

Nutrition, Brain Development, and Aggressive and Violent Behavior in Young People

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Introduction

The relationship between nutrition and aggressive or violent behavior has received increasing attention from neuroscience, developmental psychology, psychiatry, criminology, and public health. The underlying premise is straightforward: the developing brain requires adequate energy and specific nutrients for normal growth, neurotransmitter production, myelination, synaptic development, and regulation of emotion and behavior. Consequently, inadequate nutrition during childhood and adolescence may interfere with neural processes that are important for impulse control, emotional regulation, decision-making, and responses to stress [1]. This could, on occasion, lead to aggressive and violent behaviors, including crimes.

The evidence, however, requires careful interpretation. There is considerably stronger evidence that poor nutrition can impair cognitive development, attention, executive functioning, mood, and emotional regulation than there is evidence that nutritional deprivation independently causes serious interpersonal violence. Consider this claim from a leading scholar in criminology, discussing the interrelated nature of nutrition and crime. According to Fishbein [2]: “Clinical evidence indicates that, for some persons, diet may be associated with, or exacerbate, such conditions as learning disability, poor impulse control, intellectual deficits, a tendency toward violence, hyperactivity, and alcoholism and/or drug abuse. These behaviors have been closely associated with, or are precursors to, criminal delinquent behavior”. Indeed,

criminal delinquent behavior is a complex behavior produced by interactions among biological, psychological, social, and environmental factors [3]. Nutrition should therefore be understood as a potentially modifiable developmental risk or protective factor, rather than as a singular explanation for violent behavior.

This distinction is particularly important for young people because childhood and adolescence are periods of substantial brain development. Nutritional deficiencies occurring during these periods can have consequences that extend beyond temporary hunger and may influence neural systems involved in behavioral self-regulation.

Literature Review

This paper reports findings from a literature review using the database Academic Search Complete, using the terms “diet OR nutrition” AND “aggression OR violence”. In this literature review, the following topics are analyzed and discussed—why nutrition matters for the developing brain; the prefrontal cortex and behavioral control; omega-3 fatty acids and aggression; iron deficiency and brain development; zinc and neurobehavioral regulation; iodine and cognitive development; B Vitamins, Folate, and B12; blood glucose, hunger, and aggression; food insecurity, stress, and the HPA Axis; nutrition and the amygdala; and nutrition and inflammation; nutrition and neurotransmitters. Then, the review turns to the most direct evidence on nutritional supplementation and antisocial behavior; replication and subsequent research; the broader literature on diet and aggression; adolescence is a particularly important developmental period; poor nutrition does not operate in isolation; a developmental model; nutrition may be a protective factor rather than simply a risk factor; what the research does and does not establish; and implications for juvenile

justice and violence prevention. These subtopics reflect a review of the literature on issues related to “nutritional psychiatry” and “nutritional criminology” [4].

Why Nutrition Matters for the Developing Brain. The brain is metabolically demanding. Although it represents only a small proportion of total body weight, it consumes a substantial amount of the body’s energy [5]. During childhood and adolescence, the brain also undergoes extensive changes involving synaptic pruning, myelination, development of neural networks, and maturation of the prefrontal cortex and associated regulatory systems.

Adequate nutrition provides the substrates necessary for these processes. Important nutritional components include adequate calories and glucose, protein and amino acids, essential fatty acids (particularly omega-3 fatty acids), iron, zinc, iodine, folate, vitamin B12, vitamin D, magnesium, selenium, choline, and a wide variety of vitamins and minerals [6]. These nutrients are involved in neurotransmitter synthesis, membrane formation, myelination, cellular metabolism, antioxidant protection, and neural signaling. Thus, malnutrition is not simply a problem of physical growth. It can potentially alter the biological systems upon which cognition and behavioral regulation depend.

Interestingly, a study of child malnutrition at age 3 years and its later effects on behavior at ages 8, 11, and 17 years found “the children with malnutrition signs at age 3 years ... were more aggressive or hyperactive at age 8 years, had more externalizing problems at age 11, and had greater conduct disorder and excessive motor activity at age 17 ... There was a dose response relationship between degree of malnutrition and degree of externalizing behavior at ages 8 and 17”. According to the authors: “These results indicate that malnutrition predisposes to neurocognitive deficits, which in turn predispose to persistent externalizing behavior problems throughout childhood and adolescence”. That is, what we eat affects our brains and that leads to changes in our behaviors. The authors conclude: “The findings suggest that reducing early malnutrition may help reduce later antisocial and aggressive behavior” [7].

The Prefrontal Cortex and Behavioral Control. One of the most important brain regions in understanding aggression is the prefrontal cortex. The prefrontal cortex contributes to impulse control, planning, consideration of consequences, decision-making, emotional regulation, inhibition of inappropriate responses, and regulation of behavior in socially complex situations [8]. The prefrontal cortex continues developing throughout adolescence and into early adulthood. This developmental timetable is relevant to aggression because young people already have relatively strong emotional and reward-processing systems while the neural systems involved in behavioral regulation are still maturing.

Nutrition can influence this developmental process. Severe or chronic nutritional deficiencies can affect myelination, synaptic development, neurotransmitter systems, and overall brain maturation [1]. The implication is not that an undernourished adolescent will necessarily become aggressive. Rather, nutritional

inadequacy may reduce the neurobiological resources available for regulating emotional impulses, potentially increasing susceptibility to aggressive responses under stressful circumstances, consistent with the theory of low self-control.

Omega-3 Fatty Acids and Aggression. Among nutritional factors, omega-3 polyunsaturated fatty acids have received particularly substantial attention. Omega-3 fatty acids may influence several systems relevant to aggression, including serotonergic functioning, dopamine signaling, inflammatory processes, neuronal membrane fluidity, stress responses, synaptic functioning, and emotional regulation [9].

Some observational studies have reported relationships between low omega-3 intake or status and behavioral problems, while experimental supplementation studies have produced mixed results. A particularly important meta-analysis by Gajos et al. [10] examined randomized controlled trials of omega-3 supplementation and found evidence of a small reduction in aggression, although the magnitude of the effect was modest and varied according to characteristics of the participants and interventions. This is significant because randomized trials provide stronger evidence than simple correlations. Nevertheless, omega-3 supplementation should not be interpreted as an established treatment for serious violence. The most defensible conclusion is that omega-3 status appears to be one potentially modifiable biological factor involved in emotional and behavioral regulation, with effects that are likely to be relatively small compared with the influence of broader developmental and social environments.

Still, studies illustrate that changing the diets of children changes their behavior in positive ways. For example, a study of 290 children ages 11-12 years old that administered omega-3s, multivitamins, and minerals along with cognitive behavioral therapy (CBT) found lower involvement in externalizing behaviors [11]. Another study of 282 children ages 7-16 years found that children administered omega-3s “showed a short-term reduction (at 3 and 6 months) in self-report reactive aggression, and also a short-term reduction in overall antisocial behavior” [12].

Still another study, this time of forensic psychiatric inpatients, found that fatty acids were associated with aggression and psychopathology, but not mineral or vitamin levels [13]. Omega-3 fatty acids—especially EPA and DHA—are important components of neuronal membranes. DHA is highly concentrated in the brain and contributes to neuronal membrane structure, synaptic functioning, and signaling. Importantly, studies link low blood and brain tissue levels of omega-3s to homicide, suicide, and other forms of aggressive behaviors [14-20].

Iron Deficiency and Brain Development. Iron is another particularly important nutrient because iron deficiency is relatively common among children and adolescents and can affect the developing brain [21]. Iron is necessary for oxygen transport, mitochondrial energy production, myelination, neurotransmitter synthesis, dopamine metabolism, and neuronal development [22].

Iron deficiency during critical developmental periods has been associated with changes in brain structure and function and with deficits in attention, learning, memory, and behavior [1].

Longitudinal research has found associations between early-life iron deficiency and later behavioral and developmental problems. Again, however, the appropriate interpretation is cautious. Iron deficiency does not establish a pathway to violence. Instead, nutritional iron deficiency may contribute to neurodevelopmental and behavioral vulnerabilities that can interact with other risk factors.

Zinc and Neurobehavioral Regulation. Zinc is involved in numerous neurological processes, including neurotransmission, gene expression, cellular signaling, and brain development [23]. Zinc deficiency has been associated with impaired neurodevelopment and altered emotional and behavioral functioning [24]. Zinc also interacts with systems involving dopamine, glutamate, and other neurotransmitters relevant to behavioral regulation.

There is less direct evidence connecting zinc deficiency specifically to serious violence than there is for some of the broader behavioral consequences of nutritional deficiency. Nevertheless, zinc represents another example of how inadequate nutrition can affect biological systems involved in cognition and emotional regulation.

Iodine and Cognitive Development. Iodine is essential for the production of thyroid hormones, which play a critical role in brain development. Severe iodine deficiency can produce substantial cognitive and neurological impairment [25]. Even less severe deficiency during pregnancy and childhood can affect cognitive development and academic functioning [25]. A study of offspring ages 7-10 years of age found that the diets of their mothers during pregnancy predicted later outcomes such as depression, anxiety, attention-deficits/hyperactivity, and aggression; more inflammatory diets were associated with increases in these outcomes [26]. This makes sense, given that studies generally find that nutritional interventions as well as healthier diets focused on whole grains, lean meats, and fruits & vegetables are associated with greater mental health and focus, including less depression [27-32].

Because executive functioning and cognitive development are relevant to behavioral self-regulation, nutritional deficiencies affecting cognitive development may indirectly influence behavioral outcomes. The evidence here is considerably stronger for cognitive impairment than for aggression or violence specifically. Consequently, claims that iodine deficiency causes aggression would go beyond the evidence.

B Vitamins, Folate, and B12. Several B vitamins are essential for neurological functioning. Folate and vitamin B12 are involved in DNA synthesis, methylation, cellular metabolism, myelin formation, and neurotransmitter-related processes [33]. Deficiencies can interfere with neurological functioning and have been associated with cognitive and psychiatric symptoms [34].

The importance of these nutrients illustrates a broader point: brain functioning depends upon a complex nutritional system rather than a single “aggression nutrient”. A diet that is chronically deficient in multiple nutrients may therefore have substantially different consequences from an isolated deficiency.

Blood Glucose, Hunger, and Aggression. There is also evidence that acute hunger and blood-glucose regulation can affect irritability and self-control. The brain relies heavily on glucose for energy. When people become hungry, physiological stress responses can increase, and the subjective experience of hunger can contribute to irritability and difficulty regulating emotions [35]. Experimental research on glucose and self-control has produced mixed results, and popular claims that low blood sugar straightforwardly causes aggression are too simplistic [36]. Nevertheless, energy availability clearly affects brain function.

Importantly, chronic food insecurity is different from an occasional missed meal. Children experiencing persistent food insecurity may encounter recurrent hunger, inadequate nutrient intake and thus nutritional deficiencies, chronic physiological stress, sleep disruption, anxiety about food availability, instability in family environments, as well as obvious impacts on school performance [37]. Consequently, food insecurity can influence behavior through both nutritional and psychosocial pathways.

Food Insecurity, Stress, and the HPA Axis. One of the most important mechanisms connecting nutrition and aggression may actually involve stress. The brain’s hypothalamic-pituitary-adrenal (HPA) axis regulates responses to stress. Chronic stress can alter cortisol functioning and influence brain regions involved in emotion and behavioral control, including the prefrontal cortex, hippocampus, and amygdala.

Food insecurity can be a significant source of chronic stress for children and families. Thus, the pathway may look something like: Food insecurity leads to inadequate nutrition, which when combined plus chronic stress, can lead to altered physiological functioning including impaired emotional regulation/executive functioning, which can then produce a greater vulnerability to aggressive behavior. Yet, this is fundamentally different from claiming: Poor diet causes violence. The first formulation is consistent with a multifactorial developmental model; the second is not supported by the evidence.

An example of such a developmental model comes from Liu [38], who writes: “Early health risk factors that influence negative behavioral outcomes include prenatal and postnatal nutrition, tobacco use during pregnancy, maternal depression, birth complications, traumatic brain injury, lead exposure, and child abuse. There is an ample literature to suggest that these early health risk factors may increase the likelihood of childhood externalizing behaviors, aggression, juvenile delinquency, adult criminal behavior, and/or violence”. Note that nutrition is part of the model!

Nutrition and the Amygdala. The amygdala plays a central role

in detecting emotionally significant stimuli, particularly potential threats. Aggressive behavior can occur when threat detection and emotional arousal overwhelm regulatory processes [39,40]. Effective behavioral regulation requires communication between the amygdala and prefrontal cortex. Research in developmental neuroscience suggests that adolescence involves continuing maturation of these regulatory networks [41].

Nutritional deficiencies and chronic stress can potentially influence these systems. Thus, poor nutrition could theoretically contribute to aggression by affecting the balance between rapid emotional/threat responses and slower cognitive control and inhibition. This provides a useful neurodevelopmental framework for understanding why nutritional disadvantage might matter during adolescence.

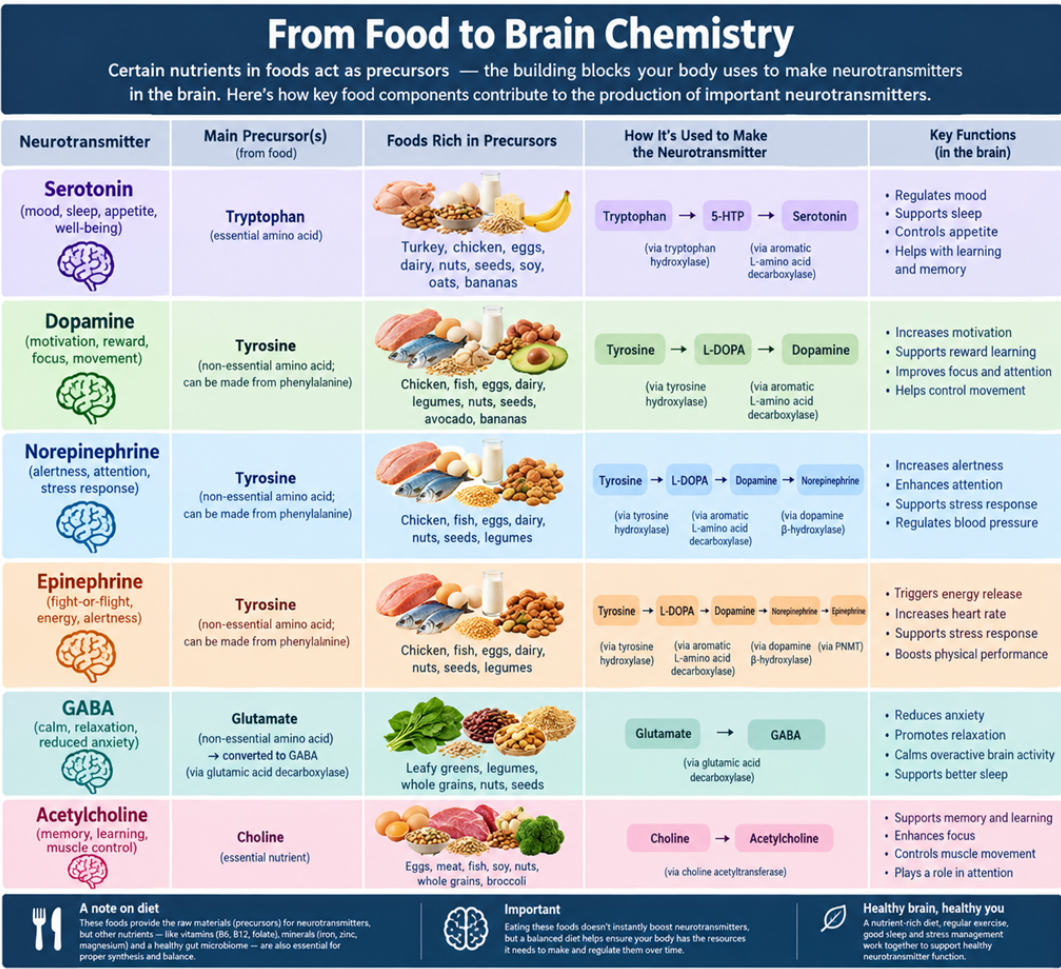
Nutrition and Inflammation. Another emerging area concerns neuroinflammation. Diet influences systemic inflammation. Diets characterized by high consumption of highly processed foods and low consumption of fruits, vegetables, whole grains, fish, and other nutrient-dense foods have been associated with less favorable inflammatory profiles. Inflammatory processes can influence brain functioning, neurotransmission, and mood.

There is growing interest in whether chronic low-grade inflammation contributes to behavioral and psychiatric disorders [42]. However, the evidence linking dietary inflammation specifically to youth violence remains substantially less developed than the evidence connecting nutrition and inflammation to physical and mental health. Therefore, inflammation represents a plausible biological pathway, but one that requires considerably more research before strong conclusions about violence can be drawn. Still, some studies find markers of inflammation related to outcomes such as criminal offenses among people with severe mental illnesses [43,44].

Nutrition and Neurotransmitters. Nutrition supplies the raw materials and cofactors required by the brain’s chemical signaling systems. This helps explain why nutritional interventions sometimes produce behavioral changes even when they are not specifically designed as “anti-aggression” interventions, as they change brain chemistry.

Figure 1 illustrates how precursors found in certain foods produce specific neurotransmitters. The key functions of each neurotransmitter are also identified in the figure.

When it comes to aggression, there is evidence that low levels of



serotonin and norepinephrine, as well as high levels of dopamine, are associated with higher levels of aggression and antisocial behavior. There is also anecdotal evidence that higher levels of acetylcholine may be associated with some acts of violence [3]. Given that diet impacts these brain chemicals, this suggests nutrition is relevant for helping to understand some forms of crime.

The dopamine system is especially relevant to behavioral regulation. Dopamine is involved in motivation, reward, attention, and executive functioning, and iron is necessary for several enzymes involved in dopamine metabolism [45].

One of the most frequently discussed mechanisms involves serotonin. Serotonin plays an important role in mood regulation, impulse control, emotional processing, and aggression [46]. Abnormalities in serotonergic functioning have been associated with impulsive aggression across a substantial body of psychological and biological research.

Nutrition is relevant because serotonin is synthesized from the amino acid tryptophan, which must be obtained through the diet. Experimental research has shown that temporarily reducing tryptophan availability can influence mood and behavior, although effects differ substantially among individuals and experimental conditions [47]. Importantly, the relationship is not simply less tryptophan equals more violence. Rather, nutritional availability of precursors can interact with existing biological vulnerabilities and environmental circumstances. Research on serotonin and aggression therefore provides a plausible biological pathway through which nutrition might influence aggression, but it does not establish that dietary deficiencies independently produce violent behavior.

The Most Direct Evidence: Nutritional Supplementation and Antisocial Behavior. One of the most important studies in this field is the randomized controlled trial conducted by Gesch et al. [48]. The researchers provided young adult prisoners with either nutritional supplements containing vitamins, minerals, and essential fatty acids or placebo supplements. The study found a significant reduction in disciplinary incidents among prisoners receiving the active nutritional supplementation. The investigators reported that disciplinary incidents declined by approximately 26% in the active-treatment group relative to placebo [48]. This study is particularly important because it moved beyond correlation. Participants were randomly assigned to conditions, making it possible to investigate whether improving nutritional intake could influence behavior. Other studies are consistent with these findings [49-51].

However, several qualifications are necessary. The participants were young adult prisoners, not community-based children or adolescents. Moreover, the intervention contained multiple nutrients, meaning that the study could not determine which particular nutrient produced the effect. The study therefore provides evidence that improving nutritional status may influence antisocial behavior under some circumstances, but it does not

establish that nutritional deficiency is a major independent cause of youth violence.

Replication and Subsequent Research. The Gesch et al. [48] findings stimulated substantial interest, but subsequent research has produced a more complicated picture. For example, Zaalberg et al. conducted another randomized controlled trial involving prisoners and reported reductions in antisocial behavior associated with nutritional supplementation. Their findings provided additional support for the possibility that nutritional status can influence behavioral regulation. However, the literature has not produced a uniformly large effect. Different studies have varied in participant age, baseline nutritional status, nutrient formulations, duration of supplementation, behavioral measures, study populations, and methodological quality. Consequently, the literature supports continued investigation rather than a simple conclusion that nutritional supplementation prevents violence.

The Broader Literature on Diet and Aggression. A major review by Benton [52] examined the relationship between diet and antisocial, violent, and aggressive behavior. Benton concluded that nutritional factors can influence behavior through several pathways, including effects on brain development, neurotransmitter functioning, blood glucose, micronutrient status, and essential fatty acids. The review also emphasized that nutritional interventions appeared more promising when nutritional inadequacy was present. This is an important qualification. The behavioral effects of correcting a nutritional deficiency may be substantially different from giving already well-nourished individuals additional nutrients. In other words, the relevant question may not be: "Can we give children supplements to make them less aggressive?" but rather: "Does ensuring that children receive adequate nutrition remove a biological barrier to healthy brain development and behavioral regulation?" The second question is much better supported by current knowledge.

Adolescence Is a Particularly Important Developmental Period. Adolescence is particularly relevant because it represents a period of substantial neurological reorganization. The prefrontal cortex continues to mature while reward, emotional, and threat-related systems are highly active [41]. At the same time, adolescents may experience irregular eating patterns, increased independence in food choices, greater consumption of highly processed foods, dieting or restrictive eating, socioeconomic food insecurity and increased nutritional requirements associated with growth. Consequently, inadequate nutrition during adolescence potentially intersects with an already sensitive period of brain development. Research on adolescent nutrition has consistently linked dietary quality to aspects of cognitive and psychological functioning, although the evidence specifically connecting dietary quality to violent behavior remains relatively limited [53].

Still, studies do show that what people eat matters for their behavior. For example, a study of 14,880 students, aged 6–18 years, living in 30 provinces in Iran, found that: "Daily consumption of fast foods, sweets, soda, salty snacks and fried foods was higher among those participants who reported frequent experience of

physical aggression and bullying. Bullying to others increased significantly with consumption of fast food ... and red meat. Salty snack consumption showed a significant association with physical fighting” [54]. This study suggests a direct link between nutrition and behavior. It is important to point out that there is a growing literature on the harms associated with ultra-processed foods and their link even to bad behaviors such as aggressive crimes [55].

Poor Nutrition Does Not Operate in Isolation. This is perhaps the most important conclusion from the literature. Violence among young people is influenced by multiple interacting factors, including, but not limited to exposure to violence, family environment, peer influences, parenting influences, poverty, neighborhood conditions, substance use, trauma, mental and behavioral disorders, educational experiences, quality and duration of sleep, personality traits such as impulsivity, social marginalization, parenting, access to weapons, and socioeconomic status or poverty [3].

Nutrition potentially interacts with many of these variables. For example: Poverty can produce food insecurity and poor nutrition, which can lead to impaired cognitive/emotional functioning [56]. Additionally, people living in conditions of poverty are likely to experience higher levels of neighborhood violence, chronic stress/ altered stress physiology, as well as family instability. Results can include sleep disruption and irregular eating, which can produce impaired behavioral regulation or lower levels of self-control [3]. It is therefore difficult, and scientifically inappropriate, to isolate nutrition as the sole cause of aggressive behavior.

A Developmental Model. The existing research supports a conceptual model in which nutrition influences aggression through several interconnected pathways: Nutritional disadvantage lead to deficiencies in energy and/or essential nutrients, which produces changes in brain development and physiological functioning through effects on neurotransmitters, myelination, synaptic functioning, stress regulation, and executive functioning. This can lead to outcomes such as reduced attention, impulse control, emotional regulation, or cognitive flexibility, producing greater vulnerability to irritability and aggressive responses, including aggressive behavior under sufficiently stressful environmental circumstances. Such a developmental model is particularly useful because it does not claim that nutrition determines behavior. Instead, nutrition may alter the probability that an individual will respond aggressively when exposed to provocation, frustration, stress, or perceived threat.

Nutrition May Be a Protective Factor Rather Than Simply a Risk Factor. An important implication of the research is that nutrition should not be viewed exclusively in terms of preventing deficiency. Adequate nutrition may promote healthy brain development, cognitive functioning, greater executive control and emotional regulation, better academic functioning and resilience to stress, as well as general physical and psychological health.

From this perspective, nutritional interventions may be part of

a broader violence-prevention strategy rather than a stand-alone treatment. This is particularly relevant to public health because nutritional interventions can potentially address multiple outcomes simultaneously. Improving children’s diets may benefit physical health, cognition, educational performance, and psychological functioning regardless of whether it produces measurable reductions in violence.

What the Research Does and Does Not Establish. The evidence can be summarized in several levels of confidence. Starting with what is relatively well-established: There is strong evidence that adequate nutrition is important for normal brain development and that serious nutritional deficiencies can affect cognition, neurological development, and behavior [1]. Moving on to what is moderately supported: There is evidence that particular nutrients, including omega-3 fatty acids and iron, influence biological systems involved in emotional and behavioral regulation [1,10]. Then there is what is promising but less conclusive: Randomized trials suggest that nutritional supplementation can reduce some measures of antisocial behavior, particularly among populations with potentially inadequate nutrition [48]. And this is what has not been well-established: The evidence does not demonstrate that poor nutrition independently causes serious violent behavior among children or adolescents. Nor does the evidence establish that nutritional supplementation is an effective stand-alone treatment for youth violence.

Implications for Juvenile Justice and Violence Prevention. The research has potentially important implications for juvenile justice. If adequate nutrition supports brain development and behavioral regulation, then nutritional deprivation may represent an underrecognized component of the developmental risk environment surrounding some young offenders.

This suggests several areas for further research and intervention:

1. Screening for food insecurity among justice-involved youth.
2. Assessment of nutritional status among children with severe behavioral problems.
3. Improving nutritional quality in juvenile detention facilities.
4. Ensuring adequate micronutrient intake during adolescence.
5. Providing access to healthy foods in disadvantaged communities.
6. Studying nutritional interventions alongside established violence-prevention programs.
7. Examining whether nutritional improvements affect recidivism and disciplinary infractions.

Importantly, such interventions should complement rather than replace evidence-based approaches addressing trauma, family functioning, education, substance use, peer relationships, and exposure to violence.

Conclusion

The research increasingly supports the proposition that nutrition is relevant to brain development and behavioral regulation, particularly during childhood and adolescence. Nutritional

deficiencies can affect neural development, neurotransmitter functioning, myelination, energy metabolism, stress regulation, and cognitive processes. These systems are all relevant to the capacity to control impulses and regulate emotional responses [1].

There is also evidence—most notably from randomized supplementation trials—that improving nutritional intake can reduce certain measures of antisocial behavior [48]. Research involving omega-3 fatty acids provides additional evidence that nutrition may influence aggression, although effects are generally modest and heterogeneous [10].

The strongest conclusion, therefore, is that poor nutrition should be regarded as one potentially modifiable developmental risk factor for aggression rather than as a direct or sufficient cause of violence. Its effects are likely to be greatest when nutritional disadvantage interacts with other established risk factors, including chronic stress, poverty, trauma, family instability, substance use, and exposure to violence.

From a criminological perspective, this suggests a potentially important shift in thinking. The question is not simply whether “bad diets cause crime”. Rather, the research raises the possibility that the social distribution of adequate nutrition may contribute to the distribution of developmental capacities that protect against antisocial and violent behavior. Food insecurity and nutritional deprivation may therefore be relevant not only to public health but also to the broader social ecology of crime and violence.

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