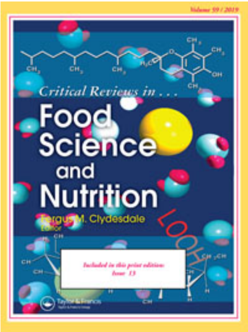

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REVIEW

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Is vegetarianism healthy for children?

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ABSTRACT

According to the Academy of Nutrition and Dietetics' influential position statement on vegetarianism, meat and seafood can be replaced with milk, soy/legumes, and eggs without any negative effects in children. The United States Department of Agriculture endorses a similar view. The present paper argues that the Academy of Nutrition and Dietetics ignores or gives short shrift to direct and indirect evidence that vegetarianism may be associated with serious risks for brain and body development in fetuses and children. Regular supplementation with iron, zinc, and B_{12} will not mitigate all of these risks. Consequently, we cannot say decisively that vegetarianism or veganism is safe for children.

KEYWORDS

Vegetarianism in children; veganism in children; growth; cognitive development; phytoestrogens in pregnancy; birth ratio

Introduction

Vegetarian (or lacto-ovo-vegetarian) diets do not include meat, fowl, or seafood. Vegan diets do not include any animal source foods. According to the Academy of Nutrition and Dietetics' (AND) position statement on vegetarianism: "appropriately planned vegetarian, including vegan, diets are… appropriate for all stages of the life cycle, including pregnancy, lactation, infancy, childhood, [and] adolescence," and "may provide health benefits in the prevention and treatment of certain diseases" (Melina, Craig, and Levin 2016). The United States Department of Agriculture (USDA) treats vegetarianism and veganism as healthy alternatives. Both the AND and the USDA recommend that vegetarians replace meat and seafood primarily with soy (and other legumes), dairy, and eggs. According to the USDA, vegans can substitute fortified soy products for dairy and eggs.

Is there sufficient evidence to say definitively that an "appropriately planned" vegetarian or vegan diet adhering to the USDA's recommendations is healthy for "*all stages of the life cycle*"? There have been a number of long-term epidemiological studies of *adult* vegetarians/vegans, the results of which suggest that, although vegetarians have a lower incidence of certain diseases, all-cause mortality in comparable populations of vegetarians and omnivores is similar (Appleby et al. 2016; Key, Appleby, and Rosell 2006; Mihrshahia et al. 2017). There is much less evidence available concerning the health effects of meatless diets in children. The present paper focuses on the health consequences of vegetarianism and veganism for children from conception to the end of the growing period. It does not argue that vegetarianism or veganism is unhealthy for children, but considers whether there is enough evidence to justify the AND's unqualified statement, which suggests that there is *definitive* evidence that vegetarian and vegan diets can be as healthy for children as diets that include meat and seafood. It will be argued that the AND ignores or gives short shrift to evidence that vegetarianism may be harmful during pregnancy, that milk, soy/legumes, and eggs are not equal substitutes for meat, and that realistic vegetarian diets put children at risk for deficiencies that may have both short-term and permanent negative health consequences.

Vegetarianism during pregnancy

Regarding the effect of vegetarianism during pregnancy, the AND says that "Limited research indicates that where food access is adequate, vegetarian pregnancy outcomes, such as birth weight and pregnancy duration, are similar to those in nonvegetarian pregnancy" (Melina, Craig, and Levin 2016). This is an incomplete summary of the evidence.

In most populations, the male/female sex ratio of newborns is around 105:100. Environmental stress is associated with a lower sex ratio due to the selective spontaneous abortion of male fetuses (Bruckner et al. 2014; Fukuda et al. 1998; Kanninen and Karhula 2016). Malnutrition specifically has been linked to a lower sex ratio (Andersson and Bergström 1998; Williams and Gloster 1992). One possible test of whether vegetarianism is healthy during pregnancy is to determine whether it has an effect on the sex ratio of newborns. If it is healthy, it should have no effect on or should raise the sex ratio; if unhealthy, then vegetarianism should lower it.

Hudson and Buckley (2000) found that among a sample of almost 6,000 pregnant women at a British hospital, about 5% of whom were vegetarian (and almost all of whom were white), the sex ratio was considerably lower among children

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born to vegetarians compared with those born to omnivores: 81.5:100 vs. 106:100. That is, vegetarians were 23% less likely to give birth to a boy. Given the known association between environmental stress, including malnutrition, and a lower chance of giving birth to a boy, a possible explanation for these findings is that vegetarianism increases the chance of spontaneous abortion, particularly for male fetuses. The AND does not mention Hudson and Buckley's study, or the effect of vegetarianism/veganism on the sex ratio/spontaneous abortion, in its position statement on vegetarianism (Melina, Craig, and Levin 2016).

As discussed below, vegetarians/vegans are at risk for a number of nutritional deficiencies that could potentially harm the fetus.

Are milk, soy, and eggs equally beneficial substitutes for meat?

The AND, the USDA, and other health authorities claim that dairy and legumes (especially soy) and, to a lesser extent, eggs can be substituted for meat with no ill effects. This section examines evidence that raises doubts about this position.

Milk

Physical and cognitive development

There has been only one controlled study on the effects of milk versus meat consumption in children. Subjects in the study were 6–14-year-olds (median 7.4 years) in Embu, Kenya. Due to poverty, the children were largely vegetarian, with more than 75% of their energy intake coming from maize and beans, less than 6% from animal source foods. Their daily intake of milk and meat was very low at approximately 35 g and 11 g, respectively. Researchers divided a large group of children into four conditions: Meat, Milk, Energy, and Control. Every school day, children in the Meat, Milk, and Energy groups received a local plant-based dish supplemented with 60 g of ground beef, 200 mL of milk, or an extra 3 g of oil, respectively. The meals in each of these three groups had approximately the same number of calories. Children in the Control group did not receive any extra meals. The researchers measured several outcomes related to growth, intellectual ability, school performance, and social behavior (Neumann et al. 2003).

After 2.25 years, the Meat group had the best health outcomes. The Meat group showed the greatest improvement on Raven's Progressive Matrices (RPM—a measure of fluid intelligence), while the Milk group showed the least improvement, significantly below the other three groups (including the Control). While all groups started off with roughly the same RPM scores, Meat ended up approximately 0.65 standard deviations higher than Milk (Hulett et al. 2014), corresponding to a difference of around 10 IQ points. The Meat and Energy groups showed significantly more improvement on arithmetic tests than the Milk and Control. The Meat group showed a significantly larger percentage increase in end-of-term test scores compared to the others, with the greatest increase being in the arithmetic subtest. Over the course of the study, the Meat group had the highest levels of physical activity during free play, the greatest increase in leadership activities, and the greatest increase in initiative behavior. The Milk group had the lowest level of physical activity and leadership and initiative behavior among the three intervention groups. Regarding growth: Only children in the Milk group who were below age 6 or had stunted growth experienced a greater rate of height increase. All three intervention groups experienced an improvement in weight gain relative to the Control. Children in the Meat group gained approximately 50% more mid-upper-arm muscle area than those in the Milk group, and 100% more than those in the Energy and Control.

Neumann et al. (2007) suggest that the "improved cognitive performance, increased [physical activity] and leadership and initiative behaviors in the Meat group" may be due to their consumption of vitamin B_{12} and more bioavailable iron and zinc, since meat improves the absorption of iron and zinc from "fiber and phytate-rich plant staples." Micronutrients and high-quality protein in meat may be important for cognitive performance. As to why the Milk group obtained the lowest scores on RPM, Neumann et al. suggest that this may be due to the high casein and calcium content of milk that interferes with iron absorption, which is essential for optimum cognitive performance. They attribute the increase in mid-upper-arm muscle area in the Meat group to the "intake of zinc and complete protein, which both promote protein synthesis … , and iron and protein, which are essential to myogloboin synthesis in striated muscle … ."

This study of Kenyan children does not decisively refute the AND's claim that "appropriated planned" vegetarian/vegan diets can be as healthy as diets that include meat. For one thing, none of the children were on diets meeting the USDA's recommendations. Also, it is unfortunate that the study compared meat and milk supplementation with oil supplementation rather than soy. The study does not say whether a soy product such as tofu could produce outcomes equal to meat. However, the AND and the USDA say that dairy can be used as an equal substitute for meat. The Kenyan study casts serious doubt on that claim. Children in the Milk group had significantly worse outcomes than those in the Meat group in terms of RPM scores, academic performance, muscle growth, and physical and social activity. Despite the limitations of the study, it is still the only controlled experiment comparing the benefits of milk versus meat in children, and it suggests that milk is not an equal substitute for meat. The AND does not mention this study in its position statement on vegetarianism (Melina, Craig, and Levin 2016).

Acne vulgaris

Contrary to some oft-repeated claims that diet is unrelated to acne, there is overwhelming evidence that diet is a major factor in acne. Acne appears to be absent in populations that have not adopted a Western diet. For example, Kitavans of the Trobriand Island live by horticulture and fishing. They consume virtually no dairy or alcohol, and a "negligible" amount of cereals, sugar, and salt. Lindeberg examined 1,200 Kitavans for the presence of acne. All 1,200 were at least 10 years old and 300 were between 15 and 25 years old. Lindeberg did not find *one single papule, pustule, or open comedone in any of the 1,200 Kitavans* (Cordain et al. 2002). The Aché of Paraguay engage in a combination of hunting and gathering and farming. Western foods such as wheat and sugar comprise only around 8% of the diet. Hurtado examined 115 Aché including 15 who were between the ages of 15 and 25. After Hurtado's examinations, family practitioner physicians conducted the same examination every six months for two years. "Not a single papule, pustule, or open comedo was observed in the entire population" (Cordain et al. 2002). The nonexistence of acne among Kitavans and Aché cannot be explained entirely by genetics. More Westernized South American Indians and Pacific Islanders show high rates of acne (though not quite as high as the white population) (Fleischer, Feldman, and Bradham 1994; Freyre et al. 1998).

Cordain et al. (2002) hypothesize that acne in Western populations is caused by diet-induced hyperinsulinemia, and this could explain the relationship between milk and acne: Despite its low glycemic load, dairy triggers a large insulin response (Holt, Brand Miller, and Petocz 1997; Hoyt, Hickey, and Cordain 2005; Östman, Liljeberg Elmståhl, and Björck 2001). Observational studies have found a significant association between dairy intake and acne in adolescents (Adebamowo et al. 2006, 2008; Adebamowo et al. 2005; Ismail, Manaf, and Azizan 2012). Controlled experiments have found that a high protein, low-insulin-response-triggering diet significantly improves symptoms in acne patients (Kwon et al. 2012; Smith et al. 2007). While there is still a debate about exactly why dairy consumption is associated with acne, the association appears to be causal and significant.

Acne is a negative health outcome that is expensive to treat and which has a strong association with depression and suicide in adolescents (Purvis et al. 2006). There is reason to believe that substituting dairy for meat increases the risk of developing acne during childhood/adolescence (assuming it would involve consuming more dairy on average than omnivores). This is a negative health outcome not discussed in the AND's position statement on vegetarianism.

Soy and other legumes

Phytoestrogens

Phytoestrogens, particularly isoflavones, are found in high concentrations in legumes and especially in soy. Vegetarians/vegans tend to have very high blood levels of phytoestrogens compared with omnivores. While phytoestrogens have been associated with some health benefits in adults, there are serious concerns about their potential negative health effects on infants and children (Patisaul and Jefferson 2010).

Animal studies show that interfering with estrogen during critical periods in development "leads to a myriad of adverse health outcomes including malformations in the ovary, uterus, mammary gland and prostate, early puberty, reduced fertility, [and] disrupted brain organization" (Patisaul and Jefferson 2010). Patisaul and Jefferson note that these consequences correspond to some public health trends that emerged in Western countries, which have occurred in tandem with greater consumption of soy. North and Golding (2000) found that males born to vegetarian mothers in England were more than 3.5 times as likely to have hypospadias (i.e., malformed genitalia), which was statistically linked to the consumption of high-phytoestrogen legumes (hypospadias rates were 2.2% and 0.6% for boys born to vegetarian and omnivorous mothers, respectively).

Rodent studies have found that phytoestrogens such as genistein (which is abundant in soy) interfere with the development of brain regions that are sensitive to estrogen levels in both male and female rodents—regions that are sexually dimorphic (Bateman and Patisaul 2008; Kouki et al. 2003; Lund et al. 2001; Scallet et al. 2004). Whether or to what extent these findings generalize to humans is uncertain (Patisaul and Jefferson 2010).

Jefferson, Padilla-Banks, and Newbold (2005) found that administering genistein to neonatal female mice at "environmentally relevant doses"—i.e., doses comparable to what human neonates can be exposed to—led in later life to "abnormal estrous cycles, altered ovarian function, early reproductive senescence, and subfertility/infertility." Nagao et al. (2001) obtained similar results. It is not clear whether these findings apply to humans.

Antinutrients: Iron and zinc absorption

Legumes, particularly soy, are high in phytate, which significantly inhibits the absorption of minerals including iron (Hurrell et al. 1992) and zinc (Lönnerdal 2000). Iron and zinc deficiency can have devastating effects in children/fetuses. Iron deficiency in infancy leads to impaired processing speed, affect, learning, and memory (Fretham, Carlson, and Georgieff 2011). Zinc deficiency during pregnancy increases the risk of preterm delivery. In children it can impair growth, cause hypogonadism in males, neurosensory disorders, and other problems (Nishi 1996; Prasad 1988).

The AND acknowledges that the high phytate content of vegetarian diets interferes with iron and zinc absorption, and that the bioavailability of the nonheme iron of plants, dairy, and eggs is lower than that of heme iron in meat and seafood (Melina, Craig, and Levin 2016). But the danger of deficiency, particularly in regard to iron, may be greater than the AND suggests in its position statement.

Studies on vegetarians have generally shown them to be at much greater risk for iron deficiency. Although most studies show that vegetarians/vegans tend to have a similar or higher daily intake of iron compared with omnivores, the former tend to have significantly lower mean serum ferritin concentrations due to the lower bioavailability of iron in the vegetarian diet (see, e.g., Baines, Powers, and Brown 2007; Ball and Bartlett 1999; Pawlak and Bell 2017; Snyder, Dvorak, and Roepke 1989; Wilson and Ball 1999). Wilson and Ball (1999), for example, found that among Australian men, iron intake among vegetarians and vegans was 29–49%

higher than that of omnivores, but their serum ferritin concentrations were *much* lower: Vegetarians had mean concentrations of 64, vegans 65, and omnivores 121 ng/ml. None of the omnivores in their sample, but 20.5% of vegetarians and 30% of vegans had low concentrations of <25 ng/ml. 3% of vegetarians and 25% of vegans were technically deficient, with ferritin concentrations <12 ng/ml. The other studies cited above report similar findings.

Most studies find vegetarians/vegans to have a zinc intake that is similar to omnivores, and to have a slightly to moderately elevated risk of deficiency. Low serum zinc levels can be caused in both vegetarians and omnivores by high phytate intake (Bindra, Gibson, and Thompson 1986; Donovan and Gibson 1995; though see Ball and Ackland 2000).

Eggs

Eggs are a high-quality source of protein and are high in iron and zinc. They may be promising as a substitute for meat. However, there are a few reasons to question whether it would be healthy for pregnant women and children to rely on eggs as a primary source of these nutrients.

One whole egg contains approximately 1 mg nonheme iron and 1 mg zinc, corresponding to around 10% of the USDA's recommended dietary allowance (RDA) for each of these minerals for children aged 9–12. Because the iron in eggs is of the less bioavailable nonheme form, and because egg consumption itself reduces iron absorption (Hallberg and Hulthén 2000), children would have to consume somewhat more than the RDA of iron from eggs in order to meet their requirements. An egg contains 6 g protein, which is 11% of the RDA for males 14 years and older. Children who are relying on eggs as a major source—or even their primary source—of protein, iron, and zinc will (depending on their age, sex, and body size) have to eat several every day in order to meet the USDA's recommendations. This may be an unrealistic dietary plan.

The $n-6/n-3$ polyunsaturated fatty acid (PUFA) ratio in eggs is a little over 15:1, and eggs would therefore contribute to the already high $n-6/n-3$ PUFA ratio of the vegetarian diet. As shall be discussed below, there is a possibility that a high $n-6/n-3$ ratio promotes chronic systemic inflammation and the pathogenesis of autoimmune diseases.

Potential deficiencies and their consequences for brain and body development

As mentioned in the previous section, the AND acknowledges that vegetarians must pay close attention to iron and zinc intake (Melina, Craig, and Levin 2016), though its position statement may underestimate the risk of deficiency. This section discusses vegetarians' risk of deficiencies in vitamin B_{12}, creatine, taurine, and long-chain $n-3$ PUFAs, which could have serious consequences for children. Although the AND notes that vegetarian diets are low in B_{12} and long-chain $n-3$ PUFAs, it may underestimate the risk of B_{12} deficiency and the negative consequences of lower long-chain $n-3$ fatty acid intake in children.

Vitamin B_{12}

Herrmann et al. (2003) found vitamin B_{12} deficiency—defined as concentrations <156 pmol/L—in 26% of adult vegetarians, 52% of vegans, and 1% of omnivores. Average levels for vegans, vegetarians, and omnivores were 148, 192, and 287 pmol/L, respectively. 148 pmol/L is considered clinically deficient in the U.S., but symptoms of deficiency are known to occur at "marginal" levels of 148–221 pmol/L (Allen 2009). This would place the *average* vegetarian and vegan in the range for potentially experiencing negative consequences due to low B_{12} levels. It should be noted that the subjects in Herrmann et al.'s study were recruited from a conference of the German Federation of Vegetarians and a Vegan Society summer camp in the Netherlands, so there is reason to think that these vegetarians and vegans had an above-average amount of nutrition education. Indeed, 20% of vegetarians and 59% of vegans in their study reported taking vitamin B supplements, which did improve their B_{12} status. There was no significant difference between the B_{12} levels of vegetarians who took supplements and omnivores, which was in part due to extremely high levels among some vegetarians taking supplements. Vegans who took supplements still had a marginally low average level of 192, ranging from 125 to 299 pmol/L. (The lowest level among an omnivore in their study was 190 pmol/L.)

The AND says that "[v]egans must regularly consume … B-12-fortified foods or B-12-containing supplements," and "[m]ost vegetarians should" do the same (Melina, Craig, and Levin 2016). The results of Herrmann et al. (2003) suggest that even with supplementation vegans may still tend to cluster in the deficient-to-borderline-deficient range. Vegetarians can achieve adequate B_{12} levels with supplementation, but some are still in the deficient and borderline-deficient range. Whether it is realistic for vegetarians/vegans to maintain adequate B_{12} levels throughout their entire childhood via supplementation is an open question.

The consequences of B_{12} deficiency in childhood for brain and body development are extensive, severe, and can be irreversible. Potential consequences include (among many others) impaired cognitive development/school performance, depression, weakness, fatigue, nerve damage, and failure to thrive (Graham, Arvela, and Wise 1992; Rasmussen, Fernhoff, and Scanlon 2001). Breastfeeding infants whose mothers are vegetarian/vegan are also known to be at risk for B_{12} deficiency (Graham, Arvela, and Wise 1992; Kühne, Bubl, and Baumgartner 1991; Roschitz et al. 2005; von Schenck, Bender-Götze, and Koletzko 1997).

Creatine

Creatine is rarely mentioned in discussions of the health consequences of vegetarianism. However, there is some little-known evidence that creatine consumption may play an important role in cognitive functioning.

In a double-blind, placebo-controlled study, Rae et al. (2003) found that 6 weeks of oral creatine supplementation significantly improved the performance of vegetarians on a timed Raven's Advanced Progressive Matrices test (RAPM—a measure of fluid intelligence) and the backward digit span task (a measure of working memory). The difference in performance between the control and the creatine-supplemented vegetarians was enormous. On RAPM, the treatment group scored slightly more than 1 standard deviation higher than the control. There was an approximately 1 standard deviation difference between the treatment and the control group on the backward digit span task: The former could recall on average 8.5 items (SD = 1.76) while the latter could recall on average 7.05 (SD = 1.19). However, Rawson et al. (2008) found that *creatine supplementation had no effect on RAPM or backward digit span task performance for meat eaters*, suggesting that vegetarians have impaired scores due to low creatine intake.

Gale et al. (2007) found that 30-year-olds in Britain who identified as vegetarian (33.6% of whom admitted to eating fish or chicken) had, at age 10, a mean IQ of 104.8 compared with a mean of approximately 100 for the general population. At age 10, vegans had a mean IQ of 95.1 (though the sample size for vegans was low). But, to reiterate, Gale et al. report the IQ of 30-year-old vegetarians *when they were 10-year-olds*. Rae et al.'s (2003) findings suggest that vegetarianism reduces performance on tests that have a strong relationship with IQ. It is possible that, although vegetarianism appeals to people with higher intelligence, becoming vegetarian reduces fluid intelligence and working memory. Consistent with this possibility, Gale et al. (2007) report that although vegetarians were 2.4 times as likely as omnivores to have higher academic degrees or vocational qualifications, the former had no advantage in terms of annual income—in fact they were slightly overrepresented in the lowest income bracket and underrepresented in the highest. Gale et al. suggest that vegetarians may choose lower paying jobs because of "ethical considerations," and note that vegetarians are more likely to agree with the statement that "The government should redistribute income." However, other studies have found that agreeing with redistributionist policies is associated with a *lower* IQ (Carl 2014; Kanazawa 2010).

The findings reviewed so far provide suggestive evidence that the lack of creatine intake among vegetarians lowers fluid intelligence and working memory by approximately 1 standard deviation, corresponding to about 15 IQ points. People may not notice a reduction in cognitive functioning when they become vegetarian if *fluid* but not *crystallized* intelligence is affected. (That is to say, becoming vegetarianism may impair one's ability to solve problems without causing one to forget what one has learned, so the effect may not be noticeable.) The results from Rae et al. (2003) suggest that the impairment is to some extent reversible in adults by means of supplementation, and would presumably be reversible by eating meat.

There is direct evidence that childhood creatine levels affect not only performance on cognitive tests, but also real-life labor market outcomes in adulthood. As part of the Young Finns Study in 1980, researchers measured the urinary concentrations of creatinine in 3,596 Finns aged 3–18. (Creatinine is a breakdown product of creatine, and so the former is a proxy for the latter.) Böckerman et al. (2017) found a significant relationship between subjects' creatinine levels in 1980 and their income 20 years later. A one SD increase in creatinine corresponded to an increase of 7.36% in earnings. As the authors note, since urinary creatinine levels do not perfectly reflect actual *creatine* levels, their results probably underestimate the true effect of creatine.

While impaired creatine metabolism has been linked to psychiatric disorders (Allen 2012), whether chronic low creatine intake in childhood has nonreversible negative effects on brain development has not been studied. We cannot say for sure whether long-term creatine supplementation for vegetarian or vegan children would be a solution to this potential problem. (The AND's 2016 statement does not mention creatine, though its 2009 statement said that "vegetarian athletes may have lower muscle creatine concentration [and] may benefit from creatine supplementation" [Craig and Mangels 2009]. Neither the 2016 nor the 2009 statement mentions the possible consequences of chronic low creatine intake for physical and mental development, which are in fact unknown.)

Taurine

As to the significance of taurine, Wu and Prentice (2010) report: "Taurine demonstrates multiple cellular functions including a central role as a neurotransmitter, as a trophic factor in CNS development, in maintaining the structural integrity of the membrane, in regulating calcium transport and homeostasis, as an osmolyte, as a neuromodulator and as a neuroprotectant." Vegetarians and especially vegans have low taurine intake and, consequently, low levels of plasma taurine and urinary taurine excretion (Laidlaw et al. 1988). The effects of chronically low levels of taurine intake as seen in vegetarians and vegans are largely unknown, though there is some direct evidence that low levels in infancy—even if they are within the normal range—may impair brain development. Wharton et al. (2004) found that "[l]ow plasma neonatal taurine was associated with lower scores on the Bayley mental development index at 18 months and the WISC-R arithmetic subtest at 7 years." They suggest that dietary taurine intake may be responsible for the benefits of breast milk for neurodevelopment. If they are right, then consuming breastmilk from mothers with low taurine intake, including vegetarians/vegans (Rana and Sanders 1986), may put infants at risk for impaired neurodevelopment. Low taurine levels during pregnancy may have an effect on fetal development.

Long-Chain n−3 PUFAs

Development

Without supplementation, vegans consume virtually no eicosapentaenoic acid (EPA) or docosahexaenoic acid

(DHA). Vegetarians can obtain some DHA from eggs (Davis and Kris-Etherton 2003). However, a small percentage of ingested alpha-linolenic acid (ALA) from plants can be converted to EPA and DHA through endogenous processes. Rosell et al. (2005) found that, compared with omnivores, vegetarians had plasma concentrations of EPA and DHA that were 27.8% and 31.4% lower, respectively. Plasma concentrations in vegans were, respectively, 52.8% and 58.6% lower than in omnivores. Investigations by Kornsteiner, Singer, and Elmadfa (2008) and Sanders (2009) led to similar findings. Could there be negative consequences associated with having low levels of EPA and DHA during childhood?

DHA is crucial for brain and retinal development, particularly in the first 2 years of life (Birch et al. 2010; Drover et al. 2011; Echeverría et al. 2017; Innis, Gilley, and Werker 2001; McCann and Ames 2005; Uauy and Dangour 2006). Both DHA and EPA deficiencies are linked to a variety of neurocognitive disorders including “attention-deficit hyperactivity disorder (ADHD), dyslexia, dyspraxia and autism spectrum disorders” (Schuchardt et al. 2010).

The AND states:

> The clinical relevance of reduced EPA and DHA status among vegetarians and vegans is unknown. Long-chain $n-3$ fatty acids are important for the development and maintenance of the brain, retina, and cell membranes and favorably impact pregnancy outcomes and risk for [some] chronic diseases. Yet, vegetarian and vegan children do not appear to experience impairment in visual or mental development .... (Melina, Craig, and Levin 2016)

But since, as the AND itself says, the significance of the low EPA and DHA status among vegetarians is “unknown,” it does not seem justified to say definitively that there is no risk. Some indirect evidence suggests that low EPA and DHA levels in vegetarian children could be associated with risks.

Supplementation with plant-based sources of ALA (such as flaxseed oil) can improve the EPA levels of vegetarians and vegans, but may have little or no effect on DHA levels (Lane et al. 2014). The AND suggests that vegetarians who are pregnant or lactating or who have reduced conversion ability due to disease could benefit from “[l]ow-dose microalgae-based DHA supplements” (Melina, Craig, and Levin 2016). (Recently algae-based supplements containing EPA have also been developed.). However, the below-normal levels of EPA and DHA typically found in vegetarians could potentially put children at risk for impaired brain and CNS development.

Mental health

There is currently an epidemic of depression among young people in developed countries, including the U.S. (Kessler et al. 2005; Nesse 2000). Supplementation with EPA (but not DHA) has been shown to significantly improve depression (Martins 2009; Sublette et al. 2011). A recent meta-analysis found an association between low fish intake and depression, presumably due to the high EPA content of fish (Li, Liu, and Zhang 2016). This gives some reason to believe that young vegetarians and vegans, who consume very little EPA or none at all, may be at increased risk for depression. In fact, there is empirical evidence linking vegetarianism (and low meat consumption) to depression and to contemplating and attempting suicide in adolescents (Larsson et al. 2002; Perry et al. 2001).

$n-6/n-3$ PUFA ratio

Hunter–gatherers consume $n-6$ and $n-3$ fatty acids in a ratio of about 1:1, while Westerners consume them in a ratio of around 15:1 or higher (Simopoulos 2002a). There is an ongoing controversy about the significance of the $n-6/n-3$ PUFA ratio in the diet. Some evidence seems to connect a high ratio with chronic systemic inflammation that can potentially lead to (or aggravate) autoimmune diseases, some of which often manifest in adolescence (Harbige 2003; Kang 2003; Sierra et al. 2006; Simopoulos 2002a, b, 2008). Controlling for ethnicity, populations that consume relatively little $n-6$ relative to $n-3$ PUFA have low rates of autoimmune diseases, such as inflammatory bowel disease, relative to Western/Westernized populations (Simopoulos 2002b). The anti-inflammatory properties of $n-3$ fatty acids appear to be due largely to EPA and DHA rather than ALA (Mori and Beilin 2004).

Some evidence suggests that consuming high levels of $n-3$ fatty acids (especially EPA and DHA) in conjunction with $n-6$ fatty acids leads to anti-inflammatory effects regardless of the ratio (Pischon et al. 2003). Whether the ratio itself, or only the amount of EPA and DHA consumed, is the crucial factor in reducing inflammation has not been resolved.

Vegetarian and vegan diets necessarily have high $n-6/n-3$ PUFA ratios (Kornsteiner, Singer, and Elmadfa 2008). Rosell et al. (2005) found the ratio of plasma levels of linoleic acid to EPA + DHA in British omnivores, vegetarians, and vegans to be 12.6, 20.0, and 35.7, respectively. Again, the possibility that the high ratio is harmful per se is not settled science. But we also cannot say decisively that this is not harmful. The AND’s position statement on vegetarianism does not address the question of the $n-6/n-3$ PUFA ratio. In any case, low EPA and DHA intake appears to lead to chronic systemic inflammation regardless of the ratio. Thus, it is possible that the low intake of EPA and DHA, perhaps in conjunction with a high intake of $n-6$ fatty acids, in vegetarians might increase the risk of developing autoimmune diseases such as Crohn’s disease, ulcerative colitis, psoriasis, and lupus in childhood or adolescence.

Conclusion

This paper has reviewed direct and indirect evidence that vegetarian and vegan diets may be associated with serious risks for fetuses and growing children. This evidence for the dangers of vegetarianism is not necessarily decisive. However, the question is whether the AND is justified in making a blanket claim that “appropriately planned” vegetarian and vegan diets that substitute milk, soy/legumes, or eggs for meat are as healthy as appropriately planned omnivorous diets for children. The evidence reviewed here suggests that there are still many unknowns about the health effects of meatless diets in children. Parents ought to be informed that the debate about the health effects of vegetarianism in children is not settled one way or the other.

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