Birth weight is associated with dietary factors at the age of 6–8 years: the Physical Activity and Nutrition in Children (PANIC) study

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Abstract
Objective: Low and high birth weight have been associated with increased risk of type 2 diabetes and CVD. Diet could partly mediate this association, e.g. by intra-uterine programming of unhealthy food preferences. We examined the association of birth weight with diet in Finnish children.
Design: Birth weight standard deviation score (SDS) was calculated using national birth register data and Finnish references. Dietary factors were assessed using 4 d food records. Diet quality was defined by the Finnish Children Healthy Eating Index (FCHEI).
Setting: The Physical Activity and Nutrition in Children (PANIC) study.
Subjects: Singleton, full-term children (179 girls, 188 boys) aged 6–8 years.
Results: Birth weight was inversely associated (standardized regression coefficient β; 95 % CI) with FCHEI (–0·15; –0·28, –0·03) in all children and in boys (–0·27; –0·45, –0·09) but not in girls (–0·01; –0·21, 0·18) after adjusting for potential confounders ($P = 0{\cdot}044$ for interaction). Moreover, higher birth weight was associated with lower fruit and berries consumption (–0·13; –0·25, 0·00), higher energy intake (0·17; 0·05, 0·29), higher sucrose intake (0·19; 0·06, 0·32) and lower fibre intake (–0·14; –0·26, –0·01). These associations were statistically non-significant after correction for multiple testing. Children with birth weight >1 SDS had higher sucrose intake (mean; 95 % CI) as a percentage of energy intake (14·3 E%; 12·6, 16·0 E%) than children with birth weight of –1 to 1 SDS (12·8 E%; 11·6, 14·0 E%) or <–1 SDS (12·4 E%; 10·8, 13·9 E %; $P = 0{\cdot}036$).
Conclusions: Higher birth weight may be associated with unhealthy diet in childhood.

Keywords
Birth weight
Diet
Diet quality
Children
PANIC study

Both low and high birth weight have been associated with increased risk of type 2 diabetes and CVD in adulthood in epidemiological studies[(1)]. Children born small- and large-for-gestational-age have been reported to have higher insulin resistance than children born appropriate-for-gestational-age[(2)], suggesting that abnormal prenatal growth increases cardiometabolic risk already in childhood.

One possible mechanism for the relationship between birth weight and later disease risk is programming of metabolism during fetal life[(3)]. It has been suggested that also appetite and taste preferences may be programmed by the intra-uterine environment[(4,5)]. For example, lower birth weight has been associated with a higher acceptance of salty taste[(4)] and sweet taste[(5)] in childhood, which may lead to higher intakes of salty and sweet foods. Alternatively, the association of low and high birth weight with later diseases could be mediated by harmful parental lifestyle factors, such as an unhealthy diet, related to the birth weight of the offspring.

Evidence on the associations of birth weight with dietary factors in later life is limited. One previous study reported that undernutrition during fetal life was associated with a higher intake of fat, particularly saturated fat, in adults born in the 1940s[(6)]. In similar vein, a lower birth weight was associated with a higher intake of fat and a lower intake of carbohydrates in adults born in the 1930s to 1940s[(7)]. In contrast, severe intra-uterine growth

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restriction was associated with a higher carbohydrate intake in a study among young Brazilian adults born in the 1970s[8]. Children born preterm at very low birth weight had a lower consumption of vegetables, fruit, berries and dairy products than children born at term in a study among young Finnish adults born in the 1970s to 1980s[9].

There are few reports on the associations of birth weight with dietary habits among healthy, full-term children in Western countries in recent decades, when famine is absent and when overnutrition during pregnancy is more common than undernutrition[10,11]. Only two studies among children born in the early 1990s have reported a relationship between a lower birth weight and a higher intake of fat[10] and a higher intake of saturated fat[11] at pre-school age. However, there are no studies on the associations of birth weight with overall diet quality or eating frequency in healthy, full-term children. We therefore explored the associations of birth weight with overall diet quality, food consumption, energy and nutrient intakes, and the number of main meals and snacks daily at the age of 6–8 years in a population sample of Finnish girls and boys born at term in the early 2000s.

Methods

Study design and study population

The present analyses are based on the baseline data of the Physical Activity and Nutrition in Children (PANIC) study, which is an ongoing physical activity and dietary intervention study in a population sample of primary-school children from the city of Kuopio, Finland (ClinicalTrials.gov registration number NCT01803776). Altogether 736 children born in 1999–2002 were invited to participate in the study by letters delivered to their parents via schools when the children were 6–8 years old. Of 736 invited children, 512 (70 %) participated in the baseline examinations that were conducted in 2007–2009. The participants did not differ in sex distribution, age or BMI standard deviation score (BMI-SDS) from other children of the same age living in the city of Kuopio based on available school health examination data (data not shown). Of the whole PANIC study sample, we excluded fifty-five children who had no valid data on birth weight or gestational age in the national register, who were not singletons and who were born before 37 gestational weeks. Moreover, we excluded seventy-five children who had inaccurate data on food consumption and fifteen children who had severe chronic, diagnosed diseases or conditions that could affect fetal growth or diet (e.g. epilepsy, rheumatic disease, type 1 diabetes, inflammatory bowel disease, Asperger's syndrome, attention-deficit hyperactivity disorder). The final study sample for these analyses consisted of 367 children (179 girls, 188 boys).

Assessment of gestational age and birth size

We collected data on gestational age, birth weight and birth length retrospectively from the birth register provided by the National Institute for Health and Welfare. We calculated birth weight SDS based on Finnish population birth size reference values[12]. These reference values were developed using Finnish birth register data from all Finnish infants born from 1996 to 2008. The values are specific for sex, gestational age and plurality. We also divided birth weight SDS into three categories (< -1 SDS, -1 to 1 SDS, >1 SDS).

Assessment of diet

We assessed food consumption, energy and nutrient intakes, and the number of main meals and snacks daily at the age of 6–8 years by food records administered by the parents on four predefined consecutive days, including either two weekdays and two weekend days or three weekdays and one weekend day. The parents were instructed to record all foods and drinks using household measures (e.g. tablespoons, decilitres, centimetres) and to ask their child about foods eaten outside their home. Schools and afternoon nurseries were asked for the menus and details on the foods served to the children; for example, cooking fat and spread on bread. A clinical nutritionist reviewed and completed the food records at return. For details on portion sizes, a picture booklet of portion sizes was used. We analysed the food records and calculated the intakes of energy and nutrients using the Micro Nutrica® dietary analysis software, version 2.5 (The Social Insurance Institution of Finland), that utilizes Finnish and international data on nutrient composition of foods[13]. Food consumption was analysed in grams divided by total energy intake to control for energy intake in a population that varies a lot in size and energy needs. A clinical nutritionist defined main meals and snacks according to the recorded time and type of foods. Breakfast, lunch and dinner were classified as main meals and all eating and drinking occasions between them as snacks.

As an indicator of a healthy diet, we used the Finnish Children Healthy Eating Index (FCHEI) that has been reported to describe well the dietary quality in 1-, 3- and 6-year-old Finnish children[14]. In 6-year-old children, higher FCHEI has been strongly correlated with lower intakes of saturated fat (correlation coefficient $r = -0{\cdot}27$) and sugars ($r = -0{\cdot}40$), lower energy density ($r = -0{\cdot}24$) and higher intakes of vitamin E ($r = 0{\cdot}24$) and vitamin D ($r = 0{\cdot}37$), indicating that a higher FCHEI reflects a healthier diet[14]. We computed the FCHEI as described previously[14]. In brief, the consumption of five food groups, including vegetables, fruit and berries, oils and vegetable oil-based margarines (fat ≥60 %), foods containing high amounts of sugar (sugar-sweetened beverages, fruit juice, added sugar, chocolate, sweets, pastries, biscuits, ice cream and puddings), fish and skimmed milk, were divided by energy intake and categorized to deciles according to their variation. The lowest decile achieved the minimum score of 1 and the other deciles were scored ascendingly. Reverse scoring was applied for foods containing high amounts of sugar. The resulting component scores were summed to create the overall FCHEI (range 5–40). A higher score indicates a higher diet quality.

Other assessments

We measured body height of children at the age of 6–8 years successively three times using a wall-mounted stadiometer in the Frankfurt position. The mean of the nearest two values was used in the analyses. Body weight was measured successively twice using the InBody® 720 device (Biospace, Seoul, Korea) after overnight fasting, empty-bladdered and standing in light underwear. The mean of the two values was used in the analyses. BMI-SDS was calculated based on Finnish references[15]. Chronic diseases and conditions and parental education and household income were asked by a questionnaire administered by the parents. Parental education was defined as the highest completed or ongoing degree of the parents (vocational school or less, polytechnic, university). Annual household income was reported to accuracy of 10 000 € and was categorized as ≤30 000 €/year, 30 001–60 000 €/year or >60 000 €/year.

We collected data on maternal age at child's birth, possible multiple pregnancy, number of previous births (0 or ≥1) and smoking during pregnancy (no smoking, smoked but quit during the first trimester, smoked after the first trimester) retrospectively from the birth register of the National Institute for Health and Welfare. We also collected data on maternal body weight and height before pregnancy and gestational diabetes mellitus from the birth register of Kuopio University Hospital. Maternal BMI before pregnancy was calculated as weight (in kilograms) divided by the square of height (in metres). The data on BMI were available only for a sub-sample of 294 mothers and the data on gestational diabetes for a sub-sample of 299 mothers, who had delivered in the Kuopio University Hospital.

Statistical methods

We performed all data analyses using the statistical software package IBM SPSS Statistics version 21.0. The level of significance was set at $P<0{\cdot}05$. We also used the Bonferroni correction for multiple testing, with the level of significance at $P<0{\cdot}002$. The sample size of the present study was based on the original power calculation of the PANIC study[16]. A *post hoc* power calculation indicates that the minimally detectable effect size is 0·15 with a power of 80 %, a two-sided level of significance $P<0{\cdot}05$ and the sample size of 367 children.

We compared the characteristics between girls and boys using Student's t test and Pearson's χ^2 test. The associations of birth weight SDS with dietary factors were investigated using multivariate linear regression analyses adjusted for sex, gestational age, age and BMI-SDS at the time of dietary data collection, maternal age at child's birth, number of previous births, smoking during pregnancy, BMI before pregnancy and gestational diabetes, and parental education and household income at the time of dietary data collection. These covariates were chosen based on prior evidence[14,17]. The linear regression analyses included only those participants with complete data (n 278). We used general linear models to test the interaction of sex and birth weight on dietary factors. If there was a statistically significant interaction, linear regression analyses on the association of birth weight with dietary factors were additionally performed for girls and boys separately. We present the results of the multivariate linear regression analyses as standardized regression coefficients (β) with 95 % CI that are standardized so that the variances of dependent and independent variables are 1. The standardized coefficients refer to how many standard deviations a dependent variable will change per one standard deviation increase in the predictor variable.

Because the association of birth weight with the risk of type 2 diabetes and CVD has been found to be U-shaped[1], also the association of birth weight with diet is potentially non-linear. We therefore analysed the differences in dietary factors across three categories of birth weight SDS (<−1 SDS, −1 to 1 SDS, >1 SDS) using general linear models adjusted for same covariates as in the primary analyses. We did pairwise comparisons among all categories as *post hoc* tests and report the mean intakes and 95 % CI of those two categories that differed statistically significantly from each other. The presented P values are the P value for trend across the three categories.

Results

Characteristics

Boys were heavier and longer at birth and taller at the age of 6–8 years than girls (Table 1). Boys were also more likely to have a parent with a university degree and less likely to have a parent with a polytechnic degree than girls. Moreover, boys had lower vegetable and fruit and berry consumption, higher sausage consumption and higher energy intake than girls (Table 2).

The association of birth weight with dietary factors

A higher birth weight SDS was associated with a lower FCHEI in all children adjusted for child's sex, gestational age, age and BMI-SDS at dietary data collection, maternal age at child's birth, number of previous births, smoking during pregnancy, BMI before pregnancy and gestational diabetes, and parental education and household income (Table 3). This association was observed in boys ($\beta=-0{\cdot}27$, 95 % CI −0·45, −0·09, $P=0{\cdot}003$) but not in girls ($\beta=-0{\cdot}01$, 95 % CI −0·21, 0·18, $P=0{\cdot}911$; $P=0{\cdot}044$ for interaction). A higher birth weight SDS was also associated with lower fruit and berry consumption, higher total energy intake, higher sucrose intake and lower fibre intake in all children after these adjustments (Table 3).

Table 1 Characteristics of children and their parents, the Physical Activity and Nutrition in Children (PANIC) study, Kuopio, Finland, 2007–2009

	All children (*n* 367)		Girls (*n* 179)		Boys (*n* 188)		
	Mean or %	SD or *n*	Mean or %	SD or *n*	Mean or %	SD or *n*	*P* value*
Characteristics of children at birth							
Gestational age (weeks), mean and SD	40·1	1·2	40·1	1·2	40·1	1·1	0·924
Birth weight (g), mean and SD	3620	467	3551	444	3686	480	0·006
Birth length (cm)†, mean and SD	50·2	1·9	49·8	1·8	50·7	1·8	< 0·001
Birth weight SDS‡, mean and SD	0·0	1·0	0·0	0·9	0·0	1·0	0·784
Birth weight SDS‡, % and *n*							
< – 1 SDS	13·4	49	13·4	24	13·3	25	0·858
–1 to 1 SDS	72·2	265	73·2	131	71·3	134	
> 1 SDS	14·4	53	13·4	24	15·4	29	
Characteristics of children at the age of 6–8 years							
Age (years), mean and SD	7·6	0·4	7·6	0·4	7·6	0·4	0·361
Weight (kg), mean and SD	26·9	4·8	26·7	5·1	27·1	4·4	0·185
Height (cm), mean and SD	129·0	5·5	128·2	5·6	129·7	5·3	0·007
BMI-SDS§, mean and SD	– 0·2	1·1	– 0·2	1·1	– 0·2	1·1	0·526
Parental characteristics							
Maternal age at birth (years), mean and SD	30·3	5·2	30·2	5·3	30·5	5·1	0·597
Maternal number of previous births, % and *n*							
0	41·1	151	42·5	76	39·9	75	0·618
≥ 1	58·9	216	57·5	103	60·1	113	
Maternal smoking during pregnancy‖, % and *n*							
No smoking	89·8	318	88·4	152	91·2	166	0·669
Smoked but quit during first trimester	3·7	13	4·1	7	3·3	6	
Smoked after the first trimester	6·5	23	7·6	13	5·5	10	0·743
Maternal BMI before pregnancy¶ (kg/m^2), mean and SD	23·5	4·3	23·6	4·5	23·4	4·0	
Maternal gestational diabetes**, % and *n*							
No	92·6	277	93·9	138	91·4	139	0·281
Yes	7·4	22	6·1	9	8·6	13	
Household income††, % and *n*							
≤ 30 000 €/year	20·3	73	24·3	43	16·4	30	0·113
30 001–60 0001 €/year	41·7	150	41·8	74	41·5	76	
> 60 000 €/year	38·1	137	33·9	60	42·1	77	
Parental education, % and *n*							
Vocational school or less	15·8	58	13·4	24	18·1	34	0·007
Polytechnic	47·4	174	55·9	100	39·4	74	
University	36·8	135	30·7	55	42·6	80	

SDS, standard deviation score.
*Differences between girls and boys were assessed using Student's *t*-test and Pearson's χ^2 test.
†*n* 177 in girls, *n* 185 in boys.
‡Calculated based on Finnish references[12].
§Calculated based on Finnish references[15].
‖*n* 172 in girls, *n* 182 in boys.
¶*n* 145 in girls, *n* 149 in boys.
***n* 147 in girls, *n* 152 in boys.
††*n* 177 in girls, *n* 183 in boys.

None of these associations remained statistically significant after Bonferroni correction for multiple testing.

The association of birth weight categories with dietary factors

Children who had a birth weight of >1 SDS had higher sucrose intake as a percentage of energy intake (mean intake 14·3 E%, 95 % CI 12·6, 16·0 E%) than children with a birth weight of –1 to 1 SDS (mean intake 12·8 E%, 95 % CI 11·6, 14·0 E%) or < – 1 SDS (mean intake 12·4 E%, 95 % CI 10·8, 13·9 E%) adjusted for child's sex, gestational age, age and BMI-SDS at dietary data collection, maternal age at child's birth, number of previous births, smoking during pregnancy, BMI before pregnancy and gestational diabetes, and parental education and household income ($P = 0·036$ for trend across the categories). Other differences in dietary factors across three categories of birth weight were not observed (data not shown).

Discussion

The results of the current study showed that higher birth weight was associated with poorer overall diet quality at the age of 6–8 years independent of child's sex, gestational age, age and BMI-SDS at dietary data collection, maternal age at child's birth, number of previous births, smoking during pregnancy, BMI before pregnancy and gestational diabetes, and parental socio-economic status in a population sample of full-term, healthy children and particularly in boys. Moreover, higher birth weight was related to lower fruit and berries consumption, higher energy and sucrose intakes and lower fibre intake. However, none of

Table 2 Dietary factors of children at the age of 6–8 years, the Physical Activity and Nutrition in Children (PANIC) study, Kuopio, Finland, 2007–2009

	All children (*n* 367)		Girls (*n* 179)		Boys (*n* 188)		
	Mean	SD	Mean	SD	Mean	SD	*P* value*
Diet quality							
Finnish Children Healthy Eating Index	23·0	7·0	23·5	6·5	22·5	7·4	0·257
Food consumption							
High-fibre grain products (g/MJ)	9·3	5·8	9·3	5·9	9·3	5·8	0·999
Low-fibre grain products (g/MJ)	16·5	7·1	16·8	6·6	16·1	7·6	0·328
Potatoes (g/MJ)	11·3	6·4	11·6	6·7	11·1	6·2	0·505
Vegetables (g/MJ)	14·7	8·5	15·7	8·9	13·9	8·1	0·042
Fruit and berries (g/MJ)	16·2	12·7	17·6	13·2	14·7	12·1	0·029
Skimmed milk (g/MJ)	57·5	42·7	55·9	42·3	59·0	43·0	0·487
Milk, ≥1 % fat (g/MJ)	25·2	30·0	26·2	30·7	24·2	29·4	0·534
Low-fat sour milk products, <1 % fat (g/MJ)	2·8	7·9	3·1	8·4	2·6	7·4	0·546
Sour milk products, ≥1 % fat (g/MJ)	12·2	10·8	12·0	10·2	12·3	11·4	0·817
Cheese (g/MJ)	2·2	2·1	2·2	2·1	2·1	2·2	0·624
Red meat (g/MJ)	8·4	4·5	8·2	4·4	8·5	4·7	0·534
Sausages (g/MJ)	3·3	3·3	2·7	2·8	3·8	3·7	0·001
Poultry (g/MJ)	2·5	3·1	2·5	3·3	2·4	3·0	0·671
Fish (g/MJ)	2·3	3·1	2·3	3·0	2·4	3·3	0·695
Vegetable oils (g/MJ)	0·6	0·6	0·5	0·5	0·6	0·6	0·320
Vegetable oil-based margarines, 60–80 % fat (g/MJ)	1·0	1·1	1·1	1·1	1·0	1·1	0·400
Vegetable oil-based margarines, <60 % fat (g/MJ)	0·6	1·1	0·5	0·9	0·7	1·2	0·230
Butter or butter–oil mixtures (g/MJ)	0·9	1·0	0·8	0·9	0·9	1·1	0·544
Sugar-sweetened beverages (g/MJ)	19·5	17·5	19·1	17·5	19·9	17·6	0·633
Fruit juices (g/MJ)	5·8	10·6	5·7	9·4	5·9	11·7	0·885
Sweets and chocolate (g/MJ)	4·4	3·5	4·1	3·2	4·7	3·8	0·120
Energy and nutrient intakes							
Energy (MJ)	6·9	1·3	6·5	1·2	7·3	1·3	< 0·001
Total fat (E%)	29·9	5·1	29·6	4·9	30·1	5·2	0·417
SFA (E%)	12·1	2·8	12·0	2·8	12·2	2·9	0·607
MUFA (E%)	9·9	1·9	9·8	1·8	10·0	1·9	0·263
PUFA (E%)	4·9	1·3	4·9	1·3	5·0	1·3	0·510
Protein (E%)	16·7	2·5	16·7	2·4	16·8	2·6	0·598
Carbohydrates (E%)	52·0	5·1	52·3	4·7	51·8	5·5	0·284
Sucrose (E%)	12·7	3·6	12·7	3·3	12·7	3·8	0·789
Fibre (g/MJ)	2·1	0·6	2·2	0·6	2·1	0·6	0·086
Eating frequency							
Number of main meals daily	2·7	0·3	2·7	0·3	2·8	0·3	0·060
Number of snacks daily	2·7	0·9	2·7	0·9	2·8	0·9	0·328

E%, percentage of energy intake.
*Differences between girls and boys were assessed using Student's *t* test.

these associations remained statistically significant after correction for multiple testing.

We found that higher birth weight was associated with poorer diet quality assessed using a diet quality index. This association was independent of many potential confounding factors but weakened after correction for multiple testing. This finding increases our understanding on eating habits related to birth weight in a more holistic approach. Instead of a preference for single nutrients or foods, as previously reported[6–11], a higher birth weight may be related to an overall unhealthier diet that can be slightly different at different periods of time. Moreover, we found that birth weight was associated with diet quality in boys but not in girls, when sexes were studied separately. Some previous studies have also reported that the associations of birth weight with dietary factors were stronger in boys than in girls in young children[10,11]. However, another study reported no interactions between the effects of sex and birth weight on diet in adults[7]. Because these associations were not statistically significant after the correction for multiple testing, these findings need to be verified in other large samples of children.

Only few previous studies have investigated the association of birth weight with food consumption. In Finnish studies, lower birth weight has been associated with lower consumption of fruit and berries[7,9], vegetables[9] and dairy products[9] in adults. In contrast, we found that higher birth weight was associated with lower consumption of fruit and berries in children. One possible explanation for these inconsistent findings is that these previous studies investigated diet in adults, whereas we investigated diet in primary-school children. Diet in children reflects probably more the diet of their mothers, which has also affected the birth weight of the child, than diet in adults. Because we found an association between higher birth weight and lower quality of diet, such as lower consumption of fruit and berries, this may explain the associations of birth weight with diet found in the present

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Table 3 The associations of birth weight standard deviation score (SDS) with diet quality, food consumption, energy and nutrient intakes, and eating frequency at the age of 6–8 years (*n* 278), the Physical Activity and Nutrition in Children (PANIC) study, Kuopio, Finland, 2007–2009

	Birth weight SDS*		
	β	95 % CI	*P* value
Diet quality			
Finnish Children Healthy Eating Index	−0·15	0·28, −0·03	0·019
Food consumption			
High-fibre grain products (g/MJ)	−0·05	−0·18, 0·07	0·418
Low-fibre grain products (g/MJ)	0·04	−0·09, 0·17	0·557
Potatoes (g/MJ)	−0·07	−0·20, 0·06	0·277
Vegetables (g/MJ)	−0·08	−0·18, 0·04	0·234
Fruit and berries (g/MJ)	−0·13	−0·25, 0·00	0·048
Skimmed milk (g/MJ)	−0·06	−0·19, 0·07	0·392
Milk. ≥1 % fat (g/MJ)	−0·02	−0·14, 0·10	0·761
Low-fat sour milk products, <1 % fat (g/MJ)	0·08	−0·04, 0·21	0·193
Sour milk products, ≥1 % fat (g/MJ)	0·07	−0·06, 0·19	0·312
Cheese (g/MJ)	0·02	−0·10, 0·14	0·732
Red meat (g/MJ)	−0·02	−0·15, 0·10	0·718
Sausages (g/MJ)	0·11	−0·02, 0·22	0·097
Poultry (g/MJ)	0·00	−0·13, 0·14	0·949
Fish (g/MJ)	−0·07	−0·20, 0·06	0·304
Vegetable oils (g/MJ)	0·01	−0·13, 0·14	0·913
Vegetable oil-based margarines, 60–80 % fat (g/MJ)	−0·08	−0·21, 0·04	0·212
Vegetable oil-based margarines, <60 % fat (g/MJ)	−0·07	−0·21, 0·05	0·245
Butter or butter–oil mixtures (g/MJ)	0·05	−0·08, 0·18	0·434
Sugar-sweetened beverages (g/MJ)	0·06	−0·07, 0·19	0·343
Fruit juices (g/MJ)	0·02	−0·11, 0·16	0·748
Sweets and chocolate (g/MJ)	0·12	−0·05, 0·24	0·060
Energy and nutrient intakes			
Energy (MJ)	0·17	0·05, 0·29	0·008
Total fat (E%)	−0·02	−0·14, 0·11	0·787
SFA (E%)	0·05	−0·07, 0·18	0·417
MUFA (E%)	0·00	−0·12, 0·12	0·990
PUFA (E%)	−0·11	−0·24, 0·01	0·076
Protein (E%)	−0·09	−0·22, 0·04	0·156
Carbohydrates (E%)	0·06	−0·07, 0·19	0·345
Sucrose (E%)	0·19	0·06, 0·32	0·004
Fibre (g/MJ)	−0·14	−0·26, −0·01	0·036
Eating frequency			
Number of main meals daily	0·07	−0·05, 0·20	0·256
Number of snacks daily	0·08	−0·05, 0·20	0·245

E%, percentage of energy intake.
Data are standardized regression coefficients (*β*), 95 % CI and *P* values from linear regression models adjusted for gestational age, age and BMI-SDS at dietary data collection, and sex when appropriate, maternal age at birth, number of previous births, smoking during pregnancy, BMI before pregnancy and gestational diabetes, and parental education and household income. The threshold of statistical significance with Bonferroni correction is 0·002.
*Calculated based on Finnish references[12].

study. On the other hand, diet in children may directly reflect intra-uterinely programmed food preferences, whereas the effects of these food preferences on diet may be weakened in adults by other factors, such as diseases related to intra-uterine growth. For example, lower birth weight was found to be associated with a higher consumption of fruit and berries in a sample of 56–70-year-olds[7]. At that age, the occurrence of type 2 diabetes or CVD may have induced diet changes in a healthier direction. Moreover, one previous study investigated very-low-birth-weight preterm children[7]. Such children have more hypersensitivity and oral motor problems than children born at term[18]. These problems may affect the dietary choices of these individuals, such as avoiding bitter-tasting, hard-structured vegetables, fruit and berries. Therefore, it may be that both low and high birth weight are related to similar dietary preferences and deficiencies, although the likely mechanisms are different.

A previous Finnish study reported that higher birth weight among term-born children was associated with higher intake of sucrose in adults[7]. In similar vein, we found that this association was pronounced already in children. Instead, we did not find an association of birth weight with fat intake in contrast to previous studies that have reported a consistent association between lower birth weight and higher fat intake[6,7,10,11]. One explanation for the inconsistent findings of these studies may be that the preference for a high fat intake appears with more serious intra-uterine growth restriction but not in full-term born children with appropriate birth weight. Only 13 % of children in our population sample of children born in the early 2000s had a birth weight less than 1 SDS. Therefore, it is possible that our general population did not include enough variance at the lower end of birth weight to show the association of low birth weight with the preference for a fatty diet. Instead, it may be that the preference for a diet high in sucrose appears already in children with birth weight at the higher end of appropriate levels. Moreover, the mean intake of fat was less than 30 E%, which is lower than in a previous study that has reported an association of lower birth weight with higher fat intake[7]. In that study, an association of lower birth weight with higher fat intake was observed for an average fat intake of 33 E%[7]. It may be that the average diet in the 2000s includes less high-fat products than earlier.

Previous studies have reported that high birth weight is associated with an increased cardiometabolic risk in adolescence[19] and with an increased risk of type 2 diabetes in adulthood[1]. Our results suggest that these associations may be partly mediated by poor diet quality. For example, a lower consumption of fruit and berries has been linked to a higher risk of CVD[20]. On the other hand, poor diet may also be associated with a higher adiposity, which then may lead to a higher risk of CVD. Moreover, poor diet quality may increase the risk of other chronic diseases in children with a high birth weight. For example, a higher sucrose intake may lead to an increased risk for poor dental health[21].

The relationship of birth weight with diet is likely to be explained by a complex aetiological network of both biological and social mechanisms. For example, previous studies have suggested that one potential mechanism for the association between birth weight and diet in adulthood is the biological early programming of appetite and taste preferences during fetal life[22]. On the other hand, the associations of birth weight with dietary factors have also been suggested to be mediated by factors related to the health or socio-economic status of the mother or the whole family. Surprisingly, we found the association of higher birth weight with lower dietary quality after adjustment for several maternal characteristics, including age, previous births, smoking during pregnancy, BMI before pregnancy and gestational diabetes, and parental socio-economic status. Another potential social explanation for these associations is that poor quality of diet of the mother during pregnancy is related to higher birth weight of the child who then adopts the poor diet of the family. However, we had no data on maternal diet and thus were unable to test the confounding effect of maternal diet on the association of birth weight with diet in childhood. Nevertheless, women at reproductive age and their families may be a target for dietary interventions to prevent future generations from dietary shortcomings and chronic diseases. The reason for observing the association of higher birth weight with poor diet in boys but not in girls is unknown. One explanation for this finding could be that parents feed girls and boys with a higher birth weight differently, because a large boy may be more desired than a large girl. Moreover, in the present study, boys had a slightly larger standard deviation in birth weight and a higher consumption of foods, which may have affected the statistical power due to a higher frequency of extreme values in boys than in girls. However, we only found potential signals on possible differences between girls and boys, since the results were not statistically significant after correction for multiple testing. Possible sex differences need to be replicated in other samples of children.

The strengths of the present study are that gestational and birth data were obtained from reliable national records instead of self-reports and that dietary intake was assessed using 4 d food records that were individually instructed, reviewed and completed. The food record method has previously been validated against the observation method in primary-school children[23,24]. We were also able to adjust the associations for several possible confounding factors. One of the main strengths was the relatively large representative population sample of children. Because of detailed background data, we were able to exclude twins and preterm-born children and children who had severe diseases that could have affected or mediated the studied associations. Due to our population sample, we had a low number of children with birth weight in the very extremes and were not able to divide the sample according to generally accepted cut-offs for small-for-gestational-age (<−2 SDS), appropriate-for-gestational-age (−2 to 2 SDS) and large-for-gestational-age (>2 SDS). Instead, we used cut-offs at −1 SDS and 1 SDS. A limitation of the study is the lack of data on maternal diet and other lifestyle factors during pregnancy, which could have confounded the observed associations. Moreover, we had data on maternal BMI before pregnancy and gestational diabetes only in a sub-sample of mothers, which may have limited the statistical power related to these variables. Another limitation is the large number of analyses, which raises the concern that the associations may have been found by chance. Moreover, our findings are specific to healthy, full-term born Finnish children aged 6–8 years and the generalizability of the findings in other populations needs to be investigated.

Conclusion

In conclusion, the findings of the current study suggest that children with a high birth weight may have a higher risk of having an overall unhealthy diet, particularly lower fruit and berries consumption, higher energy and sucrose intakes and lower fibre intake at the age of 6–8 years. However, this was an exploratory analysis and because the associations did not remain statistically significant after correction for multiple testing, the findings present only potential signals that need to be replicated in other samples of children. Then, dietary counselling targeted to children with a high birth weight could potentially decrease the risk of chronic diseases among these individuals.

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