Nutrition and Student Performance at School

Howard Taras

ABSTRACT: *This article reviews research from published studies on the association between nutrition among school-aged children and their performance in school and on tests of cognitive functioning. Each reviewed article is accompanied by a brief description of its research methodology and outcomes. Articles are separated into 4 categories: food insufficiency, iron deficiency and supplementation, deficiency and supplementation of micronutrients, and the importance of breakfast. Research shows that children with iron deficiencies sufficient to cause anemia are at a disadvantage academically. Their cognitive performance seems to improve with iron therapy. A similar association and improvement with therapy is not found with either zinc or iodine deficiency, according to the reviewed articles. There is no evidence that population-wide vitamin and mineral supplementation will lead to improved academic performance. Food insufficiency is a serious problem affecting children's ability to learn, but its relevance to US populations needs to be better understood. Research indicates that school breakfast programs seem to improve attendance rates and decrease tardiness. Among severely undernourished populations, school breakfast programs seem to improve academic performance and cognitive functioning.* (J Sch Health. 2005;75(6):199-213)

Parents, educators, and health professionals have long touted the association between what our children eat and their school performance. Evidence for this correlation is not always apparent, and biases on both sides of the argument sometimes override data when this topic is discussed. Understanding existing evidence linking students' dietary intake and their ability to learn is a logical first step in developing school food service programs, policies, and curricula on nutrition and in guiding parents of school-aged children.

The National Coordinating Committee on School Health and Safety (NCCSHS) comprises representatives of several federal departments and nongovernmental organizations working to develop and enhance coordinated school health programs. The NCCSHS has undertaken a project to enhance awareness of evidence linking child health and school performance and identifying gaps in our knowledge. NCCSHS has conducted a search of peer-reviewed, published research reporting on the relationship between students' health and academic performance. In addition to nutrition, NCCSHS has sponsored research reviews of the association between academic performance and asthma, diabetes, sickle cell anemia, sleep, obesity, and physical activity.

SELECTION OF ARTICLES

Articles meeting the following specific characteristics were selected. (1) Subjects were school-aged children (5 to 18 years), (2) article was published after 1980 in a peer-reviewed journal, and (3) findings included at least 1 of the following outcome measures: school attendance, academic achievement, a measure of cognitive ability (such as general intelligence, memory), and attention. Students' level of attention was only acceptable as an outcome measure for purposes of inclusion in this review, if attention was measured objectively in the school environment. Studies of the impact of nutritional intake in children prior to school age were not included. Studies were identified using MedLine and similar Internet-based searches. If a full article could not be retrieved, but a detailed abstract was available, the research was included. Outcomes other than academic achievement, attendance, and cognitive ability, although considered major by the authors, may not be described at all or are only briefly alluded to in the tables of research descriptions.

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LITERATURE REVIEW

The body of literature on child nutrition and its potential effects on school performance are categorized in 4 subject areas: (1) nutritional supplements and micronutrients, (2) iron deficiency and supplementation, (3) food insufficiency, and (4) effect of eating breakfast. This categorization is intrinsically artificial since nutritional problems, chronic hunger, iron deficiency, and poor breakfast patterns are frequently interrelated. Nevertheless, the major variable of evaluation, as described by each article's authors, naturally led to this classification, with only a few articles falling into more than 1 category.

Nutritional Supplements and Micronutrients

Articles listed in Table 1 examine the relationship between academic or cognitive performance and vitamin/mineral supplementation, zinc deficiency, and iodine deficiency. Researchers in the United States and United Kingdom have investigated giving multivitamin and mineral supplements to normal populations of school-aged children to determine their effect on intelligence and performance on standardized tests or levels of school achievement. Results have varied. Studies indicate there are no effects of multivitamin supplementation on the intelligence or performance of most children. Improvements on nonverbal intelligence of certain subpopulations of children are possible, but there are no predictable characteristics of these subpopulations. Commenting on this body of literature, Smith points out there may be a fundamental problem with the research. The lack of a theoretic foundation as to how minerals/vitamins improve intelligence, the small number of researchers in this field, and the uncertainty about the potential connection between the vitamin-mineral supplementation industry and the research further limit what can be concluded.[1]

Zinc naturally occurs in foods such as meats, lentils, rice, potatoes, and grains. Marginal zinc deficiencies occur in low-income groups as well as among those eating unbalanced diets that are deficient in fat as well as in proteins, especially those of animal origin. Zinc is not as well absorbed from carbohydrate-rich foods.[2] Mild zinc deficiency is thought to be more common among endurance athletes.[3] In one Chinese study (Sandstead et al. 1998; Table 1), supplementation with zinc was helpful to improved performance only when it was combined with multiple nutrients. The study's finding may be specific to the diets of Chinese children. Its relevance to school-aged children in the United States is unknown. Zinc studies in Canada and Guatemala also suggest that zinc supplementation alone is

Table 1
Articles That Address Micronutrients and Nutritional Supplements and School Performance and/or Cognitive Ability* *(Continued on next page)*

Reference	Experimental Design	Outcome
van Stuijvenberg ME, Kvalsvig JD, Faber M, Kruger M, Kenoyer DG, Benade AJ. Effects of iron, iodine, and beta-carotene fortified biscuits on the micronutrient status of primary school children: a randomized controlled trial. *Am J Clin Nutr.* 1999;69:497-503. (South Africa)	115 children (age 6-11) were matched with a control group (115 children) and for 12 months given biscuits fortified with iron, iodine, and beta-carotene. Control children received nonfortified biscuits. Micronutrient status was assessed as was cognitive function, growth, and morbidity.	In addition to improved blood tests of nutrition, there was a significant between-group treatment effect ($P < .05$) in cognitive function with the digit span forward task (short-term memory). Fewer school days were missed in the intervention than in the control group because of respiratory- ($P = .097$) and diarrhea-related ($P = .013$) illnesses.
Sandstead HH, Penland JG, Alcock NW, et al. Effects of repletion with zinc and other micronutrients on neuropsychologic performance and growth of Chinese children. *Am J Clin Nutr.* 1998;68(suppl 2):470S-475S. (China)	740 children (age 6-9) were given zinc therapy or zinc and other micronutrients or micronutrients alone (randomized) for a period of 10 weeks. Tested with Cognition Psychomotor Assessment System.	In the group receiving both zinc and other micronutrients, there was a significant improvement in fine and gross motor skills, sustained attention, and capacity for concept formation and abstract reasoning.
Cavan KR, Gibson RS, Grazioso CF, Isalgue AM, Ruz M, Solomons NW. Growth and body composition of periurban Guatemalan children in relation to zinc status: a longitudinal zinc intervention trial. *Am J Clin Nutr.* 1993;57:344-352. (Guatemala)	In a randomized, double-blind controlled study, 162 children (age 7-8) were given zinc daily, for 25 weeks.	No difference on mental concentration or short-term memory was found despite changes in body composition of zinc.
Gibson RS, Vanderkooy PD, MacDonald AC, Goldman A, Ryan BA, Berry M. A growth-limiting, mild zinc-deficiency syndrome in some South Ontario boys with low height percentiles. *Am J Clin Nutr.* 1989;49:1266-1273. (Canada)	60 relatively short boys (<15 percentile) whose height could not be explained by parental height were given either zinc or a placebo for 1 year. All had zinc hair measurements and the Detroit Test of Learning Abilities.	Although boys with zinc deficiencies given supplementation improved in height, there was no improvement in attention span or other subscales of this test.
Bautista A, Barker PA, Dunn JT, Sanchez M, Kaiser DL. The effects of oral iodized oil on intelligence, thyroid status, and somatic growth in school-age children from an area of endemic goitre. *Am J Clin Nutr.* 1982;35:127-134. (Bolivia)	100 children with goiter from a region with low iodine in diets were given iodized oil or plain mineral oil. Both groups were studied for intelligence (Stanford Binet and Bender tests).	After 22 months, urinary iodine had increased in the treated group. Those who showed goiter reduction (regardless of treatment or control group) showed improvements in overall IQ. The effect was strongest in girls. Correcting iodine deficiency may improve mental performance.

* WISC, Wechsler Intelligence Scale for Children; WRAT, Wide Range Achievement Test; WISC-R, Wechsler Intelligence Scale for Children-Revised.

Table 1
Articles That Address Micronutrients and Nutritional Supplements and School Performance and/or Cognitive Ability* *(Continued from previous page)*

Reference	Experimental Design	Outcome
Sankar R, Rai B, Pulger T, et al. Intellectual and motor functions in school children from severely iodine deficient region in Sikkim. *Indian J Pediatr*. 1994;61:231-236. (India)	Four villages were randomly selected from many known to have high prevalence of severe iodine deficiency and 90 school children selected from these villages. Children were assessed for goiter, acuity of hearing, and signs of cretinism, and urine iodine levels. Children with cretinism were excluded. The Bender Visual Motor Gestalt Test, the Binet-Kamal Test for Mental Ability (IQ), and Raven's Coloured Progressive Matrices were used.	82 of the 90 children had goiter, and 87 urinary iodine studies revealed severe iodine deficiency. Test results showed impairment in language, meaningful and nonmeaningful memory, conceptual thinking, nonverbal reasoning, numerical reasoning, motor skills, social intelligence (from 69% to 91% of population found to be below normal) and 34% of population with an IQ between 70 and 84. Correlations of degree of iodine deficiency with degree of neuropsychological impairments were not studied.
Benton D, Roberts G. Effects of vitamin and mineral supplementation on intelligence of a sample of school children. *Lancet*. 1988;1:140-143. (United Kingdom)	90 school children (age 12-13) kept a dietary diary for 3 days. A multivitamin/mineral supplement or a placebo was administered double blind for 8 months to 60 children; 30 received nothing.	Average intake of vitamins was close to the recommended daily allowance, although for a minority the intake was low. The recommended daily allowance for minerals was rarely achieved. The supplement group, but not the placebo group or the remaining 30 who took no tablets, showed a significant increase in nonverbal intelligence.
Crombie IK, Todman J, McNeill G, Florey CD, Menzies I, Kennedy RA. Effect of vitamin and mineral supplementation on verbal and non-verbal reasoning of schoolchildren. *Lancet*. 1990;335:744-747. (United Kingdom)	86 school children (age 11-13) were randomly given either vitamin and mineral supplements or placebo for 7 months. A nonverbal performance test of reasoning was studied.	A small, nonsignificant difference between the control and supplementation groups was found in a nonverbal test. Vitamin and mineral supplementation does not improve the performance of schoolchildren in tests of reasoning.
Nelson M, Naismith DJ, Burley V, Gatenby S, Geddes N. Nutrient intakes, vitamin-mineral supplementation, and intelligence in British schoolchildren. *Br J Nutr*. 1990;64(1):13-22. (United Kingdom)	227 children (7-12 years of age) consumed food and drinks, and weight was recorded for 7 consecutive days. Nonverbal and verbal IQ tests were performed. Each child was randomly allocated to 1 of 2 groups; matched for age, sex, IQ, and height; and given either vitamin-mineral supplement or placebo for 28 days.	No correlation was found between test scores and micronutrients consumed with weighted records. No significant differences were found in performance between those taking placebo and those on supplements.
Schoenthaler S, Bier ID, Young K, Nichols D, Jansenns S. The effect of vitamin-mineral supplementation on the intelligence of American schoolchildren: a randomized, double-blind placebo-controlled trial. *J Altern Complement Med*. 2000; 6(1):19-29, 31-35. (United States)	Vitamin-mineral supplementation (vitamins A, D, E, C, $B_{1\text{-}6}$, B_{12}, iron, folate, zinc, chromium, manganese, molybdenum, selenium, copper at 50% of daily recommended allowance) or a placebo was given at school daily for 13 weeks to 245 children (6-12 years of age). Nonverbal IQ (from WISC-R) was given pre- and postintervention.	When studying the data by matching pairs (placebo-supplement), there was no difference in nonverbal IQ gain. However, because 24 children taking supplements had a 16-point higher net gain in IQ than remaining 19 placebo controls, an increase in overall relative increase of 2.5 IQ points in those receiving supplements (vs placebo) existed and was statistically significant. A significantly higher number of those with supplements gained $>$15 IQ points compared to placebo group.

* WISC, Wechsler Intelligence Scale for Children; WRAT, Wide Range Achievement Test; WISC-R, Wechsler Intelligence Scale for Children-Revised.

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Articles That Address Micronutrients and Nutritional Supplements and School Performance and/or Cognitive Ability* *(Continued from previous page)*

Reference	Experimental Design	Outcome
Schoenthaler S, Amos SP, Eysenck HJ, Peritz E, Yudkin J. Controlled trial of vitamin-mineral supplementation: effects on intelligence and performance. *Pers Individ Dif*. 1991; 12(4):351-362. (United States)	615 school children were assigned to 1 of 4 treatment groups (placebo and 3 different strengths of vitamin-minerals) for 12 weeks. Pre- and postmeasures included measure of intelligence (WISC-R), the Eysenck Junior Personality Questionnaire, and the Matrix Analogies Test.	There were significant improvements on the nonverbal WISC-R (3.7 points), but no improvements for verbal tests. Supplementation with 100% of recommended daily allowances (RDA) was superior to placebo 50% or 200% of RDA.
Schoenthaler S, Amos SP, Doraz WE, et al. Controlled trial of vitamin-mineral supplementation on intelligence and brain function. *Pers Individ Dif.* 1991;2(4):343-350. (United States)	26 delinquent children from a psychiatrically oriented facility were given either a placebo or nutrition supplements (consisting of all vitamins and 11 minerals) for 13 weeks. Measures included a nutritional assessment (7-day food record), blood analysis of vitamin concentrations, intelligence testing (WISC-R), and brain electrical activity mapping (computerized electroencephalogram/ electroencephalogram).	Preintervention showed no differences in IQ scores of placebo and treatment groups (IQ 100). At end of 13-week trial, placebo group (11 children) remained the same and supplement group (15 children) IQ rose to 107. Gains in excess of normal test-retest variation (8 points) were limited to 6 children.
Carlton RM, Ente G, Blum L, Heyman N, Davis W, Ambrosino S. Rational dosages of nutrients have a prolonged effect on learning disabilities. *Altern Ther*. 2000; 6(3):85-91. (United States)	19 learning-disabled children (age 7-14) were recruited via advertisements and then tested baseline at end of study: WISC, WRAT 6 additional standardized measures of intelligence and/or achievement, blood and urine tests (chemistry, blood cell tests). Class grades and any level of mainstreaming were also measured outcomes. In Year 1, all children were given 1 or more nutrition supplements (vitamin B, zinc, magnesium, etc.) at 2 to 10 times recommended daily allowance—only investigators knew which child received which nutrient. Child required evidence of academic improvement during Year 1 (higher grades, increased mainstreaming) to remain in study. Year 2 consisted of a closed random trial of 4 rotations (2 months per rotation) with child receiving either active nutrient supplements or placebo. In Years 3 and 4, all children received only nutrition supplementation (no intermittent placebos) and all intakes became open labeled to investigators families and students.	Intelligence tests did not change significantly after Year 1 or Year 2, but all 19 improved academically or were mainstreamed after Year 1. Twelve children completed the closed trial at Year 2. All had improvements in grade scores. During Year 2, no differences existed between months on placebo versus months on nutrients. All students continued to improve academically during Year 3, on or off the nutrients. During Year 4, those remaining on nutrients further increased grade averages, while those discontinuing nutrients had lower grade averages. Authors concluded that (a) nutrient supplementation improves achievement, not intelligence, and (b) longer than 2 months off of supplements is necessary to lose supplements' beneficial effect.

* WISC, Wechsler Intelligence Scale for Children; WRAT, Wide Range Achievement Test; WISC-R, Wechsler Intelligence Scale for Children-Revised.

Table 2
Articles That Address Iron Deficiency in School-Aged Children and School Performance and/or Cognitive Ability* *(Continued on next page)*

Reference	Experimental Design	Outcome
van Stuijvenberg ME, Kvalsvig JD, Faber M, Kruger M, Kenoyer DG, Benade AJ. Effects of iron, iodine, and beta-carotene fortified biscuits on the micronutrient status of primary school children: a randomized controlled trial. *Am J Clin Nutr.* 1999;69:497-503. (South Africa)	115 children (age 6-11) were matched with a control group (115 children) and for 12 months given biscuits fortified with iron, iodine, and beta-carotene. Control children received nonfortified biscuits. Micronutrient status was assessed as was cognitive function, growth, and morbidity.	In addition to improved blood tests of nutrition, there was a significant between-group treatment effect ($P < .05$) in cognitive function with the digit span forward task (short-term memory). Fewer school days were missed in the intervention than in the control group because of respiratory- ($P = .097$) and diarrhea-related ($P = .013$) illnesses.
Walker SP, Grantham-McGregor SM, Himes JH, Williams S, Duff EM. School performance in adolescent Jamaican girls: associations with health, social and behavioural characteristics, and risk factors for dropouts. *J Adolesc Health*. 1998;21:109-122. (Jamaica)	452 girls (age 13-14) were assessed for school performance (WRAT), nutritional status (height/weight for age, hemoglobin), and health behaviors (questionnaire on hunger, sexual activity, violence).	Girls who were anemic were significantly more likely to have poor academic achievement (multiple regression analysis). Poor school attendance, early sexual activity, and not living with both parents were also associated with school dropout in the subsequent year.
Halterman JS, Kaczorowski JM, Aligne CA, Auinger P, Szilagyi PG. Iron deficiency and cognitive achievement among school-aged children and adolescents in the United States. *Pediatrics*. 2001;107(6):1381-1386. (United States)	Data were taken from National Health and Nutrition Examination Survey III (6-16 years); blood samples were available to determine iron deficiency in 3% of 5398 children. Standardized test scores for intelligence (WISC-2 subtests) and achievement (WRAT-reading and math) are available.	Average math scores (score approximately 87) lower for children with iron deficiency with and without anemia compared with children with normal iron status (score 94). Children with iron deficiency had more than twice risk of scoring below average in math than those with normal iron. No difference was found on other test scores for iron deficiency.
Hutchinson SE, Powell CA, Walker SP, Chang SM, Grantham-McGregor SM. Nutrition, anaemia, geohelminth infection, and school achievement in rural Jamaican primary school children. *Eur J Clin Nutr*. 1997;51(11):729-735. (Jamaica)	809 fifth graders (age 9-13) were randomly selected from 16 schools. WRAT achievement test, attendance records, a questionnaire to determine socioeconomic status, height, weight, blood test for anemia (hemoglobin), and stool specimens were measurements.	School achievement (arithmetic) was associated with height for age. School achievement was not associated with body mass index (measure of relative weight). Anemic children and those with parasites in their stool had lower attendance and achievement scores (reading and spelling).
Lynn R, Harland P. A positive effect of iron supplementation on the IQs of iron-deficient children. *Pers Individ Dif*. 1998;24:883-885. (United Kingdom)	208 children (12-16 years of age) were matched with 205 controls for age, sex, and IQ. Treated group received iron and ascorbic acid for 16 weeks. The Ravens Progressive Matrixes test was used to measure IQ.	An initial correlation between hemoglobin levels and IQ was found to be small but significant. There was no significant difference between treatment and control groups, excepting for those with low ferritin (measure of iron). In this group, the treated group gained 3 IQ points, whereas the placebo group lost 2 IQ points.

* WISC, Wechsler Intelligence Scale for Children; WISC-R, Wechsler Intelligence Scale for Children-Revised; WRAT, Wide Range Achievement Test.

Table 2
Articles That Address Iron Deficiency in School-Aged Children and School Performance and/or Cognitive Ability* *(Continued from previous page)*

Reference	Experimental Design	Outcome
Abalkhail B, Shawky S. Prevalence of daily breakfast intake, iron-deficiency anaemia, and awareness of being anaemic among Saudi school students. *Int J Food Sci Nutr.* 2002;53:519-528. (Saudi Arabia)	800 students were selected for blood tests for anemia (based on hemoglobin levels). Of these, 42 boys and 42 girls (age 9-21 years, mean 14) were surveyed for nutritional habits.	Anemia (20% of population) was most prevalent among those greater than age 12. Menstruating girls had twice the rate of anemia than males. Anemia was significantly more prevalent among those who failed school performance examinations. Of those surveyed, skipping breakfast was reported by 15% (same for all ages, sex, body mass index, and social classes). Skipping breakfast was significantly associated with poor school performance.
Otero GA, Aguirre DM, Porcayo R, Fernandez T. Psychological and electroencephalographic study in school children with iron deficiency. *Int J Neurosci.* 1999;99: 113-121. (Mexico)	33 children (6-12 years of age) who were iron deficient but not anemic and 33 controls with normal iron (matched for socioeconomic variables) were given psychometric tests (WISC-R for IQ and a computerized test of learning, dynamic evaluation of learning as well as an electroencephalogram (EEG).	Iron-deficient children had lower values in WISC items of information, comprehension, and verbal performance, and full-scale IQ scores than children with normal iron levels. EEGs showed slower activity among the iron-deficient children as well, suggesting developmental lag and/or a central nervous system dysfunction.
Pollitt E. Iron deficiency and educational deficiency. *Nutr Rev.* 1997;55(4):133-141. (Indonesia, Thailand, Egypt, Guatemala)	This article reviewed 4 studies. Study 1: 41 children without anemia and 78 with iron-deficiency anemia (8.2-13 years of age) were given either iron supplements or placebo at school. Cognitive tests (Raven test of nonverbal intelligence), Bourden-Wisconsin test for concentration, and another standardized test of achievement were administered. Study 2: 1358 children were classified as iron-deficiency anemia (101), iron-depleted anemia (47), or iron repleted (1210). All children then received either iron supplements for 16 weeks or placebo. IQ, language, and math tests were given at baseline and after treatment. Study 3: 28 children with iron deficiency and 40 nonanemic children (age 8-11) (anemia was determined by response to iron therapy) had measures of hemoglobin, various iron studies, a cognitive-performance test (CPT), Peabody Picture Vocabulary test, and Matching Familiar Figure Test. Iron treatment was given. Study 4: 1203 children and adults had iron determinations and were divided into iron replete, iron deficiency but no anemia, and iron-deficiency anemia. Arithmetic, reading, other complex cognitive processes, simple reaction time, short-term memory, and other elementary cognitive processes were measured.	Study 1: No significant differences were found on Raven IQ tests between nonanemic and anemic students at baseline, but anemic children performed significantly poorer in achievement tests than nonanemic. Those who received iron improved their hemoglobin counts and improved significantly more on achievement tests than those receiving placebo. Study 2: At baseline the mean IQ was 94 (iron-repleted children), 91 (iron-deficiency anemia). Those with just iron depletion had IQs that did not differ significantly from either group. The 3 groups differed significantly for language scores, favoring those with more iron stores. Iron treatment had no difference on IQ, math, or language scores. Study 3: At baseline, no differences were found between iron-deficiency anemia and nonanemic children in CPT and Peabody tests, but more errors on matching test among those with anemia. No major differences were found on these tests after treatment except that among anemic children, those treated with iron selected information faster and with fewer errors. Study 4: Iron-depleted and iron-repleted groups were similar in all but 1 test: faster responses in memory for iron repleted.

* WISC, Wechsler Intelligence Scale for Children; WISC-R, Wechsler Intelligence Scale for Children-Revised; WRAT, Wide Range Achievement Test.

Table 2
Articles That Address Iron Deficiency in School-Aged Children and School Performance and/or Cognitive Ability* *(Continued from previous page)*

Reference	Experimental Design	Outcome
Seshadri S, Gopaldas T. Impact of iron supplementation on cognitive functions in preschool and school-aged children: the Indian experience. *Am J Clin Nutr*. 1989;50:675-686. (India)	Four studies. Study 1: The study consisted of 94 children (age 5-8) of whom one third were randomly assigned to control; Experimental group was given oral iron and folic acid for 60 days, and pre- and posttested with blood tests (for anemia) and intelligence (WISC). Study 2: 14 children (age 5-6) with normal intelligence, weight for age >60% of median value, and blood work demonstrating iron-deficiency anemia were matched with 14 controls (same intelligence, weight, and blood work). All children were treated with antiparasitic agents (parasites often cause anemia), but only experimental group was given iron and folic acid supplementation. Study 3: 16 subjects were matched for age, hemoglobin levels, and baseline scores with 2 other groups of 16 each. Double blinded, 1 group received a placebo, another 30 mg of iron, and the third group received 40 mg of iron. Visual-recall tests, digit span, maze cognitive function test, and tests of visual discrimination and perception were given preinitiation and 4 months postinitiation of therapy. Study 4: 65 pairs of subjects were matched for age, hemoglobin, and total cognitive function scores and 1 group received iron, the other placebo. Cognitive tests given were same as Study 3.	Study 1: Anemic children had lower test scores at beginning of experiment. Nutrition therapy improved IQ/WISC scores for both anemic (11 points) and nonanemic students (4 points) for children aged 7 and 8 years. Study 2: Blood tests for anemia (hemoglobin levels) improved for treatment group and worsened for controls. Both groups showed statistically significant improvement in IQ scores (WISC), but higher increases for treatment (10 points verbal, 17 performance) than controls (5 points verbal, 7 performance). Iron therapy improved cognitive performance among anemic children. Study 3: Overall cognitive function scores improved with either dose of iron, except maze test for the lower dose. The 40-mg group was significantly better than control, indicating higher dose had better impact on cognition. Study 4: On supplementation for 1 school year, anemic, iron-supplemented group did significantly better on all cognitive tests than nontreated group. Nonanemic group only improved on maze test, as compared to controls.
Sever Y, Ashkenazi A, Tyano S, Weizman A. Iron treatment in children with attention deficit hyperactivity disorder. A preliminary report. *Neuropsychobiology*. 1997;35:178-180. (Israel)	14 nonanemic boys (age 7-11) with attention deficit hyperactivity disorder (ADHD) were assessed by parent and teacher for symptoms of ADHD using a standardized questionnaire (Conners) and for anemia (blood test) before and 30 days after the intervention. All children received iron supplements daily.	Iron measures increased, and parents' scores for attention problems improved, but teachers' scores remained unchanged after iron therapy.
Sungthong R, Mo-suwan L, Chongsuvivatwong V. Effects of haemoglobin and serum ferritin on cognitive function in school children. *Asia Pac J Clin Nutr*. 2002; 11(2):117-122. (Thailand)	Two schools thought to have high anemia-risk students were chosen. Children (427, average age 9.6) were tested for cognitive function (Test of Nonverbal Intelligence), hemoglobin, iron, and height/weight. Language and math scores were collected.	Cognitive function increased with increased hemoglobin concentration in children with iron deficiency but did not change with hemoglobin concentration in children with normal iron stores. Those with iron-deficiency anemia consistently had poorest cognitive function (IQ 75) and below-average math/language achievement. Those with iron deficiency but not anemia had higher cognitive function (IQ 86) and above-average math/language achievement.

* WISC, Wechsler Intelligence Scale for Children; WISC-R, Wechsler Intelligence Scale for Children-Revised; WRAT, Wide Range Achievement Test.

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Articles That Address Iron Deficiency in School-Aged Children and School Performance and/or Cognitive Ability* *(Continued from previous page)*

Reference	Experimental Design	Outcome
Bruner AB, Joffe A, Duggan AK, Casella JF, Brandt J. Randomized study of cognitive effects of iron supplementation in non-anaemic, iron-deficient adolescent girls. *Lancet*. 1996;348:1789-1792. (United States)	98 adolescent girls (13-18 years) found to have nonanemic iron deficiency were randomly assigned to iron therapy or placebo for 8 weeks. Study measured Brief Test of Attention, Symbol Digits Modalities, Visual Search and Attention, and Hopkins Verbal Learning Test.	Level of ferritin (iron deficiency) was not correlated with results of girls' performance tests prior to intervention. Treatment group improved significantly more than placebo group in 3 free recall items, but not in other performance measures.

* WISC, Wechsler Intelligence Scale for Children; WISC-R, Wechsler Intelligence Scale for Children-Revised; WRAT, Wide Range Achievement Test.

unlikely to change cognitive ability or school performance, even in children with zinc deficiencies (Gibson et al. 1989, Cavan et al. 1993; Table 1).

Iodine deficiency in a population causes increased prevalence of goiter and, more importantly, may increase the risk for intellectual deficiency in that population. Iodine deficiency has been demonstrated to affect children's intelligence and performance. Of the studies that have looked at this issue, most were conducted outside the United States and in regions where iodine deficiency is endemic. Urinary iodine studied in large national samples (National Health and Nutrition Examination Survey [NHANES] I and III) indicates that there is adequate iodine intake for the overall US population, but that urinary iodine levels are dropping over time. A trend toward iodine deficiency must be monitored in school-aged populations.[4] Iodine replacement through dietary supplementation appears to at least partially reverse cognitive adverse effects among foreign populations of children who are severely iodine deficient.

Iron Deficiency and Supplementation

Table 2, which includes 12 articles, describes the results of 18 studies. Knowledge regarding the link between iron deficiency and school achievement or cognitive ability is derived primarily from observations and evaluated interventions of populations of youth who live outside the United States. Two studies were found that are based on US populations of children.

Some studies make an important distinction between children who have iron deficiency but are not anemic and children with iron deficiency who have iron-deficiency anemia. In the first group, children with iron deficiency have normal hemoglobin values (ie, not anemic) probably because the severity or duration of their iron deficiency is inadequate to cause anemia. National large sample data (NHANES III, 2001) indicate that 3% of school children in the United States have iron deficiency and that iron deficiency may still be relatively common in adolescent girls (9% of adolescent girls of childbearing age).[5] Studies in Table 2 demonstrate that iron deficiency may be associated with poorer academic outcomes (lower scores on achievement were found for math only). Certainly for those school-aged children with iron-deficiency anemia, a preponderance of evidence demonstrates an association with poorer cognition and/or lower academic achievement. However, it cannot yet be concluded that students with iron deficiency but no anemia are at greater risk for diminished cognitive ability and/or poor academic performance.

There is a need for large-scale studies that employ carefully matched socioeconomic control groups and multiple standardized tests of cognition and academic ability to better elucidate subtle effects of iron deficiency and to more precisely define the effects on learning. It is encouraging that when iron supplements are given to school-aged children as therapy for depleted stores, academic performance seems to improve. On the other hand, iron supplements do not appear to benefit those whose iron stores are already normal.

School districts distribute medical forms to families that elicit information on students' health status. Some forms include inquiries for students' hemoglobin or hematrocrit (blood tests that screen for anemia), and they call attention to the association between anemia and school performance. The American Academy of Pediatrics recommends that blood tests for iron-deficiency anemia only need to be performed routinely if the student is a menstruating adolescent female or history reveals that the child is at risk for anemia.[6] This recommendation is based on the belief that a good medical history of children's dietary intake and/or blood loss is sufficient to identify those likely to be anemic.

Evidence listed in Table 2 highlights the importance of assessing school-aged children for iron-deficiency anemia. In any geographic region of the world with a high prevalence of iron deficiency, public health programs that effectively prevent, detect, and treat iron deficiency likely help to improve the academic performance of their school-aged populations.

Food Insufficiency

Table 3 lists published research studying whether food insufficiency (ie, the limited availability of nutritionally

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Reference	Experimental Design	Outcome
Hall A, Khanh LN, Son TH, et al. An association between chronic undernutrition and educational test scores in Vietnamese children. *Eur J Clin Nutr*. 2001;55(9):801-804. (Vietnam)	Measured test result of 3055 third-grade school children in mathematics and Vietnamese language, height for age, weight for age, and weight for height.	Low test scores in both math and language were significantly associated with low height for age, weight for age, but not weight for height. Chronic undernutrition affects educational achievement.
Ivanovic D, Vasquez M, Aguayo M, Ballester D, Marambio M, Zacarias I. Nutrition and education. III. Educational achievement and food habits of Chilean elementary and high school graduates. *Arch Latinoam Nutr*. 1992;42(1):9-14. (Chile)	550 school children (13-19 years of age) were chosen from various communities. Food habits were determined through a questionnaire by trained interviewers. Educational achievement was determined by test results of various academic tests taken routinely at these ages. Multiple regression between academic achievement (dependent variable) and consumption of different foods.	Achievement was significantly and positively correlated with frequency of consumption of dairy, meats, and eggs in both elementary and high schools. Significant and inverse correlations were found between academic achievement and consumption of fruits and vegetables. Food habits explained 24% (elementary) and 17% (high school) of variance in academic achievement. Dairy products had greatest independent influence on achievement.
Ivanovic D, Olivares MG, Castro CG, Ivanovic RM. Nutrition and learning in Chilean school-aged children: Child's Metropolitan Region Survey 1986-1987. *Nutrition*. 1996;12(5): 321-328. (Chile)	More than 523,000 students in first, second, fourth, and eighth grades and 2 grades of high school were studied. Scholastic achievement was measured using a previously piloted language and mathematics test. This was compared to head circumference for age, weight for age, and height for age.	Head circumference for age is the most important anthropometric parameter associated with scholastic achievement. Signs of chronic undernutrition are associated with educational achievement.
Murphy JM, Wehler CA, Pagano ME, Little M, Kleinman RE, Jellinek MS. Relationship between hunger and psychosocial functioning in low-income American children. *J Am Acad Child Adolesc Psychiatry*. 1998;37:163-170. (United States)	204 children in grades 3-8 (and their parents) were interviewed. Ninety-six were reinterviewed 4 months after a free breakfast program was initiated. Assessments included psychosocial, academic, and food sufficiency/hunger measures.	Hungry and at risk for being hungry children were twice as likely to have impaired functioning (by parent or child report). Teachers reported higher levels of hyperactivity, absenteeism, and tardiness among hungry/at-risk than among nonhungry children. Intermittent experiences of food insufficiency are associated with poor academic functioning in low-income children.
Alaimo K, Olson CM, Frongillo EA Jr. Food insufficiency and American school-aged children's cognitive, academic, and psychosocial development. *Pediatrics*. 2001;108(1):44-53. (United States)	Data on 5344 children (age 6-16 years) from a large database (NHANES III) were studied for families who reported not getting enough food to eat as compared to those families who were food sufficient. Regression analysis was conducted to test this food insufficiency against cognitive (WISC-R), academic (WRAT subtests), school attendance, suspensions, and other measures.	Regression analysis (and adjustment for confounding socioeconomic and other factors) showed that food insufficiency was significantly associated with WRAT arithmetic scores (0.4 points lower), grade repetition (1.44 times as likely), but not associated significantly with cognitive outcomes, reading scores. It did not appear that diminished health status was the cause of food insufficiency's effect on these outcomes. Effect was found on children aged 6-11 years, not on those aged 12-16 years.

* NHANES, National Health and Nutrition Examination Survey; WISC, Wechsler Intelligence Scale for Children; WRAT, Wide Range Achievement Test.

Table 3
Articles That Address Food Insufficiency in School-Aged Children and School Performance and/or Cognitive Ability* *(Continued from previous page)*

Reference	Experimental Design	Outcome
Upadhyay SK, Agarwal KN, Agarwal DK. Influence of malnutrition on social maturity, visual motor coordination and memory in rural school children [abstract]. *Indian J Med Res* 1989;90:320-327. [Abstract] (India)	1336 rural school children (age 6-8) were evaluated for malnutrition (grades I, II, III) and for visual motor coordination and memory function.	Increasingly higher grades of malnutrition were associated with increasingly lower scores on social competence. Memory scores were weakly associated with malnutrition, with some differences between boys and girls on memory for picture and memory for words.
Walker SP, Grantham-McGregor SM, Himes JH, Williams S, Duff EM. School performance in adolescent Jamaican girls: associations with health, social, and behavioural characteristics, and risk factors for dropouts. *J Adolesc Health*. 1998;21:109-122. (Jamaica)	452 girls (age 13-14) were assessed for school performance (WRAT), nutritional status (height/ weight for age, hemoglobin), and health behaviors (questionnaire on hunger, sexual activity, violence).	Girls who were sexually active, anemic, or aggressive were significantly more likely to have poor academic achievement (multiple regression analysis). Poor attendance, early sexual activity, and not living with both parents were associated with school dropout in the subsequent year.
Hutchinson SE, Powell CA, Walker SP, Chang SM, Grantham-McGregor SM. Nutrition, anaemia, geohelminth infection, and school achievement in rural Jamaican primary school children. *Eur J Clin Nutr*. 1997;51(11):729-735. (Jamaica)	809 fifth graders (age 9-13) were randomly selected from 16 schools. WRAT achievement test, attendance records, a questionnaire to determine socioeconomic status, height, weight, blood test for anemia (hemoglobin), and stool specimens were measurements.	School achievement (arithmetic) was associated with height for age. School achievement was not associated with body mass index (measure of relative weight). Anemic children and those with parasites in their stool had lower attendance and achievement scores (reading and spelling).
Kleinman RE, Murphy JM, Little M, et al. Hunger in children in the United States: potential behavioral and emotional correlates. *Pediatrics*. 1998;101(1):e3 (United States)	328 families (parent with at least 1 child younger than 12 years of age) were identified from a large Community Childhood Hunger Identification Project database. Parents completed questionnaires (Pediatric Symptoms Checklist, standard food insufficiency questions, and questions on repeating a grade and receiving special education).	Of this sample, 56 were described as hungry, 157 described as at risk, and 108 described as not hungry. Hungry children had higher scores than at-risk and not-hungry children for school problems and attention problems, but the findings did not reach statistical significance. Aggression and anxiety had the strongest (and statically significant) degrees of association with experiences of hunger.
Mukudi E. Nutrition status, education participation, and school achievement among Kenyan middle-school children. *Nutrition*. 2003;19:612-616. (Kenya)	Data collected from 851 students from 5 elementary schools included height, weight, attendance records, and raw scores from standardized tests.	29% of students fell below 90% cutoff of acceptable weight for height (described as a measure of nutrition). The measure of "weight for height" was the second strongest predictor of achievement on standardized tests (school attendance was the strongest predictor).

* NHANES, National Health and Nutrition Examination Survey; WISC, Wechsler Intelligence Scale for Children; WRAT, Wide Range Achievement Test.

adequate and safe foods) affects cognition in school-aged children. Of 10 articles found, 7 were conducted on populations outside the United States. The majority describe impoverished school-aged populations of foreign countries, where food scarcity was sufficiently severe to alter children's height-weight ratios. Effects on cognitive ability and/or reported school achievement were found in the foreign studies. In some of the studied populations, poverty and parasites confounded the effects of undernutrition.

In 2 of the 3 studies conducted in the United States, food insufficiency was associated with significantly poorer cognitive functioning, decreased school attendance, or

Table 4
Articles That Address Role of Breakfast in School Performance and/or Cognitive Ability*
(Continued on next page)

Reference	Research Design	Outcome
Abalkhail B, Shawky S. Prevalence of daily breakfast intake, iron deficiency anaemia, and awareness of being anaemic among Saudi school students. *Int J Food Sci Nutr*. 2002;53:519-528. (Saudi Arabia)	800 students were selected for blood tests for anemia (based on hemoglobin levels). Of these, 42 boys and 42 girls (age 9-21 years, mean 14) were surveyed for nutritional habits.	Of those surveyed, skipping breakfast was reported by 15% of girls of all ages, sex, body mass index, and social classes. A significant association was found between skipping breakfast and poor school performance.
Chandler AK, Walker SP, Connolly K, Grantham-McGregor SM. School breakfast improves verbal fluency in undernourished Jamaican children. *J Nutr*. 1995;125:894-900. (Jamaica)	97 undernourished (low weight for age) and 100 adequately nourished children (third and fourth grades) were given either a full breakfast or a quarter of an orange. A battery of 4 cognitive tests were given. After a few weeks, the treatments were reversed and tests repeated.	Undernourished children's performance improved significantly on a test of verbal fluency when they received breakfast. Adequately nourished children did not change. Other test scores did not change as a result of breakfast.
Cromer BA, Tarnowski KJ, Stein AM, Harton P, Thorton DJ. The school breakfast program and cognition in adolescents. *J Dev Behav Pediatr*. 1990;11:295-300. (United States)	34 adolescents (mean age 14.2) were selected, of which 18 were randomly assigned to get breakfast (doughnut, chocolate milk, orange juice); others consumed a low-energy breakfast (diet gelatin, powdered milk). All were given cognitive tests 4 hours after breakfast (Peabody Picture Vocabulary, auditory-verbal learning, matching figure test, continuous performance test, an anxiety inventory).	Cognitive tests did not discriminate between breakfast and low-energy breakfasts.
Edward HG, Evers S. Benefits and barriers associated with participation in food programs in three, low-income Ontario communities. *Can J Diet Pract Res*. 2001;62:76-81. (Canada)	Focus groups were held after initiating a food program at schools in 3 communities.	Parents and teachers of children attending a "breakfast club" noted improvements in behavior at school: teachers felt children who had eaten breakfast were better inclined to study and listen better, concentrate better. Parents felt the children were absent less often.
Grantham-McGregor SM, Chang S, Walker SP. Evaluation of school feeding programs: some Jamaican examples. *Am J Clin Nutr*. 1998;67(suppl):785S-789S. (Jamaica)	100 undernourished children (based on weight for age) aged 8-11 years in 4 schools were matched for school, class, and sex with a child with normal weight for age. Children were randomly assigned to receive breakfast or a slice of orange. This continued for 1 week. Two weeks later, the breakfast and nonbreakfast groups were reversed. A battery of cognitive function tests were given and classroom behavior was observed.	Nutritional status had no significant effect on the cognitive function test. Undernourished children performed better after they had received breakfast, whereas adequately nourished children showed no change in scores. Children's attention to task in school increased significantly with breakfast, and in 1 school, gross motor behavior declined. Authors postulate that the quality of a school may modulate the effects of breakfast and no breakfast.

* WISC, Wechsler Intelligence Scale for Children; WRAT, Wide Range Achievement Test.

Table 4
Articles That Address Role of Breakfast in School Performance and/or Cognitive Ability*
(Continued from previous page)

Reference	Research Design	Outcome
Jacoby ER, Cueto S, Pollitt E. When science and politics listen to each other: good prospects from a new school breakfast program in Peru. *Am J Clin Nutr*. 1998;67(suppl): 795S-797S. (Peru)	More than 500,000 school children received school breakfast under this program, but the numbers from 1 town used for this study were not provided in this published paper.	School breakfast significantly increased energy intake, protein, and iron. School attendance rates improved substantially (not defined). Nutritionally at-risk children in the program improved their performance in the short term (not defined) on a vocabulary test (1 of 4 tests given).
Lopez I, de Andraca I, Perales CG, Heresi E, Castillo M, Colombo M. Breakfast omission and cognitive performance of normal, wasted, and stunted school children. *Eur J Clin Nutr*. 1993;47:533-542. (Chile)	279 children (age 8-10) from low socioeconomic backgrounds were categorized as normal, wasted, or stunted. Children were randomized as receiving breakfast and others in a fasting situation. Children were given 3 cognitive tasks on a microcomputer.	Stunted children performed poorer than others in attention test. No associations were found between consuming breakfast and children's short-term visual memory, problem solving, or attention tasks in normal, wasted, or stunted children.
Meyers AF, Sampson AE, Weitzman M, Rogers BL, Kayne H. School breakfast program and school performance. *AJDC*. 1989;143: 1234-1239. (United States)	More than 1000 students in third through sixth grades attending 6 elementary schools were selected (in a school district with a new school breakfast program). The school tested all grades in the spring using the Comprehensive Test of Basic Skills (CTBS); tests were given in the mornings. Attendance and tardiness data were collected from district administrative records. Data were collected for the year before and year after implementation of the school breakfast program.	Participation in the school breakfast program contributed significantly to higher CTBS scores (5 points on the total score) and to lower tardiness and absence rates.
Murphy JM, Pagano ME, Nachmani J, Sperling P, Kane S, Kleinman RE. The relationship of school breakfast to psychosocial and academic functioning: cross-sectional and longitudinal observations in an inner-city school sample. *Arch Pediatr Adolesc Med*. 1998;152:899-907. (United States)	In 3 elementary schools, parents and students (133 in grades 3 and higher) were interviewed and school data were collected both prior to and after implementation of a school breakfast program.	Students who increased their participation in the school breakfast program had significantly greater increases in their math grades (+0.3 grade), decreases in rates of school absences (−0.1 days), and decreases in tardiness (−0.4 days). Students who decreased their participation in school breakfast had lower math grades (−0.9 of a grade), higher absences (+1.6 days), and higher tardiness (+0.9 days).
Kleinman RE, Hall S, Green H, et al. Diet, breakfast, and academic performance in children. *Ann Nutr Metab.* 2002;46(suppl 1):24-30. (United States)	Information was gathered from 97 students (grades 4-6) prior to start of a school breakfast program and after the program had been in place for 6 months. Validated dietary recall instruments were used, as were hunger indices and other symptom checklists. Students' daily attendance records and participation in breakfast program were collected.	Prior to the school breakfast program, study children classified from questionnaires as being nutritionally at risk had significantly poorer attendance, punctuality, and grades at school. Six months after the free school breakfast program, those students who decreased their nutrition risk showed significantly greater improvements in attendance and improvements in math grades than children who did not decrease their nutritional risk.

* WISC, Wechsler Intelligence Scale for Children; WRAT, Wide Range Achievement Test.

Table 4
Articles That Address Role of Breakfast in School Performance and/or Cognitive Ability*
(Continued from previous page)

Reference	Research Design	Outcome
Pollitt E, Leibel RL, Greenfield D. Brief fasting, stress, and cognition in children. *Am J Clin Nutr.* 1981; 34:1526-1533. (United States)	32 children (age 9-11) ate dinner and slept at a clinical research center for 2 nights (1 week apart). Each was randomly assigned to either breakfast in the morning or no breakfast (reversed at next night's stay). Blinded psychologists administered memory, matching, attention, and other standardized tests. Blood samples were tested for beta-hydroxybutyrate glucose, lactate fatty acids.	Interaction between having breakfast and IQ score accounted for a significant portion of variance in errors on a test of competence in discrimination of similar visual stimuli. As measured glucose concentrations dropped, the number of errors increased. Correct recall of incidental objects in the memory test was better among those who did not have breakfast.
Pollitt E, Lewis NL, Garza C, Schulman RJ. Fasting and cognitive function. *J Psychiatr Res.* 1982-1983;17:169-174. (United States)	39 children (age 9-11) ate dinner and slept at a clinical research center for 2 nights (1 week apart). Each was randomly assigned to either breakfast or no breakfast (reversed at next night's stay). Blinded psychologists administered memory, matching, attention, and other standardized tests. Blood samples were tested for glucose and insulin.	Errors on a test of competence in discrimination of similar visual stimuli were greater among those without breakfast. Correct recall of incidental objects in the memory test was better among those who did not have breakfast.
Pollitt E, Cueto S, Jacoby ER. Fasting and cognition in well- and under-nourished school children: a review of three experimental studies. *Am J Clin Nutr.* 1998;67(suppl):779S-784S. (Peru)	23 undernourished and 29 well-nourished boys (age 9-11) enrolled in fourth or fifth grade were chosen based on weight or height as a sign of nourishment. They were either given breakfast or no breakfast (sugar-free soda). Blood samples and a battery of psychological tests were given (Number Discrimination, Peabody Picture Vocabulary Test, Raven Progressive Matrices, and computer tests of reaction time, stimulus discrimination, and memory).	Only performance on a memory search test (speed of scanning memory) was slower in the "no breakfast" than in the "breakfast" group for undernourished boys. Nutritionally at-risk boys were vulnerable to adverse effects of fasting as compared to well-nourished children.
Powell C, Grantham-McGregor S, Elston M. An evaluation of giving the Jamaican government school meal to a class of children. *Hum Nutr Clin Nutr.* 1983;37C:381-388. (Jamaica)	Seventh-grade children (all in bottom one third of scholastic ability) were divided into 3 groups, those receiving (1) a school lunch (milk and cake or meat-filled pastry), (2) a syrup drink, and (3) nothing. Students were tracked for 2 semesters: baseline measured during first and intervention occurring during second. School achievement was measured using the Wide Range Achievement Test.	Those receiving a school meal performed better on arithmetic test and had better attendance. Provision of a meal in school was determined to attract some students to attend. When attendance was controlled, arithmetic scores were still higher among those who had received a meal.
Powell CA, Walker SP, Chang SM, Grantham-McGregor SM. Nutrition and education: a randomized trial of the effects of breakfast in rural primary school children. *Am J Clin Nutr.* 1998;68:873-879. (Jamaica)	All students (grades 2-5) in 16 schools were weighed. The 405 students identified as undernourished by low weight for age were each matched with a same sex, age, schoolmate who was not malnourished.	Breakfast group (compared to control group) had improved height, weight, and attendance. Neither breakfast nor control group improved in WRAT achievement test.

* WISC, Wechsler Intelligence Scale for Children; WRAT, Wide Range Achievement Test.

Table 4
Articles That Address Role of Breakfast in School Performance and/or Cognitive Ability*
(Continued from previous page)

Reference	Research Design	Outcome
	Attendance, a breakfast questionnaire, and socioeconomic status measures as well as tests for achievement (WRAT; reading, spelling, arithmetic) were study instruments. Researchers also made home visits. All were assigned to either control or breakfast group (at-school breakfast every day for 1 year).	
Richter LM, Rose C, Griesel RD. Cognitive and behavioural effects of a school breakfast. *S Afr Med J*. 1997;87:93-100. (South Africa)	108 children from a school known to have undernutrition (second and third grades) were divided into the experimental class (55 students, mean age 10.5 years) and control class (53, mean age 8.3 years). Attention, distractibility, and short-term memory were measured (pre- and postintervention) using teacher ratings, standard psychomotor tests, and video recordings of classroom. All children in the experimental class received breakfast for period of 6 weeks.	Between the pre- and postintervention periods, both experimental and control groups improved in overall performance (as well as coding and vigilance) on the WISC, but the experimental group improved more on the vigilance tests. Only the experimental group improved significantly on digit span. Changes in absenteeism were not significant. School breakfast was felt to improve cognitive performance of socially disadvantaged, undernourished children.
Simeon DT, Grantham-McGregor S. Effects of missing breakfast on the cognitive functions of school children of differing nutritional status. *Am J Clin Nutr*. 1989;49:646-653. (Jamaica)	Subjects included 3 groups of 30 children each (age 9-11) who were (1) hospitalized for malnutrition during first 2 years of life, (2) stunted in growth (height for weight), and (3) nonstunted. All were given cognitive battery (WISC and Peabody), matching figures, and others. Half received and half did not receive breakfast after sleeping overnight at research center.	Performance on the fluency test and mental arithmetic were poorer for the undernourished groups when breakfast was omitted. Omitting breakfast made no difference on the nonstunted group. Unexpectedly, the nonstunted group performed better in arithmetic when breakfast was omitted.
Wyon DP, Abrahamsson L, Jartelius M, Fletcher RJ. An experimental study of the effects of energy intake at breakfast on the test performance of 10-year-old children in school. *Int J Food Sci Nutr*. 1997;48:5-12. (Sweden)	195 families with 10-year-old children recruited from 5 schools (10 classes) altered their children's breakfast regimen over a period of 4 successive days for 1 week. Standard breakfast was delivered to each boy's home, with uneaten food quantitatively evaluated. Children, not parents, were blinded to purpose of study. Over 4 days, different breakfasts were offered (high vs low nutritional value). Teachers blinded to nature of breakfasts assessed physical endurance, mathematical and creativity tests, and other measures of mood and behavior.	Children's energy intake when offered a higher energy breakfast (20% of recommended daily values) was always higher than when offered a lower energy breakfast (<10% of recommended daily values). Among those who ate the higher energy breakfast, there were fewer errors made on the following tests: number checking (boys) and addition (girls and boys) and higher scores for creativity (boys). Girls worked faster on number checking. No differences were found for multiplication or grammatical reasoning with high-energy breakfast. Physical endurance was also better among those with higher energy breakfasts. Intake at school lunch was not affected by type of breakfast.

* WISC, Wechsler Intelligence Scale for Children; WRAT, Wide Range Achievement Test.

diminished academic achievement. The 3 studies employed different research methodologies and measures to form their conclusions; for example, 1 used parent report to gauge academic achievement. The volume and quality of data from research in this field are modest. This may be partially explained by the fact that prospective, controlled studies on chronic undernourishment (which require that clinicians not intervene in cases of hunger) are not ethically feasible. Modest evidence in this small body of literature should be sufficient to raise concern that food insufficiency exists among school-aged children and that the issue must be addressed. Academic outcomes appear to be among the important consequences of inaction.

Breakfast

Of the 18 articles identified here (Table 4) that describe the effects on school-aged children of eating, or not eating, breakfast, fewer than one-half studied populations in the United States.

Research studies of populations in Jamaica, Chile, Peru, and South Africa typically included children known to have signs of undernourishment, such as low weight for age. Populations studied in the United States, Sweden, and Canada were not reported to have signs or symptoms of undernourishment. Studies of absenteeism rates among students offered breakfast at school found that children are more likely to attend school and have low rates of tardiness when a school breakfast program exists.[7]

Positive short-term effects of eating breakfast on students' school performance are almost consistently found among severely undernourished populations. The specific function that improved as a result of having had breakfast was inconsistent. Improved functions found in studies were verbal fluency, arithmetic, tests of attention, memory, creativity, physical endurance, and general tests of academic achievement and cognitive functioning. Some studies looked at the effects of missing breakfast on students' performance on the same day the morning meal was missed. Others studies investigated the positive effects of instituting a school breakfast program over longer periods of time. Others investigated breakfast versus fasting, while yet others investigated the quality of breakfast eaten. These vastly different study designs may explain the variation found in cognitive functioning and school performance associated with eating breakfast.

It is not clear from research on US populations that breakfast prior to school actually improves academic performance or cognitive ability. Those US studies that did find improvements among students who had eaten breakfast were usually not carefully controlled. One California study found a strong association between percentages of students eating breakfast and schools that had higher academic scores.[8] This study is purely retrospective, is without a control group, is not yet published in a peer-reviewed journal, and its research methodology has yet to be fully described and exposed to objective critical analysis. However, the information is derived from an impressive database of 500,000 students, which is far bigger than published studies that precede it in this field, and therefore cannot be ignored.

In summary, there appears to be a positive impact of breakfast on various cognitive skills in the short term.[9] Long-term effects of healthy breakfasts on a student's school performance are still unknown. Long-term studies are recommended as an important next step for researchers in the field of school nutrition.

CONCLUSION

Children with iron deficiencies sufficient to cause anemia are at a disadvantage academically, unless they receive iron therapy. Students with mild iron deficiencies and no anemia do not routinely exhibit problems in cognition or academic performance. There is no evidence that micronutrients such as zinc and iodine are deficient in US school children in amounts that affect their academic performance. There is also no evidence that population-wide vitamin and mineral supplementation will lead to any benefits for academic performance in this country. Food insufficiency is a serious problem affecting children's ability to learn, but its relevance to US populations needs to be better understood. School breakfast programs seem to improve attendance and decrease tardiness. Offering a healthy breakfast is an effective measure to improve academic performance and cognitive functioning among undernourished populations. Eating breakfast, in contrast to fasting, may improve performance on the morning eaten. The long-term effects of eating breakfast on the performance of school children who do not have physical signs of severe undernourishment is less certain. ■

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