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Diet quality and academic achievement – A prospective study among primary school children

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1 **Abstract**

2 Purpose: Poor diet quality may impair academic achievement in children, but such evidence is
3 limited. Therefore, we investigated the associations of healthy diet in Grade 1 assessed by
4 Mediterranean Diet Score (MDS), Baltic Sea Diet Score (BSDS), and Finnish Children Healthy
5 Eating Index (FCHEI) with academic achievement in Grades 1–3 in children.

6 Methods: The participants were 161 Finnish children who were 6–8-year-old in Grade 1 and
7 attended in a large ongoing physical activity and dietary intervention study. Dietary factors were
8 assessed using 4-day food records and MDS, BSDS, and FCHEI were calculated. Academic
9 achievement was assessed by reading fluency, reading comprehension, and arithmetic skill tests.
10 The data were analyzed using linear regression analysis and analysis of covariance adjusted for age,
11 sex, parental education, household income, body fat percentage, physical activity, the PANIC Study
12 group, and total energy intake.

13 Results: MDS was positively associated with reading comprehension in Grade 3 (standardized
14 regression coefficient $\beta=0.167$, $P=0.032$). BSDS was positively associated with reading fluency in
15 Grades 2–3 and reading comprehension in Grades 1–3 ($\beta=0.161$ to 0.274 , $P<0.05$). FCHEI was
16 positively related to reading fluency in Grades 1–2 and reading comprehension in Grades 1–3
17 ($\beta=0.190$ to 0.344 , $P<0.05$). Children in the highest third of BSDS and FCHEI had better reading
18 fluency and reading comprehension in Grades 1–3 than children in the lowest third ($P<0.05$). None
19 of the diet scores was associated with arithmetic skills.

20 Conclusions: Healthier diet assessed by BSDS or FCHEI in Grade 1 was associated with better
21 reading skills, but not with arithmetic skills, among children in Grades 1–3. Long-term intervention
22 studies are needed to investigate the effects of improvements in diet quality on academic
23 achievement among children.

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30 **Introduction**

31 Poor nutrition may impair the rapidly developing brain and cognitive functions and low quality diet
32 may also deteriorate children's academic achievement [1]. Therefore, recent evidence suggesting
33 that children's dietary patterns typically include a high intake of saturated fat and sucrose, a high
34 consumption of fast foods, and a low consumption of vegetables is alarming [2–6]. Poor academic
35 achievement in childhood has been linked to increased risk of adulthood obesity, unemployment,
36 and low socioeconomic positioning in adulthood, suggesting that it is important to identify
37 possibilities to support academic achievement in childhood [7–9].

38 A few studies suggest that a higher intake of some nutrients, such as iron and polyunsaturated fatty
39 acids, and a lower intake of saturated fatty acids are related to better cognitive functions and
40 academic achievement in children [10–13]. However, improvements in dietary patterns may be
41 more easily translated to real life conditions than those in single nutrients, because single nutrients
42 do not normally exist in isolation and are interrelated and synergistic [14, 15]. Although evidence
43 on the associations of dietary patterns with academic achievement is limited, some studies suggest a
44 direct relationship of adherence to the Mediterranean style diet assessed by the KIDMED index [16,
45 17], and the Healthy Eating Index [18] with academic achievement in children and adolescents.
46 Moreover, a dietary pattern including a high consumption of sausage, fast food, snacks, and sugar
47 sweetened beverages at the age of three years has been related to poorer academic achievement at
48 the age of 10 years among children [19].

49 There are differences in food cultures and food choices between geographical regions and
50 populations. Although the Mediterranean style diet has frequently been used to describe healthy diet
51 [15], it may not be easily translated to other countries, such as the Nordic countries. The Baltic Sea
52 Diet Score (BSDS) [20] and the Finnish Children Healthy Eating Index (FCHEI) [21] were
53 developed to illustrate a healthy dietary pattern in the Nordic countries, including Finland. We have
54 previously reported that a lower consumption of vegetables and a higher consumption of red meat
55 and sausage were related to poorer cognition but that poorer overall diet quality assessed by BSDS
56 had the strongest association with worse cognition in children and particularly in boys [22].
57 However, there are no reports on the associations of BSDS or FCHEI with academic achievement in
58 children.

59 Due to the increased emphasis on education and learning, evidence on the associations of diet
60 quality with academic achievement among children would provide valuable information for schools
61 and parents to implement actions to support learning and academic achievement. We therefore

62 investigated the relationships of diet quality in Grade 1, assessed by the Mediterranean Diet Score
63 (MDS) [23], BSDS, and FCHEI, to academic achievement in Grades 1–3 among Finnish primary
64 school children.

65 **Methods**

66 *Study design and study population*

67 Data for the present analyses were obtained from the Physical Activity and Nutrition in Children
68 (PANIC) Study [24] and the First Steps Study [25], two independent studies that are being
69 conducted simultaneously in the City of Kuopio, Finland. The PANIC Study is an ongoing
70 controlled family-based and individualized physical activity and dietary intervention study in a
71 population sample of children. We invited 736 children 6–8 years of age who were in Grade 1 in
72 2007–2009 to participate in the baseline examinations of the study in that timeframe. Of the 736
73 invited children, 512 (70%) participated. The First Steps Study is an ongoing follow-up study in a
74 population-based sample of 2000 children from four municipalities in different parts of Finland that
75 was initiated in 2006. Altogether 207 children from the City of Kuopio participated both in the
76 PANIC Study and in the First Steps Study. We obtained data on dietary and confounding factors in
77 Grade 1 from the PANIC Study and data on reading and arithmetic skills in Grades 1–3 from the
78 First Steps Study. Complete data on variables used in the present analyses were available for 161
79 children (87 boys, 74 girls) in Grade 1, for 158 children (86 boys, 72 girls) in Grade 2, and for 152
80 children (83 boys, 69 girls) in Grade 3.

81 Children who were excluded from the present analyses because of incomplete data were less likely
82 to be at risk for reading disability ($P=0.026$) and had poorer reading comprehension in Grade 2
83 ($P=0.002$), a higher maximal workload in exercise test per lean body mass ($P=0.021$), and a higher
84 MDS score ($P=0.013$) than the included children.

85 The PANIC Study protocol was approved by the Research Ethics Committee of the Hospital
86 District of Northern Savo, Kuopio, and the First Steps Study protocol was approved by the
87 Research Ethics Committee of the University of Jyväskylä. All participating children and their
88 parents provided their written informed consent.

89 *Assessment of maturity and anthropometrics*

90 All children underwent a clinical examination at baseline of the PANIC Study. A research physician
91 assessed pubertal status using the 5 stage criteria described by Tanner [26]. The boys were defined

92 as having entered clinical puberty, if their testicular volume assessed by an orchidometer was >3 ml
93 (Stage ≥ 2). The girls were defined as having entered clinical puberty if their breast development had
94 started (Stage ≥ 2). Body weight and height were measured using standard protocols described
95 earlier [24]. The prevalence of overweight and obesity was defined using age and sex-specific
96 reference values published by Cole and co-workers [27].

97 *Assessment of dietary factors*

98 We assessed energy and nutrient intake and food consumption by food records administered by the
99 parents on four predefined consecutive days, including two weekdays and two weekend days (99%)
100 or three weekdays and one weekend day (1%) [24]. A clinical nutritionist gave detailed instructions
101 to the parents to record all food and drinks using household or other measures, such as tablespoons,
102 deciliters, and centimeters. The parents were also instructed to ask their children about food eaten
103 outside home. A clinical nutritionist asked about details of menus and recipes of food served at
104 schools and afternoon daycare from the catering company that provided the food for the schools. A
105 clinical nutritionist used all this information and also a picture booklet of portion sizes to complete
106 the missing information with the families at return [28]. Clinical nutritionists analyzed the food
107 records using the Micro Nutrica® dietary analysis software, Version 2.5 (The Social Insurance
108 Institution of Finland), that utilizes Finnish and international data on nutrient composition of foods
109 [29]. We computed MDS, BSDS, and FCHEI as described in Table 1, with higher score indicating
110 better diet quality. We assessed the number of meals per day based on data from the food records.
111 We classified breakfast, lunch, and dinner as meals and all eating and drinking occasions between
112 the meals as snacks. We categorized the children as those who had eaten all meals daily and those
113 who had skipped any of the meals. The Kappa coefficient was 0.134 ($P=0.004$) between MDS and
114 BSDS, 0.097 ($P=0.023$) between MDS and FCHEI, and 0.224 ($P<0.001$) between BSDS and
115 FCHEI, suggesting that these diet quality indices reflect different aspects of healthy diet.

116 *Assessment of academic achievement*

117 We assessed academic achievement at the spring semester of Grades 1, 2, and 3. Reading fluency
118 was assessed using a group-administered subtest of the nationally normed reading achievement test
119 battery for primary schools called Ala-asteen lukutesti (ALLU) in Finnish [30]. The test score was
120 the number of correct answers, ranging from 0 to 80, during a 2-minute time limit for items that
121 involved identifying the correct word from four phonologically similar alternatives linked to an
122 adjoining picture.

123 Reading comprehension was assessed using another group-administered subtest of the ALLU
124 battery [30]. After reading a short text, children were asked to answer to 12 multiple-choice
125 questions including facts, causal relationships, interpretations or conclusions drawn from the text.
126 The test score was the number of correct answers, ranging from 0 to 12, during the 30-minute test
127 period when children were allowed to refer to the original text.

128 Arithmetic skills were assessed using a basic arithmetic test with a set of visually presented addition
129 and subtraction tasks [31]. Children were asked to perform as many calculations as they could. The
130 test score was the number of correct answers, ranging from 0 to 28, during the 3-minute time limit.

131 *Assessment of confounding factors*

132 Physical performance, adiposity, physical activity, and socioeconomic status have been associated
133 with academic achievement in children [32–34]. The parents were asked to report their completed
134 or ongoing educational degrees and household income. The degree of the more educated parent was
135 used in the analyses. Maximal workload in exercise test per lean mass as an indicator of
136 cardiovascular performance [35], 50-meter agility shuttle run test time as a measure of motor
137 performance [36], body fat percentage and lean mass by dual-energy X-ray absorptiometry [37],
138 and physical activity [38, 39] were assessed in the PANIC Study as described previously. The risk
139 of reading disability was determined in the First Steps Study using children’s scores in the
140 kindergarten-age assessments of letter knowledge, phonemic awareness, and rapid automatized
141 naming, and the parental self-report of reading difficulties [40]. The PANIC study group
142 (intervention vs. control) was used as a covariate, because the physical activity and dietary
143 intervention in the PANIC Study started before the assessments of academic achievement in the
144 First Steps Study.

145 *Statistical methods*

146 We performed all data analyses using the SPSS Statistics, Version 21.0 (IBM Corp., Armonk, NY,
147 USA). We compared basic characteristics between boys and girls using the Student’s t-test and the
148 Chi Square-test. We investigated the associations of MDS, BSDS, and FCHEI in Grade 1 with
149 reading fluency, reading comprehension, and arithmetic skills in Grades 1–3 using linear regression
150 analysis by forcing MDS, BSDS, or FCHEI with age, sex, parental education, household income,
151 body fat percentage, physical activity, the PANIC Study group, and total energy intake into the
152 models. We also adjusted the data on the associations of MDI, BSDS, or FCHEI with reading and
153 arithmetic skills in Grades 2–3 for the corresponding academic skill in Grade 1. Furthermore, we

154 compared reading fluency, reading comprehension, and arithmetic skills in Grades 1–3 among
155 children in the thirds of MDI, BSDS, or FCHEI in Grade 1 using Repeated Measures Analysis of
156 Covariance. The data were adjusted for age, sex, parental education, household income, body fat
157 percentage, physical activity, the PANIC Study group, and total energy intake and Sidak correction
158 for multiple comparisons. All data were additionally adjusted for clinical puberty, maximal
159 workload in exercise test, 50-meter agility shuttle run test time, the risk of reading disability, or
160 skipping meals. We investigated the effect modification of sex using General Linear Models by
161 analyzing the association of sex*dietary quality index interactions with academic achievement
162 scores. We performed all analyses by combining data on boys and girls because of a limited
163 statistical power to analyze these associations separately in boys and girls and because sex did not
164 modify the associations of diet quality with academic achievement (P for interaction > 0.05 for all
165 models).

166 **Results**

167 *Characteristics*

168 The characteristics of the study sample are presented in Table 2. There were no differences in MDS,
169 BSDS, or FCHEI between boys and girls. The boys had poorer reading fluency in Grades 1 and 3,
170 and poorer reading comprehension in Grade 2 than the girls (data not shown).

171 *Associations of MDS, BSDS, and FCHEI with academic achievement*

172 MDS was associated with reading comprehension in Grade 3 after adjustment for age, sex, parental
173 education, household income, body fat percentage, physical activity, the PANIC study group, and
174 total energy intake (Table 3). A higher BSDS was related to better reading fluency in Grades 2–3
175 and reading comprehension in Grades 1–3 after adjustment for age, sex, parental education,
176 household income, body fat percentage, physical activity, the PANIC study group, and total energy
177 intake. A higher FCHEI was associated with better reading fluency in Grades 1–2 and reading
178 comprehension in Grades 1–3 after adjustment for age, sex, parental education, household income,
179 body fat percentage, physical activity, the PANIC study group, and total energy intake. The
180 relationship of BSDS to reading fluency in Grade 3 and the association of FCHEI with reading
181 fluency in Grade 2 were no longer statistically significant after further adjustment for reading
182 fluency in Grade 1, but the association of BSDS with reading fluency in Grade 2 and with reading
183 comprehension in Grades 2–3, the association of FCHEI with reading comprehension in Grades 2–
184 3, and the association between MDS and reading comprehension in Grade 3 remained statistically
185 significant after further adjustment for corresponding reading skills in Grade 1 (data not shown).

186 Additional adjustment for clinical puberty, maximal workload in exercise test, 50-meter agility
187 shuttle run test time, the risk of reading disability, or skipping meals had no effect on these
188 associations (data not shown).

189 *Differences in academic achievement among children in thirds of MDI, BSDS, and FCHEI*

190 Children in the highest third of BSDS had consistently better reading fluency (mean difference
191 across Grades = 3.860; 95% CI = 0.089 to 7.631, $P=0.043$) and reading comprehension (mean
192 difference across Grades = 1.284; 95% CI = 0.200 to 2.368, $P=0.015$) in Grades 1–3 than children
193 in the lowest third after adjustment for age, sex, parental education, household income, body fat
194 percentage, physical activity, the PANIC study group, and total energy intake. Children in the
195 highest third of BSDS also had better reading comprehension in Grades 1–3 than children in the
196 middle third (mean difference across Grades = 1.086; 95% CI = 0.054 to 2.119, $P=0.036$).
197 Similarly, children in the highest third of FCHEI had consistently higher reading fluency (mean
198 difference across Grades 1–3 = 3.912; 95% CI = 0.027 to 7.796, $P=0.048$) and reading
199 comprehension (mean difference across Grades 1–3 = 1.894; 95% CI = 0.806 to 2.981, $P<0.001$) in
200 Grades 1–3 than children in the lowest third after adjustment for age, sex, parental education,
201 household income, and body fat percentage, physical activity, the PANIC study group, and total
202 energy intake. Moreover, children in the middle third of FCHEI had better reading comprehension
203 in Grades 1–3 than children in the lowest third (mean difference across Grades 1–3 = 1.034, 95% CI
204 = 0.049 to 2.018, $P=0.036$). Additional adjustments had no effect on these differences. There were
205 no other differences in academic skills among children in thirds of MDI, BSDS, or FCHEI.

206 **Discussion**

207 We found that better diet quality in Grade 1 assessed by BSDS and FCHEI was associated with
208 better reading skills among Finnish children. We also observed that children in the highest third of
209 BSDS and FCHEI had better reading skills through Grades 1–3 than children in the lowest third.
210 Moreover, our results provide some evidence that better diet quality is associated with better
211 reading skills in Grades 2–3 independent of reading skills in Grade 1.

212 Previous studies have shown that a better diet quality is associated with better grade point averages
213 and academic achievement reported by teachers in children and adolescents [16–18, 41]. Moreover,
214 dietary patterns characterized by a high consumption of vegetables, fruit, berries, fish, and nuts in
215 childhood and adolescence have been related to better cognitive functions and academic
216 achievement in later years in some follow-up studies [19, 42]. We found that better diet quality,
217 assessed by BSDS and FCHEI, was associated with better reading skills but not arithmetic skills.

218 These observations are supported by the results of the study of Sørensen and coworkers [43] in
219 which a 3 month intervention aimed to improving the quality of school meals improved reading
220 skills, but not arithmetic skills, in children 10 years of age. Our study with the study by Sørensen
221 and coworkers [43] are one of the first studies that have used standardized tests to assess specific
222 academic skills, such as reading and arithmetic skills, instead of overall grade point averages or
223 academic achievement reported by teachers. Taken together, the results of cross-sectional studies
224 and few prospective studies along with our observations suggest that better diet quality may
225 improve academic achievement, and particularly reading skills, during childhood and adolescence.
226 The reason why better diet quality has been linked to better reading skills but not arithmetic skills is
227 currently unknown. One reason for these observations may be that reading requires more complex
228 cognitive functions than basic arithmetic calculations and therefore unhealthy diet may be more
229 strongly related to reading skills than arithmetic skills in children. Nevertheless, more studies on the
230 specific effects of improved diet quality on reading and arithmetic skills in children are needed.

231 Although BSDS and FCHEI were positively associated with academic achievement, we found only
232 weak associations between MDS and academic achievement. This observation is in contrast to the
233 results of some earlier studies [16, 17]. One reason for these findings may be that the specific diet
234 quality indices developed for Nordic countries, such as BSDS and FCHEI, may more accurately
235 identify healthy diet related to academic achievement in our population with specific food choices
236 and culture than diet quality indices developed for other populations and geographical regions. For
237 example, BSDS and FCHEI emphasize the intake of polyunsaturated fatty acids and the
238 consumption low-fat milk whereas MDS gives emphasis to the ratio of monounsaturated to
239 saturated fatty acids and low consumption of milk. Milk is commonly fortified with vitamin D in
240 Finland, and it is the major dietary source of vitamin D among Finnish children [44]. Accordingly,
241 there is some evidence that polyunsaturated fatty acids and vitamin D support normal brain and
242 cognitive development in children [45, 46]. Another possible explanation for our findings is that the
243 median-based scoring in the MDS may not adequately classify children according to their diet
244 quality and may not cause the required variation in the score. Stricter adherence to the
245 Mediterranean style diet, assessed by the KIDMED index, has been related to better academic
246 achievement among children [16, 17]. However, we were unable to calculate the KIDMED index in
247 this study, because we used 4-day food records to assess dietary factors in children.

248 Stricter adherence to the Baltic Sea type diet has been linked to a higher intake of vitamins,
249 polyphenols, flavonoids, and dietary fiber and a lower intake of saturated fatty acids in adults [20].
250 A higher FCHEI has been associated with a higher intake of vitamin E, vitamin D, polyunsaturated

251 fatty acids, and dietary fiber and a lower intake of saturated fatty acids in children [21]. These
252 nutrients may enhance synaptic plasticity [47, 48], protect the brain from neuronal damage, support
253 cell proliferation [47], and improve the prerequisites for academic achievement, such as working
254 memory and inhibition [12, 13, 49]. There is also some preliminary evidence that a better breakfast
255 quality is associated with improved working memory, attention, and behavior in children [50, 51].
256 Thus, better overall diet quality may improve cognitive prerequisites of learning and behavior
257 during school day over a long period of time and thereby enhance learning and academic
258 achievement in children. Furthermore, we found that skipping meals had no effect on the observed
259 associations between diet quality and academic achievement among children.

260 The strengths of the present study include the rigorous methods used to assess dietary factors by 4-
261 day food records and academic achievement by standardized reading and arithmetic tests, and the
262 prospective study design. We also had the opportunity to control the data for a number of
263 confounding factors. The weaknesses of our study are that we could not draw a conclusion about
264 the causality of the associations. Moreover, we had a relatively small study sample although the
265 children quite well represented the original PANIC Study and the First Step Study populations. The
266 children also came from families with relatively high parental education, and therefore these
267 findings need to be confirmed among children with a lower socioeconomic background.
268 Furthermore, there were some differences in characteristics between the study sample and the
269 excluded children which may slightly decrease the generalizability of our results

270 All children entering public schools in Finland are eligible for free school-lunch that is prepared
271 according to the Finnish dietary recommendations [52]. Thus, all Finnish school-aged children
272 receive at least one healthy meal a day that includes vegetables, low-fat milk, and high-fiber grain
273 products. A healthy school lunch may attenuate the association of diet quality with academic
274 achievement, because it decreases differences in diet quality among children with different
275 socioeconomic backgrounds. Thus, the associations between diet quality and academic achievement
276 may be even stronger in other countries in which healthy meals are not provided by schools.

277 A higher BSDS and FCHEI were associated with better reading skills among children in their first
278 three school years. These results suggest that following the Nordic and Finnish dietary guidelines
279 [52] that results in increased consumption of vegetables, fruit, berries, and low-fat milk and
280 decreased consumption of red meat, sausage, and foods high in sucrose could improve reading skills
281 in school-aged children. Our results provide one of the first evidence on the longitudinal

282 associations of diet quality with academic achievement in children and can be used in planning
283 interventions aimed at increasing academic performance in children.

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292 **Conflicts of interest**

293 On behalf of all authors, the corresponding author states that there is no conflict of interest.

294 **Authorship**

295 EAH, AME, AMP, VL, and TAL designed the research; AME, TV, VL, AMP, TA, and TAL
296 conducted the research; EAH analyzed the data; EAH, AME, TV, AMP, TA, HJ, VL, and TAL
297 wrote the manuscript; EAH, AME, and TAL had primary responsibility for the final content of the
298 manuscript; All authors read and approved the final version of the manuscript.

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460 **Figure legend**

461 Figure 1. Differences in reading fluency, reading comprehension, and arithmetic skills in Grades 1–
 462 3 among 152 children (83 boys, 69 girls) in the thirds of the Baltic Sea Diet Score and Finnish
 463 Healthy Eating Index in Grade 1 adjusted for age, sex, parental education, household income, body
 464 fat percentage, physical activity, the PANIC study group, and total energy intake. The data are
 465 presented as estimated marginal means and their 95% confidence intervals.

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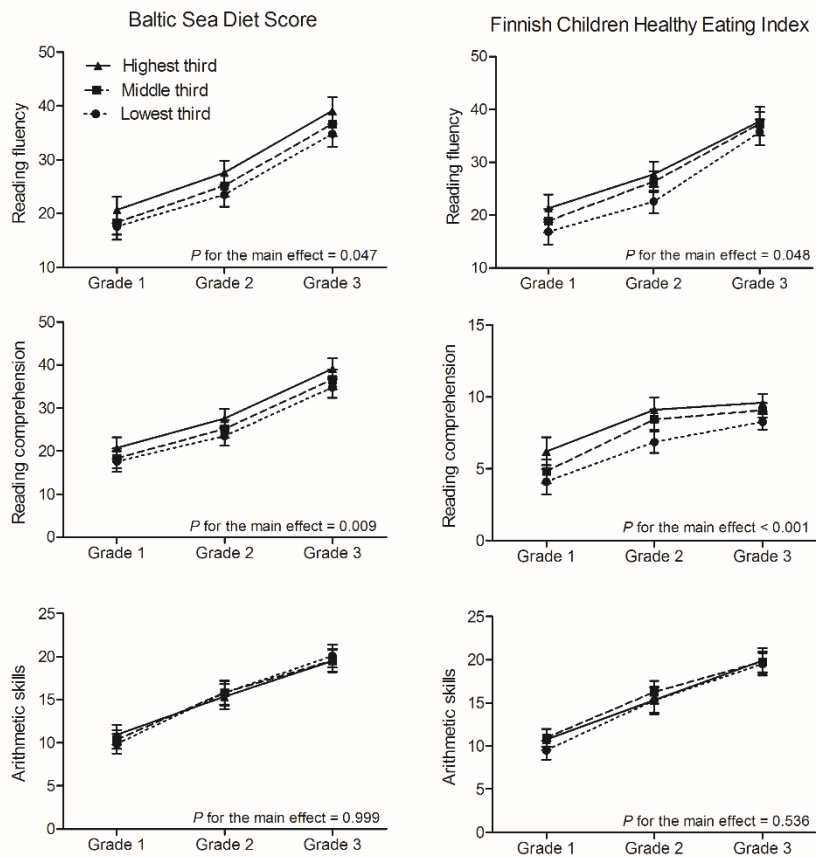


Table 1. Construction of the diet quality indices in the present study

	Components	Scoring
Mediterranean Diet Score (MDS)	Vegetables, g/d	>sex-specific median=1, else=0
	Fruit, nuts and legumes, g/d	>sex-specific median=1, else=0
	Grain products, g/d	>sex-specific median=1, else=0
	Fish, g/d	>sex-specific median=1, else=0
	Red meat and sausage, g/d	<sex-specific median=1, else=0
	Poultry, g/d	<sex-specific median=1, else=0
	Dairy products, g/d	<sex-specific median=1, else=0
	Ratio of monounsaturated to saturated fatty acids	>sex-specific median=1, else=0
Baltic Sea Diet Score (BSDS)	Fruit and berries, g/d	Quartile 1=0, Quartile 2=1, Quartile 3=2, Quartile 4=3
	Vegetables and legumes, g/d	Quartile 1=0, Quartile 2=1, Quartile 3=2, Quartile 4=3
	High-fiber ($\geq 5\%$) grain products, g/d	Quartile 1=0, Quartile 2=1, Quartile 3=2, Quartile 4=3
	Low-fat (<1%) milk, g/d	Quartile 1=0, Quartile 2=1, Quartile 3=2, Quartile 4=3
	Fish, g/d	Quartile 1=0, Quartile 2=1, Quartile 3=2, Quartile 4=3
	Red meat and sausage, g/d	Quartile 1=3, Quartile 2=2, Quartile 3=1, Quartile 4=0
	Ratio of polyunsaturated to saturated fatty acids	Quartile 1=0, Quartile 2=1, Quartile 3=2, Quartile 4=3
Finnish Children Healthy Eating Index (FCHEI)	Total fat intake, E%	Quartile 1=3, Quartile 2=2, Quartile 3=1, Quartile 4=0
	Vegetables, fruit and berries, g/d	Decile 1=1, Decile 2=2, Decile 3=3, Decile 4=4, Decile 5=5, Decile 6=6, Decile 7=7, Decile 8=8, Decile 9=9, Decile 10=10
	Vegetables, fruit and berries, g/d	Decile 1=1, Decile 2=2, Decile 3=3, Decile 4=4, Decile 5=5, Decile 6=6, Decile 7=7, Decile 8=8, Decile 9=9, Decile 10=10
	Vegetable oils and vegetable-oil-based margarine (fat $\geq 60\%$), g/day	Non-consumers=0, Decile 1=1, Decile 2=2, Decile 3=3, Decile 4=4, Decile 5=5, Decile 6=6, Decile 7=7, Decile 8=8, Decile 9=9, Decile 10=10
	Foods containing high amounts of sugar §	Decile 1=10, Decile 2=9, Decile 3=8, Decile 4=7, Decile 5=6, Decile 6=5, Decile 7=4, Decile 8=3, Decile 9=2, Decile 10=1
	Fish, g/d	Non-consumers=0, Decile 5=1, Decile 6=2, Decile 7=3, Decile 8=4, Decile 9=5, Decile 10=6
	Low-fat (<1%) milk, g/d	Non-consumers=0, Decile 2=1, Decile 3=2, Decile 4=3, Decile 5=4, Decile 6=5, Decile 7=6, Decile 8=7, Decile 9=8, Decile 10=9

§ Including sugar-sweetened beverages, fruit juice, added sugar, chocolate, sweets, pastries, biscuits, ice cream and puddings.

Table 2. Basic characteristics

	All children (N=161)
Age (years)	7.7 (0.3)
Boys/girls (N)	87/74
Body height (cm)	129.3 (5.4)
Body weight (kg)	27.4 (5.4)
Body fat percentage	18.4 (11.6)
Prevalence of overweight and obesity (%)	16
Clinical puberty (%)	4
Parental education (%)	
Vocational school or less	19
Polytechnic	39
University degree	43
Household income (%)	
≤ 30 000 €	19
30 001–60 000 €	45
> 60 000 €	36
Children in the PANIC Study intervention group (%)	65
Children with the risk of reading disabilities (%)	15
Physical activity and physical performance	
Physical activity (min/d)	106.9 (39.2)
Maximal workload per lean body mass (watts/lean mass)	3.6 (0.5)
Time in 50-meter shuttle run test (seconds)	24.0 (2.1)
Dietary factors	
Total energy intake (kcal/d)	1641 (300)
Skipping meals (%)	66
Mediterranean Diet Score	3.8 (1.4)
Baltic Sea Diet Score	11.4 (4.2)
Finnish Children Healthy Eating Index	22.9 (6.5)
Academic achievement in Grade 1	
Reading fluency	18.8 (8.9)
Reading comprehension	4.9 (3.3)
Arithmetic skills	10.3 (4.0)
Academic achievement in Grade 2	
Reading fluency	25.3 (8.0)
Reading comprehension	9.0 (4.0)
Arithmetic skills	15.6 (5.1)
Academic achievement in Grade 3	
Reading fluency	36.8 (8.7)
Reading comprehension	8.9 (2.1)
Arithmetic skills	19.6 (4.7)

Data are means (SDs) or percentages (%). Percentages are rounded and therefore they may account less or more than 100%. N=161 (87 boys, 74 girls) in Grade 1; N=158 (86 boys, 72 girls) in Grade 2; N=152 (83 boys, 69 girls) in Grade 3

Table 3. Association of the Mediterranean Diet Score, Baltic Sea Diet Score and the Finnish Children Healthy Eating Index with academic achievement in children

	Reading fluency		Reading comprehension		Arithmetic skills	
	β (95% CI)	<i>P</i>	β (95% CI)	<i>P</i>	β (95% CI)	<i>P</i>
Grade 1						
Mediterranean Diet Score	-0.031 (-0.182 to 0.121)	0.692	0.006 (-0.150 to 0.163)	0.937	0.096 (-0.059 to 0.251)	0.224
Baltic Sea Diet Score	0.142 (-0.012 to 0.297)	0.071	0.161 (0.002 to 0.320)	0.047	0.139 (-0.020 to 0.298)	0.086
Finnish Children Healthy Eating Index	0.190 (0.037 to 0.344)	0.015	0.239 (0.083 to 0.395)	0.003	0.095 (-0.065 to 0.255)	0.241
Grade 2						
Mediterranean Diet Score	0.080 (-0.077 to 0.237)	0.317	0.125 (-0.033 to 0.283)	0.119	0.004 (-0.155 to 0.164)	0.957
Baltic Sea Diet Score	0.223 (0.065 to 0.381)	0.006	0.274 (0.116 to 0.432)	0.001	0.050 (-0.114 to 0.214)	0.548
Finnish Children Healthy Eating Index	0.234 (0.073 to 0.395)	0.005	0.344 (0.187 to 0.501)	<0.001	0.064 (-0.103 to 0.230)	0.453
Grade 3						
Mediterranean Diet Score	0.043 (-0.118 to 0.205)	0.597	0.167 (0.015 to 0.319)	0.032	-0.043 (-0.205 to 0.119)	0.600
Baltic Sea Diet Score	0.199 (0.035 to 0.362)	0.035	0.263 (0.110 to 0.416)	0.001	0.000 (-0.168 to 0.167)	0.996
Finnish Children Healthy Eating Index	0.113 (-0.056 to 0.281)	0.188	0.272 (0.117 to 0.427)	0.001	0.037 (-0.133 to 0.207)	0.669

Data are standardized regression coefficients (β) and their 95% confidence intervals (CI) from linear regression models adjusted for age, sex, parental education, household income, and body fat percentage, physical activity, the PANIC study group, and total energy intake. N=161 (87 boys, 74 girls) in Grade 1; N=158 (86 boys, 72 girls) in Grade 2; N=152 (83 boys, 69 girls) in Grade 3.