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# Fatty fish intake in mothers during pregnancy and in their children in relation to the development of obesity and overweight in childhood: The prospective ABIS study

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## Summary

**Background:** Although controversial, lower maternal intake of n-3 polyunsaturated fatty acid (PUFA) during pregnancy and lower levels of omega-3 PUFA in serum phospholipids during childhood have been related to obesity. The main source of omega-3 PUFA is fatty fish in the diet.

**Objectives:** To assess the relationship between overweight/obesity and the intake of fatty fish in maternal diet during pregnancy and in children up to 8 years of age.

**Methods:** The prospective cohort All Children in South-East Sweden (ABIS) followed babies from birth to 8 years of age. A total of 6749 children at 5 years of age (boys 52.6%) and 3017 children at 8 years (boys 52.3%) participated. A "fatty-fish index" was constructed on the basis of self-reports of nutritional habits.

**Results:** The prevalence of overweight and obesity in children at 5 years were 12.9% and 4.2%, respectively. At 8 years, 12.2% of the children presented overweight and 2.3% obesity. Girls were more affected than boys by overweight/obesity. A higher fish index during pregnancy was not related to overweight/obesity in the children, whereas a higher fish index in the children during the first years of life was related to obesity at 5 and 8 years of age. This relationship disappeared in a multivariable analysis. Maternal body mass index (BMI), maternal education, maternal smoking during pregnancy, birth weight, and physical activity all remained related to overweight/obesity at both 5 and 8 years of age.

**Conclusion:** No relationships were found between a lower intake of fatty fish in the diet, neither in mothers during pregnancy nor in early childhood, and increased risk of overweight/obesity.

KEYWORDS

children, fish, obesity, omega-3, risk factors

## 1 | INTRODUCTION

Overweight and obesity in children have increased worldwide and among young adults, school children, and adolescents in Sweden during the past three decades.[1-3] Obesity in young adulthood is related to increased morbidity[4-7] and mortality[8,9] later in life. Moreover, childhood obesity is related to metabolic disorders such as insulin resistance, hypertension, serum lipid abnormalities, disease in almost every organ system[10] and, in later life, physical[11] and psychosocial problems.[12] The prevalence of overweight and obesity defined according to Cole et al[13] among Swedish preschool children born between 1997 and 2002 has been reported to be 12.9% to 22.3%.[14-18]

Overweight and obesity in childhood are related to the development of severe obesity and morbidity in adulthood.[19] Furthermore, obesity, ie, body mass index (BMI) greater than 95th percentile, among children at 1 and 2.5 years of age increased the risk of further developing obesity at 5 years of age.[16] Early predictive factors and risk factors have been studied in preschool[16,17,20] and school children.[21] Reviews of overweight and obesity risk factors in preschool children and infants in the Europe[22] have reported on early risk factors such as maternal smoking, maternal nutrition during pregnancy, rapid infant growth, sleeping behaviour, amount of physical activity, TV watching, parental socio-economic status, and parental overweight/obesity.[23,24] High parental/family psychological stress has also been reported to be risk factors for obesity in infancy.[18,25] On the other hand, exclusive breastfeeding for 4 to 6 months and siblings[26] could be protective factors. In some Swedish studies, higher prevalence of childhood obesity has been reported in girls[15,27] and in rural areas.[27,28]

There is a long tradition in paediatrics to repeatedly measure children's weight and length from birth onwards as normal growth is one of the most basal indicators for children's healthy development. In the Swedish health care system, the development of BMI in preschool children is assessed at primary child health centres until 6 years of age and in primary school in older children. Children affected by obesity are often referred to paediatricians by school nurses. Behavioural changes, pharmacotherapy, and surgery are the main therapeutic alternatives for obesity treatment.[29] In Sweden, pharmacotherapy is currently not available to children, and obesity surgery in adolescents is performed only in controlled studies.[30] In a large Swedish study,[31] clinical experience has been corroborated; behavioural treatment seems to be effective only in younger children (6 to 9 years) and not in adolescents. Thus, in addition to the above-mentioned risk factors, more precise risk factors for obesity between preschool and school age are needed to be understood to improve prevention of obesity.

A possible role of dietary omega-3 and omega-6 polyunsaturated fatty acid (PUFA) in relation to childhood obesity risk has been proposed in several previous studies.[6,32,33] The only source of omega-3 and omega-6 PUFA for the foetus during pregnancy are maternal diet and adipose tissue stores, whereas the infant is provided with PUFA from human milk or infant formula. Later in life, the only source of omega-3 and omega-6 PUFA is the diet. The main precursors are alfa-linolenic acid (ALA, C18:3, omega-3) and linoleic acid (LA, C18:2, omega-6). Their longer metabolites, the long-chain polyunsaturated fatty acids (LCPUFA), eicosapentaenoic acid (EPA, C20:5, omega-3), docosapentaenoic acid (DPA, C22: omega-3), docosahexaenoic acid (DHA, C22:6, omega-3), and arachidonic acid (AA, C20:4, omega-6), are involved in important metabolic and physiological pathways. Moreover, lower omega-3 LCPUFA levels have been suggested to be involved in the development of obesity.[32] In particular, a high ratio between the omega-6/omega-3 PUFA seems to be important as lower levels of omega-3 PUFA, ie, DHA, than of omega-6 PUFA were found in serum phospholipids of 12-year overweight children.[32,33] Lower maternal intake of omega-3 PUFA during pregnancy leading to lower levels of EPA and DHA in infant cord blood has been reported to be associated with obesity in childhood.[6] Similarly, maternal n-3 PUFA intake also influences omega-3 PUFA milk composition[34] and may partly explain the association between breastfeeding and obesity[26] as well as the relation between overweight in infancy and at 5 years of age.[16]

As the main source of n-3 LCPUFA is fatty fish in the diet, we hypothesize that low maternal intake of fatty fish during pregnancy and low intake of fatty fish during childhood is related to the development of overweight/obesity in childhood. The primary aim of this paper was to assess the prevalence of overweight/obesity at 5 and 8 years of age in a Swedish cohort prospectively followed in relation to intake of fatty fish in the diet of the mother during pregnancy and of the child during childhood. Other risk factors for developing obesity were also assessed.

## 2 | MATERIAL AND METHODS

All mothers who gave birth to a child between 1 October 1997 and 31 October 1999 in the southeast of Sweden (n = 21 700) were asked to participate in a prospective study, All Children in the South-East of Sweden (ABIS). Its main purpose was to prospectively study the aetiology of chronic autoimmune diseases, particularly type 1 diabetes but also other immune-mediated or diabetes-related diseases in childhood. Parents were instructed to fill out a diary during the child's first year of life regarding gestational age at birth, birth weight, birth height, breastfeeding, time of introduction of other foods, dietary habits in the family, and infectious diseases. Parents filled out a comprehensive questionnaire on demographic data, maternal nutrition, psychosocial factors, serious life events, disease in the family or child, and dietary habits in the family in association with a regular check-up for the child at well-baby clinics at 1, 2.5 to 3, and 5 years of age. About 99% of all Swedish parents bring their children to these check-ups, which are government

subsidized. At age 8, two questionnaires, one to a parent and one to the child, were sent home to the family and returned through the mail. Maternal and paternal height and weight were collected at the 1-year assessment. The BMI of the children at 1 and 5 years was validated between child health clinic charts and ABIS questionnaires. The weight and height development of the children in this cohort up to 5 years has been presented previously.[16]

Parents of 17 055 (78.6%) newborn children agreed to participate in the study. Of these, 15 950 answered questionnaires when the child was born. Children who were twins (n = 372) were excluded from the study. Non-twin siblings born within the ABIS inclusion time (n = 296) were accepted; however, to avoid overrepresentation of some families, one sibling was randomly chosen from each of these families. Therefore, another 148 children were excluded. Hence, the total sample for the current study was 15 430 children, corresponding to 71.2% of those who were born during the inclusion time in the studied region.

## 2.1 | Sample at 5 and 8 years

Of the 15 430 children, 6749 participated at the 5-year follow-up (boys: n = 3547, 52.6%) and 3017 at the 8-year follow-up (boys: n = 1579, 52.3%). Children with body height outside the normal distribution +/2 SD (n = 10) and children with body weight below −2SD and above 6SD (n = 20) in body weight were omitted from further analysis (Figure 1). Although the response rate decreased at 5 years of age, gender, social factors, and parental BMI were similar at baseline and at 5 years.[16]

## 2.2 | Definitions

### 2.2.1 | Underweight, overweight, and obesity

Weights and heights of the children at different follow-ups were reported by their parents. Age and gender-specific BMI were

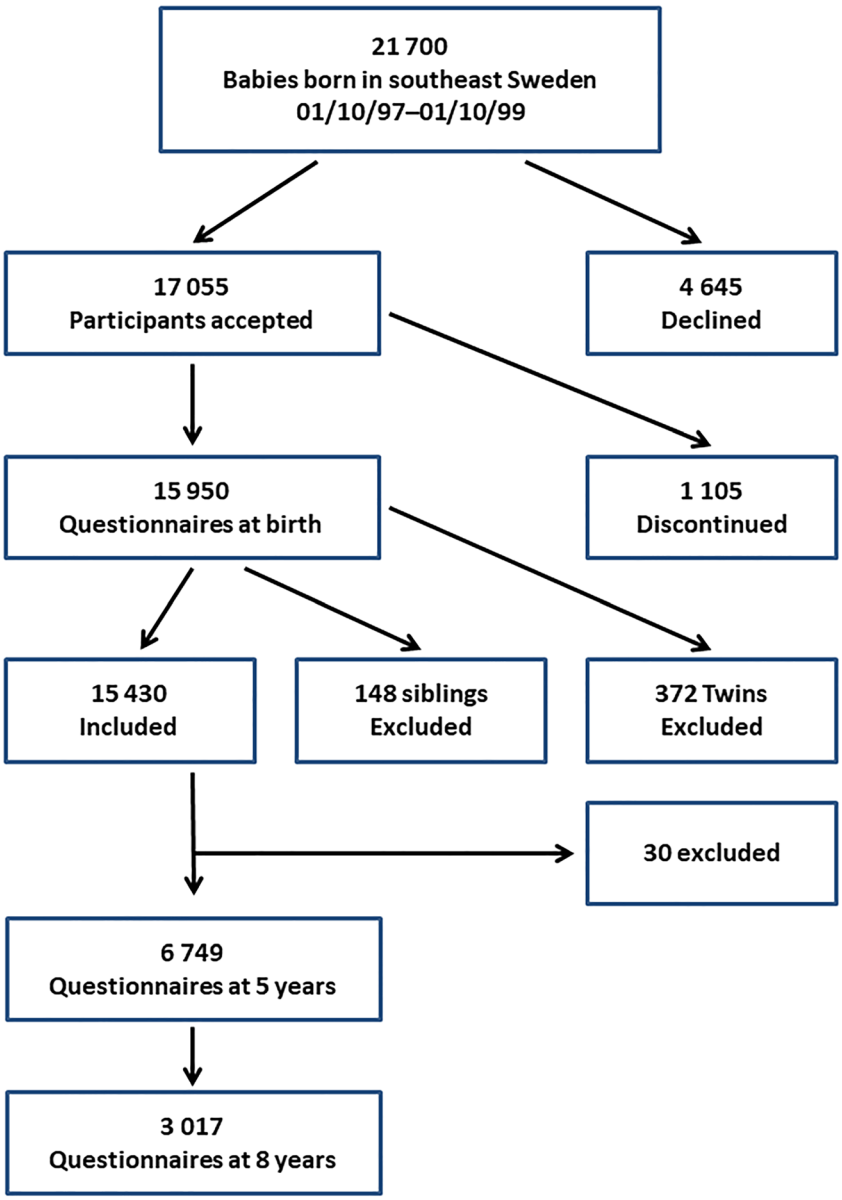


**FIGURE 1** Flow chart of the study participants

calculated and used to divide the children into four categories, underweight, normal weight, overweight, and obesity, according to international standards.[13,35]

### 2.2.2 | Diet quality index—mother's overall diet quality during pregnancy

The diet quality index was based on the Nordic Nutritional Recommendations 2012 (Swedish National Food Agency, 2012). Key questions have been chosen by a registered dietitian to construct a 20-item food frequency questionnaire (FFQ) generally reflecting dietary habits. The items included reflect the most common food for the Swedish population based on national data and not validated as a scale. The questionnaires were answered by the parents on several occasions. After delivery, mothers reported dietary habits during pregnancy, and the diet of the child was reported in FFQs at the age of 1, 2.5, 5, and 8 years.

The same data formed the basis for assessing overall diet quality by a nutritional therapist (SK). Compliance with the Nordic recommendations concerning intake of vegetables (daily), intake of fish (two times or more per week), type of fat used for cooking (vegetable oil and liquid margarine) and for spreads (none or low-fat spread), fatty dairy products (less than one time per week), and intake of meat (four times or less per week), chocolate, candy, and cookies (less than one time per week) each generated 1 point, whereas noncompliance generated 0 points for each item. A total score, ranging from 0 to 7, was calculated for each mother from the sum of each item. The higher the score, the closer the compliance with the Nordic Nutritional Recommendations. The cut-off points were defined as low quality (less than 2 points), medium quality (3 to 4 points), and high quality (5 points or more).

### 2.2.3 | Fatty-fish index

A fatty-fish index, to estimate the intake of long-chain omega-3 fatty acids, was constructed by a professional nutritional therapist (SK) for mothers during pregnancy and for the children at 1, 2.5, 5 and 8 years of age. Three of the questions in the respective FFQs addressed the consumption frequency of fish intake and whether it was freshwater fish, Baltic Sea fish, or other fish. The consumption frequencies in each of the questions were as follows: daily; three to five times per week; one to two times per week; and more seldom. As typical Swedish freshwater fish, such as zander, pike, and bass, contain very little long-chain omega 3 fatty acids, consumption of these fish types was omitted from the index. Fish from the Baltic Sea and other fish were considered to be a mix of fish with a high content of omega-3 PUFA, such as salmon or herring, and fish with a low content of omega-3 PUFA, such as cod and flatfish. When the consumption frequencies of fish from the Baltic Sea and other fish were summed up, four categories were constructed: less than one time a week; one to two times a week; three to five times a week; and daily or almost daily.

### 2.2.4 | Social data

Disposable household income, ie, family income available after taxation, was derived from Statistics Sweden (SCB) for the year 2000 and divided into a 3-point scale (highest 20%, medium 60%, and lowest 20%). We used parent-reported data regarding mother's and father's educational level on a 3-point scale. A 4-point index of the families' early psychosocial vulnerability, previously elaborated and presented by Karlén et al,[36] was also included. Other social data measured were single motherhood at child's birth and reported serious life events in the family before 5 and before 8 years age of the child. Maternal smoking during pregnancy, parental ethnicity, and residential area at birth were also measured.

### 2.2.5 | Physical activity, TV watching, and computer/game activity

Parents reported the level of daily physical activity defined as hours running, jumping, and playing outside of the child at 5 and 8 years of age. The number of hours the child spends daily on TV watching or computer/game activity at home in general basis was also assessed. The levels were defined as low activity (less than 30 minutes), medium activity (greater than 30 minutes to 4 hours), and high activity (greater than 5 hours a day) for all three variables.

### 2.2.6 | Anthropometrics and neonatal factors

A set of basic anthropometrical variables was also reported, including maternal age at parity, gestational week, means of delivery, and breastfeeding duration. Birth weight and birth height were reported, and size for gestational age was calculated according to Marsal et al.[37]

### 2.2.7 | Statistical analysis

Statistics were analysed using the Statistical Package for the Social Sciences version 24 (SPSS, Chicago, IL, USA). Statistical analyses for comparisons between groups were made using the Chi-squared test and analysis of variance (ANOVA) for differences in means. Multivariable linear regressions were performed to estimate the relative importance of different independent factors for weight category in three models. In model 1, we included all significant independent factors, except gender and maternal BMI, to assess the relative importance without the influence of gender and maternal BMI. In model 2, gender was added, and in model 3, both gender and maternal BMI were reported. A $P$ value less than.05 was considered statistically significant.

### 2.2.8 | Ethical considerations

The ABIS study has been ethically approved by the Research Ethics Committees of the Faculty of Health Science at Linköping University, Sweden, Ref. 1997/96287 and 2003/03-092 and the Medical Faculty of Lund University, Sweden (Nr 99227, Nr 99321). The present study is covered by these approvals. All parents of the children in the ABIS study gave their informed consent to participate.

## 3 | RESULTS

Among all children at 5 years of age, 12.9% were affected by overweight and 4.2% by obesity, whereas 77.0% presented normal weight and 5.9% underweight. Significantly more ($P < .0001$) girls than boys were affected by overweight or obesity (Table 1). At the age of 8, the total proportion of children with overweight was 12.2% and with obesity 2.3%, whereas 76.6% of the children presented normal weight, and 9.0% were underweight. Significantly more girls than boys ($P = .04$) were affected by overweight at the age of 8 (Table 1).

A more frequent intake of fatty fish at the age of 1 year was reported by children affected by obesity at 5 and 8 years of age. Additionally, children affected by obesity at 5 years of age reported a more frequent intake of fatty fish at the age of 2.5 years (Table 2).

Higher maternal nutritional quality index during pregnancy, but not maternal intake of fatty fish, was related to obesity in the children at 5 ($P = .02$) and at 8 years of age ($P = .04$). With regard to early nutrition, a shorter duration of total breastfeeding (exclusive and partial) was reported for children who were affected by obesity at 5 years of age (Table 4).

Risk factors other than nutritional were also found. Maternal and paternal BMI in the different weight groups, ie, underweight, normal weight, and children with overweight at the age of 1, 2.5, 5, and 8 years differed significantly at all follow-up ages ($P < .0001$) (Figure 2).

Sociodemographic data of the children in relation to their weight group at the age of 5 and 8 years is presented in Table 3. At the age of 5 years, maternal and paternal educational level, disposable household income, early psychosocial vulnerability, and serious life events in the family before the age of 5 were all statistically significant in relation to weight group, ie, towards overweight and obesity, as well as size for gestational age and maternal smoking during pregnancy. At the age of 8, only maternal educational level, serious life events before the age of 8, and maternal smoking during pregnancy were statistically significant in relation to weight group. Parental ethnicity, residential area of the family at the birth of the child, single motherhood, or the means of delivery were not related to weight group, either at 5 or at 8 years of age (Table 3).

For anthropometric data, the gestational week of the child at birth had a significantly positive relationship to weight group at the age of 5 but not at 8. Higher birth weight and length were significantly related to increasing weight category at both 5 and 8 years of age. Maternal age was not related to weight group at either 5 or 8 years of age (Table 4).

Short duration of daily physical activities and high frequency of TV-watching hours was significantly related to obesity at both 5 and 8 years of age (Table 5).

A multivariable analysis was performed with factors previously significantly associated with weight group at the age of 5 (Table 6) and 8 years (Table 7). Three models were assessed at both ages. In the first model, gender and maternal hereditary influence given as maternal BMI (model 1) were excluded; in the second, gender was included (model 2); and in the third, gender and maternal BMI at the child's age of 1 and 8 years were included (model 3).

Birth weight, maternal smoking during pregnancy, household income, and hours of physical activity at the age of 5 all remained significantly and independently associated with weight group in model 1 at 5 years of age. Gender and maternal BMI when the child was 1 year old were strongly associated with weight category at 5 years and did not change the results (Table 6). At the age of 8, only birth weight and TV watching at 8 years were significant in the multivariate model. These factors were still significant even after including the BMI of the mother when the child was 8 years old (model 3). Gender was not associated with weight groups at 8 years (models 2 and 3) (Table 7).

## 4 | DISCUSSION

In the present study, we found that a higher fatty-fish index during pregnancy was not related to overweight/obesity in the children. Higher fatty-fish index in the children during the first years of life was

**TABLE 1** Weight groups in boys and girls at the age of 5 and 8 years, respectively

| | Underweight | Normal Weight | Overweight | Obese | |
|---|---|---|---|---|---|
| | n (%) | n (%) | n (%) | n (%) | *P* Value[a] |
| 5 y | | | | | |
| Girls | 151 (4.7) | 2432 (76.0) | 465 (14.5) | 154 (4.8) | <.0001 |
| Boys | 250 (7.0) | 2765 (78.0) | 404 (11.4) | 128 (3.6) | |
| 8 y | | | | | |
| Girls | 144 (10.0) | 1068 (74.3) | 188 (13.1) | 38 (2.6) | .04 |
| Boys | 127 (8.0) | 1242 (78.2) | 179 (11.3) | 31 (2.0) | |

[a]Comparison between groups with Chi-squared test. *P* values less than.05 are considered significant.

**TABLE 2** Nutritional habits in mothers during pregnancy and children during the first 8 years of life in relation to weight category at 5 and 8 years of age, respectively

| | Children at 5 y | | | | | Children at 8 y | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Underweight | Normal Weight | Overweight | Obese | | Underweight | Normal Weight | Overweight | Obese | |
| | N = 401 | N = 5197 | N = 869 | N = 282 | | N = 271 | N = 2310 | N = 367 | N = 69 | |
| | n (%) | n (%) | n (%) | n (%) | *P* Value[a] | n (%) | n (%) | n (%) | n (%) | *P* Value[a] |
| Maternal fish intake during pregnancy | | | | | .14 | | | | | .99 |
| Seldom | 273 (69.1) | 3453 (68.6) | 607 (72.4) | 192 (70.1) | | 180 (66.9) | 1493 (65.9) | 235 (65.5) | 47 (69.1) | |
| 1-2 per wk | 120 (30.4) | 1493 (29.7) | 223 (26.6) | 78 (28.5) | | 84 (31.2) | 726 (32.1) | 117 (32.6) | 19 (27.9) | |
| 3-5 per wk/almost daily | 2 (0.5) | 86 (1.0) | 8 (1.0) | 4 (1.5) | | 5 (5.1) | 45 (2.0) | 7 (1.9) | 2 (2.9) | |
| Child's fatty fish intake at 1 y: | | | | | .01 | | | | | .04 |
| Seldom | 133 (91.7) | 1658 (89.9) | 270 (87.7) | 71 (78.0) | | 94 (93.1) | 727 (88.7) | 120 (88.9) | 19 (79.2) | |
| 1-2 per wk | 12 (8.3) | 175 (9.5) | 37 (12.0) | 18 (19.8) | | 7 (6.9) | 91 (11.1) | 14 (10.4) | 4 (16.7) | |
| 3-5 per wk/almost daily | 0 (0.0) | 11 (0.6) | 1 (0.3) | 2 (2.2) | | 0 (0.0) | 2 (0.2) | 1 (0.7) | 1 (4.2) | |
| Child's fatty fish intake at 2.5 y: | | | | | .02 | | | | | .82 |
| Seldom | 213 (93.8) | 2693 (90.3) | 434 (89.9) | 127 (85.2) | | 157 (91.8) | 1176 (90.6) | 170 (89.0) | 36 (2.3) | |
| 1-2 per wk | 14 (6.2) | 273 (9.2) | 42 (8.7) | 21 (14.1) | | 12 (7.0) | 114 (8.8) | 20 (10.5) | 2 (1.4) | |
| 3-5 per wk/almost daily | 0 (0.0) | 15 (0.5) | 7 (1.4) | 1 (0.7) | | 2 (1.2) | 8 (0.6) | 1 (0.5) | 0 (0.0) | |
| Child's fatty fish intake at 5 y: | | | | | .81 | | | | | .09 |
| Seldom | 238 (88.5) | 3054 (89.8) | 509 (90.1) | 169 (89.4) | | 124 (91.2) | 1065 (90.5) | 176 (95.1) | 31 (93.9) | |
| 1-2 per wk | 28 (10.4) | 330 (9.7) | 52 (9.2) | 19 (10.1) | | 10 (7.4) | 109 (9.3) | 9 (4.9) | 2 (6.1) | |
| 3-5 per wk/almost daily | 3 (1.1) | 15 (0.4) | 4 (0.7) | 1 (0.5) | | 2 (1.5) | 3 (0.3) | 0 (0.0) | 0 (0.0) | |
| Child's fatty fish intake at 8 y: | | | | | | | | | | .09 |
| Seldom | | | | | | 124 (91.2) | 1065 (90.5) | 176 (95.1) | 31 (2.2) | |
| 1-2 per wk | | | | | | 10 (7.4) | 109 (9.3) | 9 (4.9) | 2 (1.5) | |
| 3-5 per wk/almost daily | | | | | | 2 (1.5) | 3 (0.3) | 0 (0.0) | (0.0) | |
| Maternal nutritional quality index during pregnancy | | | | | .02 | | | | | .04 |
| Low quality | 120 (30.4) | 1349 (26.5) | 218 (25.8) | 73 (26.4) | | 69 (25.7) | 607 (26.5) | 100 (27.5) | 13 (18.8) | |
| Medium quality | 205 (51.9) | 2794 (54.9) | 451 (53.4) | 132 (47.7) | | 144 (53.3) | 1280 (55.9) | 178 (49.0) | 38 (55.1) | |
| High quality | 70 (17.7) | 943 (18.5) | 175 (20.7) | 72 (26.0) | | 56 (20.8) | 401 (17.5) | 85 (23.4) | 18 (26.1) | |

*Note.* N = number of children participating in the study at 5 and 8 years. n (%) = number of questionnaires answered at 5 and 8 years (percentage of all answered questionnaires).
[a]Comparison between groups with Chi-squared test. *P* values less than.05 are considered significant.

**TABLE 3** Sociodemographic data of children by weight category at 5 and 8 years of age

| | Children at 5 y | | | | | Children at 8 y | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Underweight | Normal Weight | Overweight | Obese | | Underweight | Normal Weight | Overweight | Obese | |
| | N = 401 | N = 5197 | N = 869 | N = 282 | | N = 271 | N = 2310 | N = 367 | N = 69 | |
| | n (%) | n (%) | n (%) | n (%) | *P* Value[a] | n (%) | n (%) | n (%) | n (%) | *P* Value[a] |
| Maternal educational level | | | | | .01 | | | | | .001 |
| Primary school | 29 (7.4) | 298 (5.9) | 56 (6.6) | 25 (9.1) | | 13 (4.8) | 94 (4.1) | 10 (2.7) | 5 (7.4) | |
| Secondary school | 225 (57.1) | 2945 (57.9) | 520 (61.5) | 176 (63.8) | | 121 (45.0) | 1259 (55.0) | 204 (56.0) | 48 (70.6) | |
| College/university | 140 (35.5) | 1844 (36.2) | 269 (31.8) | 75 (27.2) | | 135 (50.2) | 935 (40.9) | 150 (41.2) | 15 (22.1) | |
| Paternal educational level | | | | | .05 | | | | | .44 |
| Primary school | 47 (12.0) | 608 (12.1) | 118 (14.1) | 42 (15.4) | | 27 (10.1) | 236 (10.4) | 42 (11.7) | 9 (13.0) | |
| Secondary school | 238 (60.7) | 3120 (62.0) | 531 (63.4) | 177 (64.8) | | 149 (55.8) | 1352 (59.6) | 212 (58.9) | 46 (66.7) | |
| College/university | 107 (27.3) | 1305 (25.9) | 188 (22.5) | 54 (19.8) | | 91 (34.1) | 679 (30.0) | 106 (29.4) | 14 (20.3) | |
| Parental ethnicity | | | | | .25 | | | | | .14 |
| Both parents Swedish | 354 (89.6) | 4660 (91.6) | 774 (91.4) | 242 (88.0) | | 245 (90.7) | 2111 (92.3) | 332 (91.5) | 58 (84.1) | |
| One parent not Swedish | 33 (8.4) | 334 (6.6) | 53 (6.3) | 24 (8.7) | | 20 (7.4) | 139 (6.1) | 23 (6.3) | 7 (10.1) | |
| Both parents born abroad | 8 (2.0) | 92 (1.8) | 20 (2.4) | 9 (3.3) | | 5 (1.9) | 37 (1.6) | 8 (2.2) | 4 (5.8) | |
| Disposable household income | | | | | .01 | | | | | .27 |
| Low (20%) | 73 (18.3) | 807 (15.6 | 156 (18.0) | 64 (22.7) | | 37 (13.7) | 333 (14.4) | 60 (16.3) | 12 (17.4) | |
| Medium (60%) | 146 (36.5) | 2163 (41.6) | 356 (41.0) | 105 (37.2) | | 97 (35.9) | 955 (41.4) | 139 (37.9) | 32 (46.4) | |
| High (20 %) | 181 (45.3) | 2224 (42.8) | 357 (41.1) | 113 (40.1) | | 136 (50.4) | 1021 (44.2) | 168 (45.8) | 25 (36.2) | |
| Residential area at birth | | | | | .19 | | | | | .19 |
| Countryside | 90 (22.9) | 1245 (24.9) | 213 (25.6) | 64 (23.5) | | 58 (21.8) | 552 (24.5) | 86 (24.2) | 13 (19.1) | |
| Small village | 100 (25.4) | 1118 (22.3) | 213 (25.6) | 71 (26.1) | | 49 (18.4) | 442 (19.6) | 88 (24.7) | 17 (25.5) | |
| City | 203 (51.7) | 2644 (52.8) | 407 (48,9) | 137 (50.4) | | 159 (59.8) | 1263 (56.0) | 182 (51.1) | 38 (55.9) | |
| Single motherhood at birth | | | | | .09 | | | | | .07 |
| Yes | 4 (1.0) | 54 (1.1) | 14 (1.7) | 7 (2.5) | | 1 (0.4) | 17 (0.7) | 6 (1.7) | 2 (2.9) | |
| No | 391 (99.0) | 5031 (98.8) | 834 (98.3) | 269 (97.5) | | 269 (99.6) | 2271 (99.3) | 356 (98.3) | 66 (97.2) | |
| Psychosocial vulnerability | | | | | .002 | | | | | .67 |
| Low | 127 (33.4) | 1859 (38.4) | 282 (35.4) | 98 (30) | | 98 (37.4) | 863 (39.2) | 136 (39.7) | 26 (40.0) | |
| Medium | 212 (55.8) | 2614 (54.0) | 440 (55.3) | 125 (48.4) | | 146 (55.7) | 1189 (54.2) | 184 (53.6) | 31 (47.7) | |
| Relatively high | 41 (10.8) | 366 (7.6) | 74 (9.3) | 35 (13.6) | | 18 (6.9) | 143 (6.5) | 23 (6.7) | 8 (12.3) | |
| Serious life events before 5-8 y | | | | | .02 | | | | | .03 |
| Yes | 78 (20.3) | 987 (19.9) | 197 (23.6) | 67 (25.4) | | 53 (20.9) | 558 (25.2) | 92 (26.5) | 25 (38.5) | |
| No | 306 (79.7) | 3969 (80.1) | 637 (76.4) | 199 (71.8) | | 200 (79.1) | 1657 (74.8) | 255 (73.5) | 40 (61.5) | |
| Means of delivery | | | | | .68 | | | | | .80 |
| Normal | 326 (83.4) | 4214 (83.4) | 688 (81.8) | 219 (79.9) | | 219 (81.7) | 1867 (82.1) | 294 (81.2) | 61 (88.4) | |

(Continues)

**TABLE 3** (Continued)

| | Children at 5 y | | | | | Children at 8 y | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Underweight | Normal Weight | Overweight | Obese | | Underweight | Normal Weight | Overweight | Obese | |
| | N = 401 | N = 5197 | N = 869 | N = 282 | | N = 271 | N = 2310 | N = 367 | N = 69 | |
| | n (%) | n (%) | n (%) | n (%) | *P* Value[a] | n (%) | n (%) | n (%) | n (%) | *P* Value[a] |
| Cesarean section | 44 (11.3) | 580 (11.5) | 104 (12.4) | 49 (14.6) | | 31 (11.6) | 282 (12.4) | 45 (12.4) | 6 (8.7) | |
| Other complications | 21 (5.4) | 257 (5.1) | 49 (5.8) | 15 (5.5) | | 18 (6.7) | 126 (5.5) | 23 (6.4) | 2 (2.9) | |
| Size for gestational age: | | | | | <.0001 | | | | | .18 |
| Small | 16 (4.1) | 98 (2.0) | 13 (1.6) | 1 (0.4) | | 10 (3.8) | 50 (2.2) | 6 (1.7) | 2 (3.0) | |
| Appropriate | 364 (93.6) | 4682 (94.1) | 753 (90.5) | 242 (89.3) | | 247 (92.9) | 2102 (93.6) | 332 (92) | 64 (95.5) | |
| Large | 9 (2.3) | 193 (3.9) | 66 (7.9) | 28 (10.3) | | 9 (3.4) | 93 (4.1) | 23 (6.4) | 1 (1.5) | |
| Maternal smoking during pregnancy | | | | | <.0001 | | | | | .04 |
| No | 28 (92.9) | 380 (92.2) | 86 (89.8) | 42 (84.7) | | 28 (93.3) | 380 (94.6) | 86 (92.8) | 42 (87.0) | |
| Yes | 367 (7.1) | 4707 (7.5) | 759 (10.2) | 233 (15.3) | | 367 (6.7) | 4707 (5.4) | 759 (7.2) | 233 (13.0) | |

*Note.* N = number of children participating in the study at 5 and 8 years. n (%) = number of questionnaires answered at 5 and 8 years (percentage of all answered questionnaires).
[a]Comparison between groups with Chi-squared test. *P* values less than.05 are considered significant.

**TABLE 4** Birth characteristics and breastfeeding by weight category in 5-year-old and 8-year-old children in the ABIS cohort

| | Children at 5 y | | | | | Children at 8 y | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Underweight | Normal Weight | Overweight | Obese | | Underweight | Normal Weight | Overweight | Obese | |
| | n = 397 | n = 5107 | n = 857 | n = 278 | | n = 185 | n = 1720 | n = 268 | n = 51 | |
| | Mean (SD) | Mean (SD) | Mean (SD) | Mean (SD) | *P* Value[a] | Mean (SD) | Mean (SD) | Mean (SD) | Mean (SD) | *P* Value[a] |
| Gestational week | 39.5 (1.9) | 39.7 (1.7) | 39.8 (1.7) | 39.8 (1.6) | .015 | 39.3 (1.7) | 39.5 (1.6) | 39.5 (1.7) | 39.7 (1.5) | .12 |
| Birth weight | 3391 (672) | 3 564 (546) | 3 713 (573) | 3 778 (556) | <.0001 | 3 417 (583) | 3590 (523) | 3 702 (577) | 3 656 (524) | <.0001 |
| Birth length | 50.2 (2.7) | 50.5 (2.4) | 50.8 (2.4) | 51.0 (2.4) | <.0001 | 50.2 (2.7) | 50.7 (2.2) | 51.0 (2.4) | 50.6 (2.4) | <.0001 |
| Maternal age at parity | 30.0 (4.5) | 29.9 (4.4) | 29.8 (4.5) | 29.9 (5.0) | .91 | 30.0 (4.3) | 29.7 (4.4) | 29.9 (4.6) | 29.4 (5.3) | .62 |
| Partial breastfeeding, mo | 7.1 (2.4) | 7.3 (2.3) | 7.1 (2.4) | 6.8 (2.5) | .02 | 7.6 (1.9) | 7.5 (2.2) | 7.4 (2.3) | 6.8 (2.5) | .12 |
| Exclusive breastfeeding, mo | 4.5 (1.8) | 4.5 (1.8) | 4.4 (1.8) | 4.4 (2.0) | .22 | 4.8 (1.7) | 4.6 (1.7) | 4.6 (1.8) | 4.1 (2.1) | .06 |

*Note.* n = number of questionnaires answered at 5 and 8 years of age.
Abbreviation: ABIS, All Children in South-East Sweden.
[a]Comparison of means with analysis of variance (ANOVA) test. *P* values less than.05 are considered significant.

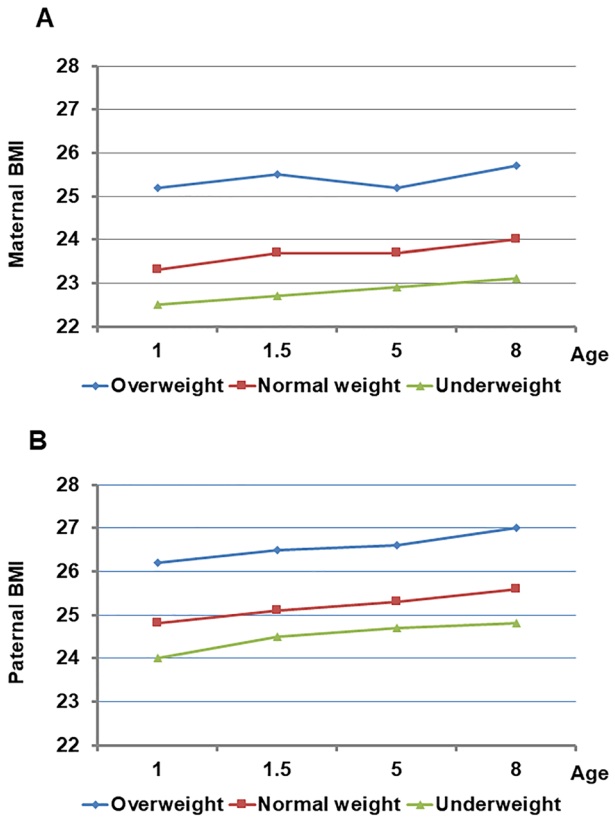


**FIGURE 2** The mean maternal and paternal body mass index (BMI) in the group of children defined as underweight (), normal weight (), and overweight/obese (◊) at the age of 1, 2.5, 5, and 8 years in the children. The figure is descriptive

related to obesity at 5 and 8 years of age. This relationship disappeared in a multivariate analysis when including other risk factors for overweight/obesity in children. Maternal BMI, maternal education, maternal smoking during pregnancy, birth weight, and physical activity all remained related to overweight/obesity at both 5 and 8 years of age. Girls were more affected than boys by overweight/obesity. The prevalence of overweight and obesity has been reported among 4- to 10-year-old children from various parts of Sweden.[14,17,38] Our report is comparable with the prevalence of obesity/overweight in Sweden, with a range of 17% to 28% in 4-year-old children and 20% to 28% among 10-year-old children during the same period.

Our hypothesis was that low maternal intake of n-3 LCPUFA during pregnancy and low intake of n-3 LCPUFA during childhood were related to the development of overweight and obesity in childhood. However, we could not confirm this hypothesis. Higher maternal intake of omega-3 PUFA during pregnancy, defined as a fatty-fish index, was related to neither overweight nor obesity in these children. In contrast, a higher fish index in the children, particularly during the first year of life, increased the risk of obesity at 5 and 8 years of age. The samples were small in some of the weight categories. However, merging the groups with overweight and obesity to increase the number of children did not change the results. Maternal or child intake of

**TABLE 5** Leisure time activity for 5-year-old and 8-year-old children by weight category in the ABIS cohort

| | Children at 5 y | | | | | Children at 8 y | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Underweight N = 401 | Normal Weight N = 5197 | Overweight N = 869 | Obese N = 282 | | Underweight N = 271 | Normal Weight N = 2310 | Overweight N = 367 | Obese N = 69 | |
| | n (%) | n (%) | n (%) | n (%) | P Value[a] | n (%) | n (%) | n (%) | n (%) | P Value[a] |
| Physical activity | | | | | <.0001 | | | | | .03 |
| Low (≤30 min) | 34 (8.6) | 528 (10.3) | 101 (11.8) | 54 (19.4) | | 2 (0.8) | 20 (0.9) | 6 (1.6) | 0 (0.0) | |
| Medium (>30 min-4 h) | 165 (41.9) | 2232 (43.7) | 378 (44.3) | 140 (50.2) | | 82 (30.8) | 751 (33.1) | 149 (40.6) | 28 (41.2) | |
| High (≤5 h) | 195 (49.5) | 2352 (46.0) | 374 (43.8) | 85 (30.5) | | 182 (68.4) | 1499 (66.0) | 212 (57.8) | 40 (58.8) | |
| TV watching | | | | | .003 | | | | | <.0001 |
| Low | 22 (5.5) | 285 (5.6) | 55 (6.4) | 20 (7.2) | | 13 (16.2) | 104 (14.6) | 15 (11.7) | 4 (10.1) | |
| Medium | 307 (77.3) | 4013 (78.6) | 647 (75.5) | 190 (68.3) | | 143 (54.2) | 1357 (51.8) | 197 (43.4) | 34 (30.4) | |
| High | 68 (17.1) | 809 (15.8) | 155 (18.1) | 68 (24.5) | | 29 (29.5) | 259 (33.7) | 56 (44.8) | 13 (59.4) | |
| Computer/video game | | | | | .06 | | | | | .70 |
| Low | 131 (31.1) | 1508 (29.3) | 282 (33.0) | 96 (34.3) | | 58 (56.8) | 487 (53.7) | 80 (53.9) | 16 (51.2) | |
| Medium | 207 (52.3) | 2935 (57.1) | 476 (55.7) | 145 (51.8) | | 110 (25.5) | 1020 (28.4) | 162 (28.7) | 29 (23.5) | |
| High | 58 (14.6) | 698 (13.6) | 97 (11.3) | 39 (13.9) | | 19 (17.7) | 225 (17.9) | 31 (17.4) | 7 (25.5) | |

*Note.* N = number of children participating in the study at 5 and 8 years. n (%) = number of questionnaires answered at 5 and 8 years (percentage of all answered questionnaires).
Abbreviation: ABIS, All Children in South-East Sweden.
[a]Comparison between groups with Chi-squared test. *P* values less than.05 are considered significant.

**TABLE 6** Multivariate analysis of factors significantly associated with weight group (underweight, normal weight, overweight, and obesity) of the child at 5 years of age. In model 2, we include the gender of the child. In model 3, we include gender and maternal BMI when the child was 5 years old

| | **Model 1** | | Model 2 Including Gender | | Model 3 Including Gender and Maternal BMI | |
|---|---|---|---|---|---|---|
| Factors associated with weight group: | *t* Value | *P* Value | *t* Value | *P* Value | *t* Value | *P* Value |
| Gender | - | - | 6.38 | <.0001 | 4.33 | <.0001 |
| Maternal BMI (at child 1 y) | - | - | - | - | 4.42 | <.0001 |
| Birth weight | 4.07 | <.0001 | 4.57 | <.0001 | 3.96 | <.0001 |
| Size for gestational age | 1.22 | .22 | 0.89 | .37 | 0.96 | .34 |
| Breastfeeding duration | −0.22 | .82 | −0.23 | .82 | 0.17 | .87 |
| Fatty fish consumption in the child at 1 y. | 1.52 | .13 | 1.63 | .10 | 1.18 | .24 |
| Fatty fish consumption in the child at 2.5 y | 1.24 | .22 | 1.39 | .17 | 1.47 | .14 |
| Maternal nutritional quality during pregnancy | 1.49 | .14 | 1.67 | .10 | 1.38 | .17 |
| Mother smoking during pregnancy | 2.40 | .02 | 2.35 | .02 | 2.48 | .01 |
| Psychosocial vulnerability in the family | −0.37 | .71 | −0.34 | .73 | −0.39 | .70 |
| Household income | −2.28 | .02 | 2.42 | .02 | −2.30 | .02 |
| Mother's education | −1.49 | .14 | −1.68 | .09 | −1.07 | .28 |
| Serious life events before the child is 5 y old | 0.13 | .90 | −0.03 | .98 | −0.02 | .99 |
| Physical activity at 5 y of age | −1.98 | .05 | −1.93 | .05 | −2.07 | .04 |
| TV watching at 5 y of age | 0.16 | .87 | 0.48 | .63 | −0.35 | .72 |
| Constant | 7.18 | <.0001 | 6.81 | <.0001 | 5.04 | <.0001 |

*Note.* Analysis of factors significantly associated with weight group with Multivariate linear regression. A *P* value less than.05 is considered significant. Model 1: Df = 13, F = 3.99, *P* < .0001. Model 2: Df = 14, F = 5.05, *P* < .0001. Model 3: Df = 15, F = 5.86, *P* < .0001.
Abbreviation: BMI, body mass index.

**TABLE 7** Multivariate analysis of factors significantly associated with weight group (underweight, normal weight, overweight, and obesity) of the child at 8 years of age. In model 2, we include the gender of the child. In model 3, we include gender and maternal BMI when the child was 8 years old

| | **Model 1** | | Model 2 Including Gender | | Model 3 Including Gender and Maternal BMI | |
|---|---|---|---|---|---|---|
| Factors associated with weight group: | *t* Value | *P* Value | *t* Value | *p* Value | *t* Value | *P* Value |
| Gender | - | - | 1.48 | .14 | 1.10 | .27 |
| Maternal BMI (at child 8 y) | - | - | - | - | 6.10 | **<.0001** |
| Birth weight | 3.86 | **<.0001** | 4.00 | **<.0001** | 3.48 | **.001** |
| Fatty fish consumption in the child at 1 y. | 1.21 | .23 | 1.17 | .24 | 1.07 | .29 |
| Maternal nutritional quality during pregnancy | 1.32 | .19 | 1.37 | .17 | 0.73 | .47 |
| Mother smoking during pregnancy | 1.14 | .25 | 1.12 | .26 | 0.67 | .50 |
| Mother's education | −1.24 | .22 | −1.18 | .24 | −0.28 | .78 |
| Serious life events before the child is 8 y old | −1.70 | .09 | −1.76 | .79 | −1.47 | .14 |
| Physical activity at 8 y old | −1.61 | .11 | −1.45 | .15 | −1.47 | .14 |
| TV watching at 8 y old | 2.80 | **.005** | 2.85 | **.004** | 1.80 | .07 |
| Constant | 7.18 | **<.0001** | 6.81 | **<.0001** | 5.04 | **<.0001** |

*Note.* Analysis of factors significantly associated with weight group with multivariate linear regression. A p value<0.05 is considered significant. Model 1: Df = 8, F = 4.67, *P* < .0001. Model 2: Df = 9, F = 4.40, *P* < .0001. Model 3: Df = 10, F = 7.76, *P* < .0001.
Abbreviation: BMI, body mass index.

omega-3 PUFA was not related to obesity at 5 or 8 years of age in the multivariate analysis. This is in contrast to previous reports.[6,32,33]

We assessed the dietary intake of fatty fish as a proxy for dietary intake of omega-3 LCPUFA. As we were unable to assess the intake of omega-6 PUFA in maternal and infant diet, we believe that a higher intake of not only omega-3 but also of omega-6 PUFA in the diet of children who are overweight or obese may lead to a similar or even higher omega-6/omega-3 ratio and may explain our results.

Alternately, families with children who are overweight/obese might overestimate their intake of quality nutrients and fish. Besides these speculations, we must conclude that our results do not support our initial hypothesis. Instead, we conclude that early higher omega-3 fatty acid consumption does not protect against childhood obesity in modern society.

We found a higher frequency of overweight/obesity in girls than in boys both at 5 and 8 years of age. A higher prevalence of overweight/obesity in girls, as in the present study, was also reported by others[15,27] in Sweden and internationally.[39] In a previous Swedish study based on occupation, parental education, and parental income,[15] a higher prevalence of overweight/obesity in girls was attributed to living in municipalities with lower socio-economic conditions. Another explanation may be the differences between girls and boys in the intake of different food groups reported previously.[40]

At 5 years of age, maternal education, maternal smoking during pregnancy, birth weight, birth size, and physical activity are related to overweight/obesity. At 8 years of age, only birth weight and TV watching remain related to the development of overweight/obesity. If maternal BMI when the children are 1 year of age is included in the analysis, the relationship to birth size disappears, likely because maternal BMI at birth influences the size of the newborn.

Risk factors early in life, such as exclusive breastfeeding for 4 to 6 months, number of siblings, maternal smoking, maternal nutrition during pregnancy, rapid infant growth, sleeping behaviour, amount of physical activity, TV watching, parental socio-economic status, and parental overweight/obesity, have been reported to influence the development of overweight/obesity in preschool and school children.[22,23,26]

In this study, we corroborate the hereditary influence of the parents on the development of weight in childhood; maternal and paternal BMI was significantly and strongly related to overweight/obesity in preschool and school children.[16,41] Among early risk factors for overweight/obesity at 5 years of age, we found that parental (both paternal and maternal) educational level, household income, and maternal smoking during pregnancy were related to overweight/obesity, indicating a strong socio-economic gradient that has previously been shown by others.[23,24] At 8 years of age, only maternal educational level and maternal smoking during pregnancy were still related to overweight/obesity in the children. Similarly, gestational birth size (a proxy for birth weight and length) and gestational age at birth were related to overweight/obesity in the children at 5 but not at 8 years of age.

In line with previous reports,[23,24] we also show that low physical activity and increased TV time are related to overweight/obesity at 8 years of age. In a mutually adjusted analysis, particularly when heredity defined as maternal BMI was included, gender, birth weight, maternal smoking, household income, and physical activity were related to overweight/obesity in children at 5 years of age, whereas heredity, birth weight, and TV time are more important at 8 years of age.

A more nutritional maternal diet during pregnancy was related to more frequent obesity in the children at 5 and 8 years of age. These results may be explained by mothers with obesity developing healthier dietary habits during pregnancy and not continuing so after the child is born. The relationship between breastfeeding and obesity is complex as less frequent and shorter breastfeeding by itself is related to maternal smoking and socio-economic factors, among other factors.

More than 90% of all children visit the child health care centres between 6 weeks and 5.5 years of age in Sweden. The common recommendation in Sweden is to introduce small amounts of solid foods from the age of 4 months. This may explain our results with the mean length of exclusive breast feeding of 4 to 5 months and no significant differences between the weight groups, neither at 5 nor at 8 years of age. Looking at the total duration of breastfeeding, however, there is a significant relationship between shorter breastfeeding and increasing infant obesity at 5 years, which is in line with other studies.[26]

The strengths and limitations of this study are related to its design. It is a prospective, observational study following a large cohort of children from birth to 8 years of age. The weight and height of the children were reported by the parents, but the questionnaires were timed with measurements of weight and height of the children in the general child health care system and are reliable. A general health movement in the population, particularly in families with children who are overweight/obese, may have influenced the results of the questionnaires, particularly in respect of dietary habits and physical activity. Moreover, recall bias may have influenced the results of the questionnaires in general. A relatively large drop-out (50.3%) when the children were 5 years old and particularly at 8 years of age (80.4%) jeopardize the representability of the population as families with obesity may be prone to discontinue. Similar assumptions can, however, be made about otherwise healthy families. Nonetheless, the relatively large number of participants suggests that the results are reliable and that significantly small differences between small groups could be identified.

In conclusion, this study does not support the hypothesis that lower intake of fatty fish in the maternal diet during pregnancy or in the early diet of preschool and school children is related to obesity risks. Instead, important factors were parental heredity, maternal education, maternal smoking during pregnancy, birth weight, and physical activity, which were all related to overweight/obesity in Swedish preschool and school children. We found a higher frequency of overweight/obesity in girls than in boys at 5 and 8 years of age.

The clinical implications of this study are that to prevent or treat overweight/obesity in childhood, the whole family must undergo counselling to address risk factors for developing obesity in the children. Counselling of women with obesity during pregnancy, prevention of smoking in the family, promotion of breastfeeding, and facilitation of physical activity in preschool and school children must be cornerstones in the prevention and treatment of overweight/obesity in childhood.

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## CONFLICT OF INTEREST STATEMENT

The authors do not have any conflicts of interest to report.

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K.D. conceived the research question, J.L. started and conceived the epidemiological study, S.K. developed the nutritional indices, and K.D., Å.O.F., and T.F. analysed the data. All authors were involved in writing the paper and had final approval of the submitted and published versions. Special thanks to the participating families in the ABIS study and all staff at obstetrics departments and well-baby clinics.

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