Diet Quality and Academic Performance*

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ABSTRACT

BACKGROUND: Although the effects of nutrition on health and school performance are often cited, few research studies have examined the effect of diet quality on the academic performance of children. This study examines the association between overall diet quality and academic performance.

METHODS: In 2003, 5200 grade 5 students in Nova Scotia, Canada, and their parents were surveyed as part of the Children's Lifestyle and School-performance Study. Information on dietary intake, height, and weight and sociodemographic variables were linked to results of a provincial standardized literacy assessment. Diet Quality Index—International was used to summarize overall diet quality. Multilevel regression methods were used to examine the association between indicators of diet quality and academic performance while adjusting for gender and socioeconomic characteristics of parents and residential neighborhoods.

RESULTS: Across various indicators of diet quality, an association with academic performance was observed. Students with decreased overall diet quality were significantly more likely to perform poorly on the assessment. Girls performed better than boys as did children from socioeconomically advantaged families. Children attending better schools and living in wealthy neighborhoods also performed better.

CONCLUSIONS: These findings demonstrate an association between diet quality and academic performance and identify specific dietary factors that contribute to this association. Additionally, this research supports the broader implementation and investment in effective school nutrition programs that have the potential to improve student access to healthy food choices, diet quality, academic performance, and, over the long term, health.

Keywords: nutrition and diet; child and adolescent health; public health.

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LITERATURE REVIEW

The academic performance of children impacts their future educational attainment and health and has therefore emerged as a public health concern.[1] Generally, as levels of education increase, there is an associated increase in income and social status.[2] This associated increase in socioeconomic status affects health by influencing access to health care, quality of housing, work environment, lifestyle factors, such as nutrition and recreation, and social psychological factors, such as self-esteem and health awareness.[3] Given the demonstrated importance of academic performance and resulting educational attainment to future health, it is imperative to understand the determinants of school performance. A number of factors are recognized as affecting school performance including gender, ethnicity, quality of school and school experience, nutrition, child health, and socioeconomic factors.[4] This paper focuses on the importance of nutrition, specifically overall diet quality, to academic performance.

In past decades, poor diet, characterized by excess intake of dietary fat and refined sugars and inadequate intake of fruits, vegetables, and whole grains, has been identified as one of the primary mechanisms underlying the rising prevalence of overweight and obesity in school-age children.[5,6] The prevalence of childhood overweight and obesity is particularly high in North America and more specifically in the province of Nova Scotia where the prevalence of childhood overweight is significantly higher than the national average.[7-9] Examination of the prevalence of overweight among grade 5 students in Nova Scotia indicates that 32.9% of students were at risk for overweight, with 9.9% being overweight.[10] The diminishing diet quality and increasing body weights among children draw renewed public health attention to the effects of diet on academic performance and future health.

The relationship between diet and academic performance is often stated; however, few studies have examined the effects of diet quality on academic performance. Studies of nutrition and academic performance have typically focused on hunger, malnutrition, and micronutrient deficiency.[11-13] Undernourished children have been shown to have decreased attendance, attention, and academic performance as well as experience more health problems compared to well-nourished children.[11,14] More recently, studies have examined the impact of breakfast on cognition, behavior, and academic performance of school-age children.[11,15-17] This research suggests some positive effect of breakfast on performance of specific cognitive tasks.[11,16,17] However, gaps exist in the literature examining the long-term effects of breakfast on school performance and how the observed effects of breakfast on cognition are modified by age, sex, and nutritional status.[11,17] The single study not restricted to breakfast demonstrated a positive association between the consumption of regular meals and school performance.[18]

The predominant approach to studying diet has focused on the role of individual nutrients or foods.[19] However, individuals do not consume single nutrients but combinations of foods.[20] In recognition of the multidimensional nature of diet, studies of the interrelations of nutrition and health have examined the effects of overall diet quality using summary measures of food and nutrient intake.[20,21] The current study employs such an approach to investigate the association between diet quality and academic performance in a sample of 5200 grade 5 students in the province of Nova Scotia, Canada.

METHODS

Subjects

The 2003 Children's Lifestyle and School-performance Study (CLASS) is a large study of health, nutrition, physical activity, school performance, and socioeconomic determinants among grade 5 students in Nova Scotia, Canada, where 98.4% of students attend public school.[22] Of the 291 Nova Scotia public schools with grade 5 classes, 282 (96.9%) participated in the recruitment of participants by distributing a consent form and short survey to parents. Parental consent was received for 5517 students, giving an average response rate of 51.1% per school. Trained CLASS representatives visited participating schools during school hours to administer a survey on children's activities and a modified version of the Harvard Youth/Adolescent Food Frequency Questionnaire (YAQ).[23] Height and weight of participating students were also measured by CLASS representatives in a discreet manner behind a mobile screen in student classrooms. Height was measured to the nearest 0.1 cm after students had removed their shoes and body weight to the nearest 0.1 kg on calibrated digital scales. Generally, the administration of the surveys and measurement of heights and weights took less than 45 minutes to complete. Further details on the conduct of the CLASS are provided elsewhere.[10,24,25]

Ethics Approval. This study, including the informed consent procedure, was approved by the Health Sciences Human Research Ethics Board of Dalhousie University. Informed consent was obtained from parents before the participation of their children.

Instruments

Assessment of Diet Quality. The YAQ is a validated food frequency questionnaire suitable for grade 5 students. Information obtained from the YAQ allows calculation of student's intake of foods from

recommended food groups as well as energy and nutrient intakes. On the basis of the latter, we calculated the Diet Quality Index—International (DQI-I), a composite measure of diet quality.[26] A composite measure of diet quality is preferable to multiple analyses of nutrients and food groups.[20,21] The DQI-I overall score ranges from 0 to 100, with higher scores indicating better diet quality. Further information on the development, validation, and scoring of the DQI-I is available elsewhere.[21,26,27]

The DQI-I has been demonstrated as an effective means of cross-national comparisons of diet quality.[26] However, it has been suggested that DQI-I scoring is more in line with US recommendations, and therefore, DQI-I interpretations should be carefully interpreted in other countries where dietary recommendations are based on existing food patterns that are different from those in the United States.[28] In order to provide a comparative measure of overall diet quality, the Healthy Eating Index (HEI), an alternative measure of diet quality, was also calculated based on YAQ responses.[29]

In addition to examining the association between overall diet quality and academic performance, it is also valuable to determine which specific aspects of diet quality are most important to academic performance. The DQI-I was chosen as it encompasses adequacy, variety, balance, and moderation as components of diet quality and provides a score for each.[26] The association between each of these DQI-I component scores and academic performance was examined independently. The dietary adequacy component of the DQI-I represents the intake of foods and nutrients essential to a healthy diet such as fruits, vegetables, grains, dietary fiber, protein, iron, calcium, and vitamin C. Intake of less healthful dietary components such as saturated fat, salt, and ''empty calorie foods'' is reflected in the DQI-I moderation score. The DQI-I variety score reflects the diversity of foods in the diet, whereas overall dietary balance, in terms of the proportion of energy intake from carbohydrate, fat, and protein, is indicated by the DQI-I balance score.[26]

Increased consumption of fruits and vegetables and moderate fat intake are considered as indicative of high-quality diet and are emphasized as part of the total diet approach to improving nutrition among children.[5,20] In order to determine their specific associations with academic performance, the number of servings of fruits and vegetables and percentage of caloric intake from dietary fat were examined independently. With the exception of DQI-I balance component score, which had a skewed distribution, diet quality indicators were considered as tertiles.

Assessment of Academic Performance. The Elementary Literacy Assessment is a standardized test administered by the Nova Scotia Department of Education in the fall of 2003. The assessment was administered approximately 6 months following the CLASS survey when participating students were enrolled in grade 6. Completion of the assessment required students to read a variety of materials and answer written questions based on those readings. Materials included a short story, information texts, a poem, and a visual media text. Reading and writing assessments were marked centrally by a team of experienced grade 6 teachers under the supervision of the Nova Scotia Department of Education. Both individual- and school-level test results were linked to the CLASS database and were considered in the present study. Data available from the Nova Scotia Department of Education included individual results as a dichotomous outcome (pass/fail) for both the reading and the writing assessments. At the student level, academic performance was treated as a dichotomous variable with good academic performance defined as passing both the reading and the writing assessments and poor academic performance as failing either the reading or the writing assessment or both. Of the 4966 grade 5 students remaining after exclusion for outlying observations for energy intake, 4589 (92.4%) were successfully linked with the Elementary Literacy Assessment. At the school level, the percentage of students passing both assessments was a marker of performance.

Assessment of Other Covariates. At risk for overweight and its more severe form, overweight, were defined using the international body mass index cutoff points established for children and youth by the World Health Organization's International Obesity Task Force.[30] The Nova Scotia public school system is administered through 7 school boards, 1 of which did not allow height and weight measurements to be taken. For the 816 students without these measurements, weight status was considered as a missing category. Sociodemographic factors including student gender, urban or rural residency, parental marital status, education, and income were assessed using the questionnaire completed by parents of the participating students. Age was not considered as a covariate as the vast majority of grade 5 students were either 10 or 11 years old at the time they completed the CLASS survey. School neighborhood income was estimated by averaging postal code–level estimates of household income, available through Census Canada, of students attending that particular school. School neighborhood average income was divided into tertiles for analysis.

Data Analysis

Multilevel logistic regression was used to examine the associations between indicators of diet quality and academic performance. Multilevel methods account for the clustering of student's observations within schools and allow for quantification of second-level factors such as neighborhood income and school-level

academic performance. Gender of the student and parental marital status, income, and educational attainment were considered as first-level covariates. Odds ratios and 95% confidence intervals are presented for all analyses. Missing values for all covariates were considered as separate categories, but their estimates are not presented here.

Of the 5517 children who received parental consent, 5200 completed the YAQ. We excluded 234 (4.5%) students with outlying observations based on energy intakes less than 500 kcal or greater than 5000 kcal/day in accordance with established recommendations for outliers in nutritional research.[31] Following established recommendations, all analyses involving dietary factors were adjusted for energy intake.[31] Examination of cross-level interactions revealed no significant effects. All analyses were performed using the HLM6 (Scientific Software International, Inc., Lincolnwood, IL) software program.

Response Weights. Evaluation of nonresponse was conducted using postal code–level estimates of household income available through Census Canada for participating and nonparticipating grade 5 students. As participation rates were slightly lower in residential areas with lower postal code–level estimates of average household income, weighting factors were constructed to adjust for this difference. These weighting factors were used in all statistical analyses in order to adjust for nonresponse and provide provincial estimates.

Table 1. **Weighted Prevalence Estimates of Sociodemographic Characteristics of Participants in the CLASS***

Independent Variable	No. of Students	%
Gender		
Female	2386	52.1
Male	2193	47.9
Urban/rural residence		
Rural	1485	32.4
Urban	3094	67.6
Parental marital status		
Married or common law	3415	74.4
Separated or divorced	491	10.7
Single or widowed	215	4.7
Preferred not to answer	468	10.2
Parental education		
Secondary or less	1217	26.6
Community college	1567	34.2
University	969	21.1
Graduate university	383	8.4
Preferred not to answer	444	9.7
Annual household income ($)		
<20,000	371	8.1
20,000-40,000	762	16.6
40,000-60,000	918	20.0
>60,000	1396	30.5
Preferred not to answer	1133	24.8
School neighborhood average income		
First tertile (lowest)	1621	35.4
Second tertile	1413	30.9
Third tertile (highest)	1546	33.7

*The findings originate from 4589 students participating in the 2003 CLASS and are weighted for nonresponse to reflect provincial estimates.

RESULTS

Information on the sociodemographic characteristics of study participants is presented in Table 1. Of the 4589 students with complete information on diet quality and school performance, 875 (19.1%) failed 1 or both of the components of the literacy assessment. Table 2 presents unadjusted results for DQI and other dietary indicators on school performance. The overall diet quality scores ranged from 26.0 to 86.0, with an average score of 62.4. Students reporting increased diet quality were significantly less likely to fail the literacy assessment. Relative to students in the lowest DQI-I tertile, students in the second and third tertiles were 26% and 41% less likely to fail. Variety and adequacy rather than moderation and balance were the DQI-I components most significantly associated with academic performance. Students with an increased fruit and vegetable intake and lower caloric intake of fat were significantly less likely to fail the assessment. Analysis of HEI, an alternative summary measure of diet quality, yielded results similar to the association between DQI-I and academic performance.

Relative to girls, boys were twice as likely to fail their literacy assessments (Table 3). Increased parental income and educational attainment were significantly associated with decreased odds of poor academic performance. Parental marital status was also associated with academic performance: those children living in a lone-parent household had increased odds of failing 1 or both assessments. Students attending school in an urban area were significantly less likely to fail than those living in rural areas. Additionally, school neighborhood income was found to be significantly associated with academic performance. Children living in neighborhoods with increased average income levels were less likely to fail 1 or both assessments. Meanwhile, children attending schools with a poorer average performance on the literacy assessment had significantly increased odds of failing the assessment.

Adjusting for differences with respect to gender, parental income and education, and school, students in the second and third DQI-I tertiles were, respectively, 18% and 30% less likely to fail the literacy assessment (Table 3). Parental education and income remained significantly associated with students' academic performance. Overall school performance continued to be strongly associated with student's academic performance. Urban or rural residence, weight status, and marital status of parents were not independently associated with academic performance after adjustment.

Table 2. **Indicators of Diet Quality and Associations With Poor Academic Performance: Unadjusted Odds Ratios and 95% CIs**

Independent Variable	Odds Ratio (95% CI)
DQI-I[26] overall score	
First tertile (lowest)	1
Second tertile	0.74 (0.61-0.90)
Third tertile (highest)	0.59 (0.48-0.72)
DQI-I variety score	
First tertile (lowest)	1
Second tertile	0.71 (0.58-0.88)
Third tertile (highest)	0.67 (0.54-0.83)
DQI-I moderation score	
First tertile (lowest)	1
Second tertile	0.85 (0.68-1.06)
Third tertile (highest)	0.80 (0.63-1.02)
DQI-I balance score	
<1	1
≥1	1.13 (0.97-1.33)
DQI-I adequacy score	
First tertile (lowest)	1
Second tertile	0.52 (0.43-0.64)
Third tertile (highest)	0.30 (0.22-0.41)
HEI[29] score	
First tertile (lowest)	1
Second tertile	0.76 (0.63-0.92)
Third tertile (highest)	0.54 (0.44-0.67)
Percent energy from fat	
First tertile (lowest)	1
Second tertile	1.32 (1.11-1.59)
Third tertile (highest)	1.43 (1.20-1.72)
Fruit and vegetable intake	
First tertile (lowest)	1
Second tertile	0.66 (0.55-0.79)
Third tertile (highest)	0.60 (0.47-0.75)
Iron intake	
First tertile (lowest)	1
Second tertile	0.68 (0.54-0.84)
Third tertile (highest)	0.60 (0.42-0.84)

CI, confidence interval.
All odds ratios are adjusted for energy intake following established recommendations.[31]
Findings presented are adjusted for nonresponse.
The findings originate from 4589 students and their parents participating in the 2003 CLASS.

Table 3. **Diet Quality, Weight Status, and Sociodemographic Characteristics: Associations With Poor Academic Performance**

Independent Variable	Odds Ratio (95% CI)	Multivariate Odds Ratio (95% CI)
DQI-1 overall score*		
First tertile (lowest)	1	1
Second tertile	0.74 (0.61-0.90)	0.82 (0.67-1.00)
Third tertile (highest)	0.59 (0.48-0.72)	0.70 (0.56-0.88)
Gender		
Female	1	
Male	2.04 (1.75-2.93)	2.16 (1.82-2.57)
Urban/rural residence		
Rural	1	
Urban	0.70 (0.58-0.85)	
Weight status*		
Normal	1	
At risk for overweight	1.09 (0.91-1.32)	
Overweight	1.41 (1.10-1.81)	
Parental marital status		
Married or common law	1	
Separated or divorced	1.17 (0.94-1.47)	
Single or widowed	1.72 (1.27-2.34)	
Parental education		
Secondary or less	1	1
Community college	0.79 (0.67-0.92)	0.90 (0.75-1.08)
University	0.34 (0.28-0.43)	0.44 (0.33-0.57)
Graduate university	0.39 (0.29-0.53)	0.55 (0.39-0.78)
Annual household income ($)		
<20,000	1	1
20,000-40,000	0.63 (0.48-0.82)	0.73 (0.54-0.97)
40,000-60,000	0.38 (0.29-0.50)	0.50 (0.37-0.67)
>60,000	0.30 (0.23-0.39)	0.50 (0.38-0.67)
School-level academic performance		
<10% failure	1	1
10-19% failure	2.10 (1.71-2.60)	1.82 (1.45-2.29)
20-29% failure	3.65 (2.89-4.63)	2.77 (2.12-3.61)
30-39% failure	7.41 (5.37-10.24)	5.63 (3.95-8.64)
School neighborhood average income		
First tertile (lowest)	1	
Second tertile	0.86 (0.68-1.10)	
Third tertile (highest)	0.63 (0.50-0.79)	

CI, confidence interval.
*Odds ratios are adjusted for energy intake following established recommendations.[31]
Findings presented are adjusted for nonresponse.
The findings originate from 4589 students with available information on weight status and academic performance participating in the CLASS.

DISCUSSION

These findings demonstrate an independent association between overall diet quality and academic performance among grade 5 students in Nova Scotia, Canada. Dietary adequacy and variety were identified as specific aspects of diet quality important to academic performance, thereby highlighting the value of consuming a diverse selection of foods in order to meet the recommended number of servings from each food group. Additionally, fruit and vegetable consumption and dietary fat intake, 2 critical nutritional concerns among children,[5] were demonstrated as important to academic performance. The contribution of diet to academic performance is frequently stated; however, the focus of much of the research has been on hunger, malnutrition, micronutrient deficiency, and the effects of breakfast on cognition. In separate reviews, Taras and Rampersaud conclude that the provision of a healthy breakfast through school breakfast programs is effective in improving cognitive functioning and academic performance, especially among undernourished populations.[11,16] This study extends current knowledge in this area by demonstrating the independent importance of overall diet quality to academic performance and by identifying specific dietary factors that contribute to the association between nutrition and academic performance. The consistency of this association across various indicators of diet quality gives emphasis to the importance of children's nutrition not only at breakfast but also throughout the day.

Academic performance influences future educational attainment and income, which, in turn, affect

health and quality of life.[2] The socioeconomic benefits of educational attainment carry forward to future generations as children from socioeconomically advantaged backgrounds are more likely to succeed in school. Moreover, as increased levels of educational attainment and income facilitate increased understanding of nutrition messages and access to healthy food,[24,32,33] children from socioeconomically advantaged families are more likely to consume healthy diets. Increased diet quality among these children will provide further benefit to their academic performance and, in terms of health, contribute to healthy child development, which influences health throughout the life course. In addition, healthy eating behaviors adopted in childhood are likely to continue through adolescence and adulthood and result in decreased risk of chronic diseases.[34] Alternatively, children from socioeconomically disadvantaged backgrounds are more likely to have poor diets and poor academic performance resulting in lower levels of educational attainment and poorer health outcomes. Over time, the cyclical and compounded effects of socioeconomic factors and diet quality on academic performance may contribute to future increases in socioeconomic disparities in health. This research supports previous research demonstrating that academic performance varies according to the student's gender and that male students are more likely to perform poorly in terms of literacy.[4] This relationship has been observed as steady across different levels of socioeconomic status.[4]

In light of the current childhood overweight epidemic and underlying poor dietary habits, prevention is a public health priority. Our findings suggest enhanced learning as an additional benefit of a healthy diet in childhood. In a review of overweight and student school performance, Taras and Potts-Datema note the consistency of the association between childhood overweight and poorer levels of academic achievement.[35] Clearly, overweight results from an imbalance between diet and physical and sedentary activities, and thus, each of these lifestyle factors may hold an association with academic performance. However, in the present study, weight status was not independently associated with academic performance when the associations between diet quality, socioeconomic factors, and academic performance were considered. The lack of an independent association of weight status suggests that underlying diet quality may be largely contributing to the previously observed association between childhood overweight and academic achievement. School-based programs that promote healthy eating and physical activity may therefore be effective in both preventing childhood overweight and improving academic performance.[25,36] Our findings further highlight the importance of promoting dietary adequacy and variety, increased fruit and vegetable intake, and moderate consumption of dietary fat as key nutrition messages for school-based programs and policies.

This study involved a population-based sample in a relatively homogenous setting where almost all elementary school children attend public schools that are similarly funded. The high response rate, relative to other school-based surveys requiring parental consent, and the use of a weighting factor in analyses to adjust for nonresponse bias should be considered as strengths. Conversely, the rate of nonresponse does introduce the potential for bias of results. Systematic differences between responders and nonresponders other than income may introduce bias, which would adversely affect the results and limit the generalizability of the findings.

Our analyses were adjusted for various confounders, most importantly socioeconomic confounders; however, we may not exclude confounding by factors that were not considered. The consistency of the relationship between diet quality and academic performance across the various indices of diet quality is a further strength of the present study. A variety of outcomes for academic performance have been examined in the research.[11,16,35,36] This study is unique in that it linked nutritional information with census-level data and standardized test results, minimizing bias in the assessment of academic performance. However, this study is limited by the extent to which 2 standardized tests accurately measure academic performance. The nutritional information was collected using the YAQ, a validated food frequency questionnaire suitable for this age-group; however, self-administered responses remain subject to error. Results of this study highlight the associations between diet quality and academic performance. However, the direction of these associations cannot be ascertained from a cross-sectional study. Interpretation of the demonstrated association between diet quality and academic performance is based on the literature surrounding this association and related theory that led to the development of the research objectives. In order to demonstrate the temporal sequence of the relationship, further longitudinal research examining diet quality and academic performance would need to be conducted. These strengths and limitations should be considered when interpreting the present findings and making comparisons with other studies.

In summary, we demonstrated that, above and beyond socioeconomic factors, diet quality is important to academic performance. This association is important to children's future educational attainment and herewith future income, socioeconomic status, and health. These findings support the broader implementation and investment in effective school nutrition programs[25] that have the potential to improve student's diet quality, academic performance, and, over the long term, their health.

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