European Journal of Clinical Nutrition (2017) **71**, 1259–1262

www.nature.com/ejcn

PERSPECTIVE

To vegan or not to vegan when pregnant, lactating or feeding young children

R Pawlak

European Journal of Clinical Nutrition (2017) **71,** 1259–1262; doi:10.1038/ejcn.2017.111; published online 26 July 2017

INTRODUCTION

In 2016, two professional organizations, the Academy of Nutrition and Dietetics (AND) and the German Nutrition Society (DGE), each issued conflicting with each other statements regarding a vegan diet. According to AND, 'Well-planned vegan, lacto-vegetarian, and lacto-ovo-vegetarian (LOV) diets are appropriate for all stages of the life cycle, including pregnancy and lactation'.[1] Yet, just a few months earlier, DGE has stated that, 'With a pure plant-based diet, it is difficult or impossible to attain an adequate supply of some nutrients. The most critical nutrient is vitamin B12. […] The DGE does not recommend a vegan diet for pregnant women, lactating women, infants, children or adolescents'.[2] To confuse the matter further, the American Academy of Pediatrics in its Pediatric Nutrition Handbook, in one place repeated the AND's position, while in another place it stated that vegan diets should not be recommended for children.[3] Most recently, the European Society for Paediatric Gastroenterology, Hepatology, and Nutrition Committee on Nutrition, in its position paper on complementary feeding stated that, 'Vegan diets have generally been discouraged during complementary feeding. Although theoretically a vegan diet can meet nutrient requirements when mother and infant follow medical and dietary advice regarding supplementation, the risks of failing to follow advice are severe, including irreversible cognitive damage from vitamin B12 deficiency, and death. If a parent chooses to wean an infant onto a vegan diet this should be done under regular medical and expert dietetic supervision and mothers should receive and follow nutritional advice'.[4]

During pregnancy, vitamin B12 (B12) deficiency and/or hyperhomocysteinemia, which can be caused by inadequate B12 status, have been associated with several adverse health outcomes that include preeclampsia, recurrent fetal losses, intrauterine growth retardation, preterm delivery, low birth weight and neural tube defects.[5–7] Infants born to mothers with inadequate B12 status during pregnancy have a high risk of developing a variety of hematological, neurological and developmental abnormalities that include growth failure indicative in weight, height and/or head circumference below 10th or even 5th percentile, anorexia, involuntary movements, hyperpigmentation, abnormal EEG and delays in speech development.[8]

Vegan diets are free of all flesh foods, eggs and dairy products and sometimes honey. Vegan diets seem to becoming increasingly popular for reasons such as health, animal welfare and the environment. According to a recent poll based on a nationally representative sample of 2015 adults, in the United States, an estimated 3.7% of Americans are vegans.[9] According to another poll from 2010, conducted among 1258 children aged 8–18 years, about 2% of that population follows a vegan diet (1% who does not eat honey and another 1% who does).[10]

VITAMIN B12 STATUS OF VEGAN PREGNANT AND LACTATING WOMEN, INFANTS AND CHILDREN

Although vegans are at risk of not meeting dietary recommendations and thus developing inadequate status of more than one nutrients, such as eicosapentaenoic acid, docosahexaenoic acid, calcium or iron, B12 is a nutrient of the most concern as, naturally, B12 does not occur in products of plant origin. Studies with adults that evaluated B12 status among vegan, vegetarian and non-vegetarian participants showed a consistent pattern. Vegan individuals have the lowest serum B12, the highest homocysteine (Hcy) and the poorest status of other B12 biomarkers, such as methylmalonic acid (MMA) or holotranscobalamin II (holoTC). Consequently, a substantial proportion of vegans included in the various studies have consistently shown to have suboptimal B12 status.[11] In published research studies, serum B12 has been reported in pmol/l, pg/ml (~1.35 × pmol/l) and in ng/l (~1.35 × pmol/l). A meta-analysis, based on 17 studies (6 cohort and 11 case–control) with 3230 participants, published by Obersby *et al.*[12] found the average serum B12 among vegans of 172 pmol/l, compared with 209 pmol/l among vegetarians and 303 pmol/l among non-vegetarians. Vegans had the highest Hcy concentration from all three groups (mean and s.d. = 16.41 (4.8) μmol/l, compared with 13.91 (3.5) μmol/l among vegetarians and 11.3 (2.89) μmol/l among non-vegetarians).[12]

Data regarding B12 status among pregnant and/or lactating vegan women, infants and/or children are very limited, and most of the research findings were published more than a decade ago. Findings published by Carter *et al.*[13] showed all 10 pregnant and 6 lactating women, along with all 44 children from a vegan community living in the United States on 'the farm', having inadequate intake of B12. Biochemical assessment showed 8% of children, 1 month–6 years of age, having B12 < 80 pg/ml, 17% having B12 between 81 and 200 pg/ml and 75% having B12 > 200 pg/ml. Similarly, 24% of pregnant and 17% of lactating women had a B12 level ⩽ 200 pg/ml. B12 levels were rechecked 3 months after participants ingested B12-fortified soymilk (authors also stated that the diet of the farm residents changed to what they described as LOV). Serum B12 was > 200 pg/ml in all participants. The lowest serum B12 in the follow-up assessment was 470 pg/ml as opposed to 0 pg/ml prior to ingesting the B12-fortified soymilk.[13]

Specker *et al.*[14] compared serum B12 along with MMA concentrations among 17 macrobiotic vegan breastfeeding

Department of Nutrition Science, East Carolina University, Greenville, NC, USA. Correspondence: Dr R Pawlak, Department of Nutrition Science, East Carolina University, Greenville, NC 27858, USA.
E-mail: pawlakr@ecu.edu
Received 15 March 2017; revised 4 June 2017; accepted 8 June 2017; published online 26 July 2017

mothers and 6 of their non-vegetarian counterparts. Among the vegan mothers, 56% had serum B12 < 200 pg/ml. They found the vegan infants having a statistically significant higher concentration of urinary MMA (uMMA) adjusted for creatinine compared with the non-vegan group ($P = 0.05$). The infants' uMMA concentration was inversely correlated with maternal serum B12 concentrations ($r = -0.681$, $P < 0.001$). Six of the 17 infants breastfed by vegan mothers had uMMA greater than the 95th percentile.[14,15]

In another published manuscript, Specter *et al.*[16] reported B12 concentration in milk of 13 of the 17 vegan lactating mothers from the original sample and compared it with B12 milk concentration of 6 omnivorous counterparts. B12 milk concentration correlated to serum B12 concentration ($r = 0.787$; $P < 0.001$). Also, among vegan mothers, B12 milk concentration was inversely correlated with the length of adherence to a vegan diet ($r = -0.605$; $P = 0.03$). Most importantly, Specker *et al.*[16] estimated that, at a B12 milk concentration < 362 pmol/l, biochemical B12 deficiency exits indicative by raised uMMA/creatinine. B12 concentration among the majority of the 13 vegan women in this study was below this cutoff value with 6 of the women having B12 milk concentration considerably < 200 pmol/l.[16]

An important lesson can be drawn from the study by Koebnick *et al.*[17] Their sample did not include vegan participants but did include 27 pregnant LOV, 43 pregnant low meat consumers and 39 pregnant controls who consumed a 'Western diet'. Koebnick *et al.*[17] used the following criteria for what they considered 'low serum concentration of vitamin B12': < 130 pmol/l in the first trimester, < 120 pmol/l in the second trimester, and < 100 pmol/l in the third trimester. The prevalence of B12 deficiency based on these cutoffs in at least one trimester was found in 39% of ovo-lacto vegetarians, 9% of low-meat eaters and 3% of the control group ($P < 0.001$). Also, the odds ratio of having a low serum B12 during at least one trimester was 3.9 (95% confidence interval, 1.9–6.1) times higher among LOV and 1.8 (1.0–3.9) times higher among low meat consumers, compared with the odds among women from the control group.

Most importantly, B12 status in this study was reported not only as serum B12 but also as haptocorrin and holoTC. The data showed that most of the serum B12 was found in haptocorrin and that some participants in all diet groups actually had no B12 carried via holoTC. LOV's median holoTC was 10 pmol/l in the first trimester, 9 pmol/l in the second trimester and 5 pmol/l in the third trimester (normal holoTC > 35 pmol/l). Nexo and Hoffmann-Lucke[18] suggested that holoTC is a better marker of B12 status than the assessment of serum B12. Morkbak *et al.*[19] came to the same conclusion. According to Quadros and Sequeira,[20] the demand for B12 in the developing fetus has to be met by maternal holoTC. Thus the bulk of LOV pregnant women had holoTC that was vastly inadequate to supply the fetal demand.

Miller *et al.*[21] assessed B12 status among macrobiotic adults and children who adhered to a macrobiotic, mainly vegan or vegetarian, diet. They had shown 55% of the 42 children, 1.5–11.7 years, having elevated uMMA/creatinine (> 4.3 μmol/mol creatinine). Among those children who consumed a vegetarian diet during their entire lifetime, 67% had elevated uMMA.[21]

DISCUSSION

The data on B12 status among vegan pregnant and lactating vegan women is very limited. The same is true of available data on infants and children born and breastfed by vegan mothers. Nonetheless, available data indicate that an inadequate B12 status among vegan pregnant and lactating women is a real problem. This conclusion is further supported by several dozens of published case studies with infants and young children who were breastfed by their vegan mothers or who adhered to a vegan diet since weaning and who developed a variety of B12 deficiency symptoms that often included profound neurological and developmental delays, including failure to thrive, cognitive and speech delays.

Although the described-above findings regarding B12 status are based on data collected more than a decade ago, and even though since that time additional vegan-friendly B12-fortified food items have been made available in grocery stores, there are reasons to believe that these findings still hold true today. According to data by Haddad,[22] 45% of vegan adults had Hcy $\geqslant 15$ μmol/l. B12 is the dominant factor in Hcy status among vegetarians and vegans.[23] Also, Madry *et al.*[24] in a study with young adults who adopted a vegan diet for a period of 5 years showed a steady decline in serum B12 concentration that was much more pronounced among participants who did not ingest any foods that were fortified with B12 in comparison to those who ingested such foods. In the only meta-analysis that assessed the status of homocysteine among vegetarians, Obersby *et al.*[12] stated that those who choose to omit or restrict animal products are destined to become B12 deficient and that most vegans can be classified as being likely to suffer from hyperhomocysteinemia due to a deficiency of B12.

VITAMIN B12 IN PREGNANCY

There is a strong positive relationship between maternal and fetal B12 concentrations.[25] B12 concentration in the fetal compartment is almost double the maternal B12 level of the umbilical cord. This indicates that there is a high demand for B12 during fetal growth and development. The findings reported by Koebnick *et al.*[17] indicated that vegetarian pregnant women's B12 concentration in holoTC was vastly inadequate to meet the high fetal demand for this vitamin. It is reasonable to assume that vegan pregnant women may have even poorer B12 status than the LOV participants from the study by Koebnick *et al.*,[17] unless they use reliable sources of B12, such as oral supplements. Thus it is unlikely that pregnant vegan women who do not use B12 supplements have sufficient B12 concentration to meet the demand of their developing unborn child.

VITAMIN B12 IN LACTATION

Specker *et al.*[16] have showed that B12 milk concentrations are highly correlated with maternal serum B12 ($r = 0.787$, $P < 0.001$). Specker *et al.*[16] also estimated that biochemical B12 deficiency in breastfed infants develops when B12 milk concentration is < 362 pmol/l. B12 breast milk concentrations are lower than maternal serum B12 concentrations.[26] This finding indicates that in order to have adequate B12 concentration in milk, vegan lactating women need to have serum B12 considerably > 362 pmol/l. Such high serum B12 among vegan adults is seldom observed. It is very likely that, unless oral B12 supplements are utilized, vegan breastfeeding women may not be able to achieve such high serum B12.

INFANTS AND CHILDREN

Reports of cases of B12 deficiency among infants and children breastfed by vegan mothers are not rare.[27] Similarly, several cases of infant and/or toddler deaths due to B12 deficiency have been reported. Compromised B12 status among these infants is attributed to maternal B12 depletion.[27] Symptoms usually occur within 4–10 months of infancy, although they sometimes are seen earlier in life and are also seen in older children. Dror and Allen[27] identified the following most common symptoms seen in such infants: 'Irritability, failure-to-thrive including a falling-off in growth rate, apathy, anorexia, refusal of solid foods, megaloblastic anemia, and developmental regression'. However, an array of other symptoms may also be seen in these children. They include

hypotonia, muscular weakness, delays in speech development, lack of responses to stimuli, lack of interaction with people, involuntary movements, hyperpigmentation, enlarged liver and spleen, diarrhea, low bone mineral density and pancytopenia.[28]

RECOMMENDED VITAMIN B12 INTAKE

It is unclear what constitutes a sufficient intake of B12 whether via foods fortified with B12 or by oral B12 supplement to maintain adequate B12 status. As described above, findings reported by Carter *et al.*[13] showed that switching from a vegan to LOV diet and ingesting B12-fortified soymilk resulted in a profound increase in serum B12. No data on the actual intake of B12 after switching to such dietary pattern was reported. Several studies have shown that the current Institute of Medicine's recommendation for B12 intake (2.6 μg/day for pregnant and 2.8 μg/day for lactating women) are underestimated.[29] Cases of infants with B12 deficiency born to mothers who ingested the amount of B12 consistent with the above recommendation have been described. For example, according to Guez *et al.*,[30] despite the fact that a mother was treated with a multivitamin preparation that provided 2.5 μg/day of B12, in the first month of life her infant showed clinical signs clearly attributable to B12 deficiency that included failure to thrive and pallor. The newest recommendations for B12 intake issued by the European Food Safety Authority (EFSA) call for intake of 4.5 μg/day during pregnancy and 5 μg/day during lactation.[31] Such amounts can be supplied via foods fortified with B12 but the actual amount ingested depends on specific food selections.

In the United States, foods that have been fortified with B12, such as cereal and some soybean products, including soymilk, tofu and soy meat substitutes, contain between as much as 6 μg to as little as about 0.5 μg per serving.[32] Thus the contribution of B12-fortified foods to the overall intake depends on specific food selection. In the United States, a multivitamin usually contains 6 μg and prenatal supplements usually contain between 4 and 12 μg. In combination with B12 from foods fortified with this vitamin, taking either of these supplements would greatly enhance B12 intake and status. Considering the importance of adequate B12 during pregnancy and lactation, and considering that B12 is considered non-toxic, a weekly or perhaps even biweekly ingestion of a higher dose of B12 supplement (for example, 250 μg) would further ensure that the status of this vitamin is not compromised.

EFSA set adequate intake for children 7 months–6 years as 1.4 μg/day. In the United States, baby cereal products contain considerably lower amounts of B12, 0.12–0.15 μg per serving.[31] Thus suitable for infants foods fortified with B12 will unlikely provide adequate B12. Unfortunately, few if any additional dietary B12 sources exists for parents who want their children to follow a vegan diet. Parents of infants may need to utilize children's multivitamin in order to meet the EFSA recommendation. Toddlers should be able to ingest adequate B12 amounts from foods fortified with B12, such as those listed in the previous paragraph. In order to optimize intake of B12 and other nutrients, vegan mothers would greatly benefit from dietary advice by a registered dietitian.

SUMMARY AND CONCLUSIONS

To summarize, limited available literature shows that B12 status among vegan pregnant or lactating women is inadequate to supply adequate amounts of this vitamin to their fetus and/or breastfed children. It should thus be concluded that, unless pregnant and/or lactating vegan women habitually use reliable B12 sources, they place their offspring at risk of B12 deficiency. Although it might be possible to ingest enough B12 to maintain adequate B12 status from fortified foods, the easiest way to ensure these women have optimal B12 status is by using oral B12 supplements. Also, infants and toddlers who were weaned should be given reliable B12 sources. It is likely that foods fortified with B12, such as cereal, soymilk and/or other soy products, may provide sufficient amounts of B12 for growing and developing young children but not for infants whose B12 sources are limited. In order to optimize intake of B12 and other nutrients, vegan mothers would greatly benefit from dietary advice by a registered dietitian.

It should be thus concluded that vegan diets are appropriate for pregnant and lactating women only if these women habitually use reliable B12 sources, preferably oral supplements. In light of available research findings, it is also correct to conclude that the recommendation stated in the DGE position paper: 'Persons who nevertheless wish to follow a vegan diet should permanently take a vitamin B12 supplement' seems prudent. Additional well-designed studies need to be conducted to further clarify the efficacy of concerns raised by the DGE and/or confirm the efficacy of AND's position.

CONFLICT OF INTEREST

The author declares no conflict of interest.

REFERENCES

1 Melina V, Craig W, Levin S. Position of the Academy of Nutrition and Dietetics: vegetarian diets. *J Acad Nutr Diet* 2016; **116**: 1970–1980.
2 Richter M, Boeing H, Grünewald-Funk D, Heseker H, Kroke A, Leschik-Bonnet E *et al.* For the German Nutrition Society. Vegan diet. *Ernahrungs Umschau* 2016; **63**: 92–102.
3 American Academy of Pediatrics. Pediatric Nutrition Handbook. 6th edition. https://www.amazon.com/Pediatric-Nutrition-Handbook-AAP-Committee/dp/1581102984.
4 Fewtrell M, Bronsky J, Campoy C, Domellöf M, Embleton N, Fidler Mis N *et al.* Complementary feeding: a position paper by the European Society for Paediatric Gastroenterology, Hepatology, and Nutrition (ESPGHAN) Committee on Nutrition. *J Pediatr Gastroenterol Nutr* 2017; **64**: 119–132.
5 Villalpando S. Discussion: effects of folate and vitamin B12 deficiencies during pregnancy on fetal, infant, and child development. *Food Nutr Bull* 2008; **29** (Supplement): S112–S115.
6 Molloy AM, Kirke PN, Brody LC, Scott JM, Mills JL. Effects of folate and vitamin B12 deficiencies during pregnancy on fetal, infant and child development. *Food Nutr Bull* 2008; **29**: S101–S111.
7 Thompson MD, David EC Cole, Joel G Ray. Vitamin B-12 and neural tube defects: the Canadian experience. *Am J Clin Nutr* 2009; **89**(Suppl): 697S–701S.
8 Bailey HD, Miller M, Langridge A, de Klerk NH, van Bockxmeer FM, Attia J, Scott RJ, Armstrong BK, Milne E. Maternal dietary intake of folate and vitamins B6 and B12 during pregnancy and the risk of childhood acute lymphoblastic leukemia. *Nutr Cancer* 2012; **64**: 1122–1130.
9 The Vegetarian Resource Group. How many adults in the US are vegetarian or vegan? http://www.vrg.org/nutshell/Polls/2016_adults_veg.htm (last accessed 12 February 2017).
10 The Vegetarian Resource Group. How many youth are vegetarian? http://www.vrg.org/press/youth_poll_2010.php (last accessed 12 February 2017).
11 Pawlak R, Parrott SJ, Raj S, Cullum-Dugan D, Lucus D. How prevalent is vitamin B12 among vegetarians? *Nutr Rev* 2013; **71**: 110–117.
12 Obersby D, Chappell DC, Dunnett A, Tsiami AA. Plasma total homocysteine status of vegetarians compared with omnivores: a systematic review and meta-analysis. *Br J Nutr* 2013; **109**: 785–794.
13 Carter JP, Furman T, Hutcheson HR. Preeclampsia and reproductive performance in a community of vegans. *South Med J* 1987; **80**: 692–697.
14 Specker BL, Miller D, Norman EJ, Greene H, Hayes KC. Increased urinary methylmalonic acid excretion in breast-fed infants of vegetarian mothers and identification of an acceptable dietary source of vitamin B-12. *Am J Clin Nutr* 1988; **47**: 89–92.
15 Specker BL. Nutritional concerns of lactating women consuming vegetarian diets. *Am J Clin Nutr* 1994; **59**(Suppl): 1825–1865.
16 Specker BL, Black A, Allen L, Morrow F. Vitamin B-12: low milk concentrations are related to low serum concentrations in vegetarian women and to methylmalonic aciduria in their infants. *Am J Clin Nutr* 1990; **52**: 1073–1076.

17 Koebnick C, Hoffmann I, Dagnelie PC, Heins UA, Wickramasinghe SN, Ratnayaka ID *et al.* Long-term ovo-lacto vegetarian diet impairs vitamin B-12 status in pregnant women. *J Nutr* 2004; **134**: 3319–3326.
18 Nexo E, Hoffmann-Lücke E. Holotranscobalamin, a marker of vitamin B-12 status: analytical aspects and clinical utility. *Am J Clin Nutr* 2011; **94**: 359 S–365 S.
19 Morkbak AL, Hvas AM, Milman N, Nexo E. Holotranscobalamin remains unchanged during pregnancy. Longitudinal changes of cobalamins and their binding proteins during pregnancy and postpartum. *Haematologica* 2007; **92**: 1711–1712.
20 Quadros EV, Sequeira JM. Cellular uptake of cobalamin: transcobalamin and the TCblR/CD320 receptor. *Biochimie* 2013; **95**: 1008–1018.
21 Miller DR, Specker BL, Ho ML, Norman EJ. Vitamin B-12 status in a macrobiotic community. *Am J Clin Nutr* 1991; **53**: 524–529.
22 Haddad E. The vitamin B12 story: why is it still a concern? Lecture presented at the 6th International Vegetarian Nutrition Congress, Loma Linda University, Loma Linda, CA, USA, 26 February 2013.
23 Green R, Miller JW. Vitamin B12 deficiency is the dominant nutritional cause of hyperhomocysteinemia in a folic acid-fortified population. *Clin Chem Lab Med* 2005; **43**: 1048–1051.
24 Mądry E, Lisowska A, Grebowiec P, Walkowiak J. The impact of vegan diet on B-12 status in healthy omnivores: five-year prospective study. *Acta Sci Pol Technol Aliment* 2012; **11**: 209–212.
25 Molloy AM, Kirke PN, Brody LC, Scott JM, Mills JL. Effects of folate and vitamin B12 deficiencies during pregnancy on fetal, infant and child development. *Food Nutr Bull* 2008; **29**: S101–S111.
26 Baatenburg de Jong R, Bekhof J, Roorda R, Zwart P. Severe nutritional vitamin deficiency in a breast-fed infant of a vegan mother. *Eur J Pedia* 2005; **164**: 259–260.
27 Dror DK, Allen LH. Effect of vitamin B12 deficiency on neurodevelopment in infants: current knowledge and possible mechanisms. *Nutr Rev* 2010; **66**: 250–255.
28 Black MM. Effects of vitamin B12 and folate deficiency on brain development in children. *Food Nutr Bull* 2008; **29**: S126–S131.
29 Institute of Medicine. Dietary reference intakes for thiamin, riboflavin, niacin, vitamin B_6, folate, vitamin B_{12}, pantothenic acid, biotin, and choline. https://www.ncbi.nlm.nih.gov/books/NBK114310/ (last accessed 22 February 2017).
30 Guez S, Chiarelli G, Menni F, Salera S, Principi N, Esposito S. Severe vitamin B12 deficiency in an exclusively breastfed 5-month-old Italian infant born to a mother receiving multivitamin supplementation during pregnancy. *BMC Pediatrics* 2012; **12**: 85.
31 European Food Safety Authority. Scientific opinion on dietary reference values for cobalamin. www.efsa.europa.eu/efsajournal (last accessed 22 February 2017).
32 United States Department of Agriculture. USDA Food Composition Databases. https://ndb.nal.usda.gov/ndb/ (last accessed 22 February 2017).