

The Abell Report

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VITAMINS AND VIOLENCE: Can Micronutrients Make Students Behave, Schools Safer and Test Scores Better?

Vitamins-and-violence theories remain tantalizing; the idea seems like common sense to many.

by Joann Ellison Rodgers

The notion that vitamins, minerals, and other “supplemental” nutrients profoundly change behavior, mood, and intellect has origins as old as recorded history. Plato, Ovid, and Hippocrates all weighed in with dietary advice for the ideal mental life, long ago connecting nutrition, behavior, and the brain. By the 18th century, aggression, irritability, and depression were linked to pellagra and beriberi, diseases treatable with foods rich in what would later be identified as thiamin and niacin, members of the vitamin B family. Vitamins-and-violence theories built steam as epidemiologists compared diets and behavior across large populations, and fish became fashionable as “medicine for hot tempers” long before omega-3 fatty acids (found abundantly in seafood) were linked by U.S. government researchers to reduced homicides and aggression.

In the 20th century, scientists began exploring the molecular make-up of foods and their links to hormones, brain chemistry, and behavior, and by 1968, Nobel Laureate Linus Pauling would contribute the concept of “orthomolecular” psychiatry in a famous paper in the journal *Science*, promoting treatments based on “the provision of the optimum molecular environment for the mind.” Although his belief that mega doses of vitamins could prevent or cure serious mental illness was discredited, his work reinforced the idea that nutrients and foods have powerful effects on behavior.

These days, aided by the \$60 billion-a-year U.S. supplements industry, all man-

ner of advocates tout the behavioral wonders of an alphabet of nutrients, notably B vitamins (including folic acid, niacin, thiamin, and riboflavin), zinc, magnesium, iron, chromium, calcium, selenium, choline, essential fatty acids, tryptophan, cysteine, and glutamine. Foods rich in antioxidants and other micronutrients are said to “rebalance” neurotransmitters like dopamine and serotonin to reduce depression, aggression, irritability, and learning problems. Adding to the movement is mounting worry about stress hormones, environmental chemicals, food additives, and a trans-fat rich Western diet that puts our Stone Age biologies under siege—all topped off by the output of the 1990’s “Decade of the Brain,” a neuroscientific juggernaut that led to a growing appreciation of an energy-hungry brain that’s 2 percent of our body mass but uses 20 percent of our energy intake.

While scientifically distorted hypotheses like the “Twinkie Defense,” which blamed sugar for violent behavior, deservedly fell by the wayside, assorted vitamin, mineral, and fatty-acid schemes for improving intellect, and preventing or reducing antisocial and criminal behavior in children, teens, and young adults, have aligned nicely with urban America’s growing rate of “fast food” addiction, school failures, and rising juvenile-delinquency rates.

Research has indeed suggested *connections* between nutrient deficiencies and behavior problems, but correlations are not the same as causality. Historical-

ly, leaps of faith in supplementation so lack scientific affirmation that “the taint of pseudoscience,” as one expert puts it, falls on almost everyone studying diet and behavior. Unsurprisingly, a vast majority of credible educators, nutritional scholars, funding organizations, and behavioral scientists consider claims in support of the vitamins-and-violence hypothesis intellectually dead on arrival, “junk science,” or the province of unprincipled vitamin peddlers.

Their skepticism is understandable. Consider the case of Ariel Academy, a neighborhood public “magnet” school on Chicago’s heavily minority and poor South Side. In 2004, Ariel signed on with Pfeiffer Treatment Center (PTC) in nearby Warrenville, Illinois, a self-described “world leader” in nutrient treatment of “chemical imbalances” to treat autism, for a study of a small number of students with behavior and/or learning problems. After a battery of chemical tests, 20 students got specially compounded supplement capsules twice a day. Five dropped out because of nausea; of the 15 who remained, PTC reported “dramatic improvements... especially in the cases of severe behavioral problems.”

But experts in the design of clinical trials say it is unclear what was wrong if anything with the children’s “chemical balances” to begin with, because there are no agreed upon standards or predictable consequences of the “imbalances.” There was no control group of similarly affected children to compare to the treated group, nor did PTC or the

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school submit its data for independent peer review.

Similar is the story of an Appleton, Wisconsin, high school, which in 1997 was reported to be full of students described in one news account as “rude, obnoxious, and ill-mannered.” Several years later, the student body was reputedly transformed into a happy band of the “calm and well behaved.” According to a popular documentary, the change came after the principal replaced all the soda pop machines with water coolers, and the usual fat- and starch-laden school menu with fresh fruits, whole grains, and salad bars.

Scientists, however, point out that any number of factors besides dietary changes could have altered student behavior over a period of years. How about different (better) teachers? A turned-over student population with more involved parents? Economic prosperity and better home diets? Differences in how teachers and security staff sorted out normal rambunctiousness from “disciplinary” problems?

In one other example, William J. Walsh, a chemical engineer and founder of PTC and its Health Research Institute, gave proprietary “customized” collections of vitamins, minerals, amino acids, and other nutrients to 207 patients with attention deficit disorder, physical aggression, destructive behaviors, and “oppositional defiant” disorders diagnosed by analyzing 90 biochemical “factors.” All were reported to have “imbalances” in copper/zinc ratios, depressed blood histamine, heavy metal overload, and glucose “dyscontrol.”

PTC published a paper concluding that 92 percent of the test subjects *themselves* reported reduced frequency of assaults. There were no independent comparisons between or among test populations, only observations or self reports of “before-and-after” symptoms in the

same subject, a study design considered so weak that even Walsh and his team concluded that “to confirm these results and evaluate the potential of biochemical therapy as a crime-prevention measure will require double-blind, placebo-controlled studies.”

The bottom line is that *no one* can figure out what actually happened to those at Ariel or Appleton or the PTC subjects, because studies like these are highly unreliable, and carry hidden booby traps for the unwary seeker of simple solutions to complicated problems.

Nevertheless, vitamin-violence theories remain tantalizing because if there were reliable evidence that supplements make a difference in behavior and learning, school and prison officials are likely to want to try them. The costs and risks of daily vitamin pills are generally considered low and their use, like chicken soup, widely perceived as harmless at worst. Finally, the idea just seems like “common sense” to many. “Suggesting that the vast changes in human nutrition in the past 50 or 100 years haven’t had something to do with alterations in behavior doesn’t pass the silly test,” says Bernard Gesch, a British criminologist and nutrition researcher.

The problem is that before even “chicken soup” becomes public policy, scientists insist on clarity of purpose, proof of principle, and measurable outcomes.

Critics of the idea of supplementation say opportunities for misunderstanding, misinterpretation of data, unethical “labeling” of “troublesome” children, and unintended consequences are vast. They argue that the complexity of the interactions of nutrients cries out for paying more attention to an overall balanced diet similar to what our evolutionary biology was built on: occasional meat and fat; lots of fish, fruits, nuts, and vegetables; and certainly no processed carbohydrates, or sugary treats from the 7-11 cave.

Champions of mass supplementation

in the schools say opportunities to safely and effectively improve the lives and achievements of children are equally vast. Some blame the failure of their cause on close-minded thinking, the lack of cross-talk and cooperative research between behavioral scientists and neuroscientists, and the complexity of information pouring out of nutrition research and neuroscience. Says one noted British psychobiologist, David Benton, “nutritionists know nothing of the brain, mental illness, and criminal behavior; social scientists know nothing of biology or psychology; and physicians and biologists often know nothing of nutritional, environmental, social, or psychological influences.”

For its part, the pharmaceutical and supplements industries, which would appear to have vested interests in getting better information, know they cannot get patents on vitamins, minerals, and other micronutrients, so the cost of expensive, rigorous, “gold standard” clinical trials are trumped by promoting their products more cheaply on the basis of anecdotal or suggestive evidence.

Into this morass of uncertainty has in fact come a small cadre of American, British, Dutch, and other European investigators who have conducted and published—in peer-reviewed journals—more rigorous and competitively funded studies tying nutrient deficiencies to misconduct and academic failure.

This *Abell Report* is an attempt to get past the “he said/she said” debate, and to review, analyze, and come to some conclusions about the evidence for and against providing mass supplementation in the schools as a means of influencing behavior and cognition. It looks for common ground between the skeptics and the advocates, and offers some next steps if school officials find sufficient evidence to warrant a look at designing a supplementation pilot program or study in Baltimore City schools.

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The Scope of the Problem

The nationwide rise in school-age youth violence and aggression over the past 50 years has been amply documented, with estimates of the direct financial cost alone at \$158 billion in 2006. Stealing, vandalism, tantrums, bullying, irritability, impulsivity, and disruptive behaviors, along with depression, substance abuse, and learning problems are creating costly, sometimes devastating, problems for schools, children, the labor markets, and civil society.

Less clear is why. School-based violence and aggression are recognized as part of a constellation of juvenile behaviors ranging from tantrums and discipline problems, to bullying, attention deficit disorder, and outright assaults and psychosis. But scientists have yet to find reliable and predictable common origins, or any “unified theory” of causation.

Some things are *complicated*—sending a man to the moon requires lots of steps but the tools needed are clear. Human behavior, however, is *complex*, and needs and rational interventions are difficult to find. In a “State of the Science Report on Violence Prevention,” published in 2006 in the *Journal of Abnormal Child Psychology* by the National Institute of Mental Health and the universities of Pittsburgh and Alabama, the authors concluded that there is not even a fully comprehensive or manageable systematic picture of the published research, nor agreement on whether there are common roots to child and youth aggression, delinquency, drug abuse, and sexual risk taking.

Even if nutritional deficiencies are a “common” link, the issue is compounded by general community food shortages, skipped meals, and the poverty-laden life that accompanies these phenomena. An *Abell Report* in 1998, for example, documented the impact of a semester-long, in-classroom school breakfast pilot program on academic achievement and classroom behavior, concluding that the absence of breakfast alone can have as much to do

with poor behavior as coming from a broken home or being exposed to street or domestic violence.

The Claims

In the last decade, the search for affordable solutions has produced fertile ground for those convinced of micronutrient solutions.

Typical are those of Stephen Schoenthaler, a criminologist at California State University, who claims low levels or imbalances of nutrients “can seriously disturb the electrical activity in the brain,” particularly the making of serotonin and other brain chemicals tied to mood and learning. His beliefs are rooted in neuroscience showing that poor brain function is driven by disruptions in serotonin, dopamine, and other neurotransmitters, which, in turn, are associated with memory and learning problems, depression, sleep deprivation, irritability, and some antisocial behaviors.

Other claims center around particular minerals or amino acids, or around too-low cholesterol levels or sugar overloads. Deficiencies in essential fatty acids, notably omega-3 fatty acids commonly found in seafood, are especially *au courant* in research into the causes and prevention of aggressive behavior.

The most reasonable claims fall into the “promising if unproven” category, summarized well by Michael Jacobson, a microbiologist by training and co-founder of the Center for Science in the Public Interest. “More and more research is showing that supplementing diets with vitamins, minerals, or omega-3 fatty acids can significantly improve the behavior of prisoners, people in mental hospitals, and possibly poor nourished students,” Jacobson stated recently. “While more research needs to be done, health departments have major opportunities to utilize inexpensive dietary supplements to conduct studies and improve the welfare of people in the city/county/state’s custody....”

The Evidence

So what is the credible evidence for using vitamins, minerals, or fatty-acid

supplementation to reduce childhood and youth aggression and improving behavior? And how strong is it?

The evidence falls into several categories: studies on youthful offenders in a prison setting that reduce so-called “crime diets;” studies that attempt to reduce the “expected” number of behavioral problems in populations by using supplements; studies that infer from undernourished populations the role of micronutrients in behavior and learning; and “literature review” articles that try to analyze and make sense of dozens of studies that lack standardized study designs, treatments, or outcomes.

Most compelling are studies by a small number of investigators associated with major academic institutions or government organizations whose experiments satisfy at least some of the requirements of well-designed protocols. These scholars provide details of their work to colleagues and the public, subject their studies to peer review, and seriously acknowledge the limitations of their findings. Here is a sampling:

- In a multi-year study begun in 2003, Stephen Schoenthaler at California State University, and his colleague Ian D. Bier, partnered with Anthony Elementary School in Leavenworth, Kansas, because the school’s officials suspected that their students’ inadequate academic performances were due to high amounts of delinquency and violence related to lifestyle and nutrition factors. In a study designed to reduce antisocial behavior and improve math and English scores on statewide tests, children in kindergarten through fifth grade got low-dose vitamin and mineral tablets, nutrition education, more nutritious school lunches, daily exercise, and family-style group meals. The economically disadvantaged elementary school, with 350 students, two-thirds of whom were minorities, was chosen for its similarity to large East Coast inner-city schools, marked by the highest levels of violence and antisocial behav-

ior, and lowest scores on standardized tests in the 10-school district. The daily supplement supplied 100 percent of the U.S. Recommended Daily Allowance (RDA) for everything except calcium and magnesium. Violent and nonviolent delinquencies were measured by official school disciplinary records and scores on the Kansas Assessment tests given to fourth- and fifth-grade Kansas school children each year. Results showed that before supplements, two students every day were referred to the principal's office for disciplinary action related to "out of control" behavior, or a total of 428 incidents for that baseline year. During the vitamin "intervention," referrals dropped to 18, or by 95 percent. Referrals stayed low the second year; suspensions dropped from 52 to 13, and violent acts from three to one. Scores on math and English tests rose from 10th to first in the district.

- To the degree that better nutrition and improved learning are linked to lower levels of antisocial behavior, a report published in the *American Journal of Clinical Nutrition* in 2007 has also received positive attention. Researchers with the Nutrition Enhancement for Mental Optimization Study Group assessed the effect of vitamins, minerals, and omega-3 fatty acids in a double-blind test in Adelaide, South Australia, and at six primary schools in Jakarta, Indonesia. Some 396 children, ages 6 to 10 years, in Australia, and 384 in Indonesia, got drinks with various nutrient mixes comprised of iron; zinc; folate; vitamins A, B6, B12, and C; the fatty acid docosahexaenoic acid (DHA) or eicosapentaenoic acid (EPA); or a placebo. The one-year study showed that the micronutrient therapy resulted in "significant increases" in scores on tests representing verbal learning and memory.

- A study by Schoenthaler and Bier, reported in 2000 in the *Journal of Alternative and Complementary Medicine*, gave school children, ages 6 to 12 years old, low-dose vitamin and mineral tablets in line with National Academy of Sciences supplement guidelines to see if they would behave better in school than classmates given placebos. The researchers chose two working-class Hispanic elementary schools in Phoenix, Arizona. Violent and delinquent behavior was measured by the number of students referred to the principal's office. Eighty students disciplined at least once between September and May served as the research sample. During the pill-giving phase, the 40 children who got active tablets were disciplined, on average, one time each, a 47 percent lower mean rate of antisocial behavior than the 1.875 times each for the 40 on placebo. The children who took the real pills were reported to be involved in fewer threats, fights, vandalism, disrespectful behavior, and obscenities. The study was small and the differences between the treatment and placebo groups were small as well. Yet even critics agree that this study as well as their later research have some value. Wendy Smith, Ph.D., of the National Institutes of Health, in a commentary written for the *Journal of Alternative and Complementary Medicine* in 2000 said the "authors continue to strive to improve their own work" with randomization and other better measures and assessment features.
- Bernard Gesch, a criminology and nutrition researcher at the University of Oxford's Department of Physiology, is best known for his notion that "crime diets" can be replaced with "peace diets," and that vitamins can prevent fights even among adjudicated delinquents and prison populations. In 2002, writing in the *British Journal of Psychiatry*, Gesch report-

ed results of a study on 231 offenders, 18 to 21 years old, in a maximum security prison in England. The prisoners were divided into two groups, with one group given supplements with meals in the same amounts that would approximate a One-A-Day style supplement for fatty acids, vitamins, and minerals; the other group got look-alike placebos. Neither prisoners, nor guards, nor researchers knew who got the real pills. Before the supplements were given, Gesch and his colleagues tracked the prisoners' behavior for nine months, recording incidents of such antisocial behavior as "mouthing off" to guards and fights. The prison, they noted, offered fairly healthy choices of foods, but many prisoners opted for the "chips" instead of the salad bar. At the end of the 18-month study period, those who got the nutrient supplements for at least two weeks were reported to be involved in 35 percent fewer disciplinary infractions than those on placebo. Minor offenses were reported to have dropped by 33 percent and serious offenses, including violence, fell 37 percent.

- Spurred by these results, in 2008, Britain's Wellcome Trust announced it would bankroll a \$2.3 million trial of supplements among more than 1,000 prisoners from three United Kingdom prisons. The three-year study, which began in the spring of 2009, will include more rigorous measures of blood chemistries and computerized behavioral and IQ tests to confirm the earlier study, and try to figure out just how and why vitamins might do what they are doing. Gesch believes that the most common diets in the Western world now—full of refined sugars and meat fats—"wash out" or replace essential nutrients such as omega-3 fatty acids that contributed to our ancestors' survival. Whether or not theirs was a more peaceable king-

dom is arguable, but Gesch says that “to look at the quirk of evolution that made our brain such an energy hog, and conclude that nutrition has nothing to do with behavior and learning is bizarre thinking.”

- A study in the Netherlands, published in 2010 in the journal *Aggressive Behavior*, tested the effects of nutritional supplements on rule-breaking, aggression, and psychopathology among young adult offenders in eight Dutch prisons. Sponsored by the Dutch Ministry of Justice and Radboud University, a team of university psychiatrists led by Ap Zaalberg gave vitamins, minerals, and essential fatty acids, or placebos, to 221 young adults ages 18 to 25 years over a one- to three-month period. Reported incidents were significantly reduced in the active intervention group of 116, compared to the placebo group of 106. The reductions were observed and recorded by prison staff. The supplements included 25 vitamins and minerals, and four separate fatty acids, a regimen similar to what Gesch devised but more comprehensive, and in larger doses, in some instances. The Dutch study supplied substantially more magnesium and different amounts of vitamin D, phosphorus, and beta-carotene, for example. Before supplementation began, the prisoners completed questionnaires to assess aggression, and prison staff also rated the level of hostile and aggressive behavior using incident reports for infractions such as possessing illegal drugs and bad behavior. Again, neither participants, nor staff members, nor researchers knew which prisoners were getting real supplements or placebos. After the intervention period, the same questionnaires and assessments were administered again, and one subgroup of prisoners

was asked whether it believed it had gotten supplements or placebos—an effort to see if the subjects themselves noticed differences in their feelings and behaviors.

Results showed a 34 percent drop in the number of reported incidents for the group on supplements, and a 14 percent increase in reported incidents in the placebo group. The reductions in violent incidents, documented by the prison staff did not, however, reflect any real differences reported by the subset of prisoners asked about its level of aggression or general health.

- In a 14-year study, a research team at the University of Southern California (USC) showed that malnutrition in the first years of life leads not only to lower IQ but also to antisocial behavior later in life, including teenage aggression. In their study, reported in 2004 in the *American Journal of Psychiatry*, Jianghong Liu, then a postdoctoral student, and Adrian Raine, then a professor of psychology at USC (now at the University of Pennsylvania), followed the diet, behavior, and learning of about 1,000 children on Mauritius, an island in the Indian Ocean off the coast of Africa. The group included children with Indian, Creole, Chinese, English, and French backgrounds. After testing them at age 3 for deficiencies in B vitamins, protein, zinc, and iron, the children got IQ tests and home visits to document living conditions. The researchers checked behavior at ages 8, 11, and 17. Teachers were asked to assess the children at age 8 for such things as irritability, picking fights, and acting out; at age 11, parents were asked to tell researchers about whether or how much their children got into fights, bullied others, lied, cursed, and vandalized property. Further, at age 17, parents and teachers both were asked to report again on antisocial behaviors

such as illicit drug use, cruelty, and stealing. Compared to those without nutritional deficiencies, the malnourished children showed a 41 percent increase in aggression at age 8, a 10 percent increase in aggression and delinquency at age 11, and a 51 percent increase in violent behavior at age 17. At the time, Raine noted that 7 percent of American toddlers had iron deficiencies, as many as 16 percent of teen girls were anemic, and up to 22 percent of black and Mexican-American girls were anemic as well.

- Raine says the study suggests that “biological disposition to antisocial and aggressive behavior” can be changed and has received NIH grants to further test and refine the violence-and-vitamins hypothesis. He currently is recruiting 500 male and female 11-year-olds from high-risk communities in Philadelphia for a “biosocial” study integrating genetics, brain imaging, hormone levels, and nutritional and psychological factors, along with neighborhood, family, school, and social factors, and mental-health features such as ADHD, depression, anxiety, post-traumatic stress disorder, and schizophrenia. Describing the new study as “perhaps the most systematic” look yet at the neurological and social foundations of aggression, Raine says the goal is to “predict and treat” both proactive and reactive aggressions, which he believes are likely to have different origins and responses to treatment.

The group at Penn also plans to develop a genetic mouse model of aggression to test nutritional treatments and prevention of aggression. Of the 500 children Raine hopes to recruit, 300 will get baseline assessments for aggression risk factors and then be randomly assigned to one of four, three-month interventions: treatment as usual, cognitive behavioral therapy,

nutritional supplementation, or a combination of cognitive behavioral therapy and supplementation. Over the four years of the study, Raine predicts that those with low omega-3 fatty acid levels and high lead exposure will benefit most from supplementation, while those with cognitive and emotional risk factors will benefit most from behavioral intervention.

- Psychobiologist David Benton of the University of Wales in Swansea, UK, has spent decades studying the impact of diet on antisocial, violent, and criminal behavior in children and adults, as well as the impact of micronutrient supplements on intelligence and learning in children. He also has studied the impact of sugar on behavior and learning, concluding essentially there is no evidence of an adverse effect on behavior, irritability, aggression, or attention deficit from consuming sucrose. In one of his earliest studies, in 1988, he asked 90 12- and 13-year-olds to keep a daily diary for three days and found the average intake of vitamins was close to the recommended amounts for most of the children. He then gave a multivitamin and mineral supplement, or placebo, in a double-blind trial for eight months to 60 of the children. The supplement group, but not the placebo group or the remaining 30 who took nothing, showed “a significant increase in nonverbal intelligence on a standardized test. In 1991, he followed up with a report in the *Journal of Personal and Individual Differences*. Along with colleague Richard Cook, he gave 47 6-year-olds either a placebo or tablet with vitamins and minerals, and took baseline measures before and after up to two months of treatment. The intelligence scores of those taking the active tablets increased by 7.6 points on tests that looked at their behavior

when performing a difficult task. Those on placebo declined 1.7 points. Most tellingly, perhaps, was when they were faced with a difficult task, they were more likely to concentrate longer, sustain efforts, and deal better with frustration, an underlying theoretical element in antisocial behavior.

In Benton’s and Cook’s study, for example, the reactions of the children were observed while they played a commercially available electronic game called Tele Match 4. It consists of an electronic representation of a ball moving from the left to the right of a TV screen. By moving a knob, the subject can try to “bat” the ball. The experimenters made the task very hard for 6-year-olds because the *real* test wasn’t their ability to bat the ball, but to see how they reacted to failure and frustration. Researchers wrote down the behavior of each child as falling into one of four categories: quietly concentrating; fidgeting/shuffling; roughly handling the controls, kicking their feet, sighing, and other signs of frustration; and negative comments.

These same children were randomized to get vitamin supplements. The experimenters also asked the parents to report a food diary using a list of 24 foods, including the frequency with which the children ate foods such as milk, eggs, fruits, vegetables, grains, meat, fish, sugar, and so on. Benton and Cook concluded that there was a small decline in performance in those taking placebo, and improvements in concentration and intelligence in those who got the supplements. The authors were quick to point out that it is almost impossible to determine or “even begin to suggest” what the critical ingredients were that made the difference because of the wide variety of nutrients used in their own and so many different studies. But the results suggest further work if not vitamin

pills for all. “The brain,” Benton wrote, “is the most complex and metabolically active organ in the body, thus behavior reflects the summated outcome of countless millions of metabolic processes.” The big question, Benton says, is “what are the active ingredients in the effects seen in the positive trials so far? Many think fatty acids are the key, but no one is sure.”

- If there is a “granddaddy” of research on nutritional factors in antisocial and violent behaviors, he is Joseph R. Hibbeln, a physician, psychiatrist, lipid biochemist by training, Commander in the U.S. Public Health Service, and a long-time researcher at the National Institute of Alcohol Abuse and Alcoholism of the NIH. He has spent decades in international collaborations for clinical trials of omega-3 fatty acids for the prevention of suicide, depression, and violence, and was one of the first scientists to bring attention to the potential role of omega-3 fatty acids in psychiatric disorders. In a 2004 paper published in the *Journal of Biological Psychiatry*, Hibbeln and a team from the NIH and the University of Mississippi Medical Center in Jackson sought evidence that omega-3 fatty acid deficiencies had an impact on those predisposed to commit domestic violence. They chose 21 convicted domestic abusers, all with documented tendencies to develop rage and panic-like responses to anxiety. The researchers then obtained samples of cerebrospinal fluid and plasma from the subjects after three days in which participants were on a diet that lowered blood levels of monoamine neurotransmitters such as serotonin. Low serotonin levels have long been linked to anxiety and other psychological mood disorders. Fatty acids were then measured along with blood levels of corticotrophin-releasing hormones (CRH) in the

spinal fluid because inflammatory chemicals called prostaglandins increase the genetic expression of these hormones and omega-3 fatty acids have been found to decrease prostaglandin release.

Their results showed low levels of omega-3 fatty acids associated with elevated CRH levels, and that the elevated levels increased fear and anxiety, common components of defensive and violent behavior.

- In a second study published in 2004 in the *European Journal of Clinical Nutrition*, Hibbeln and another team studied the relationship between hostility, the development of coronary disease in young adults, and the dietary intake of fish and fatty acids. They sampled 3,581 urban white and black young adults, using a standard assessment of hostility, and found that the odds of scoring in the upper fourth on the hostility scale were linked to increases in DHA, one of those essential fatty acids. Eating any fish rich in fatty acids, compared to having none, was associated with lower odds of hostility. Again, association does not prove causality, but the results, Hibbeln says, are cause for further study. Hibbeln's studies also suggest that lower levels of essential fatty acids and low cholesterol are associated with self harm, impulsivity, and bad mood. Others have suggested a role in aggression for imbalances in the ratios of omega-3 and omega-6 fatty acids (the former associated with lower levels of inflammation and the latter to higher levels). In one of a series of studies examining the effects of omega-3 and omega-6 fatty-acids levels on aggression, hostility, and homicides, Hibbeln and his colleagues analyzed measures of omega-6 consumption over time and in many countries to see if these

were related to trends in murder rates and found “a striking correlation” between what appears to be more intake of linoleic acid (an omega-6 fatty-acid source) from vegetable and seed oils and increased risk of murders from 1961 to 2000. Hibbeln's conclusion is that lowering linoleic-acid intake and improving omega-3 fatty acids and other basic nutrients “can potentially become relatively cost-effective measures for reducing the pandemic of violence in western societies, just as dietary interventions are reducing cardiovascular mortality.” The consumption of omega-6 linoleic acid (found in soy, corn, and sunflower oils; used for frying, prepared meals, potato chips, and ice cream) has vastly increased relative to seafood-derived omega-3 fatty acids.

Conclusions and Recommendations

Although suggestive studies continue to pile up, ongoing scientific uncertainty remains a major obstacle to public-health initiatives to feed supplements to at-risk populations. Too little is understood about the role each nutrient might be playing in these studies. There is no agreement on doses, relative ratios in relation to each other across a life span, or what dangers there might be in supplementation. Excessive doses of vitamins, especially vitamin E; minerals; herbals such as ginkgo biloba and turmeric; and salmon oil have caused disease, including increased bleeding and clot formation. Vitamins A, B6, B12, C, E, and K, along with niacin, calcium, magnesium, iron, zinc, and folic acid can be dangerous in combination with some prescription drugs and cold remedies.

So if there is a reasonable next step for urban school systems interested in using supplements to prevent or reduce anti-social behavior, what would it look like?

Experts consulted for this report all said that further research is needed to make the case for vitamins against violence, and that projects must be the “Caesar's wives” of studies—i.e., scientific-

ly unimpeachable. Steven Goodman, a professor and biostatistician at Johns Hopkins University, read two of the studies conducted among young offenders and concluded that from what was reported, supplementation seems at best marginally significant and that culling consistent, applicable lessons from them is tricky if not impossible. If a pilot study were to be done in Baltimore City, Goodman says the following elements must be made a high priority:

- Recruitment of subjects from classrooms with balanced and similar groups of students, along with teachers who supervise them.
- Study designs that follow best practices for reducing biased interpretations, errors, deceptive behavior, and self deception—especially difficult in studies that try to measure subtleties in human behavior.
- Study “designs” that are “double-blinded,” i.e., tests in which neither those conducting the study nor the subjects know which people are in a “control” group for comparison, and which people are getting the vitamins or other interventions.
- Double-blinded, independent verification of all behavioral measures and observations, meaning that neither those conducting the study nor the subjects have influence over the outcomes or interpretations of measurements and observations.
- Impeccable selection, measurement, and accounting of relevant “covariates,” a fancy term for factors that are likely to affect one or more of the groups being studied, and thus likely to distort the outcome. These could include patterns of disciplinary actions in a particular school, or profiles of teachers' human tendencies to treat students with the same behavior problem in different ways.
- Direct observation of supplement use.

- Scientifically sensible and agreed-upon “endpoints” and study procedures in which all children who are randomized (assigned at random to be “controls” or treated groups) are counted in the final results.

Ruth Faden, director of the Johns Hopkins Berman Institute of Bioethics, says any pilot study or program of supplementation must be grounded in understanding the benefits and risks for the children, the schools, and the larger society. A proper study would also focus on younger, rather than older, children. “If poor nutrition is a behavioral issue, then the earlier the intervention, the better because of what scientists already know about brain development. Focusing on older kids, like teenagers, would continue to disadvantage the group that needs prevention most,” Faden says.

Several experts argued for programs that give consideration to “broader outcomes” such as overall well-being and health, but that still answer questions about supplementation and violence reduction. If there is reason enough to think there would be a benefit, the ethical framework is better if a study looks at outcomes that go beyond antisocial behavior, because just going after the narrower outcome risks negatively “labeling” already disadvantaged children. Getting informed consent from parents and older children is also vital, Faden adds, along with agreement about how the vitamins would be given and options for parents to continue what they are already doing at home, such as special diets.

Gary Goldstein, a physician, head of the Kennedy Krieger Institute, and an expert on developmental brain chemistry and biobehavioral science, says, “There’s no question that good nutrition has an impact on behavior and cognitive development. The question is whether it’s possible to properly and convincingly *measure* a reduction in antisocial behavior by giving vitamin supplements.”

Highlighting the statistical, logistical,

scientific, and ethical challenges, Goldstein suggests a “reasonable first step” is to convene an international assembly of experts to plan a specific and direct assault on the uncertainties that make the vitamins-and-violence hypothesis so unsettling to mainstream scientists. In separate interviews, Gesch and Benton agree and would help organize such a meeting if invited to do so.

The goal “is not a talk-fest,” Goldstein says, but a roll-up-your-sleeves workshop with a diverse group of eight to 10 serious experts, both proponents and skeptics. Attendees should include an epidemiologist, nutritionist, criminologist, behavioral psychologist with knowledge of neuroscience, an ethicist, and a pediatrician with special knowledge of brain development and childhood behavior.

The workshop, he says, would produce a proposal that identifies very specific behavioral outcomes, and a working group to design a pilot study for Baltimore schools as close to ideal as possible. One arm of the study, Goldstein says, should include the benefits of a generally healthy diet. “If you examine only children with a terrible diet and see a benefit, that might lead parents and schools to think that a pill can substitute for a good diet.”

“It’s plausible to me,” says David Benton, “that if people are marginally malnourished, giving vitamins in correct arrays would bring measurable improvements in behavior. But what and how to do that is easy to oversimplify. When you change diet, you are changing biological *potential*, but that potential is also under the influence of social and environmental forces. To think that after a lifetime of bad social environment, poor parenting, and negative feedback that giving someone a vitamin pill or better diet is going to keep him out of prison is delusional. This is an area of work that is dear to my heart, but we need to move forward with scientific rigor and caution.”

The recommendation to conduct more studies—or just better ones—is likely to frustrate those who want faster action, but the credible experts in the field see no real

alternative. Supplements, notes Gesch, are no “magic bullet” to stop violence, antisocial behavior, depression, or any other behavior in schools or anywhere else. If solutions to complex problems were that simple, they would long since have been applied. “We’re not,” Gesch says, “going to be able to transform society with our teeth.”

Joann Ellison Rodgers, an award-winning science journalist, directed Johns Hopkins Medicine’s media relations and public affairs division for 25 years, and now serves as senior advisor. A graduate of Boston University and the Columbia University Graduate School of Journalism, she is a board member and past president of the Council for the Advancement of Science Writing; past president of the National Association of Science Writers; a Fellow of the American Association for the Advancement of Science (AAAS); and a member of Sigma Xi, the Scientific Research Society. The author of seven books, including *Sex: A Natural History* (Henry Holt and Company, NY), she has contributed articles on medicine, genetics, risk communications, and psychology for The New York Times Magazine, Psychology Today, The Los Angeles Times, and other magazines. Her awards include a Lasker Award for medical journalism.

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