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REGULAR ARTICLE

Fish consumption and school grades in Swedish adolescents: a study of the large general population

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Abstract

Aim: To study the associations between fish intake and academic achievement as cognitive parameter among Swedish adolescents.

Methods: In 2000, a questionnaire including respiratory items, socioeconomic conditions and dietary information was mailed to all schoolchildren (n = 18 158), aged 15 and living in Västra Götaland region of Sweden. The questionnaire was returned by 10 837 subjects. One year later, the total school grades for each subject who had completed the questionnaire and who included their full personal identification number were obtained from the national registers. Multiple linear regression models were applied to evaluate the association between fish intake and academic grades among 9448 schoolchildren, while adjusting for potential confounders, e.g. parents' education.

Results: Grades were higher in subjects with fish consumption once a week compared with subjects with fish consumption of less than once a week (reference group) [increment in estimate 14.5, 95% confidence interval (CI) 11.8–17.1]. Grades were even higher in subjects with fish consumption of more than once a week compared with the reference group (increment in estimate 19.9, 95% CI 16.5–23.3). In the model stratified for parents' education, there were still higher grades among subjects with frequent fish intake in all educational strata ($p < 0.01$).

Conclusion: Frequent fish intake among schoolchildren may provide benefits in terms of academic achievement.

INTRODUCTION

Over the years, fish consumption has been proposed to give multiple health benefits (1–5). Fish contains abundant n-3 polyunsaturated fatty acids (PUFAs), such as docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA), which are not synthesized in the human body but are necessary components for growth and development. PUFA consumption through diet, therefore, is the main pathway to obtain these types of essential fatty acids.

Dietary intake of PUFAs influences cell membrane structure and the function of membrane associated proteins in a variety of tissues, particularly in the brain and retina (6,7). Deficiency of DHA or EPA related to neuronal arborization deficits and synaptic pathological changes may limit the regulation of cell membrane function, affecting membrane lipid-protein interactions and facilitating inter- and intracellular signalling (8). Consequently, it may lead to neurocognitive deficits, anxiety, aggression and depression (9,10). Several other mechanisms have been proposed to explain the potential protective effect of omega-3 on cognition, including its anti-inflammatory and vascular properties, and also, its ability to suppress cytokines (5).

As *infants* obtain long-chain PUFA through the placenta and after birth, and through human breast milk (11), fish/fish oil supplementation during pregnancy plays an important role in early cognitive development in infants (4,12). Moreover, several reports have confirmed enhanced visual acuity (13) and long-term intellectual advantage in infants who have been fed human breast milk over those who have been fed infant formula (13–16). There have also been studies of effects of PUFA among the *elderly people*, e.g. advantages in terms of cognitive decline with age (17,18).

Although the effects of PUFA on human health have been extensively studied for years, most of the studies have largely focused on the effects of PUFA supplement intake rather than direct fish consumption. In addition, the studies have been performed in infants and the elderly people rather than in healthy young adults. A study of the relationship between fish intake and cognitive function is particularly important as young adulthood is a critical period for brain plasticity that underlies higher cognitive functions as well as social and emotional behaviour (19). Also, we consider the timing of this cognition assessment very significant for the individual, as the final grades in high school determine the subsequent educational career and profession.

Therefore, we took advantage of the large ALLOOO project (ALLERGY 2000) among all schoolchildren aged 15 in

Västra Götaland region. In this project, over 10 000 schoolchildren filled in an extensive lifestyle questionnaire in the year 2000. We have previously reported on respiratory health (20) as well as diet and cognitive function among boys (21). Here, we present results on associations between fish consumption and school grades among both girls and boys.

MATERIALS AND METHODS

Study population

This study was designed as a prospective register-based follow-up of the previous questionnaire survey, ALLOOO (ALLERGY 2000). In the year 2000, the survey was carried out in all 49 municipalities in Västra Götaland, the third largest region in Sweden, with an area of 24 000 km^2 and 1.5 million inhabitants. A self-administered questionnaire was mailed to all schoolchildren (n = 18 158), aged 15 and living in Västra Götaland region, with instruction to answer it in cooperation with their parents. The questionnaire was returned by 10 837 subjects (response rate 59.7%).

One year later, the total school grades (see School grade below) of each subject who had completed the questionnaire and included their full personal identification number were obtained from the national registers. There were 1299 subjects who had not given their full personal identification number. They were excluded because of missing data on grades. In addition, 90 subjects were excluded because of missing data on fish consumption. Consequently, the study population was restricted to 9448 schoolchildren.

The study was approved by the Ethics Committee of the University of Gothenburg and the Secrecy Clearance at Statistics Sweden (Statistiska Centralbyrån, SCB).

Questionnaire

In addition to respiratory items, the questionnaire contained questions on the frequency of physical exercise, socio-economic conditions and some dietary habits including fish consumption.

Fish consumption was assessed by the following question: 'How often do you eat a meal containing fish?' The three answer alternatives were 1 = less than once a week; 2 = approximately once a week and 3 = more than once a week.

The frequency of physical exercise during the subjects' spare time was obtained by asking, 'How often during your free time do you usually do physical exercise that makes you breathless or sweat?' There were seven answer alternatives to this question, namely, 0 = never; 1 = less than once a month; 2 = once or a few times a month; 3 = once a week; 4 = twice or three times a week; 5 = four or five times a week and 6 = everyday.

Socioeconomic conditions were assessed by questions on several different items, such as residence area (1 = city/densely populated area; 2 = countryside), type of housing (1 = detached/terrace house; 2 = apartment), foreign descent (0 = no; 1 = yes) and having a dishwasher at home (0 = no; 1 = yes). In addition, parents' educational levels (1 = elementary school; 2 = secondary modern school (middle school/high school/folk high school); 3 = college/university) were obtained from Statistics Sweden (SCB). If data on one of the parents' educational level were missing, then the educational level was substituted by the spouse's education.

In addition, weight and height of the schoolchildren were obtained by the same questionnaire. For statistical analyses, body mass index (BMI) was calculated by weight (kg), divided by the square of the height (m^2). Subjects with BMI values between 85th percentile and 95th percentile for age and gender were classified as 'overweight' and those with BMI values greater than 95th percentile for age and gender were classified as 'obese', following the international cut-off points for child BMI (22).

School grade

In Sweden, compulsory school comprises 9 years, 6 years in elementary school and 3 years in middle school (= junior high school). Most Swedish children attend these public schools and obtain their school grade in the 9th year as their total grade. The total grade is calculated by summing grades in 16 different subjects. The grade for each subject is defined as 0, 10, 15 or 20 scores. Therefore, the maximum total grade is 320 scores. Total grade is the standard way of expressing the cumulated knowledge of 9 years in compulsory schools and is used as the entrance criterion to senior high school in Sweden.

We received information on school grades from the Swedish pupil register at the Division for Statistics on the Labour Market and Education at SCB. The methodology for selection of the study population and definition of school grades has been described elsewhere (20).

Statistical methods

Arithmetic mean values with standard deviation (SD) were calculated for total grades, and unpaired *t*-test or linear trend test in one-way analysis of variance was used to analyse the difference in grades regarding several explanatory variables. Explanatory variables that were significantly associated with total grades were added as covariates for multivariate analysis. The total grades fit a marginal normal distribution with a slight left-skew (skewness = −0.8, kurtosis = 1.6, mean = 213, median = 215, SD = 60, inter-quartile range = 75). For the analyses, we therefore used the total grades as dependent variable without any additional transformation.

Multivariate analysis was performed using generalized linear models (PROC GLM), adjusting for potential confounding factors. The level of parents' education was coded using only one parental educational level. Where one of the parents had a higher educational level than their spouse, the higher level was chosen. Moreover, the categories of physical exercise were simplified to four categories, as following: 0 = never; 1 = occasionally (less than once/week, once to a few times/month); 2 = frequently (once/week, two to three times/week, four to six times/week) and 3 = daily. For statistical calculations in

the regression models, the polychotomous categorical variables were handled by creating binary dummy variables. The reference group was defined as the lowest value among the variables following an ascending order, for all explanatory variables.

Multiple regression analysis with stratifications for relevant covariate variables was also performed. As multi-collinearity can affect the results in multiple regression analysis, multi-collinearity was tested to detect the effect of inter-correlation among explanatory variables by using the variance inflation factor (VIF) (23). The results of regression analysis are presented as estimate coefficients with a 95% confidence interval (CI). All statistical analyses were performed using SAS for Windows, version 9.2, (SAS Institute, Inc., Cary, NC, USA). In all statistical analysis, two-tailed tests and a 5% level of significance were applied.

RESULTS

Table 1 presents the background characteristics in relation to grades of the study sample. Of 9448 schoolchildren, 49.5% were boys and 11.7% were of foreign descent. The mean total grade was 213, and boys had lower grades than girls ($p < 0.01$). Foreign descent was negatively associated with total grades, and having a dishwasher at home was positively associated with grades. Differences in grades regarding other independent variables such as BMI and socio-economic conditions are demonstrated in Table 1.

Fish consumption *approximately once a week* was reported by 56.5% of schoolchildren, while 19.3% consumed fish *more than once a week*. When grades of subjects in the highest category of fish consumption were compared with grades of subjects with fish consumption of *less than once a week* (the reference group), the total mean score was 225.5 vs. 196.6 ($p < 0.001$) (Table 1). The association between frequent fish intake and school grades remained statistically significant after adjustment for potential confounding factors, such as gender and socioeconomic status (Table 2). Grades were higher, with an estimated increase in score of 14.5, in the group with fish consumption *once a week* ($p < 0.0001$) and even higher in the group with fish consumption of *more than once a week* when compared with the reference group ($p < 0.001$).

The grades differed significantly ($p < 0.001$) when subjects in the lowest category level of their parents' education were compared with subjects in the higher category level of parents' education (Table 2). As there was a strong association between parents' education and school children's grades, further analyses were performed, with stratification for parents' education. As previously, significantly high grades among groups with frequent fish intake were found within all strata of parents' education ($p < 0.01$) (Table 3). There were similar patterns of associations between fish intake and school grades when stratifying for the other socioeconomic indicators such as type of housing, residence area and dishwasher ownership ($p < 0.001$): the range of increments in estimates were 14.0–16.5 in the group with fish intake *once a week* and 18.2–23.1 in the group with fish intake *more than once a week*.

Table 1 School grades, fish consumption and demographic characteristics among 9448 subjects

	N (%)	Mean grade (SD)†	p-value*
Fish consumption			
Less than once a week	2283 (24.2)	196.6 (63.4)	<0.001
Once a week	5341 (56.5)	215.7 (57.5)	
More than once a week	1824 (19.3)	225.5 (58.3)	
Gender			
Boys	4674 (49.5)	202.2 (58.4)	<0.001
Girls	4774 (50.5)	223.5 (59.7)	
Foreign descent‡			
No	8346 (88.3)	215.4 (58.1)	<0.001
Yes	1102 (11.7)	194.5 (70.1)	
Parents' education			
Elementary school	705 (7.5)	178.6 (61.2)	<0.001
Secondary modern school§	4371 (46.3)	200.5 (56.7)	
College/University	4204 (44.5)	232.7 (56.1)	
Body mass index			
Normal	6580 (69.6)	216.2 (58.9)	<0.001
Overweight	550 (5.8)	198.7 (59.1)	
Obese	171 (1.8)	189.2 (61.9)	
Type of housing			
Apartment	1958 (20.7)	194.8 (70.4)	<0.001
Detached/terrace house	7490 (79.3)	217.7 (56.0)	
Residence area			
Countryside	2791 (29.5)	207.8 (58.3)	<0.001
City/other densely populated area	6657 (70.5)	215.1 (60.5)	
Dishwasher			
No	2233 (23.6)	197.5 (67.2)	<0.001
Yes	7215 (76.4)	217.7 (56.7)	
Physical exercise during free time			
Never	593 (6.3)	180.6 (69.0)	<0.001
Occasionally (A few times/month)	1199 (12.8)	198.7 (66.1)	
Frequently (A few times/week)	7142 (76.0)	217.7 (56.9)	
Daily	462 (4.9)	218.5 (57.9)	

*Difference of groups by Student's *t*-test or linear trend test in one-way Analysis of Variance.
†Arithmetic mean with standard deviation.
‡Subjects born abroad or both of their parents having been born abroad.
§Middle school, high school or folk high school.
SD = standard deviation.

Stratification for gender was also performed and the associations between high fish intake and improved grades remained the same (Table 3). Finally, there was also positive association between frequent fish intake and school grades when stratifying for physical exercise during free time ($p = 0.01$) (data not shown). The VIF as a test for multi-collinearity was performed with regression analysis and VIF values varied from 1.0 to 3.6.

DISCUSSION

The main finding of this study is that fish consumption among schoolchildren aged 15 years was significantly associated with higher school grades. The group with frequent fish consumption had a higher total grade compared with

Table 2 Association between school grades, fish consumption and demographic characteristics (n = 9448)[1]

Predictor variables	Increment in estimate[†] (95% Confidence interval)
Intercept	119.0 (112.3–125.7)**
Fish consumption	
Less than once a week	Reference
Once a week	14.5 (11.8–17.1)**
More than once a week	19.9 (16.5–23.3)**
Gender (0 = boy; 1 = girl)	23.2 (21.0–25.4)**
Foreign descent[‡] (0 = no; 1 = yes)	−4.3 (−8.1 to −0.6)*
Parents' education	
Elementary school	Reference
Secondary modern school	15.9 (11.8–20.0)**
College/University	42.6 (38.4–46.8)**
Body mass index	
Normal weight	Reference
Overweight	−5.8 (−9.3 to −2.3)*
Obese	−14.5 (−21.6 to −7.5)**
Type of housing (0 = apartment, 1 = detached/terrace house)	13.5 (10.3–16.7)**
Residence area (0 = countryside, 1 = City/other densely populated area)	7.3 (4.8–9.8)**
Dishwasher ownership (0 = No, 1 = Yes)	7.4 (6.4–16.7)**
Physical exercise during free time	
Never	Reference
Occasionally	11.5 (6.4–16.7)**
Frequently	27.6 (23.2–32.0)**
Everyday	31.7 (25.2–38.2)**

*p < 0.05; **p < 0.0001.
[†]Estimates mutually adjusted for the other explanatory variables.
[‡]Subjects being born abroad or both of their parents being born abroad.

groups with lower fish consumption. Moreover, the positive association remained significant after adjusting for potential confounding factors, such as gender and socioeconomic status.

In this study, we performed a prospective register-based follow-up of the previous questionnaire survey (ALLOOO). The study design is not clear-cut prospective as the total school grades may not only cover the same period of fish intake a year ago but also even go further back. All schoolchildren aged 15 years in all municipalities (n = 49) in Västra Götaland were invited to participate. The response rate was 59.7% and half of the subjects were boys (49.5%). The response rate is fairly low, but this may be explained by the fact that young people tend not to participate in such a study. Moreover, the large sample size in our study contributes to the sufficient statistical power, over 0.85 at 5% level of significance, to ensure that the response rate in this study is acceptable.

It was not possible to perform a drop-out analysis between responders and non-responders as no information on the non-responders was available. As the average score of the total school grade in our study population was somewhat higher than the average score of the whole of Sweden in the year 2001 (213 vs. 203 points), the outcomes of this study may be restricted in the western Swedish adolescents.

Awareness of the study purpose may cause information bias in epidemiological studies. All explanatory variables included in the analyses were collected in the same questionnaire and the questions were answered in cooperation with the subjects' parents. Schoolchildren and their parents were not aware of any potential effects of fish intake on school grades when they participated.

The academic achievements and dietary habits of schoolchildren can be associated with several socioeconomic factors. Parents with high socioeconomic status are normally health-conscious and provide healthy nutrition (24); as well, the greater interest in their children's school performance can influence the children's school performance (25). For this reason, these potential confounders were included as covariate variables in regression models. Even so, the beneficial effects of consuming fish on academic achievement remained significant. Also, in analyses stratified for parents' education and the other socioeconomic indicators, we still found a significant positive association between fish consumption and school grades. Therefore, the main finding in this study is likely not to be affected by these potential confounding variables.

When including several explanatory variables in multivariate models, inter-correlation can be a problem. We

Table 3 Association between school grades and fish consumption, stratified for gender and parents' education

Stratification	Increment in estimate (95% CI)		
	Intercept[†]	Fish intake (once/week)	Fish intake (>once/week)
Gender[‡]			
Boys	85.3 (75.7–94.9)**	14.6 (10.8–18.5)**	18.6 (13.9–23.4)**
Girls	115.2 (106.2–124.3)**	14.1 (10.4–17.9)**	21.7 (16.9–26.6)**
Parents' education[§]			
Elementary school	121.8 (101.7–142.0)**	12.5 (2.9–22.0)*	21.1 (5.9–36.2)*
Secondary modern school	134.1 (126.4–141.9)**	15.4 (11.7–19.1)**	21.5 (16.5–26.6)**
College/University	162.6 (152.8–172.3)**	13.7 (9.4–17.9)**	18.7 (13.8–23.7)**

*p < 0.01; **p < 0.0001.
[†]Fish intake *less than once a week*.
[‡]Adjusted for foreign descent, body mass index, type of housing, residence area, dishwasher ownership, parents' education and physical exercise during free time.
[§]Adjusted for gender, foreign descent, body mass index, type of housing, residence area, dishwasher ownership and physical exercise during free time.
CI = confidence interval.

evaluated the VIF in all our models and this did not indicate any serious collinearity problem (23).

A major limitation of this study is the lack of extensive dietary information. Fish consumption was only captured as frequency of overall fish intake. Hence, we lacked information on portion size as well as whether 'fish consumption' meant consumption of lean or fatty fish. Also, no information was available on other components of the diet, meaning that we were unable to adjust for total energy intake as well as other characteristics of a healthy diet, e.g. intake of fruits, vegetables and supplements. The n-6 series of PUFAs such as arachidonic acid, known as essential for brain growth, are mainly obtained through diet, particularly from unsaturated vegetable oils (26). Consequently, it was not possible from this study to conclude whether the observed effects on school grades can be attributed to fish intake or whether fish intake is a proxy for a healthy diet in general.

Nonetheless, our results are supported by supplementary trials. Effects on intellectual development have been reported in relation to supplementation of n-3 PUFA rather than of n-6 PUFA (27,28). A study by Helland et al. reports that 4-year-old children had higher intelligence scores when mothers were supplemented with n-3 PUFA during pregnancy and lactation, compared with children of mothers who were supplemented with n-6 PUFAs (29).

There have been many studies on the effects of fish intake especially in infants (12–16,29) and the elderly people (1,17,18). This is not surprising as the effects of intake of long-chain PUFAs through human milk among infants on cognitive development, and of intake of PUFA supplements among elderly subjects on cognition decline can be estimated in a relatively short period compared with healthy young adults. A review study in infants compared cognitive development in controls and in infants who had received n-3 PUFA, and estimated that elevated maternal DHA intake of 100 mg/day increased the intelligence quotient (IQ) in small children by 0.13 points (30). Morris et al. report that frequent fish intake slowed down the cognitive decline with age among the elderly people: the cognitive decline rate was 10% slower in subjects with fish meal intake of once per week than in subjects with fish consumption of less than once a week. (18).

Beneficial effects of fish consumption on cognitive development were also reported among schoolchildren. A longitudinal study of 9-year-old children whose mothers had consumed fish in the early pregnancy period had a significantly reduced risk of hyperactivity and an increased verbal IQ compared with those whose mothers never ate fish (2). Our previous study reported positive effects of fish intake on cognitive performance among the boys studied (21). Information on cognitive performance was obtained from the cognitive test at military enrolment 3-years later, enabling us to evaluate associations between fish consumption and cognitive performance among healthy young boys.

This study used a similar methodology as our previous study (21). However, the present analysis included girls and boys, and benefits for cognitive development were analysed in relation to school grades. To our knowledge, this is the first study to evaluate the direct association between fish intake and school grades.

In conclusion, our results suggest that frequent fish consumption among schoolchildren may provide benefits in terms of academic achievements.

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