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Role of Nutrition in Learning and Behavior: A Resource List for Professionals August 2011

This Food and Nutrition Information Center (FNIC) Resource List is a quick guide designed to help professionals find information related to the role of nutrition in learning and behavior in children. Opinions expressed in the publications do not necessarily reflect the views of the U.S. Department of Agriculture.

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I. General Role of Nutrition in Learning and Behavior in the United States

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.
Description*:* 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.

Association of school performance indicators with implementation of the healthy kids, smart kids programme: Case study. T.R. Nansel, et al. *Public Health Nutrition,* 13(1):116-122. 2010.
NAL Call Number: RA784.P83
Description: Objective: The purpose of the present analysis was to examine secular trends in school performance indicators in relationship to the implementation of a programme targeting the school food and physical activity environment. Design: Data on available school performance indicators were obtained; retrospective analyses were conducted to assess trends in indicators in association with programme implementation; each outcome was regressed v. year, beginning with the year prior to programme implementation. Setting: The Healthy Kids, Smart Kids programme, a grass-roots effort to enhance the school food and physical activity environment in the Browns Mill Elementary School in Georgia. Subjects: Data included publicly available school records from the years 1995 to 2006. Results: The number of nurse, counselling and disciplinary referrals per 100 students demonstrated a downward trend, while standardized test scores demonstrated an upward trend beginning in the year of programme implementation. School year was a significant predictor of all indicators. Conclusions: Promoting nutrition and physical activity within the school environment may be a promising approach for enhancing both student health and educational outcomes.

Breakfast and learning: An updated review. J.M. Murphy. *Journal of Current Nutrition and Food Science,* 3(1):3-36. 2007.
Description: Over the past five years, significant new evidence has documented the link between eating breakfast and learning. Recent studies show that skipping breakfast is relatively common among children in the U.S. and other industrialized nations and is associated with quantifiable negative consequences for academic, cognitive, health, and mental health functioning. When combined with new data on the prevalence and impact of hunger/food insecurity, the preponderance of recent evidence is that lack of optimal nutrition is a problem for millions of U.S. students and that increased breakfast eating could be part of a solution. Literature reviews published in the late 1990's set the stage for understanding this new evidence by showing the associations between regular breakfast consumption/skipping and student outcomes. Research over the past five years has provided new evidence for these associations and definitive evidence for others: most notably that universally free school breakfast programs increase the rate of overall-breakfast eating and are judged to improve learning by teachers and school principals. These findings, along with accumulating evidence for the danger of nutritional risks, provide a clear rationale for continued efforts to promote breakfast eating for children, schools, and the nation as a whole.

Effect of a two-year obesity prevention intervention on percentile changes in body mass index and academic performance in low-income elementary school children.
D. Hollar et al., *American Journal of Public Health.* Apr;100(4):646-53. Epub 2010 Feb 18. 2010
Description: OBJECTIVES: We assessed the effects of a school-based obesity prevention intervention that included dietary, curricula, and physical activity components on body mass index (BMI) percentiles and academic performance among low-income elementary school children. METHODS: The study had a quasi-experimental design (4 intervention schools and 1 control school; 4588 schoolchildren; 48% Hispanic) and was conducted over a 2-year period. Data are presented for the subset of the cohort who qualified for free or reduced-price school lunches (68% Hispanic; n = 1197). Demographic and anthropometric data were collected in the fall and spring of each year, and academic data were collected at the end of each year. RESULTS: Significantly more intervention than control children stayed within normal BMI percentile ranges both years (P = .02). Although not significantly so, more obese children in the intervention (4.4%) than in the control (2.5%) decreased their BMI percentiles. Overall, intervention schoolchildren had significantly higher math scores both years (P < .001). Hispanic and White intervention schoolchildren were significantly more likely to have higher math scores (P < .001). Although not significantly so, intervention schoolchildren had higher reading scores both years. CONCLUSIONS: School-based interventions can improve health and academic performance among low-income schoolchildren.

Effective multi-level, multi-sector, school-based obesity prevention programming improves weight, blood pressure, and academic performance, especially among low-income, minority children. D. Hollar et al. *Journal of Health Care for the Poor and Underserved* 21(2 Suppl):93-108. 2010.
Description: INTRODUCTION: Successfully addressing childhood onset obesity requires multilevel (individual, community, and governmental), multi-agency collaboration. METHODS: The Healthier Options for Public Schoolchildren (HOPS)/OrganWise Guys (OWG) quasi-experimental controlled pilot study (four intervention schools, one control school, total N=3,769; 50.2% Hispanic) was an elementary school-based obesity prevention intervention designed to keep children at a normal, healthy weight, and improve health status and academic achievement. The HOPS/OWG included the following replicable, holistic components: (1) modified dietary offerings, (2) nutrition/lifestyle educational curricula; (3) physical activity component; and (4) wellness projects. Demographic, anthropometric (body mass index [BMI]), blood pressure, and academic data were collected during the two-year study period (2004-6). RESULTS: Statistically significant improvements in BMI, blood pressure, and academic scores, among low-income Hispanic and White children in particular, were seen in the intervention versus controls. CONCLUSION: Holistic school-based obesity prevention interventions can improve health outcomes and academic performance, in particular among high-risk populations.

Food security, poverty, and human development in the United States. J.T. Cook and D.A. Frank. *Annals of the New York Academy of Sciences,* 1136:193-209. 2008.
Description: Access to food is essential to optimal development and function in children and adults. Food security, food insecurity, and hunger have been defined and a U.S. Food Security Scale was developed and is administered annually by the Census Bureau in its Current Population Survey. The eight child-referenced items now make up a Children's Food Security Scale. This review summarizes the data on household and children's food insecurity and its relationship with children's health and development and with mothers' depressive symptoms. It is demonstrable that food insecurity is a prevalent risk to the growth, health, cognitive, and behavioral potential of America's poor and near-poor children. Infants and toddlers in particular are at risk from food insecurity even at the lowest levels of severity, and the data indicate an "invisible epidemic" of a serious condition. Food insecurity is readily measured and rapidly remediable through policy changes, which a country like the United States, unlike many others, is fully capable of implementing. The food and distribution resources exist; the only constraint is political will.

Growing children's bodies and minds: Maximizing child nutrition and development. P. Engle, S.L. Huffman. *Food and Nutrition Bulletin,* 31(2 SUPPL.). 2010.
Description: For their optimal growth, and for greater long-term human capital development, children profit not only from improved nutrition but also from improved learning opportunities in the earliest years of life. This paper describes how actions to enhance optimal infant and young child nutrition can be linked with child development interventions for children under 3 years of age. In countries with high rates of malnutrition, linking these two components will result in synergies of program activities, and will bring about a greater impact at reduced cost than either activity conducted separately. New understanding of social marketing and communication strategies can increase effectiveness of linked interventions. Public-private partnerships to improve both child development and nutrition offer promise for sustainable interventions.

Household food insecurity: Associations with at-risk infant and toddler development. R. Rose-Jacobs, et al. *Pediatrics*, 121(1):65-72. 2008.
Description: OBJECTIVES: In this study, we evaluated the relationship between household food security status and developmental risk in young children, after controlling for potential confounding variables. METHODS: The Children's Sentinel Nutritional Assessment Program interviewed (in English, Spanish, or Somali) 2010 caregivers from low-income households with children 4 to 36 months of age, at 5 pediatric clinic/emergency department sites (in Arkansas, Massachusetts, Maryland, Minnesota, and Pennsylvania). Interviews included demographic questions, the US Food Security Scale, and the Parents' Evaluations of Developmental Status. The target child from each household was weighed, and weight-for-age z score was calculated. RESULTS: Overall, 21% of the children lived in food-insecure households and 14% were developmentally "at risk" in the Parents' Evaluations of Developmental Status assessment. In logistic analyses controlling for interview site, child variables (gender, age, low birth weight, weight-for-age z score, and history of previous hospitalizations), and caregiver variables (age, US birth, education, employment, and depressive symptoms), caregivers in food-insecure households were two thirds more likely than caregivers in food-secure households to report that their children were at developmental risk. CONCLUSIONS: Controlling for established correlates of child development, 4- to 36-month-old children from low-income households with food insecurity are more likely than those from low-income households with food security to be at developmental risk. Public policies that ameliorate household food insecurity also may improve early child development and later school readiness.

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

II. Role of Nutrient Status in Learning and Behavior in the United States

Are dietary patterns in childhood associated with IQ at 8 years of age? A population-based cohort study. K. Northstone et al. *Journal of Epidemiology and Community Health*, Feb 7. 2011.
Description: Background - Little is known about the effects of overall diet in childhood and intelligence later in life. Methods - The current study, based on the Avon Longitudinal Study of Parents and Children, uses data on children's diet reported by parents in food-frequency questionnaires at 3, 4, 7 and 8.5 years of age. Dietary patterns were identified using principal-components analysis and scores computed at each age. IQ was assessed using the Wechsler Intelligence Scale for Children at 8.5 years. Data on a number of confounders were collected, and complete data were available for 3966 children. Results - After adjustment, the 'processed' (high fat and sugar content) pattern of diet at 3 years of age was negatively associated with IQ assessed at 8.5 years of age - a 1 SD increase in dietary pattern score was associated with a 1.67 point decrease in IQ (95% CI -2.34 to -1.00; $p<0.0001$). The 'health-conscious' (salad, rice, pasta, fish, fruit) pattern at 8.5 years was positively associated with IQ: a 1 SD increase in pattern score led to a 1.20 point increase in IQ (95% CI 0.52 to 1.88; $p=0.001$). Conclusion - There is evidence that a poor diet associated with high fat, sugar and processed food content in early childhood may be associated with small reductions in IQ in later childhood, while a healthy diet, associated with high intakes of nutrient rich foods described at about the time of IQ assessment may be associated with small increases in IQ.

Effects of iron supplementation in nonanemic pregnant women, infants, and young children on the mental performance and psychomotor development of children: A systematic review of randomized controlled trials. H. Szajewska, et al. *American Journal of Clinical Nutrition*, 91:1684-1690. 2010.
Description: Background: Uncertainty exists regarding the effects of iron supplementation on neurodevelopmental outcomes in the absence of anemia. Objective: Our objective was to evaluate the effects of iron supplementation in nonanemic pregnant women and in nonanemic healthy children aged <3 y on the mental performance and psychomotor development of children. Design: In this systematic review, MEDLINE, EMBASE, and The Cochrane Library were searched through December 2009 for randomized controlled trials (RCTs). Results: None of 5 RCTs individually showed a beneficial effect of iron supplementation during early life on the Mental Developmental Index of the Bayley Scales of Infant Development at different ages throughout the first 18 mo. Meta-analysis of 3 RCTs (n = 561) showed that, compared with placebo, supplementation with iron had no significant effect on children's Mental Developmental Index at ≈12 mo of age (weighted mean difference: 1.66; 95% CI: -0.14, 3.47). Three of 5 RCTs showed a beneficial effect of iron supplementation on the Psychomotor Development Index at some time points, whereas 2 did not. Meta-analysis of 3 RCTs (n = 561) showed significant improvement on the Psychomotor Development Index at ≈12 mo of age in the iron-supplemented group compared with the control group (weighted mean difference: 4.21; 95% CI: 2.31, 6.12). Two RCTs showed no effect of iron supplementation on behavior. Neither of the 2 RCTs that addressed the influence of prenatal iron supplementation showed an effect of iron on either the intelligence quotient or behavioral status of the children. Conclusion: Limited available evidence suggests that iron supplementation in infants may positively influence children's psychomotor development, whereas it does not seem to alter their mental development or behavior.

Effects of long-chain polyunsaturated fatty acid supplementation on neurodevelopment in childhood: A review of human studies. A.S. Ryan, et al. *Prostaglandins Leukotrienes and Essential Fatty Acids,* 82(4-6):305-314. 2010.
Description: Omega-3 and omega-6 long-chain polyunsaturated fatty acids (LCPUFA) are critical for infant and childhood brain development, but levels of the omega-3 fatty acids docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) are often low in the Western diet. Increasing evidence from both epidemiological and intervention studies, reviewed here, indicates that DHA supplementation, during pregnancy, lactation, or childhood plays an important role in childhood neurodevelopment. Arachidonic acid (ARA) is also important for infant growth and development. Several studies have demonstrated positive associations between blood DHA levels and improvements on tests of cognitive and visual function in healthy children. Controlled trials also have shown that supplementation with DHA and EPA may help in the management of childhood psychiatric disorders, and improve visual and motor functions in children with phenylketonuria. In all studies, DHA and EPA supplementation is typically well tolerated. Further research is needed to determine optimal doses for efficacy at different developmental ages. The potential long-term benefits of early LCPUFA supplementation also require consideration.

Fish consumption, mercury exposure, and their associations with scholastic achievement in the Seychelles Child Development Study. P.W. Davidson, et al. *Neurotoxicology*, 31(5):439-447. 2010.
Description: Studies of neurodevelopmental outcomes in offspring exposed to MeHg from maternal consumption of fish have primarily measured cognitive abilities. Reported associations have been subtle and in both adverse and beneficial directions. Changes in functional outcomes such as school achievement and behavior in exposed children and adolescents have not been examined. We undertook an assessment of school success of children in the Seychelles Child Development Study (SCDS) main cohort to determine if there were any associations with either prenatal or recent postnatal MeHg exposure. The primary endpoints were Seychelles nationally standardized end-of-year examinations given when the cohort children were 9 and 17 years of age. A subgroup (n= 215) from the main cohort was also examined at 9 years of age using a regional achievement test called SACMEQ. Prenatal MeHg exposure was 6.8 ppm in maternal hair; recent postnatal exposure was 6.09 ppm at 9 years and 8.0 ppm at 17 years, measured in child hair. Multiple linear regression analyses showed no pattern of associations between prenatal or postnatal exposure, and either the 9- or 17-year end-of-year examination scores. For the subgroup of 215 subjects who participated in the SACMEQ test, there were significant adverse associations between examination scores and postnatal exposure, but only for males. The average postnatal exposure level in child hair for this subgroup was significantly higher than for the overall cohort. These results are consistent with our earlier studies and support the interpretation that prenatal MeHg exposure at dosages achieved by mothers consuming a diet high in fish are not associated with adverse educational measures of scholastic achievement. The adverse association of educational measures with postnatal exposure in males is intriguing, but will need to be confirmed by further studies examining factors that influence scholastic achievement.

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

SIG: 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.

Multivitamin/Mineral supplementation does not affect standardized assessment of academic performance in elementary school children. A.I. Perlman, et al. *Journal of the American Dietetic Association,* 110(7):1089-1093. 2010.
Description: Limited research suggests that micronutrient supplementation may have a positive effect on the academic performance and behavior of school-aged children. To determine the effect of multivitamin/mineral supplementation on academic performance, students in grades three through six (approximate age range=8 to 12 years old) were recruited from 37 parochial schools in northern New Jersey to participate in a double-blind, placebo-controlled clinical trial conducted during the 2004-2005 academic school year. Participants were randomized to receive either a standard children's multivitamin/mineral supplement (MVM) or a placebo. MVM or placebo was administered in school only during lunch or snack period by a teacher or study personnel who were blinded to group assignment. The main outcome measured was change in scores on Terra Nova, a standardized achievement test administered by the State of New Jersey, at the beginning of March 2005 compared to March 2004. Compared with placebo, participants receiving MVM supplements showed no statistically significant improvement for Terra Nova National Percentile total scores by treatment assignment or for any of the subject area scores using repeated measures analysis of variance. No significant improvements were observed in secondary end points: number of days absent from school, tardiness, or grade point average. In conclusion, the in-school daily consumption of an MVM supplement by third- through sixth-grade inner-city children did not lead to improved school performance based upon standardized testing, grade point average, and absenteeism.

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

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
Description: 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.

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.
Web site: 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.

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
Description: 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.

Position of the American Dietetic Association: Child and adolescent food and nutrition programs. American Dietetic Association. *Journal of the American Dietetic Association*, 110:791-799. 20010
NAL Call Number: 389.8 Am34
Web site: http://www.eatright.org/WorkArea/linkit.aspx?LinkIdentifier=id&ItemID=8453
Description: It is the position of the American Dietetic Association that all children and adolescents, regardless of age, sex, socioeconomic status, racial diversity, ethnic diversity, 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, social, and emotional growth and development. Appropriate food and nutrition programs include food assistance and meal programs, nutrition education initiatives, and nutrition screening and assessment followed by appropriate nutrition intervention and anticipatory guidance to promote optimal nutrition status. Food and nutrition programs create a safety net that ensures that children and adolescents at risk for poor nutritional intakes have access to a safe, adequate, and nutritious food supply and nutrition screening, assessment,

and intervention. It is important that continued funding be provided for these programs, which consistently have been shown to have a positive impact on child and adolescent health and well-being. Food and nutrition programs serve as a means to prevent or reduce hunger and food insecurity, but also as a vehicle for nutrition education and promotion of physical activity designed to prevent or reduce overweight and prevent chronic disease. It is the role of the registered dietitian to support adequate and sustained funding for food and nutrition programs, universal health care reimbursement for nutrition services, and the use of research and surveillance programs to evaluate and improve these programs. In addition, the registered dietitian and dietetic technician, registered, are responsible for serving as a nutrition resource to all groups and individuals providing services to children and adolescents, acting as an advocate for the establishment of child-care, school, and community settings conducive to the development of good nutrition habits.

Pilot study: EatFit impacts sixth graders' academic performance on achievement of mathematics and English education standards. M.K. Shilts, et al. *Journal of Nutrition Education and Behavior,* 41(2):127-131. 2009.
Description: OBJECTIVE: Investigate the impact of a nutrition education program on student academic performance as measured by achievement of education standards. DESIGN: Quasi-experimental crossover-controlled study. SETTING: California Central Valley suburban elementary school (58% qualified for free or reduced-priced lunch). PARTICIPANTS: All sixth-grade students (n = 84) in the elementary school clustered in 3 classrooms. INTERVENTION: 9-lesson intervention with an emphasis on guided goal setting and driven by the Social Cognitive Theory. MAIN OUTCOME MEASURE: Multiple-choice survey assessing 5 education standards for sixth-grade mathematics and English at 3 time points: baseline (T1), 5 weeks (T2), and 10 weeks (T3). ANALYSIS: Repeated measures, paired t test, and analysis of covariance. RESULTS: Changes in total scores were statistically different ($P < .05$), with treatment scores (T3 - T2) generating more gains. The change scores for 1 English ($P < .01$) and 2 mathematics standards ($P < .05$; $P < .001$) were statistically greater for the treatment period (T3 - T2) compared to the control period (T2 - T1). CONCLUSION AND IMPLICATIONS: Using standardized tests, results of this pilot study suggest that EatFit can improve academic performance measured by achievement of specific mathematics and English education standards. Nutrition educators can show school administrators and wellness committee members that this program can positively impact academic performance, concomitant to its primary objective of promoting healthful eating and physical activity.

School feeding for improving the physical and psychosocial health of disadvantaged students. B. Kristjansson, et al. *Cochrane Database of Systematic Reviews,* Issue 1. 2007. **Description:** Early malnutrition and/or micronutrient deficiencies can negatively affect many aspects of child health and development. School feeding programs are designed to provide food to hungry children and to improve their physical, mental and psychosocial health. This is the first systematic review on the topic of school feeding. Eighteen studies were included in this review; nine were performed in higher income countries and nine in lower income countries. In the highest quality studies (randomized controlled trials (RCTs) from low income countries, children who were fed at school gained an average of 0.39 kg more than controls over 19 months; in lower quality studies (controlled before and after trials (CBAs)), the difference in gain was 0.71 kg over 11.3 months. Children who were fed at school attended school more frequently than those in control groups; this finding translated to an average increase of 4 to 6 days a year per child. For educational and cognitive outcomes, children who were fed at school gained more than controls on math achievement, and on some short-term cognitive tasks. Results from higher income countries were mixed, but generally positive. For height, results from lower income countries were mixed; in RCTs, differences in gains were important only for younger children, but results from the CBAs were large and significant overall. Results for height from high Income countries were mixed, but generally positive. School meals may have small physical and psychosocial benefits for disadvantaged pupils. We recommend that further well-designed studies on the effectiveness of school meals be undertaken, that results should be reported according to the socio-economic status of the children who take part in them, and that researchers gather robust data on outcomes that directly reflect effects on physical, social, and psychological health.

IV. Relationship Between School-Based Physical Activity and Academic Performance in the United States

The association between school-based physical activity, including physical education, and academic performance. Centers for Disease Control and Prevention, U.S. Department of Health and Human Services. Atlanta, GA. July 2010. 84 pp. **Executive Summary:** http://www.cdc.gov/HealthyYouth/health_and_academics/pdf/pape_executive_summary.pdf **Full text:** http://www.cdc.gov/HealthyYouth/health_and_academics/pdf/pa-pe_paper.pdf **Description:** There is a growing body of research focused on the association between school-based physical activity, including physical education, and academic performance among school-aged youth. To better understand these connections, this review includes studies from a range of physical activity contexts, including school-based physical education, recess, classroom-based physical activity (outside of physical education and recess), and extracurricular physical activity. The purpose of this report is to synthesize the scientific literature that has examined the association between school-based physical activity, including physical education, and academic performance, including indicators of cognitive skills and attitudes, academic behaviors, and academic achievement

V. General Role of Nutrition in Learning and Behavior in Non-U.S. Countries

Association between unhealthful eating patterns and unfavorable overall school performance. M. Fu, et al. *Journal of the American Dietetic Assn.*, 107(11):1935-1943. 2007.
Description: The objective of this article is to evaluate the relationship between children's unhealthful 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 eating habit and its influence on attention-concentration, immediate memory and school achievement. N.S. Gajre, et al. *Indian Pediatrics*, 45(10):824-828. 2008.
Description: OBJECTIVE: To study the relationship of breakfast to the attention - concentration, immediate recall memory, nutritional status and academic achievement of school children. DESIGN: Cross-sectional study. SETTING: Two schools catering to middle class families in Hyderabad city. METHODS: 379 urban 11 to 13 years old school children studying in 6th, 7th and 8th grades. Data collected in a single way blind procedure using Letter Cancellation test, immediate memory from the PGI Memory Scale, school marks of the previous year and nutritional status. RESULTS: Comparison between groups indicated significant differences in the letter cancellation (LC) total scores with the regular breakfast group achieving the highest mean scores compared to the no breakfast group ($P < 0.05$). Marks scored by the regular breakfast group in subjects - Science, English and total Percentage were significantly higher compared to those scored by the children in the no breakfast group. Regular breakfast eating habit and weight for age percent were significantly ($P < 0.001$) associated with immediate recall memory score explaining 4.3 percent variation. CONCLUSIONS: Regular habit of eating breakfast as opposed to irregular consumption or skipping breakfast altogether had beneficial influence on attention-concentration, memory and school achievement.

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.
Description: Consumption of a mid-morning snack improves memory but not attention in school children. *Physiol Behav*, 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. Computerized 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.

Context and sequelae of food insecurity in children's development. D.W. Belsky, et al. *American Journal of Epidemiology*, 172(7):809-818. 2010.
Description: The authors examined the role of food insecurity in the etiology of children's cognitive and mental health problems. Data from a prospective longitudinal study of 1,116 United Kingdom families with twins (sample constructed in 1999-2000) were used to test associations among household food insecurity; income; maternal personality; household sensitivity to children's needs; and children's cognitive, behavioral, and emotional development. Food-insecure children had lower IQs and higher levels of behavioral and emotional problems relative to their peers. After differences in household income, the personalities of children's mothers, and the sensitivity of household organization to children's needs were accounted for, food-insecure children had moderately higher levels of emotional problems relative to food-secure children ($\beta = 0.22$, $P = 0.02$). Differences in children's cognitive development were accounted for by household income, and differences in their behavioral development were accounted for by their mothers' personalities and their households' sensitivity to children's needs. Results suggest that food insecurity was associated with school-aged children's emotional problems but not with their cognitive or behavioral problems after accounting for differences in the home environments in which children were reared. Mothers' personality and household sensitivity to children's needs may present challenges to improving outcomes of children with food insecurity.

Diet and mental health in children. D. Tomlinson, et al. *Child and Adolescent Mental Health*, 14(3):148-155. 2009.
Description: The role played by diet in mental health is of increasing interest to patients, parents, health professionals and public policy makers. This review examines the literature assessing the role of diet in childhood cognitive development, school performance and behaviour. The effects of inadequate dietary intake and of nutrient supplements are considered. Studies of diet and specific psychiatric diagnoses such as depression and psychosis are discussed, with a focus on the evidence for the child and adolescent population.

Dietary patterns in infancy and cognitive and neuropsychological function in childhood. C.R. Gale, et al. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, 50(7):816-823. 2010.
Description: Background: Trials in developing countries suggest that improving young children's diet may benefit cognitive development. Whether dietary composition influences young children's cognition in developed countries is unclear. Although many studies have examined the relation between type of milk received in infancy and subsequent cognition, there has been no investigation of the possible effect of variations in the weaning diet. Methods: We studied 241 children aged 4 years, whose diet had been assessed at age 6 and 12 months. We measured IQ with the Wechsler Pre-School and Primary Scale of Intelligence, visual attention, visuomotor precision, sentence repetition and verbal fluency with the Developmental Neuropsychological Assessment (NEPSY), and visual form-constancy with the Test of Visual Perceptual Skills. Results: In sex-adjusted analyses, children whose diet in infancy was characterised by high consumption of fruit, vegetables and home-prepared foods (infant guidelines' dietary pattern) had higher full-scale and verbal IQ and better memory performance at age 4 years. Further adjustment for maternal education, intelligence, social class, quality of the home environment and other potential confounding factors attenuated these associations but the relations between higher 'infant guidelines' diet score and full-scale and verbal IQ remained significant. For a standard deviation increase in infant guidelines' diet score at 6 or 12 months full-scale IQ rose by. 18 (95% CI .04 to .31) of a standard deviation. For a standard deviation increase in 'infant guidelines' diet score at 6 months verbal IQ rose by .14 (.01 to .27) of a standard deviation. There were no associations between dietary patterns in infancy and 4-year performance on the other tests. Conclusions: These findings suggest that dietary patterns in early life may have some effect on cognitive development. It is also possible that they reflect the influence of unmeasured confounding factors.

A good-quality breakfast is associated with better mental health in adolescence. T.A. O'Sullivan, et al. *Public Health Nutrition*, 12(2):249-258. 2009.
NAL Call Number: RA784.P83
Description: OBJECTIVE: Breakfast consumption has been associated with better mental health in adulthood, but the relationship between breakfast and mental health in adolescence is less well known. The aims of the present study were to evaluate breakfast quality in a cohort of adolescents and to investigate associations with mental health. DESIGN: Cross-sectional population-based study. Breakfast quality was assessed by intake of core food groups at breakfast, as determined from 3 d food diaries. Mental health was assessed using the Child Behaviour Checklist (CBCL), with higher scores representing poorer behaviour. SETTING: The Western Australian Pregnancy Cohort (Raine) Study, Perth, Western Australia. SUBJECTS: Eight hundred and thirty-six males and females aged between 13 and 15 years. RESULTS: Mean mental health score as assessed by the CBCL was 45.24 (sd 11.29). A high-quality breakfast consisting of at least three food groups was consumed by 11 % of adolescents, while 7 % of adolescents did not consume any items from core food groups on average over the 3 d period. The two most common core food groups consumed at breakfast in this population were dairy products followed by breads and cereals. For every additional food group eaten at breakfast, the associated total mental health score decreased by 1.66 (95 % CI -2.74, -0.59) after adjustment for potential confounding factors, representing an improvement in mental health score. CONCLUSION: These findings support the concept that breakfast quality is an important component in the complex interaction between lifestyle factors and mental health in early adolescence.

INCAP studies of malnutrition and cognitive behavior. P.L. Engle, et al. *Food and Nutrition Bulletin*, 31(1):83-94. 2010.
Description: The Institute of Nutrition of Central America and Panama (INCAP) has made major contributions to the study of the effects of malnutrition on learning. This report summarizes work on the relationship of nutrition to children's learning and development from the 1960s through 1998. The Oriente Longitudinal Study examined the effects of two types of supplementation for mothers and young children on their growth and development (an energy-only drink compared with a protein-energy drink) using a quasi-experimental design. Both drinks were supplemented with micronutrients, and were offered daily. As a result of the research on malnutrition and mental development, researchers could conclude by 1993 that supplementary feeding of infants and young children resulted in significant increases cognitive development and school performance through adolescence. The research also suggested that the pathways that link malnutrition with later development are not only through the neurological system but also operate through changes in child behavior which affect the kinds of care children receive. Other research on learning and development showed that families understood the concept of intelligence, demonstrated the link between micronutrients and cognitive development, and documented the amount of wastage or repetition and drop-out that occurs in Guatemalan schools.

Influence of having breakfast on cognitive performance and mood in 13- to 20-year-old high school students: results of a crossover trial. K. Widenhorn-Müller, et al. *Pediatrics,* 122(2):279-84. 2008.
Description: OBJECTIVE: The goal was to determine whether breakfast had effects on the cognitive performance and mood of high school students. METHODS: A crossover trial was performed in boarding schools, involving 104 students between 13 and 20 years of age. The participants were randomly assigned to 2 equal-size groups on the morning of the first testing day. One half of the total sample received a standardized breakfast, whereas the other half received no breakfast. Seven days later, the treatment order was reversed. Measurements of cognitive function included standardized tests of attention and concentration, as well as tests of verbal and spatial memory. In addition, mood was rated with a self-administered questionnaire covering the dimensions of positive and negative affect, information uptake, arousal, and alertness. Statistical analysis consisted of repeated-measures analysis of variance. RESULTS: Breakfast had no effect on sustained attention among high school students. Visuospatial memory was improved in male students. Self-reported alertness improved significantly in the entire study population. Male students reported feeling more positive after consuming breakfast, compared with the fasting condition. CONCLUSIONS: This crossover trial demonstrated positive short-term effects of breakfast on cognitive functioning and self-reported alertness in high school students.

Normative and cognitive correlates of breakfast skipping in 9-11-year-old schoolchildren in Wales. G.F. Moore**,** *Appetite.* Dec; 53(3):332-7. 2009.
Description: AIMS: This study aims to explore associations of attitudes towards breakfast, self-efficacy and normative perceptions (in relation to parents, peers and teachers) with breakfast skipping in 9-11-year-old schoolchildren in Wales. METHODS: A cross-sectional design was employed. Data were collected using self-report measures of attitudes towards breakfast, parental and peer descriptive norms, parental, peer and teacher related injunctive norms, self-efficacy for eating breakfast and self-reported habitual breakfast skipping. Participants were 1672 year 5 and 6 pupils within 52 schools in 9 local education authorities across North, South and West Wales. RESULTS: Bivariate analyses indicated that all variables, with the exception of peer-related injunctive norms, were associated with breakfast skipping. In multivariate ordinal logistic regression analyses, adjusted for clustering at the school-level, only attitudes towards breakfast, parental descriptive norms and self-efficacy for eating breakfast were significantly associated with breakfast skipping. CONCLUSIONS: The associations reported in this paper highlight the need to consider attitudinal and normative factors when attempting to facilitate change in children's breakfast eating behaviours, as well as investigating means of enhancing self-efficacy. Impacts of school breakfast provision on these factors, as well as the impact of these factors on uptake of school breakfast provision merit investigation.

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.
Description: 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.

A systematic review of the effect of dietary exposure that could be achieved through normal dietary intake on learning and performance of school-aged children of relevance to UK schools. L.J. Ells, et al. *British Journal of Nutrition,* 100(5):927-36. 2008.
Description: The aim of the present review was to perform a systematic in-depth review of the best evidence from controlled trial studies that have investigated the effects of nutrition, diet and dietary change on learning, education and performance in school-aged children (4-18 years) from the UK and other developed countries. The twenty-nine studies identified for the review examined the effects of breakfast consumption, sugar intake, fish oil and vitamin supplementation and 'good diets'. In summary, the studies included in the present review suggest there is insufficient evidence to identify any effect of nutrition, diet and dietary change on learning, education or performance of school-aged children from the developed world. However, there is emerging evidence for the effects of certain fatty acids which appear to be a function of dose and time. Further research is required in settings of relevance to the UK and must be of high quality, representative of all populations, undertaken for longer durations and use universal validated measures of educational attainment. However, challenges in terms of interpreting the results of such studies within the context of factors such as family and community context, poverty, disease and the rate of individual maturation and neurodevelopment will remain. Whilst the importance of diet in educational attainment remains under investigation, the evidence for promotion of lower-fat, -salt and -sugar diets, high in fruits, vegetables and complex carbohydrates, as well as promotion of physical activity remains unequivocal in terms of health outcomes for all schoolchildren.

VI. Role of Nutrients in Learning and Behavior in Non-U.S. Countries

The association of iron status with educational performance and intelligence among adolescents. D.S. Dissanayake, et al. *Ceylon Med J.* 54(3):75-9. 2009.
Description: INTRODUCTION: The aim was to identify the association of iron status with educational performance and intelligence of adolescents. METHOD: This was a cross sectional comparative study among adolescents aged 13-15 years. Each iron deficient student was matched with an iron sufficient student from the same school, class and sex. Iron status was based on haemoglobin and serum ferritin levels. The marks for mathematics, science, Sinhala language and social science were considered to assess educational performance. Intelligence was measured by Raven's Standard progressive matrices. All the possible confounders and effect modifiers were considered. Home visits to a sub-sample checked the quality of data. RESULTS: The final analysis included 188 students (94 matched pairs). Neither educational performance nor intelligence showed significant associations with the iron status. The severity of the iron deficiency did not relate to these cognitive variables either. Twenty-three and 8 co-variables showed statistically significant associations with educational performance and intelligence respectively. Following a multiple regression analysis intelligence, the enthusiasm of the student towards learning, occupational ambition, household possession, problems at home and private tuition for mathematics were key factors predicting educational performance. Stunting and educational level of the mother were important factors influencing intelligence. CONCLUSION: Iron status does not play a major role in educational performance and intelligence of school going adolescents. Several factors affect educational performance and intelligence. This study highlights the difficulty in extrapolating the findings of similar studies to different ecological settings.

Comparative study on supplementation of potato flour biscuits on the nutritional and cognitive profile of the selected children. P. Nazni, et al. *Iranian Journal of Pediatrics*, 19(3):285-292. 2009.
Description: Objective: Nutrition of the early childhood is of paramount importance because the foundation for life time strength and intellectual vitality is laid during this period. The present study aims to evaluate the effect of weaning biscuits supplementation of the nutritional parameters and cognitive performance of the selected children. Methods: Three Balwadies situated in Salem District, Tamilnadu, India were selected. A total number of 40 school children in Grade II malnutrition, 15 from Balwadi I, 14 from Balwadi II and 11 from Balwadi III comprised the study sample. All the 40 were selected for the experimental study. Home diet without any supplementation was followed by Group I (n=10, control group), potato flour biscuit was supplemented to Group II (n=10), Maize biscuits were given to Group III (n=10) and Green gram biscuits were given to Group IV (n=10) for the period of 3 months. Parameters like anthropometric measurements, hemoglobin content and clinical picture were analyzed before and after supplementation, cognitive performance of the supplemented children was assessed at the end of the study period. Findings: There was significant difference in height, weight, blood hemoglobin and clinical picture after three months on their home diet in group I. In groups II, III and IV significant increase in all the above parameters was noticed. More increase was found in group II children supplemented with potato flour biscuits for a period of 3 months. About cognitive performance better results were obtained in Group II followed by group IV (supplemented with green gram biscuits) and group III

(supplemented with maize biscuits). Least was obtained by control group children who were in their home diet. Conclusion: All these observations evidence that if such weaning biscuits made with potato flour, maize and green gram can form a daily ingredient in their diets, it will bring out better all round development of the children.

Dietary habits, economic status, academic performance and body mass index in school children: a comparative study. K. Kukulu et al. *Jnl of Child Health Care.* 14(4):355-66. 2010.
Description: Abstract: The changes in dietary habits and way of life of adolescents can lead to some nutrition problems. The purpose of this study was to compare dietary habits of children living in metropolitan and non-metropolitan areas regarding their physical characteristics, socio-economic milieu and educational level. A total of 737 students studying in the 6th, 7th and 8th grades of two different primary schools took part in the study. Data were collected by a questionnaire including dietary habits of participants. Furthermore, the weight and height of students were measured and their body mass index was calculated. During the study, while 4.3 percent of students living in the non-metropolitan area were found obese, this figure was 8.4 percent in the metropolitan area. A big majority of non-metropolitan students have breakfast and lunch at home. Metropolitan students not having lunch at home have their lunch at restaurants or school canteens and generally consume more snacks. The obesity risk of students participating in the study was found to be high. Intervention programs should be organized in order to inform the students about the importance of healthy nutrition and lead them to change their current consumption behavior.

Dietary micronutrients are associated with higher cognitive function gains among primary school children in rural Kenya. C.A. Gewa, et al. *British Journal of Nutrition.* 101(9):1378-87. 2009.
Description: With the exception of iodine and Fe, there is still very limited information on the effect of micronutrients on cognitive function, especially among school-age children. The present analysis evaluates the relationship between dietary Fe, Zn and B vitamins (B12, B6, folate and riboflavin) and gains in cognitive test scores among school children in rural Kenya. Data for the present study were obtained from The Child Nutrition Kenya Project, a 2-year longitudinal, randomised controlled feeding intervention study using animal source foods. Dietary nutrient values were based on monthly and bimonthly 24 h recall data collected during the study period. In longitudinal regression analyses, available Fe, available Zn, vitamin B12 and riboflavin showed significant relationships with improved cognitive test scores, after controlling for confounders such as energy intake, school, socio-economic status and morbidity. Available Fe intake was associated with significantly higher gains in Raven's Coloured Progressive Matrices test scores over time. Available Zn intake was associated with significantly higher gains in digit span-total test scores over time, while vitamin B12 and riboflavin intakes were each associated with significantly higher gains in digit span-forward test scores over time. This analysis demonstrates the influence of improved dietary micronutrient status on school children's cognitive function.

The glycaemic potency of breakfast and cognitive function in school children.
R. Micha, et al. *European Journal of Clinical Nutrition* 64(9):948-57. 2010.
Description: OBJECTIVES: The aim of this study was to assess how the glycaemic potency (blood glucose (BG)-raising potential) of breakfast is associated with cognitive function (CF) in school children, taking into account important confounders, including iron status, underlying physiological adaptations and socio-economic status. METHODS: Sixty children aged 11-14 years were selected on the basis of having breakfast habitually. Their breakfast and any snacks eaten on the morning of the study were recorded. They were categorized into four groups according to the glycaemic index (GI) and glycaemic load (GL) of the breakfast: low-GI, high-GL; high-GI, high-GL; low-GI, low-GL and high-GI, low-GL above or below the median for GI=61 and GL=27. BG levels were measured in finger-prick blood samples immediately before and immediately after the CF tests. RESULTS: A low-GI, high-GL breakfast was associated with better performance on a speed of information processing ($P<0.01$) and a serial sevens ($P<0.001$) task 90 min later; a high-GI breakfast with better performance on an immediate word recall task ($P<0.01$); and a high-GL breakfast with better performance on a Matrices task ($P<0.01$). CONCLUSIONS: GI, GL or both were associated with performance on the majority of the CF tests (4 of 7) used. This study describes the macronutrient composition of breakfast that could have a positive influence on the cognition of school children, proposes the use of both GI and GL to estimate exposure, and discusses future directions in this area of research.

Health behavior and academic achievement among adolescents: the relative contribution of dietary habits, physical activity, body mass index, and self-esteem.
A.L. Kristjánsson, *Health Education and Behavior.* 37(1):51-64. 2010.
Description: Abstract: This study tested a structural equation model to estimate the relationship between health behaviors, body mass index (BMI), and self-esteem and the academic achievement of adolescents. The authors analyzed survey data from the 2000 study of Youth in Iceland , a population-based, cross-sectional sample of 6,346 adolescents in Iceland. The model demonstrated good fit with chi-square of 2685 ($n = 5,810$, $df = 180$), $p < .001$, Comparative Fit Index value of .94, and a root mean square error of approximation of .049. Lower BMI, physical activity, and good dietary habits were all associated with higher academic achievement; however, health behavior was positively and robustly associated with greater self-esteem. Self-esteem was positively influenced both through physical activity (beta = .16) and the consumption of fruits and vegetables (beta = .14). In contrast, poor dietary habits negatively influenced self-esteem and academic achievement, and self-esteem was negatively influenced by increasing levels of BMI (beta = -.05).

The influence of dietary status on the cognitive performance of children. D. Benton. *Molecular Nutrition and Food Research*, 54(4):457-470. 2010.
Description: The rapid rate of growth of the brain during the last third of gestation and the early postnatal stage makes it vulnerable to an inadequate diet, although brain development continues into adulthood and micronutrient status can influence functioning beyond infancy. Certain dietary deficiencies during the first 2 years of life, for example iodine and iron, create problems that are not reversed by a later adequate diet. It is important that the intake of micronutrients varies greatly between individuals as they are essential for metabolism in general and in particular cell division and hence growth. In developing countries, there is consistent evidence that the adequacy of diet has lasting implications for cognitive development. In particular, attention has been directed to protein-calorie malnutrition and more specifically the intake of iron, iodine and vitamin A, a deficiency of which damages eyesight. In industrialized countries variations in diet are less influential, although a few well-designed studies have reported that multivitamin and mineral supplementations influence anti-social behaviour and intelligence. In the short term, there is increasing evidence that the missing of breakfast has negative consequences late in the morning. A working hypothesis is that meals of a low rather than high glycaemic load are beneficial.

Micronutrient status, cognition and behavioral problems in childhood. Benton D. *European Journal of Nutrition,* 47(Suppl 3):38-50. 2008.
Description: It is widely accepted that the rapid rate of growth of the brain during the last third of gestation and the early postnatal stage makes it vulnerable to an inadequate diet, although brain development continues into adulthood and micronutrient status can influence functioning beyond infancy. A deficiency of various micro-nutrients in developing countries has been found to have long-term implication for cognitive development. Vitamin A plays a critical role in visual perception and a deficiency is the leading cause of childhood blindness. A lack of iodine during a critical period in brain development is associated with reduced intellectual ability. Iron shortage is a widespread problem in the developing world but also in industrialized countries. There is evidence that iron deficiency in early life adversely effects brain development. In addition in industrialized countries a role for folate in the prevention of neural tube defects is well established and in a few individuals impaired cognitive functioning is associated with the inadequate provision of vitamin B(12.)The controversial suggestions that sub-clinical deficiencies of micronutrients may in industrialized societies influence anti-social behavior and intelligence are also discussed.

Multiple micronutrient supplementation for improving cognitive performance in children: systematic review of randomized controlled trials. A. Eilander, et al. *American Journal of Clinical Nutrition,* 91(1):115-130. 2010.
Description: BACKGROUND: Although multiple micronutrient interventions have been shown to benefit children's intellectual development, a thorough evaluation of the totality of evidence is currently lacking to direct public health policy. OBJECTIVE: This study aimed to systematically review the present literature and to quantify the effect of multiple micronutrients on cognitive performance in schoolchildren. METHODS: The Institute for Scientific Information Web of Knowledge and local medical databases were searched for trials published from 1970 to 2008. Randomized controlled trials that investigated the effect of > or =3 micronutrients compared with placebo on cognition in healthy children aged 0-18 y were included following protocol. Data were extracted by 2 independent researchers. The cognitive tests used in the trials were grouped into several cognitive domains (eg, fluid and crystallized intelligence), and pooled effect size estimates were calculated per domain. Heterogeneity was explored through sensitivity and meta-regression techniques. RESULTS: Three trials were retrieved in children aged <5 y, and 17 trials were retrieved in children aged 5-16 y. For the older children, pooled random-effect estimates for intervention were 0.14 SD (95% CI: -0.02, 0.29; P = 0.083) for fluid intelligence and -0.03 SD (95% CI: -0.21, 0.15; P = 0.74) for crystallized intelligence, both of which were based on 12 trials. Four trials yielded an overall effect of 0.30 SD (95% CI: 0.01, 0.58; P = 0.044) for academic performance. For other cognitive domains, no significant effects were found. CONCLUSIONS: Multiple micronutrient supplementation may be associated with a marginal increase in fluid intelligence and academic performance in healthy schoolchildren but not with crystallized intelligence. More research is required, however, before public health recommendations can be given.

Fish consumption and school grades in Swedish adolescents: a study of the large general population. JL Kim, et al. *Acta Paediatrica.* 99(1):72-7. 2010.
Description: AIM: To study the associations between fish intake and academic achievement as cognitive parameter among Swedish adolescents. METHODS: In 2000, a questionnaire including respiratory items, socioeconomic conditions and dietary information was mailed to all schoolchildren (n = 18 158), aged 15 and living in Västra Götaland region of Sweden. The questionnaire was returned by 10 837 subjects. One year later, the total school grades for each subject who had completed the questionnaire and who included their full personal identification number were obtained from the national registers. Multiple linear regression models were applied to evaluate the association between fish intake and academic grades among 9448 schoolchildren, while adjusting for potential confounders, e.g. parents' education. RESULTS: Grades were higher in subjects with fish consumption once a week compared with subjects with fish consumption of less than once a week (reference group) [increment in estimate 14.5, 95% confidence interval (CI) 11.8-17.1]. Grades were even higher in subjects with fish consumption of more than once a week compared with the reference group (increment in estimate 19.9, 95% CI 16.5-23.3). In the model stratified for parents' education, there were still higher grades among subjects with frequent fish intake in all educational strata ($p < 0.01$). CONCLUSION: Frequent fish intake among schoolchildren may provide benefits in terms of academic achievement.

Significance of long-chain polyunsaturated fatty acids (PUFAs) for the development and behaviour of children. P. Schuchardt, et al. *European Journal of Pediatrics*, 169(2):149-164. 2010.
Description: ω6 and ω3 polyunsaturated fatty acids (PUFAs) play a central role in the normal development and functioning of the brain and central nervous system. Long-chain PUFAs (LC-PUFAs) such as eicosapentaenoic acid (EPA, C20:5ω3), docosahexaenoic acid (DHA, C22:6ω 3) and arachidonic acid (AA, C20:4ω6), in particular, are involved in numerous neuronal processes, ranging from effects on membrane fluidity to gene expression regulation. Deficiencies and imbalances of these nutrients, not only during the developmental phase but throughout the whole life span, have significant effects on brain function. Numerous observational studies have shown a link between childhood developmental disorders and ω6:ω 3 fatty acid imbalances. For instance, neurocognitive disorders such as attention-deficit hyperactivity disorder (ADHD), dyslexia, dyspraxia and autism spectrum disorders are often associated with a relative lack of ω3 fatty acids. In addition to a high ω6 fatty acid intake and, in many cases, an insufficient supply of ω3 fatty acids among the population, evidence is increasing to suggest that PUFA metabolism can be impaired in individuals with ADHD. In this context, PUFA imbalances are being discussed as potential risk factors for neurodevelopmental disorders. Another focus is whether the nutritive PUFA requirements—especially long-chain ω3 fatty acid requirements—are higher among some individuals. Meanwhile, several controlled studies investigated the clinical benefits of LC-PUFA supplementation in affected children and adolescents, with occasionally conflicting results.

Undernutrition, fatty acid and micronutrient status in relation to cognitive performance in Indian school children: a cross-sectional study. A. Eilander et al. *British Journal of Nutrition*, 103(7):1056-64. 2010.
Description: While undernutrition and anaemia have previously been linked to poor development of children, relatively little is known about the role of B-vitamins and fatty acids on cognition. The present study aims to explore the associations between indicators of body size, fatty acid and micronutrient status on cognitive performance in 598 Indian school children aged 6-10 years. Baseline data of a clinical study were used to assess these associations by analyses of variance adjusting for age, sex, school, maternal education and cognitive tester. The Kaufman Assessment Battery for Children II was used to measure four cognitive domains, including fluid reasoning, short-term memory, retrieval ability and cognitive speediness. Scores were combined into an overall measure, named mental processing index (MPI). Body size indicators and Hb concentrations were significantly positively related to cognitive domains and MPI, such that increases of 1 sd in height-for-age and weight-for-age z-scores would each translate into a 0.09 sd increase in MPI, P = 0.0006 and 0.002, respectively. A 10 g/l increase in Hb concentrations would translate into a 0.08 sd increase in MPI, P = 0.0008. Log-transformed vitamin B12 concentrations were significantly inversely associated with short-term memory, retrieval ability and MPI (beta (95 % CI) = - 0.124 (- 0.224, - 0.023), P = 0.02). Other indicators of Fe, iodine, folate and fatty acid status were not significantly related to cognition. Our findings for body size, fatty acids and micronutrients were in agreement with previous observational studies. The inverse association of vitamin B12 with mental development was unexpected and needed further study.

VII. Role of School Meals Programs in Learning and Behavior in Non-U.S. Countries

Breakfast clubs: Availability for British schoolchildren and the nutritional, social and academic benefits. M.A. Defeyter, et al. *Nutrition Bulletin*, 35(3):245-253. 2010.
Description: Breakfast clubs are not a new resource for parents and children, but interest in them has heightened, because of both the need for improvement in school food and political interest in their availability across the devolved countries. It has been suggested that concrete scientific evidence as to their benefits to academic performance be required before a breakfast club should be available for children across the UK. It is inappropriate to correlate crude measures such as Standard Assessment Test (SAT) scores and exam results with breakfast club provision, and the focus of analysis should be individual pupil benefit (both scholastically and socially), nutrient intake, meal provision and even assisting working parents with child care. There is limited data available to investigate the adequacy of food provision in school breakfast clubs, but there is now sufficient information available for breakfast club organisers to provide a nutritionally balanced breakfast. A body of evidence is emerging that demonstrates the benefits of breakfast club attendance to mental performance and social development. However, it is unclear whether such benefits are derived from the consumption of breakfast per se, the environment or a combination of the two. It is reasonably safe to conclude that the benefits of breakfast clubs are more pronounced in deprived areas, and efforts of charities to support breakfast clubs should focus in these areas. Given the role and importance of school breakfast clubs, ContinYou, a leading national charity, pledged support in establishing 200 more school breakfast clubs over 2009 and 2010.

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.
Description: 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.

A randomized controlled trial of the effect of school food and dining room modifications on classroom behaviour in secondary school children. H.C. Storey HC, et al. *European Journal of Clinical Nutrition,* 65(1):32-8. 2011.
Description: BACKGROUND/OBJECTIVES: Adequate nutrition is considered important for learning, but there is little robust research on the association between diet and learning in school-aged children in industrialized countries. This study investigated the effect of tailored modifications to the food and dining experience in secondary schools on learning-related behaviours. SUBJECTS/METHODS: In 2008, 12 co-educational secondary schools in England were recruited. Schools were randomly allocated to receive a tailored action plan and support to modify their food provision and dining environment over a 15-week period (intervention or to control). Learning-related behaviours were systematically observed during post-lunchtime classes at all schools. Observations were made by trained observers using a validated protocol to determine whether pupils were 'on-task' (concentrating and alert) or 'off-task' (disruptive or disengaged). RESULTS: In total, 156 pupils were observed (control n = 58, intervention n = 98) at baseline (12,210 and 20,560 observations, control and intervention, respectively) and at follow-up (16,846 and 23,462, respectively). On-task and off-task behaviours were similar across treatment groups at baseline. At follow-up, intervention group pupils were 18% more likely to be on-task (odds ratio (OR) 1.18, 95% confidence interval ((95% CI) 1.05-1.33) and 14% less likely to be off-task (OR 0.86, 95% CI 0.75-0.98) compared with control group pupils.Conclusions:This study suggests that modifying food provision and the dining environment can improve learning-related behaviours of secondary school pupils in the post-lunch period. This finding supports ongoing investment and interventions by local authorities across the United Kingdom to improve school food and lunchtime dining facilities.

School lunch and learning behaviour in primary schools: An intervention study. R. Golley, et al. *European Journal of Clinical Nutrition*, 64:1280-1288. 2010.
Description: Background/Objectives: In addition to the nutritional benefits of healthier school food, anecdotes describe improvements in children's behaviour and educational outcomes when school food or the school dining room environment is improved. This study hypothesized that a school food and dining room intervention would improve pupils' learning-related classroom behaviour. Subjects/Methods: A controlled intervention trial involving six primary schools matched in triplets and randomly assigned to a 12-week intervention (promotion of healthier school food at lunchtime and changes in the school dining environment) or 12-week wait-listed control group. Study outcome was learning-related behaviours measured in a random sample of 146 pupils in years 3–5. Results: On-task and off-task behaviours were observed and used as proxy measures for concentration and disengagement (disruption), respectively. Teacher–pupil on-task engagement was 3.4 times more likely in the intervention schools compared with the control schools (adjusted model odds ratio (OR)=3.40 (95% confidence interval (CI)=1.56, 7.36), P=0.009). However, on-task pupil–pupil behaviour was less likely in the intervention group (adjusted model OR=0.45 (95% CI=0.28, 0.70), P<0.001). Similarly, off-task pupil–pupil behaviour was more likely in the intervention group than in the control group in both the unadjusted model (OR=2.18 (95% CI=1.52, 3.13), P<0.001) and the adjusted model (OR=2.28 (95% CI=1.25, 4.17), P=0.007). Conclusions: This study offers some support for the hypothesis that a school food and dining room intervention can have a positive impact on pupils' alertness. However, if raised alertness is not channelled and supervised, it may result in increased off-task behaviour when pupils are working together.

A systematic review of the effect of breakfast on the cognitive performance of children and adolescents. A. Hoyland, A., et al. *Nutrition Research Reviews,* 22(2):220-243. 2009.
Description: Breakfast is recommended as part of a healthy diet because it is associated with healthier macro- and micronutrient intakes, BMI and lifestyle. Breakfast is also widely promoted to improve cognitive function and academic performance, leading to the provision of breakfast initiatives by public health bodies. Despite this positive and intuitive perception of cognitive benefits, there has been no systematic review of the evidence. Systematic review methodology was employed to evaluate the effects of breakfast on cognitive performance in well-nourished children and nutritionally at-risk or stunted children. Acute experimental studies, school feeding programmes and studies of habitual breakfast intake are reviewed. Comparisons of breakfast v. no breakfast and breakfasts differing in energy and macronutrient composition are discussed. Included are forty-five studies described in forty-one papers published between 1950 and 2008. The evidence indicates that breakfast consumption is more beneficial than skipping breakfast, but this effect is more apparent in children whose nutritional status is compromised. There is a lack of research comparing breakfast type, precluding recommendations for the size and composition of an optimal breakfast for children's cognitive function. Few studies examined adolescents. Studies of school breakfast programmes suggest that such interventions can have positive effects on academic performance, but this may be in part explained by the increased school attendance that programmes encourage. The present systematic review considers methodological issues in this field and makes recommendations for future research design and policy priorities.

VIII. Web Sites

Breakfast for Learning
Food Research & Action Center
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.

Breakfast Resources
International Food Information Council (IFIC) Foundation
http://www.foodinsight.org/For-Consumers/Breakfast-Resources.aspx
Description: Resources for consumers and health professionals highlighting research on the benefits of breakfast.

School Meals
USDA, Food and Nutrition Service
http://www.fns.usda.gov/cnd/
Description: Program homepage includes guidance materials, program history, regulations, menu planning information, income eligibility guidelines, and more.

Healthy Meals Resource System: Nutrition, Learning and Behavior Reports and Studies
USDA, National Agricultural Library, Food and Nutrition Information Center
http://healthymeals.nal.usda.gov/hsmrs/nutritionlearning
This section of the Healthy Meals Resource System site provides online access to reports and studies related to the role of nutrition in learning and behavior.

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