 0.94; 95% CI 0.89–0.98). No association between NWC and DP at age 4 was observed.

Table 2
Associations among BW, NWC, weight trajectory, and maternal characteristics with food items/groups consumption at age 4

	Dairy ≥3/d	Vegetable soup ≥2/d	Vegetables on plate ≥1/d	Fruit ≥2/d	Fish ≥5/wk	Sugar-sweetened beverages ≥1/d	Sweets and fast food ≥1/d
Crude models, OR (95% CI)							
BW, 100 g	1.01 (0.97–1.05)	0.98 (0.94–1.02)	1.00 (0.97–1.04)	1.00 (0.96–1.03)	0.99 (0.96–1.03)	0.99 (0.96–1.02)	1.00 (0.96–1.05)
NWC, 1%	1.02 (0.95–1.09)	0.94 (0.88–1.01)	0.99 (0.94–1.05)	0.92 (0.86–0.98)*	0.96 (0.90–1.03)	1.05 (0.99–1.12)	1.05 (0.97–1.13)
Weight trajectories							
“Normal weight gain”	1	1	1	1	1	1	1
“Persistent weight gain”	0.96 (0.58–1.60)	0.51 (0.32–0.82)*	0.97 (0.63–1.51)	1.02 (0.65–1.59)	1.07 (0.67–1.71)	1.43 (0.92–2.22)	1.09 (0.61–1.92)
“Weight gain during childhood”	1.23 (0.76–1.99)	0.72 (0.46–1.13)	0.95 (0.64–1.41)	0.99 (0.66–1.47)	1.05 (0.69–1.60)	0.89 (0.59–1.33)	0.95 (0.58–1.55)
“Weight gain during infancy”	3.37 (1.19–9.58)*	0.98 (0.47–2.03)	0.77 (0.42–1.41)	1.65 (0.86–3.15)	1.27 (0.68–2.36)	1.40 (0.77–2.54)	0.90 (0.43–1.87)
Maternal education, y	0.99 (0.95–1.03)	1.07 (1.02–1.11)*	1.10 (1.06–1.14)*	1.10 (1.06–1.14)*	1.09 (1.05–1.13)*	0.88 (0.85–0.91)*	0.88 (0.84–0.92)*
Maternal age, y	0.98 (0.94–1.01)	1.04 (1.01–1.07)*	1.00 (0.97–1.02)	1.03 (1.00–1.06)*	1.05 (1.02–1.09)*	0.93 (0.91–0.96)*	0.97 (0.93–1.00)
Parity							
Multipara	1	1	1	1	1	1	1
Primipara	0.66 (0.46–0.93)*	1.07 (0.76–1.50)	1.28 (0.96–1.71)	0.81 (0.61–1.09)	0.91 (0.67–1.24)	1.06 (0.79–1.42)	0.63 (0.44–0.92)*
Adjusted model[†], OR (95% CI)							
BW, 100 g	1.01 (0.97–1.05)	0.99 (0.95–1.03)	1.01 (0.98–1.05)	1.00 (0.96–1.03)	1.00 (0.96–1.04)	0.97 (0.94–1.01)	0.99 (0.94–1.03)
NWC, 1%	1.02 (0.95–1.10)	0.95 (0.88–1.02)	1.00 (0.94–1.07)	0.93 (0.87–0.99)*	0.98 (0.92–1.04)	1.03 (0.97–1.10)	1.03 (0.96–1.11)
Weight trajectories							
“Normal weight gain”	1	1	1	1	1	1	1
“Persistent weight gain”	0.87 (0.51–1.48)	0.56 (0.34–0.91)*	1.07 (0.67–1.68)	1.12 (0.70–1.78)	1.22 (0.75–1.99)	1.30 (0.82–2.07)	0.90 (0.50–1.64)
“Weight gain during childhood”	1.31 (0.80–2.16)	0.76 (0.48–1.20)	1.09 (0.73–1.63)	1.10 (0.73–1.65)	1.19 (0.77–1.84)	0.75 (0.49–1.15)	0.83 (0.50–1.40)
“Weight gain during infancy”	3.76 (1.31–10.80)*	0.98 (0.47–2.05)	0.85 (0.46–1.59)	1.81 (0.93–3.53)	1.39 (0.73–2.64)	1.21 (0.64–2.26)	0.82 (0.38–1.77)
Maternal education, y	1.02 (0.97–1.06)	1.05 (1.01–1.10)*	1.10 (1.06–1.15)*	1.11 (1.06–1.15)*	1.08 (1.04–1.13)*	0.89 (0.85–0.92)*	0.89 (0.85–0.93)*
Maternal age, y	0.95 (0.92–0.99)	1.03 (1.00–1.07)	0.99 (0.96–1.02)	1.01 (0.98–1.04)	1.04 (1.01–1.08)*	0.94 (0.91–0.97)*	0.97 (0.93–1.01)
Parity							
Multipara	1	1	1	1	1	1	1
Primipara	0.52 (0.35–0.77)*	1.07 (0.73–1.58)	1.11 (0.80–1.54)	0.74 (0.53–1.04)	0.97 (0.68–1.38)	0.97 (0.69–1.37)	0.60 (0.39–0.92)*

CI, confidence interval; NWC, newborn weight change; OR, odds ratio

[*] $P < 0.05$.

[†] Explanatory variables: birth weight, NWC, weight trajectories, maternal education, maternal age, and parity.

Table 3
Associations among BW, NWC, weight trajectory, and maternal characteristics with dietary pattern at age 4

	Dietary pattern					
	Crude models, OR (95% CI)			Adjusted model[†], OR (95% CI)		
	Healthier ($n = 301$)	EDF+dairy ($n = 167$)	Lower in healthy food ($n = 307$)	Healthier ($n = 301$)	EDF+Dairy ($n = 167$)	Lower in healthy food ($n = 307$)
BW, 100 g	1	0.98 (0.93–1.02)	1.00 (0.96–1.04)	1	0.94 (0.89–0.98)[*]	0.99 (0.95–1.03)
NWC, %	1	1.03 (0.95–1.11)	1.05 (0.99–1.13)	1	1.00 (0.92–1.08)	1.03 (0.96–1.11)
Weight trajectories						
"Normal weight gain"	1	1	1	1	1	1
"Persistent weight gain"	1	2.10 (1.20–3.69)[*]	1.30 (0.77–2.20)	1	1.90 (1.04–3.47)[*]	1.17 (0.68–2.03)
"Weight gain during childhood"	1	1.17 (0.69–2.01)	1.26 (0.81–1.95)	1	0.99 (0.56–1.74)	1.11 (0.70–1.76)
"Weight gain during infancy"	1	0.91 (0.40–2.08)	0.99 (0.52–1.92)	1	0.66 (0.27–1.59)	0.86 (0.43–1.72)
Maternal education, y	1	0.84 (0.80–0.88)[*]	0.88 (0.84–0.91)[*]	1	0.86 (0.82–0.90)[*]	0.89 (0.85–0.92)[*]
Maternal age, y	1	0.93 (0.90–0.97)[*]	0.93 (0.90–0.96)[*]	1	0.92 (0.88–0.96)[*]	0.95 (0.91–0.98)[*]
Parity						
Multipara	1	1	1	1	1	1
Primipara	1	0.61 (0.42–0.90)[*]	1.17 (0.84–1.62)	1	0.51 (0.32–0.80)[*]	1.07 (0.73–1.56)

CI, confidence interval; EDF, energy-dense food; NWC, newborn weight change; OR, odds ratio

[*] $P < 0.05$.

[†] Explanatory variables: birth weight, NWC, weight trajectories, maternal education, maternal age, and parity.

Children in the "persistent weight gain" trajectory had almost two-fold the odds of being in the "EDF+Dairy" DP than children in the "normal weight gain" trajectory (OR = 1.90; 95% CI 1.04–3.47).

Discussion

Using data from a previously used FFQ [17], we found that higher BW was associated with lower odds of being in the "EDF+Dairy" DP and higher NWC was associated with lower odds of consuming fruit ≥2 times/d. Children in the "persistent weight gain" trajectory had lower odds of consuming vegetable soup ≥2 times/d and higher odds of being in the "EDF+Dairy" DP, whereas children in the "weight gain during infancy" trajectory had higher odds of consuming dairy products ≥3 times/d.

The mechanisms by which early inadequate nutrition and growth can affect childhood dietary habits remain to be established. One theory relates to programming of the central nervous system on appetite control and craving for specific foods [22]. Simultaneously, parents may expose their children to different feeding practices [23]. For example, parents of low BW children, children who lose an excessive amount of weight after birth, or children who grow slowly may be more likely to implement feeding practices that result in higher food intake. In contrast, those who have higher BW, higher NWC, or overweight children may be more prone to promote healthier food habits [23,24].

In our study, higher BW was associated with lower odds of having an "EDF+Dairy" DP at age 4. A sensitivity analysis was performed using a categorized variable for BW (<2500 g; 2500–4000 g; >4000 g) and, although we had few newborns in the extreme categories of BW, a tendency for decreasing odds of having an "EDF+Dairy" DP with increasing BW category was observed, and for the category of >4000 g, it was statistically significant (OR = 0.31; 95% CI 0.10–0.99 versus 2500–4000 g; data not shown). One possible explanation for this effect is that these parents may be more restrictive of their children's caloric intake because they were born heavier than average [23]. Another explanation could be programming of food preferences. It has been shown that fetuses who suffered from growth restriction develop a preference for fatty [6] and sweet [3] foods and also prefer carbohydrates to protein [4]. Our results are consistent with these findings because the "EDF+Dairy" DP was characterized by higher consumption of EDFs, which are rich in fat and sugar. This adds to the importance of intrauterine growth independently of the subsequent postnatal development.

After birth, newborns must adapt to external conditions. These adaptations lead to a physiological loss of ∼6% of BW and appetite and energy metabolism programming can occur in this short postnatal period [25,26]. No previous study has addressed the programming effect of NWC immediately after birth on dietary intake later in life. According to our results, higher NWC was associated with lower fruit intake at age 4. Programming of food preferences, similar to that occurring during intrauterine life, when inadequate growth may program a preference for sweet [3] and rich in carbohydrates foods [4], may explain this result. However, although with no statistical significance, higher NWC was also associated with lower vegetable soup intake, which points to an alternative explanation. In a previous study, we found that high NWC was associated with formula feeding [27], which in turn was associated with a more difficult weaning and picky eating behaviors later in life [28,29]. However, feeding mode in the first day of life was tested as a confounder, and no significant confounding effect was observed. Nevertheless, further research concerning the effect of NWC on dietary intake is needed.

Our results also suggest that weight trajectories during childhood play a role in the development of dietary habits. Both weight trajectories and the development of dietary habits are continuous processes that occur simultaneously during childhood [30–34]. Therefore, it is possible that a child's weight influences dietary habits [23,35,36], but that dietary habits also influence a child's weight [32–34]. In our study, children who always had higher weight than the average, those in the "persistent weight gain" trajectory, ate vegetable soup less frequently and had higher odds of belonging to "EDF+Dairy" DP at age 4. Because there is tracking in dietary habits during childhood, these children probably ate less vegetable soup and more EDF and dairy throughout childhood, this being reflected at age 4 [31,37]. Our results are consistent with previous studies showing that a diet rich in EDF and poor in healthy foods promotes childhood overweight and obesity [33,34,38].

Children who were born with lower weight and had to catch up in growth during the first year of life ate dairy products more frequently. This food habit may be explained by higher parental concern regarding child's lower weight in the first months of life, which caused them to be more prone to feed children greater amounts of dairy products because the role of calcium intake in bone mineral mass is well recognized [39]. This type of feeding may contribute to higher growth rate and the consequent catch-up growth during the first year of life [39,40]. Due to tracking in dietary habits, the higher intake of dairy products is still reflected at age 4 [31,37].

Of the 1288 children at baseline, 775 were included in this study, which was due to a 12% attrition from baseline to 4-y follow-up evaluation, to exclusions for this specific study, and to missing information on main variables. However, there was no relevant difference between those included in our analyses and those excluded, and we did not expect a great influence on the estimated associations, as was shown previously [41].

An important strength of this study is the longitudinal design that allowed the abstract of weight measurements from birth to age 4, comprising a large number of repeated observations. All weight measurements were performed by a health professional or a trained examiner prospectively, which precludes recall bias. Nevertheless, we acknowledge that standard procedures for weight measurements could be subjected to some variability because they were performed in different health units and/or by different health professionals, increasing measurement errors. These errors are random and therefore would attenuate the observed associations; in addition, the use of weight data collected in clinical settings in research has been shown to be adequate [42].

Qualitative FFQ to assess dietary intake can be a limitation because established frequency categories may not correspond to insufficient or excessive consumption levels. However, the inclusion of portion sizes in the FFQ has been shown to provide little additional information, so its inclusion in the FFQ is controversial [43].

For a subsample of 2373 children, 3-d food diaries were also completed and, to assess the validity and reliability of the FFQ, Pearson's correlation coefficients and intraclass correlation coefficients were calculated for key food groups as measured by both methods. For those food groups most frequently consumed, weak-to-moderate correlations and fair-to-moderate agreement were observed. Considering that, at age 4, a 3-d food diary may not be the ideal method to represent consumption of foods eaten less frequently, the weak-to-moderate correlations and fair-to-moderate agreement support an acceptable validity and reliability of the FFQ data [17].

Because usual dietary intake was assessed during face-to-face interviews, social desirability bias could be present. If overreporting of healthy foods and/or underreporting of unhealthy ones occurred differentially between weight trajectories, then associations may have been underestimated. Moreover, information regarding children's diets was reported by the mother, who is not always with the child. However, because children at this age ingest most of their daily energy at home, we do not expect that out-of-home intake would result in different findings [44,45].

The use of *a posteriori* DPs to evaluate the food intake in such early ages is another important strength of this work because they take into account the different effects and interactions between food components. The *a posteriori* construction of DPs takes into consideration the real eating behaviors of the population without making any assumption about protective or harmful health effects [43]. In addition, using latent class analysis to identify DPs is an advantage because it is especially well suited for categorical variables that are distributed asymmetrically, which are common in data from FFQ. This methodology also avoids subjective choice of cut points on underlying dimensions because the classification is provided directly by the model [20].

Conclusions

Intrauterine growth measured as BW, and particularly the way children gain weight during childhood, played a role in dietary intake at age 4. We believe that these results are important for public health because dietary habits acquired in childhood persist through to adulthood and are independent and modifiable risk factors for later disease risk.

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