



Role of Nutrition in Learning and Behavior: A Resource List for Professionals March 2008

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I. General Nutrition, Hunger, Learning and Behavior in the United States

A. Articles Dated 2003 – Present

Association of overweight with academic performance and social and behavioral problems: an update from the early childhood longitudinal study. S. Judge, L. Jahns *The Journal of School Health*, 77(10):672-678. 2007.

Abstract: BACKGROUND: Childhood overweight is a condition that is prevalent within our society, affecting more and more children each year. The purpose of this study was to examine the relationship between child overweight and educational outcomes. METHODS: Data are reported for 13,680 children in third grade from the Early Childhood Longitudinal Study, a set of data designed and carried out by the US Department of Education. Students were individually administered reading and math assessments. Teachers reported how often students exhibited certain social skills and behaviors. A series of 1-way analyses of covariance and multivariate analysis of covariance was used. RESULTS: Overweight children had significantly lower math and reading test scores compared with nonoverweight children in third grade. However, these differences became insignificant after including socioeconomic and maternal education variables. Third grade overweight girls had significantly more externalizing and internalizing problems as well as lower self-control scores than nonoverweight girls even after including socioeconomic and maternal education variables. CONCLUSIONS: Findings suggest that how we deal with children's overweight may have implications for the future psychological health of a considerable proportion of US children.

Breakfast habits, nutritional status, body weight, and academic performance in children and adolescents. G. Rampersaud, et al. *Journal of the American Dietetic Association*, 105(5): 743-760. 2005.

Abstract: Breakfast has been labeled the most important meal of the day, but are there data to support this claim? We summarized the results of 47 studies examining the association of breakfast consumption with nutritional adequacy (nine studies), body weight (16 studies), and academic performance (22 studies) in children and adolescents. Breakfast skipping is highly prevalent in the United States and Europe (10% to 30%), depending on age group, population, and definition. Although the quality of breakfast was variable within and between studies, children who reported eating breakfast on a consistent basis tended to have superior nutritional profiles than their breakfast-skipping peers. Breakfast eaters generally consumed



more daily calories yet were less likely to be overweight, although not all studies associated breakfast skipping with overweight. Evidence suggests that breakfast consumption may improve cognitive function related to memory, test grades, and school attendance. Breakfast as part of a healthful diet and lifestyle can positively impact children's health and well-being. Parents should be encouraged to provide breakfast for their children or explore the availability of a school breakfast program. We advocate consumption of a healthful breakfast on a daily basis consisting of a variety of foods, especially high-fiber and nutrient-rich whole grains, fruits, and dairy products.

Breakfast reduces declines in attention and memory over the morning in schoolchildren. K. Wesnes, et al. *Appetite*, 41(3): 329-331. 2003.

Abstract: Twenty-nine schoolchildren were tested throughout the morning on 4 successive days, having a different breakfast each day (either of the cereals Cheerios or Shreddies, glucose drink or No breakfast). A series of computerized tests of attention, working memory and episodic secondary memory was conducted prior to breakfast and again 30, 90, 150 and 210 min later. The glucose drink and No breakfast conditions were followed by declines in attention and memory, but the declines were significantly reduced in the two cereal conditions. This study provides objective evidence that a typical breakfast of cereal rich in complex carbohydrates can help maintain mental performance over the morning.

Nutrition and student performance at school. Howard Taras, MD. *Journal of School Health*, 75(6), 199-213. 2005.

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)



B. Articles Dated Prior to 2003

Behavioral and cognitive status in school-aged children with a history of failure to thrive during early childhood. R.A. Dykman, et al. *Clinical Pediatrics*, 40(2): 63-70. 2001.

NAL Call Number: RJ1-C55

Abstract: Twenty-seven school children (aged 8-12 years) earlier diagnosed with nonorganic failure to thrive (FTT) were compared with a normal socioeconomically matched control group (N=17) on current height and weight parameters as well as cognitive, achievement, and behavioral measures from the Child Behavior Checklist (CBCL). The former FTT children were, on average, smaller, less cognitively able, and more behaviorally disturbed than the control children and national normative samples. Sixty percent of former FTT children were below the 20th percentile in height and 48% were below the 20th percentile in weight; 52% had IQs below 80 and 30% had reading standard scores below 80; 48% had clinically adverse attention ratings and 30% had clinically adverse aggression ratings on the CBCL. Within the FTT sample, however, there were no significant associations between current growth measures and cognitive/achievement outcome measures. Mothers' IQs provided the strongest prediction of the FTT children's reading scores. The mothers of the FTT children had not achieved as high levels of education as the mothers of the control children, and more of them were single parents. Early growth problems put children at high risk for multiple adverse sequelae in middle childhood, especially if mothers are poorly educated. Careful ongoing follow-up of such children by pediatricians is encouraged.

Breakfast and performance. S. Cueto. *Public Health Nutrition*, 4(6A): 1429-31. 2001.

NAL Call Number: RA784-P83

Description: This review article summarizes information from empirical sources about the effect of breakfast consumption on energy availability, nutritional status, school attendance and performance. Evidence suggests that the effect of fasting on performance is not uniform, but it is dependent on the basal nutritional status of the subject. Breakfast consumption has a short-term effect in improving selected learning skills, especially work memory. School breakfast programs have a positive effect on the nutritional status of children, on school attendance and probably on dropout rates. The effect of breakfast consumption on school performance depends on the interaction between the program, student characteristics (malnutrition) and school organization. Unless the school setting guarantees a minimum quality standard, the benefits of breakfast consumption will not be evident in performance in complex areas like language or math.

Food insufficiency and American school-aged children's cognitive, academic, and psychosocial development. K. Alaimo, C.M. Olson, and E.A. Frongillo Jr. *Pediatrics*, 108(1): 44-53. 2001.

NAL Call Number: RJ1-P42

Abstract: This study investigates associations between food insufficiency and cognitive, academic, and psychosocial outcomes for US children and teenagers ages 6 to 11 and 12 to 16 years. Data from the Third National Health and Nutrition Examination Survey (NHANES III)



were analyzed. Children were classified as food-insufficient if the family respondent reported that his or her family sometimes or often did not get enough food to eat. Regression analyses were conducted to test for associations between food insufficiency and cognitive, academic, and psychosocial measures in general and then within lower-risk and higher-risk groups. Regression coefficients and odds ratios for food insufficiency are reported, adjusted for poverty status and other potential confounding factors. After adjusting for confounding variables, 6- to 11-year-old food-insufficient children had significantly lower arithmetic scores and were more likely to have repeated a grade, have seen a psychologist, and have had difficulty getting along with other children. Food-insufficient teenagers were more likely to have seen a psychologist, have been suspended from school, and have had difficulty getting along with other children. Further analyses divided children into lower-risk and higher-risk groups. The associations between food insufficiency and children's outcomes varied by level of risk. The results demonstrate that negative academic and psychosocial outcomes are associated with family-level food insufficiency and provide support for public health efforts to increase the food security of American families.

Nutritional influences on cognitive function: mechanisms of susceptibility. E.L. Gibson and M.W. Green. *Nutrition Research Reviews*, 15(1): 169-206. 2002.

NAL Call Number: QP141.A1N87

Description: The impact of nutritional variation, within populations not overtly malnourished, on cognitive function and arousal is considered. The emphasis is on susceptibility to acute effects of meals and glucose loads, and chronic effects of dieting, on mental performance, and effects of cholesterol and vitamin levels on cognitive impairment. New developments in understanding dietary influences on neurohormonal systems, and their implications for cognition and affect, allow reinterpretation of both earlier and recent findings. Evidence for a detrimental effect of omitting a meal on cognitive performance remains equivocal: from the outset, idiosyncrasy has prevailed. Yet, for young and nutritionally vulnerable children, breakfast is more likely to benefit than hinder performance. For nutrient composition, despite inconsistencies, some cautious predictions can be made. Acutely, carbohydrate-rich-protein-poor meals can be sedating and anxiolytic; by comparison, protein-rich meals may be arousing, improving reaction time but also increasing unfocused vigilance. Fat-rich meals can lead to a decline in alertness, especially where they differ from habitual fat intake. These acute effects may vary with time of day and nutritional status. Chronically, protein-rich diets have been associated with decreased positive and increased negative affect relative to carbohydrate-rich diets. Probable mechanisms include diet-induced changes in monoamine, especially serotonergic neurotransmitter activity, and functioning of the hypothalamic pituitary adrenal axis. Effects are interpreted in the context of individual traits and susceptibility to challenging, even stressful, tests of performance. Preoccupation with dieting may impair cognition by interfering with working memory capacity, independently of nutritional status. The change in cognitive performance after administration of glucose, and other foods, may depend on the level of sympathetic activation, glucocorticoid secretion, and pancreatic β -cell function, rather than simple fuelling of neural activity. Thus, outcomes can be predicted by vulnerability in coping with stressful challenges, interacting with nutritional history and neuroendocrine status. Functioning of such systems may be susceptible to dietary influences



on neural membrane fluidity, and vitamin-dependent cerebrovascular health, with cognitive vulnerability increasing with age.

II. Micronutrient Status, Learning and Behavior in the United States

A. Articles Dated 2003 – Present

Breakfast: A Missed Opportunity. S Affenito. *Journal of the American Dietetic Association*, 107(4): 565-569. 2007

Abstract: Breakfast has earned the title as the most important meal of the day, yet it is the meal most often missed. This statement is supported by research that has shown an association between breakfast consumption and overall nutritional quality of the diets of children and adolescents (1, 2, 3, 4, 5, 6 and 7), and national data that document a decline in breakfast consumption by youth in the United States (8). Moreover, relative to its energy contribution, breakfast provides a higher percentage of micronutrients than other meals consumed during the day (9). In addition to being a marker for an appropriate micronutrient and macronutrient intake pattern (3), regularity in breakfast consumption has been linked with improvement in academic performance and psychosocial functioning (10) as well as cognition (11) among children. Furthermore, breakfast consumption is considered an important determinant of a healthful lifestyle (12), and its association with healthful behaviors may favorably influence body mass index (BMI) (13).

Effect of iron supplementation on mental and motor development in children:

systematic review of randomized controlled trials. HJPS. Sachdev, T. Gera, P. Nestel. *Public Health Nutrition*, 8(2): 117-132. 2005. **NAL Call Number:** RA784.P83

Abstract: **OBJECTIVE:** To evaluate the effect of iron supplementation on mental and motor development in children through a systematic review of randomised controlled trials (RCTs). **DATA SOURCES:** Electronic databases, personal files, hand search of reviews, bibliographies of books, abstracts and proceedings of international conferences. **REVIEW METHODS:** RCTs with interventions that included oral or parenteral iron supplementation, fortified formula milk or cereals were evaluated. The outcomes studied were mental and motor development scores and various individual development tests employed, including Bayley mental and psychomotor development indices and intelligence quotient. **RESULTS:** The pooled estimate (random effects model) of mental development score standardised mean difference (SMD) was 0.30 (95% confidence interval (CI) 0.15 to 0.46, $P < 0.001$; $P < 0.001$ for heterogeneity). Initial anaemia and iron-deficiency anaemia were significant explanatory variables for heterogeneity. The pooled estimate of Bayley Mental Development Index (weighted mean difference) in younger children (<27 months old) was 0.95 (95% CI -0.56 to 2.46, $P = 0.22$; $P = 0.016$ for heterogeneity). For intelligence quotient scores (≥ 8 years age), the pooled SMD was 0.41 (95% CI 0.20 to 0.62, $P < 0.001$; $P = 0.07$ for heterogeneity). There was no effect of iron supplementation on motor development score (SMD 0.09, 95% CI -0.08 to 0.26, $P = 0.28$; $P = 0.028$ for heterogeneity). **CONCLUSIONS:** Iron supplementation improves mental development score modestly. This effect is particularly apparent for intelligence tests above 7 years of age and in initially anaemic or iron-deficient anaemic subjects. There is no convincing



evidence that iron treatment has an effect on mental development in children below 27 months of age or on motor development.

The evidence linking zinc deficiency with children's cognitive and motor functioning.

M.M. Black. *Journal of Nutrition*, 133(5 Suppl 1): 1473S-6S. 2003.

NAL Call Number: 389.8 J82

Description: The role of zinc in children's cognitive and motor functioning is usually assessed by the response to supplementation in populations thought to be zinc deficient. A review of published zinc-supplementation trials that examined behavior and development identified one trial in fetuses, six trials in infants and toddlers and three trials in school-age children. The three studies that examined activity reported that zinc supplementation was associated with more activity. Of the five studies that examined motor development in infants and toddlers, one found improvements among very low-birth-weight infants, one found improvements in the quality of motor development and three found no impact. Of the four studies that examined mental development in infants and toddlers, three found no impact of zinc supplementation and one found that zinc-supplemented children had lower scores than control children. Among school-age children, one study found no impact of zinc supplementation on cognitive performance and two found a beneficial impact of neuropsychological processes, specifically reasoning. The evidence linking zinc deficiency to children's cognitive and motor functioning suggests a relationship among the most vulnerable children but lacks a clear consensus, highlighting the need for additional research into the timing of zinc deficiency and the co-occurrence with other micronutrient deficiencies.

Improving the Quality of Students' Dietary Intake in the School Setting. S.K. Malone. *The Journal of School Nursing*, 21(2): 70-76. 2005.

Abstract: The dramatic increase in our understanding of the brain's development throughout childhood has increased our knowledge of the significance of micronutrients, such as iron and vitamin B-12, for this development. Deficiencies of these micronutrients have been shown to have an impact on students' cognitive development. Regardless of this knowledge, students continue to make unhealthy food choices and develop poor dietary habits. School environments are places where there is an opportunity to practice healthy eating habits. Yet many school policies fail to address the sale of foods of minimal nutritional value in the school setting. School nurses can play a vital role in planning policies at the local and national level that support and encourage healthy food environments, performing assessments of the nutritional status of students, and spearheading the implementation of evidence-based health promotion programs. It is time for school nurses to take the lead in efforts aimed at improving the quality of students' dietary intake in the school setting

Iron deficiency and the intellect. N. Gordon. *Brain and Development*, 25(1): 3-8. 2003.

Description: Children are especially liable to iron-deficiency anemia in developing countries, and in the inner cities of developed countries. Does the lack of iron cause impaired physical and mental development, and can this in certain circumstances be a permanent effect? One of the reasons that this is such a difficult question to answer is that there can be so many confounding factors, from other nutritional deficiencies, to helminthic infections and malaria in



tropical countries. If there is a definite relationship, children in the first 2 years of life will be at particular risk during the major spurt of brain growth. Lack of iron can affect brain cells, myelin, or neurotransmitters, so there is certainly a theoretical basis for possible brain damage, or there could be an effect from lack of oxygen. Also anemic children are likely to feel ill and unwilling to co-operate with tests to assess for developmental defects. Many studies of the possible results of iron deficiency on the development of children have been carried out in various countries, and some of these from 1983 onwards are recorded. It is difficult to draw conclusions from these trials, partly due to the variability in their construction, but on balance the evidence suggests that treatment of iron deficiency is justifiable, whether this is associated with anemia or not. It is equally important to stress the importance of prevention, although more research is needed on the best method to use, which is both effective and affordable.

Iron supplementation brings up a lacking P300 in iron deficient children. G.A. Otero, et al. *Clinical Neurophysiology*, 115(10): 2259-2266. 2004.

Abstract: OBJECTIVE: A decrease in iron concentration is accompanied by alterations in catecholaminergic and GABAergic neurotransmission systems, important in learning, memory and attention. It was hypothesized that iron deficient children would present attention deficits. A visual-event related potentials (ERPs) study is presented using an oddball paradigm in order to determine the P300 in ID children. METHODS: After medical examination, blood was obtained from 201 children for a complete hematological study. Two groups were selected, iron deficient (ID) (serum iron <60 microg/dl) and control (C) (serum iron >60 microg/dl). In both groups ERPs were recorded while executing a continuous performance task (oddball paradigm). Afterwards iron levels were restored in ID children by iron supplementation (ID-IS group) and all tests reapplied. RESULTS: ID children almost lacked a P300 in central and parietal regions. After iron supplementation, P300 clearly became evident although its Pz amplitude remained smaller compared to C children. CONCLUSIONS: A clear and strong correlation was found between ID and attention alterations in children. Iron supplementation nearly brings the P300 to normal levels although it is not known if the P300 difference in Pz is due to other nutritional/environmental deficits or to developmental psychomotor impairments in ID children. SIGNIFICANCE: It has been long known that iron deficient children have cognitive impairments but there is an insufficient number of electrophysiological works allowing to identify the source of this problem. In this work an attention deficit is demonstrated in ID children through a severely reduced P300, which recovers substantially after iron supplementation.

Nutrients of Cognitive Development in School-aged Children. J. Bryan, et al. *Nutrition Reviews*, 62(8): 295-306. 2004.

Abstract: This review considers the research to date on the role of nutrition in cognitive development in children, with a particular emphasis on the relatively neglected post-infancy period. Undernutrition and deficiencies of iodine, iron, and folate are all important for the development of the brain and the emergent cognitive functions, and there is some evidence to suggest that zinc, vitamin B12, and omega-3 polyunsaturated fatty acids may also be important. Considerations for future research include a focus on the interactions between micronutrients and macronutrients that might be influential in the optimization of cognitive



development; investigation of the impact of nutritional factors in children after infancy, with particular emphasis on effects on the developing executive functions; and selection of populations that might benefit from nutritional interventions, for example, children with nutrient deficiencies or those suffering from attention deficit-hyperactivity disorder and dyslexia.

B. Articles Dated Prior to 2003

The effect of vitamin-mineral supplementation on the intelligence of American schoolchildren: a randomized, double-blind placebo-controlled trial. S.J. Schoenthaler, et al. *Journal of Alternative and Complementary Medicine*, 6(1): 19-29. 2000.

Abstract: Many medical, nutrition, and education professionals have long suspected that poor diet impairs the academic performance of Western schoolchildren; academic performance often improves after improved diet. However, others have suggested that such academic gains may be due to psychologic effects rather than nutrition. To resolve this issue, two independent research teams conducted randomized trials in which children were given placebos or low-dose vitamin-mineral tablets designed to raise nutrient intake to the equivalent of a well-balanced diet. Both teams reported significantly greater gains in nonverbal intelligence among the supplemented groups. The findings were important because of the apparent inadequacy of diet they revealed and the magnitude of the potential for increased intelligence. However, none of the ten subsequent replications, or the two original trials, were without limitations leaving this issue in controversy. The objective of this study was to determine if schoolchildren who consume low-dose vitamin-mineral tablets will have a significantly larger increase in nonverbal intelligence than children who consume placebos in a study that overcomes the primary criticisms directed at the previous 12 controlled trials. The study utilized a double-blind, placebo-controlled trial employing stratified randomization within each teacher's class based on pre-intervention nonverbal intelligence. Two "working class," primarily Hispanic, elementary schools in Phoenix, Arizona, participated in the study. Intervention included administration of daily vitamin-mineral supplementation at 50% of the U.S. daily recommended allowance (RDA) for 3 months versus placebo. Outcomes were calculated by post-test nonverbal IQ, as measured by the Wechsler Intelligence Scale for Children-Revised (WISC-R), while controlling for pretest nonverbal IQ as a covariate. Findings consisted of four main results. First, a significant difference of 2.5 IQ points (95% CI: 1.85-3.15) was found between 125 children given active tablets and 120 children given placebo tablets ($p = 0.038$). Second, this finding is consistent with the mean 3.2 IQ point net gain found in the 12 similar but less rigorous studies. Third, a significantly higher proportion of children in the active group gained 15 or more IQ points when compared to the placebo group ($p < 0.01$). Fourth, although 81 matched pairs produced no difference at all in nonverbal IQ gain, the modest 2.5 IQ point net gain for the entire sample can be explained by the remaining 24 children who took active tablets, and had a 16 point higher net gain in IQ than the remaining 19 placebo controls. This study confirms that vitamin-mineral supplementation modestly raised the nonverbal intelligence of some groups of Western schoolchildren by 2 to 3 points but not that of most Western schoolchildren, presumably because the majority were already adequately nourished. Because nonverbal intelligence is closely associated with academic performance, it follows that schools with children who consume substandard diets should find it difficult to produce academic



performance equal to those schools with children who consume diets that come closer to providing the nutrients suggested in the U.S. RDA. The parents of schoolchildren whose academic performance is substandard would be well advised to seek a nutritionally oriented physician for assessment of their children's nutritional status as a possible etiology.

Iron deficiency and cognitive achievement among school-aged children and adolescents in the United States. J.S. Halterman, et al. *Pediatrics*, 107(6): 1381-6. 2001.

NAL Call Number: RJ1.P42

Abstract: Iron deficiency anemia in infants can cause developmental problems. However, the relationship between iron status and cognitive achievement in older children is less clear. The objective of the study was to investigate the relationship between iron deficiency and cognitive test scores among a nationally representative sample of school-aged children and adolescents using data collected in the National Health and Nutrition Examination Survey III 1988-1994. The National Health and Nutrition Examination Survey III provides cross-sectional data for children 6 to 16 years old and contains measures of iron status including transferrin saturation, free erythrocyte protoporphyrin, and serum ferritin. Children were considered iron-deficient if any 2 of these values were abnormal for age and gender, and standard hemoglobin values were used to detect anemia. Scores from standardized tests were compared for children with normal iron status, iron deficiency without anemia, and iron deficiency with anemia. Logistic regression was used to estimate the association of iron status and below average test scores, controlling for confounding factors. Among the 5398 children in the sample, 3% were iron-deficient. The prevalence of iron deficiency was highest among adolescent girls (8.7%). Average math scores were lower for children with iron deficiency with and without anemia, compared with children with normal iron status (86.4 and 87.4 vs 93.7). By logistic regression, children with iron deficiency had greater than twice the risk of scoring below average in math than did children with normal iron status (odds ratio: 2.3; 95% confidence interval: 1.1-4.4). This elevated risk was present even for iron-deficient children without anemia (odds ratio: 2.4; 95% confidence interval: 1.1-5.2). We demonstrated lower standardized math scores among iron-deficient school-aged children and adolescents, including those with iron deficiency without anemia. Screening for iron deficiency without anemia may be warranted for children at risk.

A randomized double-blind, placebo-controlled study of the effects of supplementation with highly unsaturated fatty acids on ADHD-related symptoms in children with specific learning difficulties. A.J. Richardson and B.K. Puri. *Progress in Neuropsychopharmacology and Biological Psychiatry*, 26(2): 233-9. 2002.

Abstract: The authors tested the prediction that relative deficiencies in highly unsaturated fatty acids (HUFAs) may underlie some of the behavioral and learning problems associated with attention-deficit/hyperactivity disorder (ADHD) by studying the effects of HUFA supplementation on ADHD-related symptoms in children with specific learning difficulties (mainly dyslexia) who also showed ADHD features. Forty-one children aged 8-12 years with both specific learning difficulties and above-average ADHD ratings were randomly allocated to HUFA supplementation or placebo for 12 weeks. At both baseline and follow-up, a range of behavioral and learning problems associated with ADHD was assessed using standardized



parent rating scales. At baseline, the groups did not differ, but after 12 weeks mean scores for cognitive problems and general behavior problems were significantly lower for the group treated with HUFA than for the placebo group; there were significant improvements from baseline on 7 out of 14 scales for active treatment, compared with none for placebo. Group differences in change scores all favored HUFA, reaching conventional significance levels for 3 out of 14 scales. HUFA supplementation appears to reduce ADHD-related symptoms in children with specific learning difficulties. Given the safety and tolerability of this simple treatment, results from this pilot study strongly support the case for further investigations.

A review of studies on the effect of iron deficiency on cognitive development in children. S. Grantham-McGregor and C. Ani. *Journal of Nutrition*, 131(2S-2): 649S-666S; discussion 666S-668S. 2001.

NAL Call Number: 389.8 J82

Description: Studies on the effect of iron deficiency on children's cognition and behavior are selectively reviewed, looking for evidence of a causal relationship. Most correlational studies have found associations between iron-deficiency anemia and poor cognitive and motor development and behavioral problems. Longitudinal studies consistently indicate that children anemic in infancy continue to have poorer cognition, school achievement, and more behavior problems into middle childhood. However, the possible confounding effects of poor socioeconomic backgrounds prevent causal inferences from being made. In anemic children <2 y old, short-term trials of iron treatment have generally failed to benefit development. Most longer trials lacked randomized placebo groups and failed to produce benefits. Only one small randomized controlled trial (RCT) has shown clear benefits. It therefore remains uncertain whether the poor development of iron-deficient infants is due to poor social backgrounds or irreversible damage or is remediable with iron treatment. Similarly, the few preventive trials have had design problems or produced no or questionable benefits only. For children >2 y old, the evidence from RCT is reasonably convincing but not conclusive RCT of iron treatment are warranted especially in younger children.

The role of zinc in the growth and development of children. M.J. Salgueiro, et al. *Nutrition*, 18(6): 510-9. 2002.

NAL Call Number: QP141.A1N866

Description: This review concerns the importance of zinc in growth, development, and cognitive function in children and the deleterious consequences of its deficiency on children's health. Possible strategies to overcome zinc deficiency and the results of some supplementation trials are discussed.



III. School Meals Programs, Learning and Behavior in the United States

A. Articles Dated 2003 – Present

Dietary Effects of Universal-Free School Breakfast: Findings from the Evaluation of the School Breakfast Program Pilot Project. M. Crepinsek, et al. *Journal of the American Dietetic Association*, 106(11): 1796-1803. 2006

Abstract: Objective: To determine the effects of offering universal-free school breakfast in elementary schools on students' dietary outcomes.

Design: Experimental study with random assignment of 153 matched elementary schools in six school districts. Treatment schools offered universal-free school breakfast, and control schools continued to operate the traditional means-tested School Breakfast Program. Twenty-four-hour dietary recalls were collected from sample students near the end of the first year.

Subjects: About 30 students in second through sixth grades were randomly selected from each school (n=4,358). Intervention: Free school breakfasts were made available to all students in treatment schools, regardless of family income, for three consecutive school years (2000-2001 to 2002-2003). Main outcome measures: Breakfast consumption and food and nutrient intake. Statistical analyses: Hierarchical mixed-models and logistic regression, adjusting for age, sex, minority status, and income eligibility for the regular school meal programs, were used to estimate effects. Results: Despite a significant increase in school breakfast participation among sample students in treatment schools (from 16% to 40%, $P<0.01$), the rate of breakfast skipping did not differ between groups (4% overall). Treatment school students were more likely to consume a nutritionally substantive breakfast ($P<0.01$), but dietary intakes over 24 hours were essentially the same. Conclusions: Making universal-free school breakfast available in elementary schools did not change students' dietary outcomes after nearly 1 year. To improve children's diets overall, efforts should focus on ensuring all students have access to a healthful breakfast, at home or at school.

Improving Access to School-Based Nutrition Services for Children with Special Health Care Needs. J. McCary. *Journal of the American Dietetic Association*, 106(9): 1333-1336. 2006

Abstract: Schools are recognized as a key setting to address the increase in overweight among youth. As part of the coordinated school health model, nutrition services can positively impact the eating habits of America's school children and play a role in reversing this trend. The requirement for school districts participating in the US Department of Agriculture's child nutrition programs to implement local wellness policies in the 2006-2007 school year presents opportunities for registered dietitians (RDs) to be directly involved in helping schools create more healthful environments. Further opportunities exist for RDs to deliver school-based nutrition services specifically for children with special health care needs. Many students come to school with physical, mental, and emotional health concerns that can impede learning. Nutrition has a critical influence on cognitive development and academic performance in children and adolescents, as undernourished children are more likely to have low energy and difficulty concentrating (1). Basic nutrition needs must be met for children to successfully learn at school. Iron deficiency, even in the absence of anemia, places a child at risk for cognitive



delay and lower math scores (1 and 2). Therefore, lack of proper nutrition can be considered a barrier to optimal learning, justifying nutrition services for school-aged children in the school setting. Nutrition may be especially important for children with disabilities and special health care needs (3). Children with disabilities and special health care needs often have more physical health-related problems that impact their education and nutrition status. It is estimated that at least 40% of children with special health care needs are at risk for nutrition-related challenges (4). Common issues include growth alterations, oral-motor problems that adversely affect feeding, medication–nutrient interactions, altered energy and nutrient needs, and partial or total dependence on enteral or parenteral nutrition (5). In addition, children with special needs have been shown to have three times as many school absence days as their age-matched peers (6). Absenteeism further threatens the ability for students to meet educational goals and when absence results from illness, poor nutrition status may be a contributing factor. Unfortunately, despite the documented need, access to and delivery of nutrition services for children with special needs presents challenges.

Improving the quality of students' dietary intake in the school setting. S.K. Malone. *The Journal of School Nursing*, 21(2): 70-76. 2005.

Abstract: The dramatic increase in our understanding of the brain's development throughout childhood has increased our knowledge of the significance of micronutrients, such as iron and vitamin B-12, for this development. Deficiencies of these micronutrients have been shown to have an impact on students' cognitive development. Regardless of this knowledge, students continue to make unhealthy food choices and develop poor dietary habits. School environments are places where there is an opportunity to practice healthy eating habits. Yet many school policies fail to address the sale of foods of minimal nutritional value in the school setting. School nurses can play a vital role in planning policies at the local and national level that support and encourage healthy food environments, performing assessments of the nutritional status of students, and spearheading the implementation of evidence-based health promotion programs. It is time for school nurses to take the lead in efforts aimed at improving the quality of students' dietary intake in the school setting.

The Kids Cafe: a program to reduce child hunger. Y. Tapper-Gardzina, N. Cotugna. *Journal of Pediatric Health Care*, 17(1): 18-21. 2003.

Description: Hunger and food insecurity affect nearly 12 million children in the United States. Poverty is the foremost reason for hunger and food insecurity, but even the working poor sometimes have difficulty providing enough food for their household. Undernourished children may not present with severe clinical symptoms, but their ability to learn and psychosocial behavior can be affected. Feeding programs such as Kids Cafe can help decrease child hunger while improving learning and overall health. Kids Cafe's are operated by local food banks and sponsored by America's Second Harvest in partnership with ConAgra Foods, Inc. This article reviews the problem of child hunger and describes the Kids Cafe Program.



Position of the American Dietetic Association: Child and adolescent food and nutrition programs. J. Stang, C.T. Bayerl. *Journal of the American Dietetic Association*, 103(7): 887-93. 2003. **NAL Call Number:** 389.8 Am34

Web site: http://www.eatright.org/Public/GovernmentAffairs/92_17504.cfm

Description: This paper explains the American Dietetic Association's stance on Child and Adolescent nutrition programs. The Association's position is that all children and adolescents, regardless of age; gender; socioeconomic status; racial, ethnic, or linguistic diversity; or health status should have access to food and nutrition programs that ensure the availability of a safe and adequate food supply that promotes optimal physical, cognitive, and social growth and development. Appropriate food and nutrition programs include food assistance and meal programs, nutrition education initiatives, nutrition screening and assessment followed by appropriate nutrition intervention, and anticipatory guidance to promote optimal nutrition status. Malnutrition has been linked to delayed physical, psychosocial, and cognitive development and is now recognized as a major contributor to the growing problem of overweight and obesity in the child and adolescent population.

B. Articles Dated Prior to 2003

Breakfast and learning in children: symposium proceedings. (CNPP 9). Center for Nutrition Policy and Promotion, U.S. Department of Agriculture. April 1999. 109 pp. Available at: http://www.usda.gov/cnpp/Seminars/symposium_on_breakfast_and_learn.htm

NAL Call Number: aLB3479.U6-B74-1999

Description: Proceedings of a conference on children's health and nutrition that reviews the most recent scientific research on breakfast and school performance, and considers its implications for public policy.

Children's perceived benefits and barriers in relation to eating breakfast in schools with or without universal school breakfast. J. Reddan, K. Wahlstrom, M. Reicks. *Journal of Nutrition Education and Behavior*, 34: 47-52. January/February 2002.

NAL Call Number: TX341 .J6

Abstract: The purpose of this study was to identify and compare perceived benefits and barriers related to breakfast consumption and concerns about weight among children in schools with or without a Universal School Breakfast Program (USBP). The study's design involved a teacher-administered survey at the end of a 3-year pilot program. Fourth, fifth, and sixth grade students in six USBP pilot schools (n = 827) and four control schools (n = 615) were matched by geographic location and socioeconomic status of students. Response rates were > 70%. The study measured the perceptions of benefits and barriers related to breakfast consumption and weight-related concerns. Chi-square tests were used to assess statistical differences in categorical responses to survey items. The majority of students perceived that eating breakfast provides benefits of increased energy and ability to pay attention in school. Commonly held perceptions of barriers to eating breakfast were lack of time and not being hungry in the morning. Compared with children in non-USBP schools, those in the USBP schools were less likely to wish they were thinner, to go on a diet, or skip breakfast because it might make them fat and more likely to believe that



eating breakfast will give them energy and help them pay attention. Based on the results of this study, nutrition educators may find it helpful to develop educational materials and programs based on the reciprocal determinism construct of Social Learning Theory to promote breakfast consumption. The focus should be on practical strategies to address barriers and encourage behavioral changes for both children and their parents.

Diet, breakfast, and academic performance in children. R.E. Kleinman, et al. *Annals of Nutrition Metabolism*, 46(1): 24-30. 2002.

NAL Call Number: RM214.N8

Abstract: The objective of this study is to determine whether nutrient intake and academic and psychosocial functioning improve after the start of a universal-free school breakfast program (USBP). Information was gathered from 97 inner city students prior to the start of a USBP and again after the program had been in place for 6 months. Students who had total energy intakes of <50% of the recommended daily allowance (RDA) and/or 2 or more micronutrients of <50% of RDA were considered to be at nutritional risk. Prior to the USBP, 33% of all study children were classified as being at nutritional risk. Children who were at nutritional risk had significantly poorer attendance, punctuality, and grades at school, more behavior problems, and were less likely to eat breakfast at school than children who were not at nutritional risk. Six months after the start of the free school breakfast programs, students who decreased their nutritional risk showed significantly greater: improvements in attendance and school breakfast participation, decreases in hunger, and improvements in math grades and behavior than children who did not decrease their nutritional risk. Participation in a school breakfast program enhanced daily nutrient intake and improvements in nutrient intake were associated with significant improvements in student academic performance and psychosocial functioning and decreases in hunger.

Evaluation of the School Breakfast Program Pilot Project: Findings from the first year of implementation. (Nutrition Assistance Program Report Series, No. CN-02-SBP). Food and Nutrition Service, Office of Analysis, Nutrition, and Evaluation, U.S. Department of Agriculture. Alexandria, VA: 2002. 506 pp. Available at:

<http://www.fns.usda.gov/oane/MENU/Published/CNP/FILES/BreakfastPilotYr1.pdf>

NAL Call Number: aLB3479.U6-E92-2002

Description: Participation in the School Breakfast Program (SBP) by children from low-income households continues to be less than their participation in the National School Lunch Program (NSLP). There is concern that children might be coming to school without eating breakfast and still not be participating in the SBP for a variety of reasons, including a perceived stigma associating school breakfast participation with poverty. One approach to increasing participation in the SBP is to offer free breakfast to all students, regardless of their household's ability to pay for the meal. It is believed that a universal-free breakfast program would result in more children consuming a nutritious breakfast and beginning the school day ready to learn. This pilot experiment was based on an experimental design in which schools within each district were randomly assigned to implement the universal-free school breakfast (treatment schools) or to continue to operate the regular SBP (control schools). There are 79 treatment and 74 control schools in the pilot. In Spring 2001,



about 4,300 students across the treatment and control schools were measured on dietary intake, cognitive function, and height and weight. Other data were also collected from parents and teachers. During the first year of implementation, the availability of universal-free school breakfast nearly doubled school breakfast participation (from 19 to 36 percent). Since most elementary school students in this study were consuming breakfast, the availability of free breakfast seems to have primarily shifted the source of breakfast from home to school. Given the low rate (less than 4 percent) of breakfast skipping, it is not surprising that the availability of universal-free school breakfast did not have a significant impact on measures of dietary intake or school performance. Whether two additional years of exposure to the availability of universal-free school breakfast will have an impact on student outcomes will be determined after data collection and analyses for all three years are completed. A report of the findings on the impact of the availability of universal-free school breakfast on elementary school students over the three-year period will be available in 2004.

IV. General Nutrition, Hunger, Learning and Behavior in countries other than the United States

A. Articles Dated 2003 – Present

Academic performance of Korean children is associated with dietary behaviours and physical status. H. Y. Kim, et al. *Asian Pacific Journal of Clinical Nutrition*, 12(2): 186-192. 2003.

Abstract: The purpose of this study was to obtain a fuller understanding of the association of dietary behaviours, physical status and socio-economic status with academic performance in Korean teenagers. The subjects in this study were 6,463 boys and girls, in grade 5, 8, and 11 in Korea. A self-administered questionnaire and the food-frequency form were used. Grade point average (GPA), height, weight, and physical fitness score for the year were recorded from the school record. The academic performance of students was strongly associated with dietary behaviours, especially with regularity of three meals even after control for parent's education level. Regular breakfast and lunch were more important in grades 5 and 8, while regular dinner was more related with academic performance in grade 11. Small, positive associations of height and physical fitness to academic performance were also found. The relative importance of regularity of meals was greater than that of socio-economic status and physical status in older teenagers. The results of this study suggest that accommodation of better dietary environment and nutrition education for three regular meals is recommended.

Association between Unhealthy Eating Patterns and Unfavorable Overall School Performance. M. Fu, et al. *Journal of the American Dietetic Association*, 107(11): 1935-1943. 2007

Abstract: The objective of this article is to evaluate the relationship between children's unhealthy eating patterns and overall school performance. The Nutrition and Health survey in Taiwan Elementary School Children, 2001-2002, was carried out by using a multistaged complex sampling design. A total of 2,222 elementary school children who had complete data



on demographics, anthropometrics, diet and lifestyle, and overall school performance were included in the analyses. Differences in characteristics between children with favorable and unfavorable overall performance were compared using t test and chi(2) test. Using factor analysis, food frequency of 22 food groups was grouped into five factors, which were used to construct dietary patterns. The association between dietary patterns and unfavorable overall performance was assessed by multiple logistic regression after adjustment for known risk factors. Prevalence of unfavorable overall performance in Taiwanese elementary school children was 7.1%. Unfavorable overall school performance was positively associated with unhealthful eating patterns, which included high intake of low-quality foods (eg, sweets and fried foods) and low intake of dairy products and highly nutrient-dense foods (eg, vegetables, fruit, meat, fish, and eggs). Children with a greater number of unhealthful eating patterns were more at risk for unfavorable overall performance in school. The study shows that children with unfavorable overall school performance were more likely to eat sweets and fried foods, and were less likely to eat foods rich in protein, vitamins, and minerals. A potential relationship between eating patterns and unfavorable overall school performance is supported by a positive relationship between frequency of food intake and food preferences in our study.

Breakfast, plasma glucose and beta-hydroxybutyrate, body mass index and academic performance in children from Extremadura, Spain. Torres MD, I. Carmona , C. Campillo , G. Perez , J.E. Campillo . *Nutricion hospitalaria*, Jul-Aug: 22(4): 487-90. 2007.

Abstract: OBJECTIVES: Nutritional aspects of breakfast, plasma levels of glucose and beta-hydroxybutyrate, body mass index and academic performance have been studied in urban and rural children (Extremadura, Spain). METHODS: Representative samples of schoolchildren (3 to 12 years old, random cluster-sampling in schools). RESULTS: Children's mean caloric intake with breakfast was 331 kcal. Rural population ingested more carbohydrates (46,9 +/- 12,3% versus 43,3 +/- 13,2% of the total caloric intake) and fewer lipids (40,5 +/- 11,8% versus 43,9 +/- 12,8% of the total caloric intake) than the urban population. Academic performance was significantly better in the children inhabiting the rural zone than in those of the urban zone. The glycaemia was higher in the urban than in the rural children, and that the contrary was the case for the beta-hydroxybutyrate values. Neither glucose nor beta-hydroxybutyrate levels were correlated with academic performance values. BMI was significantly increased in the urban versus rural children. CONCLUSION: The present results emphasize the importance of breakfast and life style in the weight and the academic performance of children.

Consumption of a mid-morning snack improves memory but not attention in school children. S. Muthayya, et al. *Physiology & Behavior*, 90(1): 142-150. 2007.

Abstract: Muthayya, S., T. Thomas, K. Srinivasan, K. Rao, A. V. Kurpad, J.-W. Van Klinken, G. Owen and E.A. de Bruin: Consumption of a mid-morning snack improves memory but not attention in school children. *Physiol Behav* 00(0) 000–000, 2006.—This study aimed to determine whether consumption of a mid-morning snack with appropriate energy compensation through a smaller breakfast or lunch, resulted in improved cognitive performance of 7–9 year old children with a low and high socioeconomic status (LSES and HSES, n = 35 and 34 respectively). The children were each randomly assigned to three iso-caloric dietary interventions: control (standard breakfast, no snack and standard lunch),



intervention A (small breakfast, snack, and standard lunch) and intervention B (standard breakfast, snack, and small lunch), using a cross-over design. The children were tested on three different days, each one week apart. Computerised tests of cognitive performance, consisting of memory, sustained attention and psychomotor speed, were performed during four sessions, i.e., prior to breakfast, after breakfast, after a mid-morning snack and after lunch. Having a mid-morning snack resulted in a smaller decline in immediate and delayed memory in LSES but not in HSES children. Having a snack did not influence sustained attention and psychomotor speed in either LSES or HSES children. This study shows that a more evenly distributed energy intake throughout the morning by consuming a mid-morning snack improves memory performance in school-age LSES children even when the total amount of energy consumed during the morning is not altered.

Malnutrition at age 3 years and lower cognitive ability at age 11 years: independence from psychosocial adversity. J. Liu et al. *Archives of Pediatrics and Adolescent Medicine*, 157(6): 593-600. 2003.

NAL Call Number: RJ1.A63

Abstract: Early malnutrition is linked to poor cognition, but long-term effects have not been extensively examined and psychosocial confounds have not always been controlled. A prospective, longitudinal study of a birth cohort of 1559 children originally assessed at age 3 years for malnutrition (low hemoglobin level, angular stomatitis, kwashiorkor, and sparse, thin hair) were followed up to age 11 years. The sample consisted of a community of 1559 children (51.4% boys and 48.6% girls) born between September 1, 1969, and August 31, 1970, in 2 towns in the island of Mauritius, with 68.7% Indians and 25.7% Creoles (African origin). Verbal and spatial ability measured at ages 3 and 11 years and reading, scholastic ability, and neuropsychologic performance measured at age 11 years. Malnourished children had poorer cognition at both ages. Deficits were stable across time, applied to all sex and ethnic groups, and remained after controlling for multiple measures of psychosocial adversity. Children with 3 indicators of malnutrition had a 15.3-point deficit in IQ at age 11 years. Malnutrition at age 3 years is associated with poor cognition at age 11 years independent of psychosocial adversity. Promoting early childhood nutrition could enhance long-term cognitive development and school performance, especially in children with multiple nutritional deficits.

Nutrients for cognitive development in school-aged children. J. Bryan, et al. *Nutrition Reviews*, 62(8):295-306. 2004.

NAL Call Number: 389.8-N953

Abstract: This review considers the research to date on the role of nutrition in cognitive development in children, with a particular emphasis on the relatively neglected post-infancy period. Undernutrition and deficiencies of iodine, iron, and folate are all important for the development of the brain and the emergent cognitive functions, and there is some evidence to suggest that zinc, vitamin B12, and omega-3 polyunsaturated fatty acids may also be important. Considerations for future research include a focus on the interactions between micronutrients and macronutrients that might be influential in the optimization of cognitive development; investigation of the impact of nutritional factors in children after infancy, with particular emphasis on effects on the developing executive functions; and selection of



populations that might benefit from nutritional interventions, for example, children with nutrient deficiencies or those suffering from attention deficit-hyperactivity disorder and dyslexia.

The long-term impact of preschool health and nutrition on education. M. Jukes. *Food and Nutrition Bulletin*, 26(2S): S193-S201. 2005.

Abstract: Malnutrition and infectious diseases in infancy and early childhood have an impact on the cognitive development of children in developing countries. The long-term effects of these diseases are less well understood. A number of studies relate early malnutrition, iron deficiency, and malaria infection to poor cognitive abilities in the school-age years. The long-term effect of randomized interventions in early childhood has been evaluated for nutrition supplementation and psychosocial stimulation of malnourished children and for malaria prevention in a community cohort. The evidence suggests that improving the health and nutrition of young children can improve their subsequent chances of attending school, the gender equity of education access, and performance of children once at school.

The role of breakfast and a mid-morning snack on the ability of children to concentrate at school. D. Benton, M. Jarvis. *Physiology & Behavior*, 90(2-3):382-385. 2007

Abstract: The effect on the ability of children to attend to their school work, of the size of breakfast and whether a mid-morning snack had been consumed, was considered. Nine year old children were studied for four days. They reported what they had eaten for breakfast and days when they either had or had not eaten a mid-morning snack were contrasted. For an hour in the late morning, while performing individual work, activity sampling was used to establish the time spent on task. Those who had eaten a small breakfast, on average 61 kcal, spent significantly less time attending to their work than those who had eaten larger meals. The adverse effect of a small breakfast was reversed by the consumption of a mid-morning snack.

B. Articles Dated Prior to 2003

An association between chronic undernutrition and educational test scores in Vietnamese children. A. Hall, et al. *European Journal of Clinical Nutrition*, 55(9): 801-4. 2001.

NAL Call Number: QP141.A1J68

Abstract: Using cross-sectional data collected during the baseline survey of a randomized trial, this study examined the association between results of educational tests and the anthropometric status of schoolchildren. The data originated from eighty-one primary schools in three districts of northern Vietnam and involved a total of 3055 schoolchildren enrolled in class 3 and born in 1990. After controlling for age, sex, district and school the results of test scores in both mathematics and Vietnamese were significantly negatively correlated with Z-scores of height-for-age ($P < 0.001$) and weight-for-age ($P < 0.001$), but not with weight-for-height ($P = 0.75$). A cross-sectional negative association was observed in Vietnamese primary school children between indicators of chronic undernutrition and tests of educational achievement.

Comparative school performance through better health and nutrition in Nsukka, Enugu, Nigeria. R.O. Abidoye, D.I. Eze. *Nutrition Research*, 20(5): 609-620. 2000.

NAL Call Number: QP141.A1N88



Abstract: School academic performance was compared among primary school pupils of different nutritional and health status in Nsukka, Enugu State of Nigeria after a simple random sampling selection of participant pupils and retrospective assessment of their health and nutritional history dating back to their gestation periods. Mothers and guardians of the pupils supplied information on their health and nutritional history through a well structured self administered questionnaire. Two hundred and eighty five (73.1%) of the pupils selected, participated in the final studies. There was predominance of malnutrition among the pupils. Only 28.9% of the pupils were of normal weight for height (using Z-scores on Nutritional Center for Health Statistics Values). 47.1% were mildly underweight, 20.1% were moderately underweight while 4.0% were severely underweight. Overall nutritional status (using weight-for-age Z-scores) significantly affects school performance ($p < 0.05$). Only 26.0% of the pupils were of normal height-for-age, the rest were stunted. Complications for pregnancy was found to significantly affect later school performance ($p < 0.05$). Birth complications also significantly affected later school performance ($p < 0.05$). There was no significant association between duration of breast feeding and later school performance ($p > 0.05$). Of the social factors that influence health and nutrition, level of maternal education was found to have a significant effect on school performance of pupils ($p < 0.05$). Prenatal and postnatal conditions were found to affect school performance of children. Sustainable human development will therefore start with effective education of women which will produce a multiplier effect on succeeding generations. Investment in female education is an effective means of improving the quality of children, their school performance and their future performance and quality of life in adulthood.

Early childhood nutrition and academic achievement: a longitudinal analysis. P. Glewwe, H.G. Jacoby, E.M. King. *Journal of Public Economics*, 81(2001):345-368. 2001.
NAL Call Number: HB9.J6

Abstract: This paper uses a longitudinal data set following a large sample of Filipino children from birth through the end of their primary education to examine the connection between nutrition and learning. Results indicated that better nourished children performed better in schools. The increased performance was attributed partly to the entrance of well-nourished children into school earlier, but, to a greater extent, because they had a greater learning productivity in school. A cost benefit analysis is provided.

Nutritional status, brain development and scholastic achievement of Chilean high-school graduates from high and low intellectual quotient and socio-economic status. D. Ivanovic, et al. *British Journal of Nutrition*, 87(1): 81-92. 2002.

Abstract: The object of the present study was to investigate the inter-relationships between nutritional status (past and current nutrition), brain development, and scholastic achievement (SA) of Chilean high-school graduates from high and low intellectual quotient (IQ) and socio-economic status (SES) (mean age 18.0 (SD 0.9) years). Results showed that independently of SES, high-school graduates with similar IQ have similar nutritional, brain development and SA variables. Multiple regression analysis between child IQ (dependent variable) and age, sex, SES, brain volume (BV), undernutrition during the first year of life, paternal and maternal IQ (independent variables) revealed that maternal IQ ($P < 0.0001$), BV ($P < 0.0387$) and severe



undernutrition during the first year of life ($P < 0.0486$), were the independent variables with the greatest explanatory power for child IQ variance (r^2 0.707) without interaction with age, sex or SES. Child IQ ($P < 0.0001$) was the only independent variable that explained both SA variance (r^2 0.848) and academic aptitude test variance (r^2 0.876) without interaction with age, sex or SES. These results confirm the hypotheses formulated for this study that: (1) independently of SES, high-school graduates with similar IQ have similar variables of nutritional status, brain development and SA; (2) past nutritional status, brain development, child IQ and SA are strongly and significantly intern-related. These finding are relevant in explaining the complex interactions between variables that affect IQ and SA and can be useful for nutritional and educational planning.

V. Micronutrients, Learning and Behavior in countries other than the United States

A. Articles Dated 2003 – Present

Effect of iron supplementation on cognition in Greek preschoolers. E. Matallinos-Katsaras, et al. *European Journal of Clinical Nutrition*, 58(11): 1532-1542. 2004.

Abstract: OBJECTIVE: To examine effects of iron supplementation on vigilance, attention and conceptual learning in preschool children in Greece. DESIGN: Randomized Double-Blind Placebo Controlled trial of iron. Randomization stratified by iron status and day care center (DCC). SETTING: Nine public DCCs in Athens, Greece. SUBJECTS: In all, 49 3-4-y olds (21 anemic, 28 good iron status) with birth weight not less than 2500 g, currently healthy; benign past medical history, IQ $>$ or $=$ 1 s.d. below the age-adjusted mean, serum Pb $<$ or $=$ 200 ppb (none exceeded 50 ppb), and height, weight and head circumference for age $>$ or $=$ 10th percentile. Anemia defined as: (1) pretreatment Hgb $<$ 112 g/l and TS $<$ 16% and ferritin $<$ 12 microg/L OR (2) Hgb rise of $>$ 10 g/l (T2-T0) with iron supplementation. Good iron status was defined as baseline levels of Hgb $>$ 120 g/l and either TS $>$ 20% or serum ferritin $>$ 12 microg/l. INTERVENTION: The intervention consisted of a 2-month supplementation of 15 mg iron (and MV) vs placebo (MV alone). RESULTS: After iron treatment, the anemic subjects made significantly fewer errors of commission (14% higher specificity, $P < 0.05$), exhibited 8% higher accuracy ($P < 0.05$) and were significantly more efficient (mean difference = 1.09, $P < 0.05$) than those given placebo. These effects of iron were not found among preschoolers with good iron status. No effects of iron treatment were found on the Oddity Learning task. CONCLUSIONS: This study demonstrated that iron supplementation of iron-deficient anemic preschoolers results in an improvement in discrimination, specifically selective attention.



B. Articles Dated Prior to 2003

A developmental view of the effects of an energy and micronutrient supplement in undernourished children in Indonesia. Pollitt, E., Jahari, A., and Walka, H. *European Journal of Clinical Nutrition*, 54(S2): S107-S113. 2000.

NAL Call Number: QP141.A1J68

Abstract: This paper presents the results of a structural equation model testing whether the longitudinal data of the Pangalengan subjects fit the theoretical model regarding the intellectual delay of undernourished children. Two cohorts of children were randomly assigned to three treatments: E = 1171 kJ + 12 mg iron; M = 12 mg iron + 209 kJ; S = 104 kJ. Supplementation was given for 6 months in six tea plantations in Indonesia. Subjects included a cohort of 2-month-olds (n = 53) and an 18-month-olds (n = 83) recruited from day-care-centers. Inclusion criteria were: no chronic disease; length-for-age = < 1 standard deviation (s.d.) and weight-for-length between -1 and -2 s.d. of the median of the reference of the World Health Organization. Twenty-four-hour dietary intakes were assessed using the weighted individual inventory technique. Body weight and length were obtained using standard procedures; motor development was assessed with the Bayley Scale and with a custom made scale for motor development leading to bipedal locomotion. Four-hour observations were made of the child's interactions with the environment. Carrying a child in the arms and exploratory behavior were used as indicators of care-giving and exploration. All measurements were obtained every 2 months. Results indicated that the original model did not fit the data. The model was then modified with the inclusion of two new pathways: from activity and from motor development to mental development. Following these adjustments the model fit the data for each cohort and for both cohorts combined.

Effects of an energy and micronutrient supplement on mental development and behavior under natural conditions in undernourished children in Indonesia. E. Pollitt, et al. *European Journal of Clinical Nutrition*, 54(S2): S80-S90. 2000.

NAL Call Number: QP141.A1J68

Abstract: This paper reports the effects of an energy and micronutrient supplement on mental development and on the social-cognitive and emotionally regulatory behaviors of nutritionally at risk infants and toddlers in Pangalengan, Indonesia. Two cohorts of children were randomly assigned to three treatments: E = 1171 kJ + 12 mg iron; M = 12 mg iron + 209 kJ; S = 104 kJoule. Supplementation was given for 12 months at six tea plantations in Pangalengan, West Java. A 12-month-old (N = 53) and an 18-month-old (N = 83) cohort were recruited from day-care-centers. Twenty children who received S belonged to the 12- and 18-month-old cohort. Inclusion criteria were: no chronic disease; length-for-age \geq -1 standard deviation (s.d.) and weight-for-length between -1 and -2 s.d. of the median of the reference of the World Health Organization. Evaluations of intake were made at baseline and every 2 months thereafter. Motor development was assessed with the Bayley Scale and with a custom-made scale to assess gross motor development leading to bipedal locomotion. Four hours of continuous observations were made of the child's interaction with the social and physical environment. In the 12-month-old cohort, as compared with the M and S groups, the children who received the E supplement walked at an earlier age, had higher scores in the Bayley



Scale and showed more mature social-cognitive and emotional regulatory behaviors. Similar intergroup differences were observed in the 18-month-old cohort in social cognition and regulation of emotions.

Effects of haemoglobin and serum ferritin on cognitive function in school children. R. Sunghong, L. Mo-suwan, and V. Chongsuvivatwong. *Asia Pacific Journal of Clinical Nutrition*, 11(2): 117-122. 2002.

NAL Call Number: QP141.A1 A74

Abstract: The association between iron deficiency anemia and cognitive function impairment has been widely reported in young children, but whether the impairment is a result of iron deficiency per se or a combination of iron deficiency and anemia, and how these conditions interact, is still questionable. Four hundred and twenty-seven school children from two schools in socioeconomically deprived communities were selected in southern Thailand. Iron status was determined by hemoglobin and serum ferritin concentrations. Cognitive function in this study was measured by IQ test and school performance, including Thai language and mathematics scores, using z-scores based on distributions within the same grade and school. Data on demography and socioeconomic status were collected by questionnaire answered by the parents. Linear regression models were used to investigate the effect of anemia and iron deficiency, reflected by hemoglobin and serum ferritin concentration, on cognitive function and school performance. We found that cognitive function increased with increased hemoglobin concentration in children with iron deficiency, but did not change with hemoglobin concentration in children with normal serum ferritin level. Children with iron deficiency anemia had consistently the poorest cognitive function (IQ, 74.6 points; Thai language score, 0.3 SD below average; and mathematics score, 0.5 SD below average). Children with non-anemic iron deficiency but with high hemoglobin levels had significantly high cognitive function (IQ, 86.5 points; Thai language score, 0.8 SD above average; and mathematics score, 1.1 SD above average). This study found a dose-response relationship between hemoglobin and cognitive function in children with iron deficiency, whereas no similar evidence was found in iron sufficient children.

VI. School Meals Programs in countries other than the United States

A. Articles Dated 2003 – Present

Academic performance of Korean children is associated with dietary behaviours and physical status. H. Y. Kim, et al. *Asian Pacific Journal of Clinical Nutrition*, 12(2): 186-192. 2003.

Abstract: The purpose of this study was to obtain a fuller understanding of the association of dietary behaviours, physical status and socio-economic status with academic performance in Korean teenagers. The subjects in this study were 6,463 boys and girls, in grade 5, 8, and 11 in Korea. A self-administered questionnaire and the food-frequency form were used. Grade point average (GPA), height, weight, and physical fitness score for the year were recorded from the school record. The academic performance of students was strongly associated with dietary behaviours, especially with regularity of three meals even after control for parent's



education level. Regular breakfast and lunch were more important in grades 5 and 8, while regular dinner was more related with academic performance in grade 11. Small, positive associations of height and physical fitness to academic performance were also found. The relative importance of regularity of meals was greater than that of socio-economic status and physical status in older teenagers. The results of this study suggest that accommodation of better dietary environment and nutrition education for three regular meals is recommended.

The Influence of the Glycaemic Load of Breakfast on the Behavior of Children in School.

D. Benton, A. Maconie, C. Williams. *Physiology & Behavior*, 92(4): 717-724. 2007.

Abstract: The impact of breakfasts of different glycaemic loads on the performance of nineteen children, aged six to seven years, was explored. Over a four week period, children attended a school breakfast club each day and ate one of three meals. Each meal offered a similar amount of energy but differed in their glycaemic load. When working individually, the behavior of a child was rated in the classroom every ten seconds for 30 min to produce a measure of time spent on task. Memory was assessed by asking for the recall of a series of objects. The ability to sustain attention was measured by asking for a response after various delays. The incidence of negative behavior was recorded when playing a video game that was too difficult to allow success. Two to three hours after a low glycaemic load breakfast had been consumed, performance on the tests of memory and the ability to sustain attention were better, fewer signs of frustration were displayed and initially more time was spent on task when working individually in class. The importance of the results was discussed in the context of the wide range of factors that influence behavior in school.

VII. Web Sites

Breakfast for Learning

Food Research & Action Center (FRAC)

http://www.frac.org/html/federal_food_programs/programs/sbp.html

Description: A brief review of the scientific research linking children's nutrition and academic performance.

Food and Nutrition Services

USDA. *Food and Nutrition Service.*

<http://www.fns.usda.gov/cnd/>

Program homepage includes guidance materials, program history, regulations, menu planning information, income eligibility guidelines, and more.

Healthy Meals Resource System

Food and Nutrition Information Center (FNIC)

http://healthymeals.nal.usda.gov/nal_display/index.php?info_center=14&tax_level=3&tax_subject=229&topic_id=1175&level3_id=5055

This Resource System includes resources, training materials and curriculums related to the School Breakfast Program.



This resource list was compiled by:

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