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ORIGINAL CONTRIBUTION

Maternal fish consumption during pregnancy and BMI in children from birth up to age 14 years: the PIAMA cohort study

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Abstract
Purpose This study aimed to investigate the association between maternal fish consumption during pregnancy and BMI in children and the development of this association between birth and 14 years of age, taking into account relevant mother and child covariates.
Methods The study population consisted of 3684 Dutch children born in 1996–1997 who participated in the PIAMA birth cohort study. Maternal fish consumption during pregnancy and the child's body weight and height (up to 11 times) were reported by questionnaire. Generalized estimating equations were used to investigate whether BMI of children differed according to maternal fish consumption during pregnancy.
Results The crude overall association between maternal fish consumption during pregnancy and BMI in children was non-significant ($P = 0.17$), but differed by the child's age (P interaction $= 0.03$). Children of mothers who consumed fish $\geq 1\times$/week during pregnancy ($n = 909$) had statistically significant lower mean BMI z scores than children of mothers who never consumed fish ($n = 1025$) at the ages 4, 7, 8.5, and 11.5 years. Adjustment for maternal covariates (particularly pre-pregnancy BMI) attenuated the differences, which remained statistically significant at the age of 7 years only (mean difference in BMI z score: −0.14 95 % CI −0.25; −0.03). Additional adjustment for child covariates hardly affected the results.
Conclusions In a population with relatively low fish consumption, higher fish consumption by pregnant women seems rather an indicator for more healthy maternal characteristics in general than a causal factor for the lower BMI in their children.

Keywords Maternal consumption · Fish · BMI · Children

Abbreviations

BMI	Body mass index
PIAMA	Prevention and Incidence of Asthma and Mite Allergy
DHA	Docosahexaenoic acid
EPA	Eicosapentaenoic acid
LCPUFA	Long-chain polyunsaturated fatty acids
FFQ	Food frequency questionnaire
GEE	Generalized estimating equations

Introduction

There is evidence that in utero exposure to docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) may have a beneficial effect on early adipose tissue development [1, 2]. These n-3 long-chain polyunsaturated fatty acids (LCPUFA) are thought to have an anti-obesogenic effect

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by blocking the maturation of adipocytes and so may lower risk of obesity in later life [3].

Fish is an important dietary source of EPA and DHA [4]. This suggests that fish consumption during pregnancy may beneficially affect children's body mass index (BMI) later in life. If this turns out to be true, this may influence dietary guidelines to prevent obesity in children already during pregnancy [5].

However, several issues need to be further investigated. To the best of our knowledge, so far, only Donahue et al. [6] investigated the association of maternal fish consumption during pregnancy and adiposity in children. They found that higher consumption of fish (expressed in servings per week) by pregnant women ($n = 1120$) at 29 week of gestation was associated with a 23 % (95 % CI 5–38) lower risk of obesity among their children at 3 years of age [6]. The association with BMI z score as continuous outcome was non-significant [mean SDS −0.03 (95 % CI −0.09; 0.03)]. Further studies are needed to elucidate this finding.

In addition, insight is needed whether maternal fish consumption during pregnancy only affects the child's body weight in the first years of life or whether the association persists throughout childhood. Prospective studies including repeated BMI measures at different ages could provide more insight into the development of the association over time [7]. In addition, such a study design reduces the risk of chance findings as compared to studies, which include outcome data observed at one specific time point only.

Another issue that needs to be clarified is whether maternal fish consumption during pregnancy may be an indicator for other healthy characteristics rather than a causal factor in decreasing the risk of obesity. Fish consumption during pregnancy may reflect a healthy lifestyle of the mother and also of her child later in life [8]. Adjustment for relevant maternal and child covariates can give more insight into the impact of those factors on the association. In the study of Donahue et al. [6], which included many maternal and child characteristics, adjustment hardly affected the association. This suggests that a higher consumption of fish by pregnant women was responsible for the observed lower obesity risk in early childhood.

The aim of the current study is to investigate the association between maternal fish consumption during pregnancy and BMI in children measured 11 times in the PIAMA birth cohort study, including 3684 mother–child pairs. We additionally aimed to investigate the development of the association by the age of the child between birth and 14 years of age. Finally, we aimed to investigate the impact of other relevant maternal and child characteristics on the observed association, if any.

Materials and methods

Study design and study population

The Dutch Prevention and Incidence of Asthma and Mite Allergy (PIAMA) birth cohort study started with 3963 children born in 1996–1997. In this study, mothers were recruited from the general population during pregnancy ($n = 4146$). A total of 183 (4.5 %) women were lost to follow-up before any data on the child had been collected. The study protocol was approved by the medical ethics committees of the participating institutes, and all parents gave written informed consent. A detailed description of the study design has been published previously [9].

Questionnaires were completed by the participating parents during pregnancy (95 % in third trimester), 3 months after the child was born, yearly from 1 to 8 years of age and at 11 and 14 years of age. The number of parents who completed the questionnaires ranged from 3934 when the children were 3 months old (95 % of the baseline study population) to 2337 when the children were 14 years old (56 % of the baseline study population).

From each multiple birth ($n = 18$ in this study), only one child was randomly selected to be part of PIAMA birth cohort. For the current study, we excluded children who were born preterm (<37 weeks of gestation, $n = 190$) or who had no information on maternal fish consumption during pregnancy ($n = 40$) or had missing information on all 11 BMI measurements ($n = 49$). This resulted in a study population of 3684 pairs eligible for analysis.

Data collection

We obtained questionnaire information during 11 waves of follow-up. Maternal diet during pregnancy was ascertained through a short food frequency questionnaire (FFQ) consisting of eight food items. Expectant mothers were asked how often they consumed vegetables, fresh fruit, fish, eggs, milk, milk products, nuts, and nut products during the last month. Answering options were (1) never, (2) 1–3 times a month, (3) once a week, (4) 2–4 times a week, (5) more than 4 times a week, (6) once a day, and (7) several times per day. Furthermore, information on maternal demographic characteristics (education, employment, household composition), anthropometric characteristics (body weight before pregnancy, height), and lifestyle factors [smoking during pregnancy, breast-feeding duration (weeks)], sex of the child, and date of delivery was obtained.

Data on the child's weight and height were reported at each wave of follow-up. Parents were asked to copy their child's weight and height data and the date of measurement from their child's medical record. When data from medical records were not available, parents were asked to measure their child's weight and height without shoes and heavy clothing themselves and report those together with the date of measurement.

The questionnaire at 7 years of age contained a FFQ asking the parents how often in the previous month their child consumed a certain food or drink (47 food items queried such as soft drinks, candy bars, fried snacks or chips, crisps or salty snacks, vegetables, fruit, fish). The questionnaire at 11 years of age contained more detailed questions on the use of sugar-containing beverages (soft drinks, fruit juices, milk drinks, energy drinks, and sport drinks) and snacks, asking the child how many times per week and how much a day he or she consumed such foods (18 food items, but not fish). In addition, the child was asked to report the number of hours a day he or she watched television, watched videos, or used the computer and how many times per week he or she practiced an active sport.

Definition of exposure

Maternal fish consumption was regrouped into three categories: never ($n = 1025$), 1–3 times a month ($n = 1750$), and once a week or more ($n = 909$). As only 132 women reported to consume fish more than once a week, it was not possible to make additional categories of maternal fish consumption. Because the short FFQ was not validated, we assessed the quality of the reported fish consumption data in a subsample of 276 women. We compared the reported fish consumption with measured EPA and DHA concentrations [10] in breast milk. Women who reported to eat fish once a week or more had the highest sum of EPA and DHA concentrations in their breast milk, while women who consumed no fish at all had the lowest concentrations ($P < 0.0001$).

Definition of outcome

Although each questionnaire was sent around a child's date of birth, the exact ages of the children at the time of height and weight measurement differed. To facilitate the longitudinal data analysis and interpretation of the results, all reported weight and height data were therefore combined and regrouped by the age of the child at the time of measurement (range 0.1 months–16.4 years). One-year age categories were constructed with round years as midpoint and 6-month boundaries before and after the midpoint (except the first category, which ranged from 0 to 0.5 years). For the analysis, ages 8 and 9, 11 and 12, and 14 and 15 years were combined to retain sufficient numbers per age category ($n \approx 2000$). This resulted in the following 11 age categories: (1) 0–0.5 years, (2) 0.5–1.5 years, (3) 1.5–2.5 years, (4) 2.5–3.5 years, (5) 3.5–4.5 years, (6) 4.5–5.5 years, (7) 5.5–6.5 years, (8) 6.5–7.5 years, (9) 7.5–9.5 years, (10) 10.5–12.5 years, and (11) 13.5–15.5 years. A total of 891 and 6 children, respectively, had two and three BMI measurements within one age category. The measurement that was closest to the midpoint of the age category was included in the present analysis. Furthermore, we deleted some BMI measurements which were outside the predefined age categories ($n = 126$; 9.5–10.5 and 12.5–13.5 years). The number of available BMI measurement per child ranged from 1 to 11, with a median of 8. For 90 % of the children, four or more BMI measurements were available.

BMI z scores were calculated using reference data from the 1997 Dutch Growth Study [11]. BMI z scores represent the deviation in measured BMI from the mean BMI of the general population of children of the same sex and age (months) in units of the population standard deviation.

Covariates

All maternal and child demographic and lifestyle factors that have been associated with obesity based on literature and for which information was collected in this study (see Table 1) were considered as covariates. Only covariates that were also associated with maternal fish consumption during pregnancy were considered as confounder.

Data analysis

To identify factors that could explain a possible association between maternal fish consumption during pregnancy and BMI in children, we evaluated differences in the selected maternal and child characteristics (*see covariates*) between maternal fish consumption groups. This was done by one-way ANOVA for normally distributed covariates, by the Kruskal–Wallis test for covariates with skewed distributions and by the Chi-square test for discrete covariates.

Generalized estimating equations (GEEs) were used to study the association between maternal fish consumption and BMI in children, taking into account the correlation between the repeated measures in the same child. A ten-dependent working correlation structure fitted the data best. BMI z scores showed a normal distribution and were used as a continuous dependent variable. Maternal fish consumption during pregnancy (ten groups, never consumers as reference) was used as independent categorical variable. Mean BMI z scores of the two groups of children whose mothers consumed fish during pregnancy were compared with the mean BMI z scores of children of mothers who never consumed fish during pregnancy (reference group). Crude models are presented as model 1. Characteristics of the mother that differed by maternal fish consumption groups based on univariate analysis (see Table 1) were added to

Table 1 Maternal and child characteristics according to maternal fish consumption during pregnancy

	Maternal fish consumption during pregnancy				# Missing values
	Never ($n = 1025$)	1–3 times a month ($n = 1750$)	Once a week or more ($n = 909$)	P value[a]	
Maternal characteristics					
Demographic					
Age at child birth (years)	29.6 ± 3.7	30.5 ± 3.9	31.0 ± 4.0	<0.0001	25
Number of older children in household (%)				0.0008	0
0	46.8	52.2	44.8		
1–2	48.4	44.8	50.8		
>3	4.8	3.0	4.4		
Education (%)				<0.0001	112
Low	31.5	19.2	20.7		
Medium	43.1	42.7	38.6		
High	25.5	38.1	40.7		
Employment (% yes)	59.3	67.7	66.9	<0.0001	199
Anthropometry before pregnancy					
BMI (kg/m^2)[b]	23.2 ± 3.9	22.8 ± 3.2	22.7 ± 3.2	0.17	430
BMI classification (%)[c]				0.03	430
Normal weight	77.1	81.1	82.6		
Overweight	17.6	15.4	13.8		
Obese	5.3	3.5	3.6		
Height (cm)	170.4 ± 6.3	170.9 ± 6.4	170.0 ± 6.3	0.008	324
Lifestyle					
Fruit consumption during pregnancy (%)				<0.0001	6
Less than once a day	31.7	20.4	17.9		
Once a day	25.8	26.3	25.3		
More than once a day	42.5	53.3	56.7		
Vegetables consumption during pregnancy (%)				<0.0001	3
Less than five times a week	21.6	11.9	9.5		
5–6 times per week	32.9	31.7	22.4		
Once a day or more	45.6	56.4	68.1		
Smoking during pregnancy (% yes)	22.7	15.6	16.2	<0.0001	28
Breast-feeding duration (wks)[b]	13.0 ± 14.5	15.6 ± 14.9	16.7 ± 15.6	<0.0001	49
Child characteristics					
% girls	46.5	48.3	50.3	0.26	0
Birth weight (g)	3545 ± 510	3578 ± 482	3535 ± 470	0.06	0
Gestational age (weeks)	40.1 ± 1.2	40.1 ± 1.2	40.0 ± 1.2	0.63	19
At 7 years of age ($n = 3173$)					
Fish consumption (range 1–5)[b, d]	2.0 ± 0.7	2.3 ± 0.7	2.6 ± 0.7	<0.0001	546
Fruit and vegetable consumption (range 3–15)[b, d, e]	10.8 ± 1.9	11.4 ± 1.7	11.6 ± 1.9	<0.0001	534
Snacks consumption (range 4–20)[b,d,f]	10.6 ± 2.3	10.3 ± 2.3	10.2 ± 2.4	0.0007	520

Table 1 continued

	Maternal fish consumption during pregnancy				# Missing values
	Never ($n = 1025$)	1–3 times a month ($n = 1750$)	Once a week or more ($n = 909$)	P value[a]	
At 11 years of age ($n = 2504$)					
Sugar-containing drinks (glasses/week)[b, g]	19.2 ± 8.5	17.9 ± 7.6	18.7 ± 9.6	0.03	1248
Screen time (hrs/wk)[b, h]	13.2 ± 8.5	12.8 ± 7.8	13.1 ± 8.2	0.82	1205
Practices active sport (%)					
Once a week or less	28.0	22.9	18.8	0.003	1199
Two times a week	22.4	24.8	24.3		
Three times a week	49.6	52.3	56.9		

The PIAMA birth cohort study ($n = 3684$)

Values are mean ± SD, unless otherwise stated

[a] ANOVA for normally distributed variables; Kruskal–Wallis test for variables with skewed distributions; Chi-square test for discrete variables

[b] Variable has skewed distribution

[c] Normal weight is defined as a BMI < 25 kg/m^2, overweight as a BMI ≥ 25 and <30 kg/m^2, and obesity as a BMI ≥ 30 kg/m^2

[d] Answer options ranged from 1 to 5 and were (1) never, (2) less than once a week, (3) 1–2 days a week, (4) 3–5 days a week, and (5) 6–7 days per week

[e] Represents the sum of three variables: consumption of (1) uncooked vegetables, (2) cooked vegetables, and (3) fruit. The combined score ranged from 3 to 15

[f] Represents the sum of four variables: candy bars, fried snacks or chips, crisps or salty snacks. The combined score ranged from 4 to 20

[g] Includes consumption of soft drinks, fruit juices, milk drinks, energy drinks, and sport drinks

[h] Includes computer screen time as well as TV screen time

model 2 to investigate whether those factors could explain a possible association. Model 3 additionally included child factors that were associated with maternal fish consumption. Adjustment for covariates obtained at 11 years of age did not alter the magnitude of the effect size (data not shown), but substantially lowered the numbers available for the analysis (see Table 1). Therefore, these covariates were not added to model 3.

To investigate whether the association between BMI in children and maternal fish consumption during pregnancy differed by the child's age, an interaction term between maternal fish consumption and age of the child at the time of measurement (11 groups) was added to the model. Mean BMI z scores of the two groups with mothers that consumed fish were compared to the reference group in each age category.

We performed several sensitivity analyses to evaluate the robustness of our results. First, the analysis was restricted to children with complete information on covariates only ($n = 3179$) to investigate the effect of missing covariate information on the association. Second, the analysis was restricted to children with more than seven BMI measurements ($n = 2321$) to get more insight in the effect of incomplete follow-up.

Data were analyzed using SAS software version 9.3 (SAS Institute, Inc., Cary, NC). P values of less than 0.05 were considered statistically significant.

Results

Women who never consumed fish during pregnancy were younger and more often overweight or obese before pregnancy compared to the other maternal fish consumption groups (Table 1). In addition, women who never consumed fish were less educated, less employed, smoked more often during pregnancy and consumed less fruit and vegetables during pregnancy.

Furthermore, children of mothers who never consumed fish during pregnancy were breast-fed for a shorter period of time. In addition, like their mothers, those children had a less healthy lifestyle. They consumed less fruit and vegetables, more snacks and soft drinks, and they practiced active sports less often than the other children.

The crude overall association between maternal fish consumption during pregnancy and repeated BMI z scores in children was non-significant ($P = 0.17$, Table 2). However, the crude association between BMI z scores in children and maternal fish consumption during pregnancy differed by the child's age (P interaction: 0.03 Fig. 1). Children of mothers who consumed fish once a week or more during pregnancy had a statistically significant lower mean BMI z score (0.14–0.17) at the ages of 4, 7, 8.5, and 11.5 years compared to the reference group. No statistically significant differences in BMI were found between children of

Table 2 Overall association between maternal fish consumption during pregnancy and BMI *z* scores of children between birth and age 14 years

Model	*N*	Maternal fish consumption during pregnancy					*P* value[c]
		Never	1–3 times a month		Once a week or more		
			Δ mean BMI *z* score	95 % CI	Δ mean BMI *z* score	95 % CI	
1. Crude	27,678	*Ref*	−0.013	−0.073; 0.047	−0.063	−0.134; 0.008	0.17
2. Maternal factors[a]	24,928	*Ref*	−0.000	−0.062; 0.062	−0.029	−0.104; 0.047	0.66
3. Maternal + child factors[b]	23,008	*Ref*	0.010	−0.058; 0.077	−0.027	−0.112; 0.057	0.59

Results are obtained by generalized estimating equation analyses with a ten-dependent working correlation structure, taking into account the correlation between up to 11 repeated measures in the same child

[a] Model adjusted for maternal highest attained education, age, pre-pregnancy BMI and height, fruit and vegetables consumption during pregnancy, number of older children in the household, and duration of breast-feeding (weeks)

[b] Model 2 additionally adjusted for child's consumption of fruit, vegetables, fish, and snacks

[c] *P* value for overall difference in BMI *z* score between maternal fish consumption groups

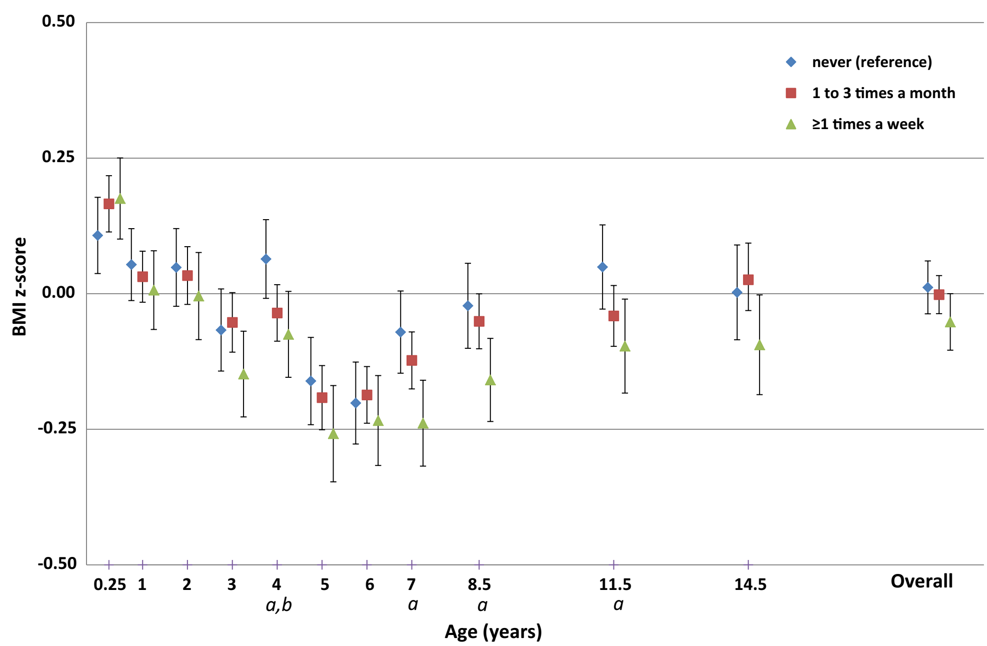

Fig. 1 Crude association between maternal fish consumption during pregnancy and BMI *z* scores in children, overall and by age, the PIAMA birth cohort study. $P = 0.03$ for interaction between maternal fish consumption and age category. *a* $P < 0.05$ for difference in mean BMI *z* score between children of mothers who consumed fish once a week or more compared to reference children. *b* $P < 0.05$ for difference in mean BMI *z* score between children of mothers who consumed fish 1–3 times a month compared to reference children

mothers who consumed fish 1–3 times a month during pregnancy and the reference group (except at the age of 4 years) in crude analyses.

After adjustment for maternal covariates, the overall association became weaker ($P = 0.66$, Table 2). Additional adjustment for child covariates hardly affected the association. The interaction term between maternal fish consumption and age of the child at the time of measurement, however, remained statistically significant ($P = 0.01$). Nevertheless, the observed difference in children's mean BMI *z* scores became smaller. This was mainly due to adjustment for maternal pre-pregnancy BMI (Fig. 2). Only at the age of 7 years, children of mothers who consumed fish once a week or more still had a statistically significant lower BMI *z* score (−0.14 95 % CI −0.25; −0.03) compared to the reference group. Additional adjustment for child covariates did not considerably affect the results (Fig. 3).

Mothers of children with incomplete follow-up more often smoked during pregnancy, were lower educated, less employed, and were more often coming from the lowest and highest maternal fish consumption category.

In the analysis among children with complete information on covariates, differences in the crude mean BMI *z* scores between children of mothers who consumed fish once a week or more and reference children became somewhat smaller and borderline statistical significant at the ages of 4, 8.5, and 11.5 years (data not shown). However, at the age of 7 years, crude differences in mean BMI *z* scores were similar for the complete and incomplete case analysis.

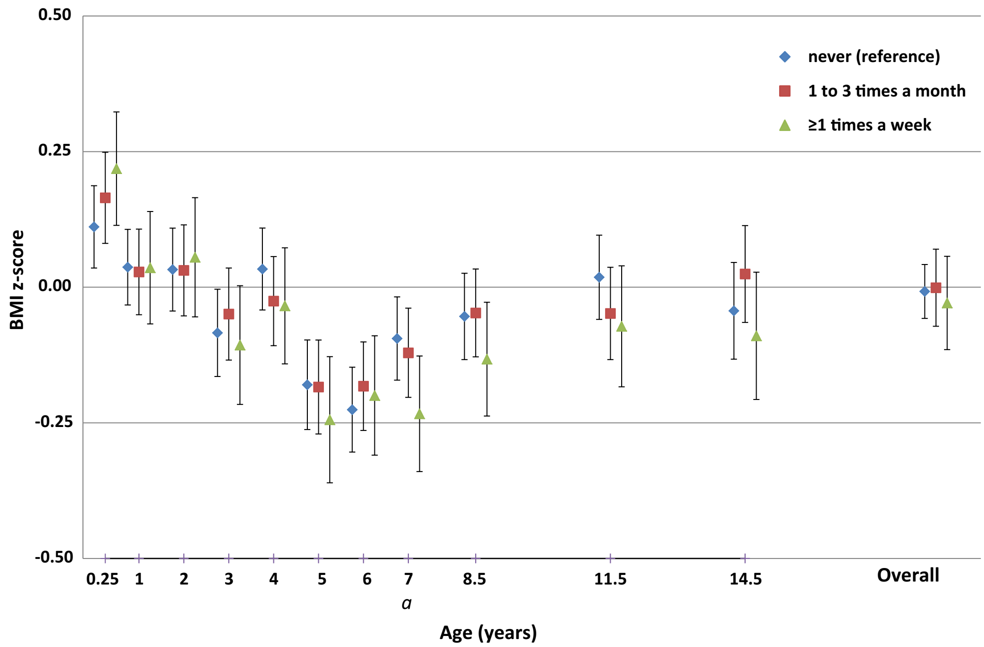

Fig. 2 Adjusted association between maternal fish consumption during pregnancy and BMI *z* scores in children overall and by age, the PIAMA birth cohort study. Adjusted for maternal pre-pregnancy BMI, $P = 0.04$ for interaction between maternal fish consumption and age category. *a* $P < 0.05$ for difference in mean BMI *z* score between children of mothers who consumed fish once a week or more compared to reference children

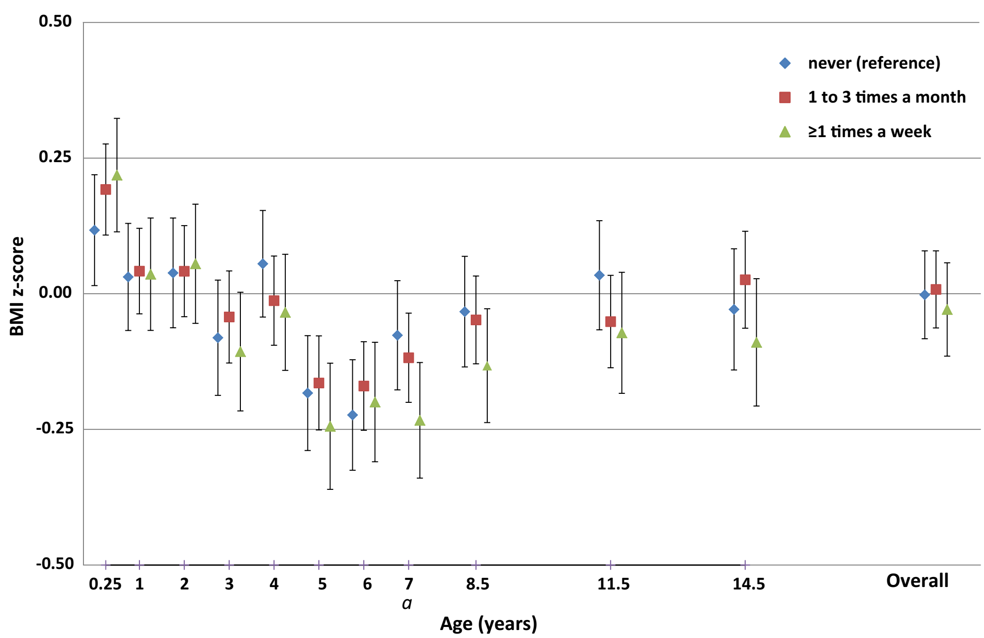

Fig. 3 Adjusted association between maternal fish consumption during pregnancy and BMI *z* scores in children overall and by age, the PIAMA birth cohort study. Adjusted for maternal highest attained education, age and height, pre-pregnancy BMI, fruit and vegetables consumption during pregnancy, number of older children in the household, and duration of breast-feeding (weeks) and child's consumption of fruit, vegetables, fish, and snacks. $P = 0.01$ for interaction between maternal fish consumption and age category. *a* $P < 0.05$ for difference in mean BMI *z* score between children of mothers who consumed fish once a week or more compared to reference children

Restricting the adjusted analysis to children with more than seven BMI measurements resulted in similar or somewhat larger differences in mean BMI z scores. Children of mothers who consumed fish once a week or more had statistically significantly lower BMI z scores at the age of 4 and 7 years ($P = 0.04$ and $P < 0.01$, respectively) compared to the reference group.

Discussion

This study shows that children of mothers who consumed fish once a week or more had a lower BMI at several ages between birth and 14 years of age as compared to children of mothers who never consumed fish during pregnancy. Differences in BMI were more apparent at higher ages, but could almost completely be explained by other health characteristics of the mothers, particularly pre-pregnancy BMI. Additional adjustment for child risk factors for obesity hardly affected the results.

The main strengths of this study were the large number of mother–child pairs and repeated outcome measurements over a long follow-up period. This allowed us to study the association over time in a large study population and reduce the possibility of chance findings because BMI was based on a considerable number of measurements instead of one, which is more common. In addition, we were able to study the independent association between maternal fish intake during pregnancy by taking into account important maternal and child covariates.

The self-reported information on maternal fish consumption may have led to misclassification. In a subsample of our study, reported fish consumption by pregnant women correlated well with EPA and DHA concentrations in their breast milk and the comparison gave no indication of differential misclassification. This suggests that our exposure measure was valid. In addition, maternal fish consumption was only assessed in the third trimester of pregnancy and this might not fully reflect diet during pregnancy. However, there is evidence that maternal dietary intake does not change significantly during pregnancy [12], and therefore, it is less likely that this has affected our results.

Data on height and weight of the children were reported by parents. It has been shown that in the PIAMA cohort parents of children in the highest BMI quartile underreport their child's body weight by 0.5 kg on average, whereas parents of children in the lowest BMI quartile tended to overreport their child's weight [13, 14]. Under the assumption of a beneficial effect of maternal fish consumption on children's BMI, this recall bias might have resulted in an underestimation of the differences in BMI between fish consumption groups.

Generally, missing data and loss to follow-up are important issues in longitudinal studies. In the current study, 17 % of the observations were excluded from the multivariate analysis because of missing covariate information. Incomplete data on covariates slightly attenuated the crude differences in mean BMI z scores but did not affect our overall conclusion. In addition, we had incomplete follow-up data on the child's BMI which was associated with some maternal characteristics (i.e., education, fish consumption, and smoking during pregnancy). This selective lack of completeness in follow-up data has only marginally affected our results as a sensitivity analysis among a more complete and selective group (children with more than seven BMI measurements available) showed similar or somewhat larger differences in mean BMI z scores.

We hypothesized that maternal fish consumption could affect BMI in children through a favorable effect of EPA and DHA on early adipose tissue development [1, 3]. Our crude results indeed showed a beneficial association between weekly fish consumption during pregnancy on the child's BMI at several ages. However, higher fish consumption during pregnancy was associated with a healthier lifestyle of both mother and child. Adjustment for maternal pre-pregnancy BMI almost completely explained the observed crude differences in children's BMI between maternal fish consumption groups. Therefore, our results do not provide evidence for a programming effect in utero by maternal fish consumption, but underline the importance of healthy body weight and lifestyle in general of mothers to be.

In general, the consumption of fish in the Netherlands is rather low and we did not have information on maternal consumption of fatty fish during pregnancy. Therefore, we cannot rule out a possible beneficial effect on children's BMI at higher maternal fish consumption levels or for maternal consumption of fatty fish during pregnancy.

We are aware of one previous study that investigated fish consumption by 1120 pregnant women in relation to BMI in their children [6]. This study found no association between maternal fish consumption and BMI z scores in children at age 3 years, crude as well as after adjustment for maternal and child characteristics. This result is in line with our results based on data at age 3 years. However, in that study [6], higher maternal fish consumption was associated with a 23 % lower risk of obesity among children at 3 years of age. In our study, prevalence of obesity among children was too low to study obesity as an outcome. Therefore, we cannot exclude the possibility that maternal fish consumption during pregnancy affects excess adiposity.

Several studies have been conducted on n-3 LCPUFA exposure or supplementation during the prenatal period on later adiposity in children. However, results from these studies are conflicting [6, 15–19]. Differences between the studies in, for example, study design make it hard to compare the individual results. For example, each study measured adiposity of the child at a different age, ranging from several months to several years. Only two studies used repeated measures of adiposity in children, but only two or three measurements during the study, i.e., at 1, 3, and 21 months [17], and at 4 and 6 years of age [15]. Our study included up to 11 BMI measurements from birth up to the age of 14 years. We observed that the development of BMI in children over time differed between groups of maternal fish consumption during pregnancy as shown by the significant interaction term. However, at each specific age differences in BMI were small and not statistically significant after adjustment for maternal and child characteristics (except at the age of 7 years). If we had only investigated BMI at 7 years of age as outcome variable instead of using repeated BMI measurements, our conclusion would have been different. This underlines the important value of multiple measurements in research.

Conclusion

The results of the present study do not provide evidence for programming of obesity in utero by maternal consumption of fish. Maternal pre-pregnancy BMI could almost completely explain the small beneficial effect of weekly fish consumption during pregnancy on BMI in children. This suggests that maternal fish consumption is rather an indicator for more healthy maternal characteristics in general than a causal factor in lowering the risk of childhood obesity. Although we cannot completely rule out an effect of maternal fish consumption on BMI development in children, such effects, if any, are likely to be small. Future studies conducted in a population with a wide range in maternal fish consumption during pregnancy and information on the type of fish consumed (lean vs. fatty fish) are of added value.

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Conflict of interest None of the authors had a conflict of interest.

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