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Fat Intake and Weight Development from 9 to 16 Years of Age: The European Youth Heart Study – a Longitudinal Study

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Key Words

Children · Fat intake · Weight change · Parental obesity · Birth weight

Summary

Objective: The literature on associations between fat intake and weight development among both children and adults is inconsistent, even if it is generally assumed that a high dietary fat intake is a major determinant of obesity. The present study aimed at investigating the association between fat intake and weight development among a cohort of children aged 9–10 years at baseline and 15–16 years at follow-up, and, further, at investigating whether parents' obesity is modifying the association. **Method:** Among 384 subjects aged 9 years, data on dietary intake, BMI z-score, physical activity, inactivity, parents' social status, parents' body mass index, child birth weight, and status of puberty was obtained in 1997. Weight and height was measured both at baseline and at 6-year follow-up, and BMI z-score was calculated. Linear regression was used to assess the role of fat intake on subsequent weight change between 1997 and 2003 with the above-mentioned variables as confounders, in 3 different models and for each sex separately. **Results:** The analysis showed no relation between fat intake (both absolute intake and fat energy percent) at 9 years and subsequent 6-year weight change. Only BMI z-score at baseline had a significant relation to weight change for both sexes, and number of obese parents had significant relation to weight change in girls. Number of overweight parents did not modify the association between fat intake and weight change. **Conclusion:** This study was unable to find a relation between fat intake and 6-year weight change among 9-year-old children. No interaction was seen between number of overweight parents on the relation between fat intake and subsequent weight change.

Introduction

Many papers conclude that dietary fat plays a particular role for development of obesity [1]. Also, official bodies such as the WHO (World Health Organization) state that the general explanation for the increasing obesity in children is too much fat and sugar and too little exercise [2]. But intervention studies on the role of fat for development of obesity are lacking. Moreover, results from studies on the impact of a high fat intake on weight development among adults and children seem inconsistent. In general, intervention studies show relations between low-fat diets and weight loss among obese [3, 4], and cross-sectional studies generally find positive associations between fat intake and weight. However, prospective studies do not provide much evidence for an association, neither among adults nor among children [5].

In fact a total of 6 prospective studies have examined associations between fat intake and weight development among children, and only 1 of 6 have found a positive association [6]. The other 5 studies were unable to find support for a positive association [7–11].

Even if fat seems generally unrelated to subsequent weight gain, certain subgroups may be susceptible to gain weight on a high-fat diet. In agreement, an earlier study on adult women found that fat intake was unrelated to subsequent 6-year weight development in general, but that those with familial obesity (defined as having at least one obese parent) had a

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very high risk of subsequent weight gain, but only if they consumed a high-fat diet [12].

The purpose of the present study was therefore to examine associations between dietary fat intake around age 9 on subsequent 6-year weight development, and if parents' overweight influence the associations between fat intake and weight development.

Participants and Methods

This study is the Danish part of the European Youth Heart Study (EYHS), which is a longitudinal study of relations between lifestyle and risk factors for heart disease. The data used in the present study represents a subset of 384 children aged 9–10 years (mean 9.7 years) at baseline. The children were selected from among 25 schools in Odense, Denmark. A total of 28 out of 35 schools in Odense were selected, and 25 agreed to participate in the study. From these schools 1,356 pupils were invited, and 1,020 (75.2%) – 589 third graders and 421 ninth graders – agreed to participate. Six years later, 384 of the earlier third graders were re-examined.

According to ethical considerations, it was not permitted to contact subjects who decided not to participate at follow-up. Possible drop-out effects were examined indirectly by comparing baseline age, BMI, and fat intake of those subjects participating only at baseline with those participating at both baseline and follow-up.

Prior to the baseline examination in 1997/1998 the children's parents were asked to fill in a questionnaire including information on their socio-economic status (SES) (educational level and income level), their weight and height. Parents' BMI was calculated from self-reported weight and height (kg/m^2). Educational level was converted according to the DUN classification [14] and was determined as the unified time of education needed to complete the education in question (from pre-school to level of scientist in 9 categories). Income was divided into 9 categories (<100,000, 100,000–150,000, 150,000–200,000, 200,000–250,000, 250,000–300,000, 300,000–350,000, 350,000–400,000, 400,000–450,000 and >450,000 DKK).

On the day of baseline examination the children's height was measured to the nearest 0.5 cm and weight to the nearest 0.1 kg. BMI was computed as weight/height^2. The BMI z-score is a value that takes into consideration age, sex, and the ongoing growth of children and adolescents [15]. Z-scores for age-specific BMI were based on the difference between the observed value of the examined population and the median reference value of the reference population, standardized against the standard deviation (SD) of the reference population. The reference z-scores were based on a Danish reference population [16]. A z-score can be used as an estimation of the child's weight by comparing it with children of the same age and height [15].

Dietary intake was determined from an interview and furthermore based on a questionnaire that the children and their parents had filled in for intake of the child over the past 24 h before the examination which took part on weekdays. All interviews were performed by the same person. Energy and dietary intake were calculated using DANKOST. The interviewer computed the dietary information in a database, by which it was possible to calculate information about nutrients on the individual food items or whole meals and diets via the national food composition tables [17]. This method has been validated in children by Lytle et al. [18] who concluded that the method was useful.

Children's activity level was measured using accelerometers (Actigraph model 7164, Manufacturing Tecnology Inc., Fort Walton Beach, FL, USA) worn by the children for 2 weekdays and 2 weekend days. Moreover, exercise was assessed by self-report in the questionnaires at three levels: i) do not exercise, ii) exercises but not regularly, and iii) exercises regularly.

Inactivity was measured through questionnaires where the children stated how many hours they spent per day with television and computer.

Puberty was determined using Tanner's method [19].

Parent's overweight was defined as BMI > 25 kg/m^2.

At follow-up examination 6 years later in 2003/2004 heights and weights were measured, and the children's BMI and BMI z-score were computed. Weight development was determined as

$$\Delta\text{BMI z-score} = \text{BMI z-score}_{\text{follow-up}} - \text{BMI z-score}_{\text{baseline}} \quad (1).$$

In the regression analysis age, BMI z-score, self-reported activity level, inactivity, macronutrients, puberty status, parent's income level, number of overweight parents, and birth weight were included. Self-reported activity level was used in the analysis instead of accelerometer measurements as the last variable contained a lot of missing values and thereby would make the statistical analysis less powerful, since accelerometer measurements were available for 255 children only (66%). Three different models relating fat intake to subsequent weight development were created:

- Model I was the crude mere model where only BMI z-score at baseline were included.
- Model II was the semi-adjusted model where the covariates that the literature had suggested as confounders were included. These were, besides the covariates in model I, age, puberty status, total energy intake (EI), parent's income level, self-reported activity, inactivity, and number of overweight parents.
- Model III was the fully adjusted model which contained protein intake and birth weight in addition to the covariates in model II.

All analyses were made separately for boys and girls. In model II and III both self-reported activity and inactivity was included since the two were not correlated (Pearson's correlation = –0.021, p = 0.681).

Additional analyses were performed as follows: i) with accelerometer measurements (counts/min) instead of self reported activity to see if this adjustment for more precise measurement of physical activity on a subgroup gave similar results; ii) with adjustment for parents' education level instead of income level; iii) using parents' BMI as continuous variables instead of presence of overweight parents to check for residual confounding; iv) using the difference in waist/height ratio between the two examinations as outcome instead of BMI z-score, and finally v) using change in BMI in 3-year follow-up instead of 6 years.

Since accelerometer measurements exist for a subgroup of children, it is possible to estimate a potential dietary underreporting. Energy expenditure (EE) can be calculated from the following formula [20]:

$$\text{EE (kcal/min)} = 0.0008\ \text{(counts/min)} + 0.08\ \text{(body weight in kg)} - 2.23 \quad (2).$$

If ratios between EE and EI differ between normal weight and overweight children, it is an indicator of reporting bias in EI. Here overweight is defined as BMI z-score above +1.33 corresponding to the 85th percentile, which is commonly used to define overweight [15].

Tests for differences in mean values and in regression coefficients between groups were carried out by F test. Differences were considered significant when $p < 0.05$. The statistical analysis was performed with the SPSS PC computer software program, version 15.0 (SPSS Inc. Chicago, IL, USA).

Results

The comparison of children participating only at baseline examination with those participating at both baseline and follow-up revealed no difference between the two groups.

Table 1. Characteristics of the study population[a]

	Girls (n = 170)	Boys (n = 138)
Baseline data		
Age, years	9.6 ± 0.4	9.7 ± 0.4
BMI, kg/m^2	17.2 ± 2.4	17.1 ± 2.0
BMI z-score	0.4 ± 1.1	0.3 ± 1.0
Puberty status (Tanner)	2.3 ± 0.5	2.0 ± 0.0
Physical activity, % who exercises regularly)	47.6	61.9
Inactivity, h/day	5.5 ± 1.4	6.0 ± 1.6
Father's income, % with lowest income category	5.1	6.1
Father's educational level, % with less than 10 years of school attendance	16.9	19.4
Mother's income, % with lowest income category	7.8	9.1
Mother's educational level, % with less than 10 years of school attendance	14.1	12.4
Total EI, MJ/day	8.8 ± 2.1	9.5 ± 2.6
Total fat intake, g/day	77.8 ± 26.0	82.6 ± 30.0
FE%	33.3 ± 6.7	32.1 ± 6.6
Father's BMI, kg/m^2	25.4 ± 3.3	25.3 ± 3.4
Mother's BMI, kg/m^2	23.1 ± 3.6	24.0 ± 3.9
Birth weight, g	3,313 ± 512	3,419 ± 584
Follow-up data		
BMI z-score	0.5 ± 1.0	0.5 ± 1.0

FE% = fat energy percent.
[a]Numbers are means ± SD at baseline where nothing else is stated.

Table 2. Baseline characteristics given by gender and number of overweight parents[a]

	Girls (n = 174)				Boys (n = 143)			
	Number of overweight parents			p value[b]	Number of overweight parents			p value[b]
	0 (n = 76)	1 (n = 74)	2 (n = 24)		0 (n = 61)	1 (n = 59)	2 (n = 23)	
Age, years	9.5 ± 0.4	9.6 ± 0.4	9.7 ± 0.5	0.21	9.6 ± 0.4	9.7 ± 0.4	9.7 ± 0.4	0.40
BMI, kg/m^2	16.7 ± 2.2	17.3 ± 2.7	18.9 ± 2.2	0.001	16.6 ± 1.7	17.3 ± 2.0	17.9 ± 2.8	0.02
BMI z-score	0.2 ± 1.0	0.4 ± 1.2	1.2 ± 0.7	0.000	0.1 ± 1.0	0.5 ± 1.0	0.7 ± 1.2	0.03
Puberty status (Tanner)	2.2 ± 0.5	2.3 ± 0.6	2.5 ± 0.6	0.10	2.0 ± 0.0	2.0 ± 0.0	2.0 ± 0.0	
Physical activity, % who exercises regularly	42.5	50.0	48.3	0.76	68.2	66.2	37.0	0.02
Inactivity , h/day	5.2 ± 0.1	5.7 ± 0.2	5.7 ± 0.3	0.10	5.8 ± 0.2	5.8 ± 0.2	6.2 ± 0.3	0.52
Father's income, % with lowest income category	1.3	4.6	13.8	0.51	1.6	3.2	3.6	0.02
Mother's income, % with lowest income category	6.3	5.6	13.8	0.13	12.5	7.7	3.6	0.36
Total EI, MJ/day	9.0 ± 1.8	8.7 ± 2.2	9.0 ± 2.3	0.76	9.4 ± 2.7	9.5 ± 2.2	9.7 ± 2.5	0.91
Total fat intake, g/day	78.5 ± 19.5	75.6 ± 27.1	82.0 ± 34.7	0.52	79.4 ± 28.3	84.5 ± 27.9	87.9 ± 38.9	0.44
FE%	33.6 ± 5.6	32.7 ± 7.3	34.2 ± 9.0	0.56	32.0 ± 5.7	33.5 ± 7.7	34.0 ± 6.9	0.32
Birth weight, g	3,333 ± 463	3,284 ± 591	3,445 ± 434	0.42	3,451 ± 494	3,382 ± 643	3,536 ± 481	0.52

FE% = fat energy percent.
[a]Numbers are means ± SD at baseline where nothing else is stated.
[b]p values reflect ANOVA one-way variance analysis, test for difference between 0, 1 and 2 overweight parents.

Table 1 gives baseline characteristics of the study population along with follow up BMI z-score among boys and girls.

Table 2 gives baseline characteristics additionally subclassified by number of overweight parents (0, 1, or 2). The number of overweight parents resulted in significant differences of baseline BMI in both girls (p = 0.001) and boys (p = 0.02). This was also true for baseline BMI z-scores in both girls (p = 0.00) and boys (p = 0.03). Moreover, there was also a significant relationship between number of overweight parents and percentage of fathers with an income below 100,000 DKK

Table 3. Regression coefficients for FE% for boys and girls in the regression analysis on change in BMI z-score

	Girls			Boys		
	$\beta_{FE\%}$	SE	p value	$\beta_{FE\%}$	SE	p value
Model I[a]	0.004	0.007	0.58	–0.011	0.008	0.17
Model II[b]	0.005	0.008	0.54	–0.011	0.009	0.20
Model III[c]	0.002	0.008	0.75	–0.010	0.009	0.27

[a]Model I is the crude model with only BMI z-score and fat intake (FE%) included. $N_{girls} = 199$; $N_{boys} = 163$.
[b]Model II moreover includes age, puberty status, total EI, parent's income level, self-reported activity, inactivity and number of overweight parents. $N_{girls} = 177$; $N_{boys} = 147$.
[c]Model III moreover includes protein intake and birth weight. $N_{girls} = 171$; $N_{boys} = 137$.

in boys (p = 0.02). With respect to percentage of children who exercise regularly the differences between children with 0, 1 or 2 overweight parents were significant in boys only (p = 0.02). All boys scored 2 in the Tanner test, thus there was no difference between groups with respect to this variable.

Table 3 gives regression coefficients for the association between FE% and change in BMI z-score for the 3 models (separated by gender). None of the models showed significant associations between FE% and weight development.

In the regression model, variables were included according to the three models described in 'Participants and Methods'. The only variables showing a significant association with weight development were BMI z-score at baseline in both genders and number of overweight parents in girls. In order to test for interaction, the product term (FE% × number of overweight parents) was added to the models, but showed no significant associations in the regression analyses. Likewise, interaction analyses did not reveal significant associations between fat intake and weight development if children are subclassified according to number of overweight parents (results not shown).

In fact, neither the main nor the subanalyses showed any significant association between fat intake (FE%) and weight development.

The EE/EI ratio was 2.5 times higher in normal-weight girls compared to overweight girls, and 1.9 times higher in normal-weight boys compared to overweight boys.

Discussion

The present study was unable to show that fat intake at age 9 years was related to subsequent 6-year weight development. This was the case irrespective of whether fat intake was investigated as g/day or as FE%. These findings are supported by results from other prospective studies among children [7–11]. Only 1 of 6 of these studies found a positive association [6]. That study was performed among pre-school children (3–5 years). Since children of this age are in a period of growth spurt where their BMI decreases whereas BMI increases in the age 9–16, it may not be possible to compare the results of this study with our data. Furthermore, the study by Klesges et al. [6] had an overrepresentation of overweight children – 40% were overweight at baseline which may have influenced their results as low fat may have a role in weight loss but not necessarily in restricting weight gain. Of the 5 studies that did not find an association between fat intake and weight gain [7–11], only 2 [8, 9] were based on children of same age as the children in the present study.

Our results are in contrast to an earlier observation among adults [12] where a strong and significant association was seen between fat intake and weight development for those with obese parents. It is possible that a genetic susceptibility may only be apparent among adults or that those subgroups who are susceptible to gain weight from a high fat intake are small as a larger subsequent study among female nurses could not demonstrate such an association [21]. No previous prospective studies have examined the role of parents' overweight in modifying associations between fat intake and weight development among children.

The study population in this study is regarded as representative of the Danish children of this age. Odense is the third largest city in Denmark and has many schools – both in the city and in more rural areas of the municipality – and, as has been described elsewhere, parents' income and educational level were representative of the Danish population in general [22]. Since no differences were found between those who participated at baseline only and those participating at both baseline and follow-up, the results from this study can reasonably be generalized to the general population of this age in Odense and hence in Denmark.

Some possible limitations should be noted. It is well known that obese subjects – both children and adults – underreport their dietary intake [8, 23–25], and underreporting may be especially widespread for food items rich in carbohydrate and fat and in-between meals [26]. This means that there is a risk that fat intake was underreported for those children who were overweight at baseline. A specific reporting bias can result in both over- and underestimation of true associations. In the present case with direct associations between fat intake and weight development, a given observed weight development for a lower than true reported fat intake will result in observed overestimated relations as long as obesity and fat intake are positively related [27, 28]. Random error on the other hand always results in attenuated associations.

In the present study, it was possible to estimate underreporting from overweight children. The ratio between EI and EE was about twice as high in overweight children compared to normal weight children, pointing to a selective underreporting of EI in children being overweight at baseline.

Another limitation is that the 24-hour recalls may not capture the full day-to-day variation in habitual fat intake, unless repeated which was not done in the present study. Hence, the use of only one 24-hour recall may have led to attenuated associations in the present study. Single 24-hour recalls are in general inferior to many other diet methods (e.g. diet histories or food records over several days). However, in small children (aged less than 11–12 years) this method, but not the other methods, is both feasible and valid [29].

Additionally, it is likely that the children's dietary intake has changed over a period of 6 years, especially those children who may have changed their diet as they developed the obesity when becoming overweight. This would tend to attenuate associations between fat intake and weight development.

There was no information about diet during Fridays and Saturdays. Since the general diet these days may be more filled with fat and sugar than in weekdays, both total EI and intake of specific food items may have been underestimated in the present study. In this study it would most likely have attenuated the true association between fat intake and weight development.

In conclusion, the results of the present study suggest that there is no association between fat intake (measured as g/day as well as FE%) at 9 years and subsequent 6-year weight development. In agreement with previous studies, this suggests that a high dietary fat intake does not play a specific role for weight development among children. This lack of association was also seen if the participants were subclassified according to the familial obesity status.

Disclosure

The authors declared no conflict of interest.

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