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Special article - Review

VITAMIN B12 IN ADULTS ON VEGETARIAN AND VEGAN DIETS

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Abstract

Plant-based dietary patterns are beneficial for cardiometabolic health and are associated with a lower risk of multiple diseases, including ischemic heart disease and several types of cancer. For these reasons, they are increasingly recommended by the main medical societies and dietary guidelines. However, if not properly planned, these dietary patterns can lead to insufficient intake of certain nutrients, including vitamin B12. Specifically, people who follow vegetarian or vegan diets usually have a low or no intake of vitamin B12, since the dietary sources of this vitamin are foods of animal origin. Given that this is an essential nutrient, whose deficiency can lead to serious health consequences, it is essential to have clear guidelines for the prevention, diagnosis and timely treatment of vitamin B12 deficiency in the population with a vegetarian and vegan diet.

Key words: vitamin B12, cobalamin, vegetarianism, plant-based diets, nutrition

Resumen

Vitamina B12 en adultos con dieta vegetariana y vegana

La adopción de patrones alimentarios basados en plantas tiene beneficios para la salud cardiometabólica y se asocia a menor riesgo de múltiples enfermedades, entre ellas la cardiopatía isquémica y varios tipos de cáncer. Por estos motivos, son cada vez más recomendados por las principales sociedades médicas y guías alimentarias. No obstante, si no se planifican adecuadamente, estos patrones alimentarios pueden llevar a una ingesta insuficiente de ciertos nutrientes, entre ellos la vitamina B12. Concretamente, las personas que siguen dietas vegetarianas o veganas suelen tener una ingesta baja o directamente nula de vitamina B12, ya que las fuentes dietéticas de esta vitamina son los alimentos de origen animal. Dado que este es un nutriente esencial, cuya deficiencia puede llevar a graves consecuencias para la salud, se hace imprescindible contar con pautas claras para la prevención, el diagnóstico y tratamiento oportuno de la deficiencia de vitamina B12 en población con alimentación vegetariana y vegana.

Palabras clave: vitamina B12, cobalamina, vegetarianismo, alimentación basada en plantas, nutrición

KEY POINTS
Current knowledge

- Properly planned vegetarian and vegan diets have multiple health benefits but are often deficient in vitamin B12. Despite its critical importance, there are no clear guidelines for the prevention and treatment of vitamin B12 deficiency in this population.

Contribution of the article to current knowledge

- This work provides an updated review of vitamin B12 in adults with vegan and vegetarian diets and proposes diagnostic and treatment algorithms meant to be easy to apply in a clinical setting.

Vitamin B12, or cobalamin, is an essential water-soluble vitamin. It has a complex chemical structure, based on a corrin ring with a central cobalt atom. It is a nutrient crucial for neurological health (it plays a central role in the formation and maintenance of myelin sheaths), the production of blood cells in the bone marrow, and DNA synthesis. Cobalamin acts as a cofactor in 3 fundamental metabolic reactions: the conversion of methylmalonic acid to succinyl-CoA, of homocysteine to methionine, and of 5-methyltetrahydrofolate to tetrahydrofolate[1,2].

The adoption of plant-based dietary patterns is associated with better cardiometabolic health, lower risk of cardiovascular events and cancer, and increased longevity[3-5]. In a recent position paper, the Academy of Nutrition and Dietetics (AND) states that, in adults, properly planned vegetarian and vegan dietary patterns may be nutritionally adequate and offer long-term health benefits, such as improved cardiometabolic health[6]. The global adoption of plant-based diets, including vegetarian and vegan diets, also has the potential to greatly mitigate the impacts of climate change, and entails a much less intensive use of natural resources such as arable land and drinking water[7]. All of this leads to an increasing number of people adopting vegan or vegetarian diets for health, environmental and/or ethical reasons.

Despite the multiple health benefits of plant-based, vegetarian, and vegan diets, these dietary patterns, if not properly planned, can lead to insufficient intake of certain nutrients such as iron, zinc, iodine, calcium, omega-3 fatty acids, vitamin D, and vitamin B12[8]. Specifically, people who follow vegetarian or vegan diets have a low or null intake of vitamin B12, since the main sources of this vitamin are meats and organ meats (see below).

The objective of this narrative review is to update and discuss the most up-to-date knowledge on vitamin B12 in people following vegetarian and vegan diets, in order to provide clear guidelines for the prevention, diagnosis and treatment of vitamin B12 deficiency in this population.

Recommended intake of vitamin B12

The Institute of Medicine (IOM) recommends an intake of cobalamin in adults of at least 2.4 µg/day, considering optimal absorption[9]. In 2015, the European Food Safety Agency (EFSA) conducted an extensive review of the evidence and increased the recommendation to more than 4 µg/day, on the grounds that these levels not only achieve adequate concentrations of serum cobalamin but are also sufficient to maintain normal concentrations of metabolites such as methylmalonic acid and homocysteine, which indicates an adequate functional status of cobalamin[10].

Absorption and bioavailability of vitamin B12

Vitamin B12 absorption involves a complex system that starts in saliva, continues in the stomach (where gastric acid releases B12 from food and binds to intrinsic factor), and ends in the terminal ileum, where it is absorbed through specific receptors. Two absorption mechanisms are described[1], which are relevant to bear in mind due to their therapeutic implications:

Active transport: Very efficient (40–80%) but saturable at 1.5–2 µg of vitamin B12 intake. It is intrinsic factor dependent and is the pathway that predominates with physiological doses (such as those from natural sources or fortified foods).

Passive transport: Not dependent on active transporters or intrinsic factor, so it is not saturable. Despite being somewhat inefficient (1–2%), it is clinically useful for megadose therapeutic strategies (see below).

Once absorbed, cobalamin passes into circulation from the enterocyte and binds to carrier proteins called holotranscobalamins (holoTCs). Within this group, binding to holoTC-II is the most relevant, since the B12-HoloTC-II complex is the one that enters cells through a specific receptor. Once inside the cell, cobalamin is re-

leased and fulfills its biological functions at cytoplasmic and mitochondrial level. B12 not bound to holoTC-II is bound to other carrier proteins, such as holoTC-III (also called haptocorrin), and has no bioactive functions.

Dietary sources of vitamin B12

Vitamin B12 is not synthesized by plants or animals, but exclusively by certain microorganisms. Animal foods contain B12 because animals incorporate these microorganisms into their diet (naturally or through supplements) or their gut microbiota. Organ meats (liver, kidney, brain) have a vitamin B12 content of 50-100 µg/100 g, egg yolks, shellfish and fatty fish provide 5-50 µg/100 g, and muscle tissue (beef, lamb, pork, chicken), whole egg, cheese, cow's milk, and lean fish provide 0.2-5 µg/100 g[1].

Plant-based foods do not provide bioavailable B12, unless they are fortified. Although it is often said that some plant foods contain B12 (certain algae, *shitake* mushrooms, fermented foods such as sauerkraut), they are usually in minuscule (trace) amounts. In Argentina and most western countries, most people consume these foods with very low frequency (if ever), and in small quantities. It is also important to note that some algae, such as spirulina, contain B12 analogues without biological activity, which can interfere with the bioavailability of active cobalamin, and spuriously raise serum B12 levels in the laboratory, potentially masking a deficiency[11].

Prevalence and risk groups for vitamin B12 deficiency

Vitamin B12 deficiency is relatively common, but underdiagnosed[12]. Populations at risk are those who follow a plant-based diet, especially vegans and vegetarians (even if eggs or dairy products are consumed), advanced age (over 50 years old, and especially 70 years old, due to hypochlorhydria and gastric atrophy).

Vitamin B12 deficiency can occur due to decreased intake, alterations in absorption, and increased utilization, the first two being the most frequent. A reduced intake can occur in people with a plant-based diet, especially vegans and vegetarians (even if they include dairy and eggs), and when there are alterations in intake such as hypo/anorexia and deglutition-related disorders. Absorption is compromised in conditions such as celiac disease, autoimmune gastritis due to anti-intrinsic factor and anti-parietal cell autoantibodies (pernicious anemia) and its evolution to chronic atrophic gastritis, bariatric surgery, gastrectomy, inflammatory bowel disease, bacterial overgrowth in the small intestine (SIBO), parasitosis, and alcoholism. Several medications interfere with the absorption of vitamin B12, the most common being proton pump inhibitors, metformin, trimethoprim/sulfamethoxazole, and vitamin C supplements. People over 50 years of age, and especially 70 years of age, are a risk group for cobalamin deficiency, since hypochlorhydria and gastric atrophy are frequent in this age range. Increased B12 utilization can be observed in neoplastic diseases, chemotherapy treatment, and hyperthyroidism[13]. There are also genetic polymorphisms that affect absorption or transport, the most frequent being those affecting the enzyme methyl-tetrahydrofolate-reductase (MTHFR)[14,15].

Clinical manifestations of vitamin B12 deficiency

Vitamin B12 deficiency can have serious health consequences, especially when severe and prolonged. The main clinical manifestations are[15]:

1. Hematological: pancytopenia, leukopenia, thrombocytopenia, and megaloblastic anemia, the latter characterized by macrocytosis (mean corpuscular volume [MCV] greater than 100 fL), increased LDH (which can reach extreme values), and hyperbilirubinemia with indirect predominance with anisocytosis and hypersegmented neutrophils in peripheral blood smears. Anemia occurs gradually, so it is usually tolerated by the patient to the point that the diagnosis is usually made with severe anemia (hemoglobin less than 7 g/dL) and macrocytosis with MCV values greater than 120 fL.

2. Metabolic: hyperhomocysteinemia and elevated methylmalonic acid (see below).

3. Neurological: myelopathy and peripheral neuropathy (manifested with symmetrical paresthesias, gait and proprioception alterations), cognitive impairment, alterations in memory and mood, optic atrophy, dementia, irritability. These may appear before hematological alterations.

4. Digestive: glossitis, loss of appetite, dysgeusia, constipation, smell disturbances.

5. Musculoskeletal: lower bone mineral density, fragility, asthenia.

Vitamin B12 status assessment

Serum vitamin B12

The most available and studied parameter is serum total vitamin B12, which includes both B12 bound to holoTC-II (usually called "active vitamin B12", since this form is the one capable of entering cells, and therefore have bioactivity) and B12 bound to other carrier proteins, mainly haptocorrin (without biological activity).

Serum vitamin B12 concentrations are reported either in pmol/L or pg/mL. In Argentina, laboratories typically use pg/mL as the reporting unit. To convert values from pmol/L to pg/mL, divide by 0.738.

There is no universally validated cut-off point, which means that the limits for defining deficiency range from <110 pmol/L to < 250 pmol/L, depending on the country[11].

Only a small fraction (between 5 and 20%) of total B12 levels correspond to the B12-holoTC-II complex, i.e. active vitamin B12. That is why, in recent years, interest has arisen in the specific measurement of the B12-holoTC-II complex. However, the reference values for holoTC-II are highly dependent on the biochemical assay, and the cut-off points for deficiency or sufficiency are not well defined, which leaves a wide range of values indeterminate, all of which limits its clinical use[14].

Functional markers: homocysteine and methylmalonic acid

Homocysteine

Homocysteine is a sulfur amino acid not found in foods but produced as an intermediate of methionine metabolism. Its accumulation in the blood has been linked for decades to adverse effects at the cardiovascular, neurological and oxidative levels[16]. It is considered a useful, although non-specific, functional biomarker for the indirect diagnosis of nutritional deficiencies, particularly vitamin B12, folate (B9) and pyridoxine (B6). In people with B12 deficiency, increased homocysteine may be the first indication, even with serum cobalamin values within the reference range.

Homocysteine as a functional marker of B12 status is especially useful when total B12 levels are in the "gray" range (271-542 pg/ml or 200-399 pmol/L) or if subclinical deficiency with normal serum B12 levels is suspected. It is also used to monitor response to treatment with B12 and/or folates. Although the normal ranges are defined between 5 and 15 µmol/L, population studies have shown that maintaining homocysteine levels below 10 µmol/L is associated with a lower risk of cognitive impairment and brain atrophy. Optimal levels of homocysteine and methylmalonic acid correlate with serum vitamin B12 values above 542 pg/ml (400 pmol/L), and for this reason we consider this value as the minimum desirable[17–19].

It is important to notice that homocysteine can be elevated by numerous factors, including deficiency of other B vitamins (folate and B6), smoking, alterations in liver, kidney, or thyroid function, inflammatory diseases, high consumption of coffee, various drugs, and genetic polymorphisms[1,16].

Methylmalonic acid

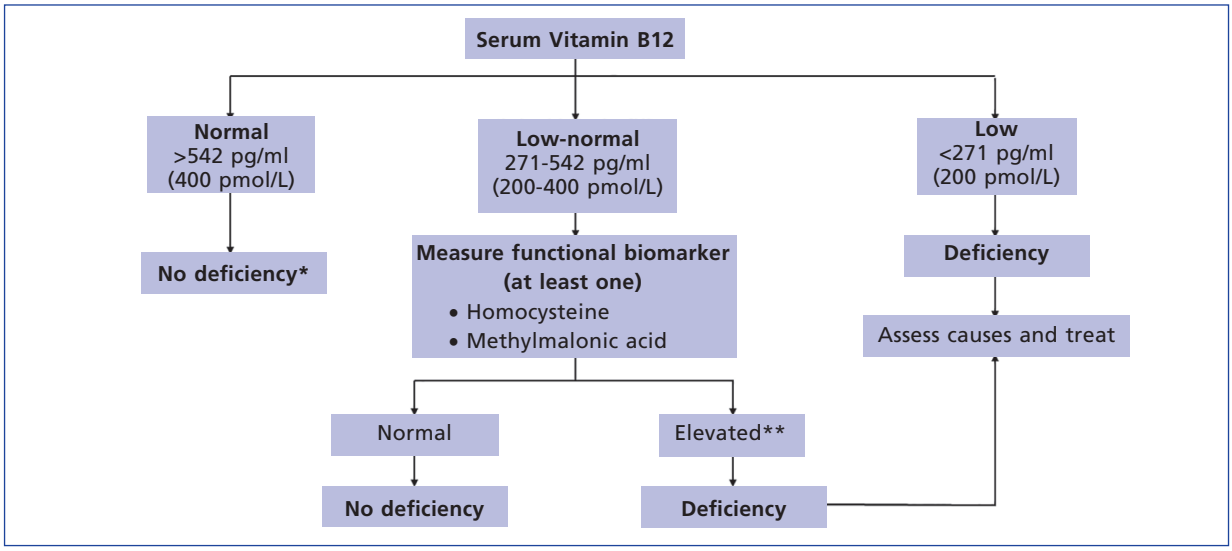
Elevated levels of methylmalonic acid are a more direct functional measure of vitamin B12 deficiency, because cobalamin is the only cofactor required by the enzyme that degrades it. However, the cut-off points for methylmalonic acid are not well established. In addition, methylmalonic acids levels are dependent of other factors such as age, hydration status, kidney function, and the presence of polymorphisms[20,21]. It should be noted that, in Argentina and many other countries, the measurement of methylmalonic acid is carried out by very few laboratories, is expensive, and the cost is not usually covered by health insurance companies, all of which markedly limits its use.

Integrating current knowledge, the availability of complementary studies in our setting, and clinical experience, we propose a diagnostic algorithm of vitamin B12 status in adults with a vegetarian or vegan diet (see Figure 1).

Vitamin B12 status in people on vegetarian and vegan diets

Not surprisingly, evidence shows that people who follow vegetarian diets (including lacto-ovo

Figure 1 | Proposed algorithm for vitamin B12 status assessment



*If clinical suspicion of deficiency or consumption of B12 analogues, measure functional biomarkers
**Consider alternative causes for elevation, age and sex cut-off points, and laboratory validation

vegetarians and vegans) have considerably lower vitamin B12 status than those who consume meat, which can lead to deficiency and even severe clinical manifestations.

A study of the EPIC-Oxford cohort, which included 6673 vegetarians and 803 vegans, evaluated the intake of cobalamin exclusively from food, and showed that the intake of this vitamin in vegetarian diets was much lower than those that included meat, especially in vegan diets in which, as expected, it was virtually absent. In vegans, the use of vitamin B12 supplements reached 50% in the initial survey and fell to 20% at the second follow-up[22]. This is certainly concerning, as a large percentage of people on this diet had virtually zero intake of this essential nutrient, which could have potentially serious consequences.

A systematic review with meta-analysis, which included 17 observational studies and 2 clinical trials, showed that people with vegetarian and vegan diets had lower levels of serum vitamin B12 and holo TC-II, and higher levels of homocysteine and methylmalonic acid, than those with omnivorous diets[23]. Notably, vitamin B12 supplementation markedly improved B12 status in vegans. See Table 1.

In the *Adventist Health Study-2*, which included more than 71,000 individuals (more than half with some variant of vegetarian diet), it was observed that, although the median intake of cobalamin in vegans was lower than in non-vegetarians, the levels reported exceeded the minimum recommended levels in all cases (7.1 and 6.3 µg/day respectively). In fact, those who followed semi-vegetarian, pesco-vegetarian, or lacto-ovo vegetarian diets had a higher intake than non-vegetarians (median of 8.3, 8.5, and 8 µg/day, respectively)[24]. This study considered cobalamin intake from both food and supplements, which shows that vitamin B12 deficiency may not be a problem when vegetarian diets are properly planned, including regular intake of fortified foods and/or cobalamin supplements. Supporting this point, a recent systematic review and meta-analysis of 4 studies conducted in the population of Seventh-day Adventists found no significant differences in serum vitamin B12 levels or B12 intake among vegetarians, vegans, and omnivores, which would be due to the extensive consumption of vitamin B12 supplements and fortified foods in this population[25].

Currently, there is no dispute that diets that exclude foods of animal origin, or that incorporate them in limited amounts, should consume a safe source of vitamin B12 in the form of supplements or fortified foods[5,6].

Table 1 | Markers of vitamin B12 status according to type of diet

	Serum B12 (pmol/L)	Holo TC (pmol/L)	AMM (nmol/L)	Hcy (umol/L)
Vegans	249.4 (87.8)	62.9 (33.9)	289 (263)	13.4 (7.8)
Vegetarians	252 (85.7)	60.6 (36.6)	213.7 (173.2)	12.5 (5.2)
Omnivores	384.9 (109.6)	75.5 (28.6)	180.5 (89)	9.7 (3.8)
Vegans with supplementation*	276.9 (154)	43 (30.4)	340.1 (429.2)	11.4 (5.2)
Vegans without supplementation	183.9 (85.7)	26 (26)	484.5 (678.9)	14.4 (9.8)

HoloTC: holotranscobalamin; MMA: methylmalonic acid; Hcy: homocystein
*Includes vitamin B12 supplements or multivitamins containing vitamin B12, without specifying dosage
Values expressed in Mean (SD) To convert values from pmol/L to pg/mL, divide by 0.738.
(Adapted from Ref. 23)

Vitamin B12 supplementation in people with vegetarian and vegan diets

Chemical form

We recommend the use of cyanocobalamin, as it is the most studied, chemically stable, effective, economical and available form[26,27]. The cyano group is used because of its great affinity to cobalamin, which gives stability to the formulation, and allows its use in supplements and fortified foods. Other forms of vitamin B12, such as methylcobalamin and adenosylcobalamin are also a possible, although they are less studied in clinical trials, less stable, and usually more expensive. In the case of people with higher circulating levels of cyanide, or impaired elimination (severe smokers, advanced renal failure), the use of methylcobalamin can be considered, since the cyanocobalamin group could contribute to raising cyanide levels even more. Nevertheless, it should be noted that the cyanide contribution of cyanocobalamin supplements is minimal, and is well below the daily doses of cyanide ingested in a standard diet.

Route of administration

A 2018 systematic review of the Cochrane collaboration compared the effectiveness of oral versus intramuscular vitamin B12 administration, with no significant differences reported in normalizing B12 levels, although the small number of studies and some methodological limitations should be considered[28]. The advantage of the oral route lies in its greater acceptance, lower cost, and its effectiveness in restoring vitamin B12 status, which is why it is recommended in the first instance as long as there are no malabsorptive disorders.

Sublingual administration has the advantage of direct absorption by sublingual capillaries, which makes possible to treat people who are deficient in B12 and have deglutory and/or absorption alterations, such as previous bariatric surgery, gastrectomy, chronic gastritis, inflammatory bowel disease, SIBO, celiac disease, chronic antacid treatment or metformin or other conditions that can affect absorption. In these cases, the sublingual route is of choice, since its absorption is direct, does not have gastrointestinal interactions, and may allow avoiding the intramuscular route (more invasive and painful)[29].

Injectable hydroxocobalamin is usually reserved for severe deficiencies with neurological involvement, for patients who cannot take the supplement orally or sublingually, or who are unable to normalize their B12 status despite treatment by any of the other routes of administration.

Dosing

Oral supplements are absorbed by paracellular transport, which has a very low efficiency (1-2%), so mega doses are usually needed. Heinrich's equation, developed in 1967, describes the absorption of a single dose of cobalamin, up to 10,000 mcg, such that: $amount\ absorbed = 1.5D/D + 1.5 + (1 - 1.5/D + 1.5) \times 0.009 \times D$, where D = dose administered[30]. In summary, the equation describes that the percentage of vitamin B12 absorption decreases as the given dose increases.

For this reason, more frequent supplementation schedules require lower doses while, in schedules with longer intervals between doses, higher doses are needed to compensate for the lower absorption efficiency. It should be noted that oral B12 supplements are best absorbed on an empty stomach, and this condition is assumed in the equation.

To establish the supplementation dose, two situations must be differentiated: people without deficiency, who must achieve the cobalamin recommended daily intake (RDI) to achieve optimal status and prevent deficiency (we will refer to this situation as "maintenance"), and the treatment of established vitamin B12 deficiency.

Maintenance

We suggest supplementation in doses of 2.000–3.000 µg/week, preferably cyanocobalamin, distributed at convenience according to patient preferences. These doses allows to reach an equivalent intake close to that proposed by EFSA[10].

Smaller daily doses are more physiological but could compromise adherence. In our clinical experience, a weekly intake is effective in sustaining a normal vitamin B12 status for most people.

In the case of not having the possibility of measuring the vitamin B12 status with a blood test, we suggest to initiate empirical supplementation in maintenance doses to anyone who adopts a vegetarian or vegan diet, to prevent vitamin B12 deficiency. Although it has been described that the human liver can store cobalamin for years, in clinical practice it is common to detect low levels of this vitamin shortly after starting a vegetarian or vegan diet. This could be due to a number of reasons, such as the gradual (sometimes unperceived) reduction in the animal foods consumption long before the consultation, and dietary factors (for example, diets high in fibre hinder enterohepatic reabsorption of vitamin B12).

Although there is no established frequency for routine monitoring B12 status, we consider that an annual analysis is reasonable in the "maintenance" setting. This frequency can be modified based on the health care provider clinical judgement.

Deficiency treatment

We suggest a dose of cyanocobalamin of 7000 to 15 000 µg/week, preferably distributed in at least 2 or 3 weekly doses, and a new control at 8 weeks, which is enough time to improve the signs and symptoms caused by a vitamin B12 deficiency[31,32]. In the event of no improvement, it should be investigated if the patient is taking the supplement adequately or if there are conditions of impaired absorption, in which case the sublingual route should be considered, as detailed above. If B12 deficiency persists despite treatment, referral to a specialist for further study is suggested. In the case of severe symptoms, especially neurological, treatment with intramuscular hydroxycobalamin in doses of 1000 mcg/day should be initiated. This being the case, management by a specialist is strongly suggested from the start.

Figure 2 presents the proposed algorithm for vitamin B12 supplementation.

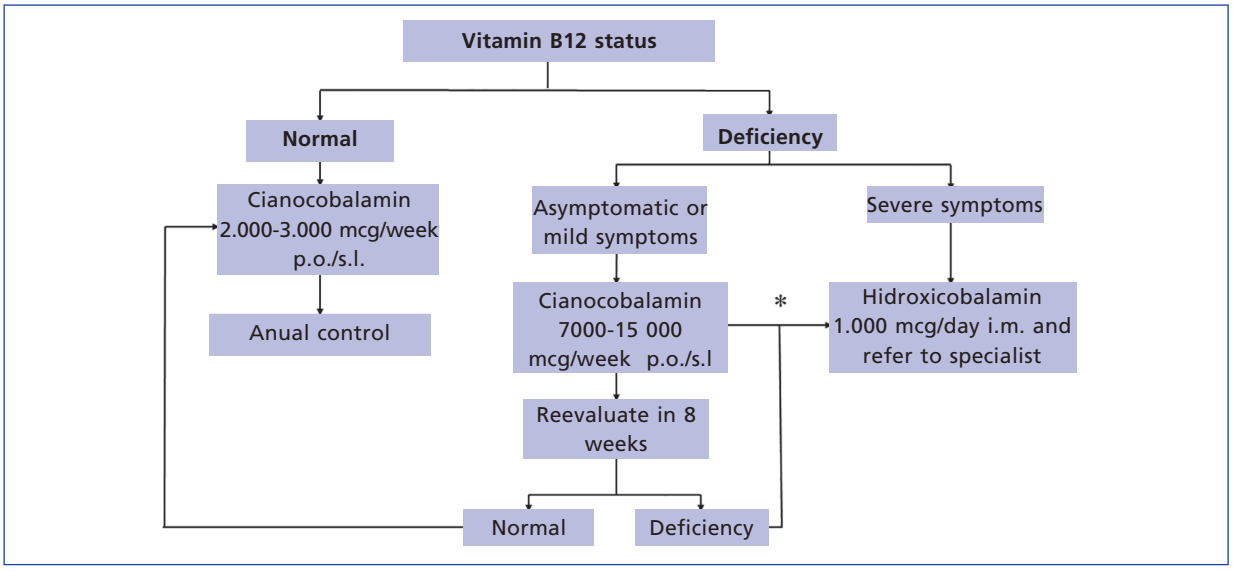
Vitamin B12 toxicity (B12 hypervitaminosis)

Serum vitamin B12 values are considered high at levels above 970 pg/ml, and very high at levels above 1500 pg/ml[33]. Although cobalamin is a water-soluble and non-toxic vitamin, in the face of high concentrations of vitamin B12, the synthesis of haptocorrin, which has a greater binding capacity to vitamin B12 than holoTC-II, increases considerably. This can cause a lower concentration of the B12-holoTC-II complex (active vitamin B12), and thus a functional deficiency of vitamin B12. For this reason, in the context of supplementation, caution should be taken to control serum vitamin B12 levels and not to use excessive doses, since the clinical manifestations of high levels of cobalamin may paradoxically be similar to those of its deficiency[33,34].

Conclusions

Vitamin B12 is a critical nutrient in vegetarian and vegan diets. Health care providers must have a proactive attitude regarding supplementation, deficiency screening and timely treatment. Vitamin B12 supplements are inexpensive, effective, and safe, which makes it easy to avoid health problems related to vitamin B12 deficiency. Unfortunately, it is still common for

Figure 2 | Proposed algorithm for vitamin B12 supplementation n in adults with vegan or vegetarian diets



p.o.: oral; s.l.: sublingual; i.m.: intramuscular
*Assess appropiate supplement intake and absorption issues. If deficiency persists or worsens, refer to specialist and consider parenteral treatment

professionals to resist the assessment of vitamin B12 status and its supplementation in individuals following vegetarian and vegan diets, putting the health of this population at risk. We hope that this document sheds light on this important topic and provides the foundations for a better clinical approach.

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Conflict of interest: None to declare

References

1. Gil Hernandez Á. Tratado de Nutrición, 3ra ed. Madrid: Panamericana; 2017.
2. Office of Dietary Supplements. National Institute of Health (US). Vitamin B12. Fact Sheet for Professionals, 2021. In: https://ods.od.nih.gov/factsheets/VitaminB12-HealthProfessional/#en52; accessed June 2025.
3. Scientific Report of the 2025 Dietary Guidelines Advisory Committee: Advisory Report to the Secretary of Health and Human Services and Secretary of Agriculture. HHS and USDA, 2024. In: https://www.dietaryguidelines.gov/2025-advisory-committee-report; accessed June 2025.
4. Visseren FLJ, Mach F, Smulders YM, et al. 2021 ESC guidelines on cardiovascular disease prevention in clinical practice. *Eur Heart J* 2021; 42: 3227-337.
5. Ministerio de Salud de la Nación. Documento de revisión sobre Alimentación Basada en Plantas, Vegetariana y Vegana. Argentina, 2023. In: https://www.fagran.org.ar/documentos/seccion/otros/2023/12/alimentacion-basada-en-plantas-vegetariana-y-vegana/; accessed June 2025.
6. Raj S, Guest NS, Landry MJ, Mangels AR, Pawlak R, Rozga M. Vegetarian dietary patterns for adults: a position paper of the Academy of Nutrition and Dietetics. *J Acad Nutr Diet* 2025; 125: 831-46.e2.
7. Willett W, Rockström J, Loken B, et al. Food in the anthropocene: the EAT-Lancet Commission on healthy diets from sustainable food systems. *Lancet* 2019; 393: 447-92.
8. Neufingerl N, Eilander A. Nutrient intake and status in adults consuming plant-based diets compared to meat-eaters: a systematic review. *Nutrients* 2021; 14: 29.

9. Institute of Medicine (US) Standing Committee on the Scientific Evaluation of Dietary Reference Intakes and its Panel on Folate, Other B Vitamins, and Choline. Dietary reference intakes for thiamin, riboflavin, niacin, vitamin B6, folate, vitamin B12, pantothenic acid, biotin, and choline. Washington (DC): National Academies Press (US); 1998.
10. EFSA Panel on Dietetic Products, Nutrition, and Allergies (NDA). Scientific Opinion on Dietary Reference Values for cobalamin (vitamin B12). EFS2. En: https://data.europa.eu/doi/10.2903/j.efsa.2015.4150; accessed June 2025.
11. Rizzo G, Laganà AS, Rapisarda AM, et al. Vitamin B12 among vegetarians: status, assessment and supplementation. *Nutrients* 2016; 8: 767.
12. Allen LH. How common is vitamin B-12 deficiency? *Am J Clin Nutr* 2009; 89: 693S-6S.
13. Guéant JL, Guéant-Rodriguez RM, Alpers DH. Vitamin B12 absorption and malabsorption. *Vitam Horm* 2022; 119: 241-74.
14. Wolffenbuttel BH, Owen PJ, Ward M, Green R. Vitamin B12. *BMJ* 2023; 383: e071725.
15. Stabler SP. Clinical practice. Vitamin B12 deficiency. *N Engl J Med* 2013; 368: 149-60.
16. Son P, Lewis L. Hyperhomocysteinemia (StatPearls), 2025. In: https://www.ncbi.nlm.nih.gov/books/NBK554408/; accessed June 2025.
17. Beaudry-Richard A, Abdelhak A, Saloner R, et al. Vitamin B12 levels association with functional and structural biomarkers of central nervous system injury in older adults. *Ann Neurol* 2025; 97: 1190-204.
18. Smith AD, Refsum H. Do we need to reconsider the desirable blood level of vitamin B12? *J Intern Med* 2012; 271: 179-82.
19. Vogiatzoglou A, Oulhaj A, Smith AD, et al. Determinants of plasma methylmalonic acid in a large population: implications for assessment of vitamin B12 status. *Clin Chem* 2009; 55: 2198-206.
20. Bailey RL, Durazo-Arvizu RA, Carmel R, et al. Modeling a methylmalonic acid-derived change point for serum vitamin B-12 for adults in NHANES. *Am J Clin Nutr* 2013; 98: 460-7.
21. Molloy AM, Pangilinan F, Mills JL et al. A common polymorphism in HIBCH influences methylmalonic acid concentrations in blood independently of cobalamin. *Am J Hum Genet* 2016; 98: 869-82.
22. Sobiecki JG, Appleby PN, Bradbury KE, Key TJ. High compliance with dietary recommendations in a cohort of meat eaters, fish eaters, vegetarians, and vegans: results from the European prospective investigation into cancer and nutrition: Oxford study. *Nutr Res* 2016; 36: 464-77.
23. Niklewicz A, Hannibal L, Warren M, Ahmadi KR. A systematic review and meta-analysis of functional vitamin B12 status among adult vegans. *Nutr Bull* 2024; 49: 463-79.
24. Rizzo NS, Jaceldo-Siegl K, Sabate J, Fraser GE. Nutrient profiles of vegetarian and nonvegetarian dietary patterns. *J Acad Nutr Diet* 2013; 113: 1610-9.
25. Janko RK, Haussmann I, Patel A. Vitamin B12 status in vegan and vegetarian seventh-day adventists: a systematic review and meta-analysis of serum levels and dietary intake. *Am J Health Promot* 2025; 39: 162-71.
26. Obeid R, Fedosov SN, Nexo E. Cobalamin coenzyme forms are not likely to be superior to cyano- and hydroxyl-cobalamin in prevention or treatment of cobalamin deficiency. *Mol Nutr Food Res* 2015; 59: 1364-72.
27. Zugravu CA, Macri A, Belc N, Bohiltea R. Efficacy of supplementation with methylcobalamin and cyancobalamin in maintaining the level of serum holotranscobalamin in a group of plant-based diet (vegan) adults. *Exp Ther Med* 2021; 22: 993.
28. Wang H, Li L, Qin LL, Song Y, Vidal-Alaball J, Liu TH. Oral vitamin B12 versus intramuscular vitamin B12 for vitamin B12 deficiency. *Cochrane Database Syst Rev* 2018; 3: CD004655.
29. Bensky MJ, Ayalon-Dangur I, Ayalon-Dangur R, et al. Comparison of sublingual vs. intramuscular administration of vitamin B12 for the treatment of patients with vitamin B12 deficiency. *Drug Deliv Transl Res* 2019; 9: 625-30.
30. Heinrich HC. Experimental principles of a high dosage vitamin B 12 therapy in man. *Ergeb Inn Med Kinderheilkd* 1967; 25: 1-24.
31. Langan RC, Goodbred AJ. Vitamin B12 deficiency: recognition and management. *Am Fam Physician* 2017; 96: 384-9.
32. Kuzminski AM, Del Giacco EJ, Allen RH, Stabler SP, Lindenbaum J. Effective treatment of cobalamin deficiency with oral cobalamin. *Blood* 1998; 92: 1191-8.
33. Sánchez-Duque JA, Arce-Villalobos LR, Erazo-Muñoz MC, Santa-Suasa M. Hipervitaminosis B12: una mirada desde la atención primaria, medicina de familia. *Semergen* 2021; 47: e3-e4.
34. Zulfiqar AA, Andres E, Lorenzo Villalba N. Hipervitaminosis B12. Nuestra experiencia y una revisión. *Medicina (B Aires)* 2019; 79: 391-6