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Review Article

Drug-Induced Nutrient Depletion in Palliative Care Patients: Clinical Implications and Management

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Abstract

Drug-Induced Nutrient Deficiencies are an important but often underappreciated adverse effect of long-term pharmacotherapies. A wide variety of medications are known to affect the absorption, metabolism, distribution, or excretion of key vitamins and minerals, including proton pump inhibitors, metformin, diuretics, anticonvulsants, antibiotics, corticosteroids, and oral contraceptives. Disturbances in vitamin B12, folate, vitamin D, calcium, magnesium, potassium, and fat-soluble vitamins are among nutrients that commonly result in clinically significant deficiencies. Although these nutrient deficiencies often develop slowly, they have the potential to cause significant disease.

Patients at highest risk include the elderly, individuals with chronic diseases, those receiving multiple medications, and patients on prolonged therapy with agents known to induce nutrient losses. It is important to ensure early identification by targeted screening, education of the patient, and routine monitoring to prevent complications. Nutrient assessment as part of therapeutic planning enables clinicians to predict the likelihood of deficiencies even before symptoms become evident.

This review synthesizes current evidence of medications most commonly associated with nutrient depletion, outlines key mechanistic pathways, and discusses clinical implications related to patient care. It also underlines strategies for monitoring and managing nutrient deficiencies, putting particular emphasis on the healthcare professional's role, especially clinical pharmacists in optimizing therapy and avoiding adverse outcomes.

Greater awareness regarding drug-induced nutrient deficiencies will lead to improved medication safety and management that is holistic in its approach to patients. Identifying at-risk individuals, instituting preventative measures, and incorporating nutritional considerations into pharmacotherapy may yield significant improvements in overall treatment outcomes.

These deficiencies are particularly significant in palliative care settings, where polypharmacy and chronic illness increase vulnerability, making early recognition essential for improving quality of life.

Keywords: Drug-Induced Nutrient Deficiencies, absorption, metabolism, distribution, vitamins and minerals

1. Introduction

The consumption of drugs has increased significantly worldwide, due to increases in chronic diseases, life expectancy, and access to medical care. Because most patients are treated for years and often with more than one type of medication, the potential for adverse effects of drug–nutrient interactions have become a significant yet often overlooked component of clinical practice. Although the therapeutic benefits of medications are widely recognized, there is little emphasis on their ability to disrupt the body's nutritional status.

Drug-Induced Nutrient Deficiencies arise when medications interfere with the absorption, metabolism, transport, storage, or excretion of important vitamins and minerals. These interferences may occur gradually and remain clinically silent for a long time until there are significant physiological changes. The following medications have been consistently implicated in the depletion of important nutrients: proton pump inhibitors, metformin, diuretics, anticonvulsants, corticosteroids, and antibiotics. The critical nutrients so far implicated include vitamin B12, vitamin D, folate, calcium, magnesium, potassium, and the fat-soluble vitamins. When these deficiencies are not identified, they contribute to a wide variety of preventable complications that include anemia, neuropathy, bone demineralization, electrolyte disturbances, immune dysfunction, and metabolic disorders.

Although the clinical relevance is great, drug-induced nutrient deficiencies remain largely unidentified in the routine health care environment. The populations more vulnerable to this kind of deficiency include the elderly, chronically ill, those on restrictive diets, and those receiving polypharmacy; However, no standard practice of screening for nutrient depletions exists in either setting.

The purpose of this review is to provide an overview of medications commonly associated with nutrient deficiencies, explain the biological mechanisms of these interactions, outline clinical consequences, and provide evidence-based strategies for monitoring and prevention. By raising awareness of such interactions, healthcare professionals may better anticipate risk, individualize therapy, and enhance patient outcomes.

2. Mechanisms of Drug-Induced Nutrient Deficiencies

Drug-Induced Nutrient Deficiencies arise from numerous pharmacological and physiological processes. These different mechanisms may act alone or in concert, and the degree to which each plays a role often depends on drug dose, duration of therapy, and individual patient factors.

A.Reduced Absorption

- Proton pump inhibitors and H2 blockers reduce gastric acid secretion, which compromises the absorption of vitamin B12, iron, calcium and magnesium.
- Metformin alters intestinal motility and calcium-dependent uptake of the vitamin B12- intrinsic factor complex in the ileum.
- Bile acid sequestrants such as cholestyramine form complexes with fat-soluble vitamins (A, D, E, K) and dietary fats, thereby impeding their absorption.

B.Enzyme Induction

- Anticonvulsants are known to induce the cytochrome P450 enzymes, which enhance the catabolism of vitamin D, folate, and other B-complex vitamins.
- Isoniazid forms inactive complexes that interfere with the metabolism of pyridoxine, increasing the body's requirement for vitamin B6.

C.Renal Excretion

- Loop and thiazide diuretics enhance renal excretion of potassium, magnesium, sodium, calcium and thiamine.
- Certain antibiotics increase urinary excretion or decrease the reabsorption of micronutrients.

D. Gut Microbiota

Broad-spectrum antibiotics significantly affect the intestinal flora that are responsible for synthesizing some vitamins.

- This reduction in gut bacteria may compromise the synthesis of vitamin K and several B vitamins.

E.Impaired Transport, Binding or Activation

Some drugs interfere with the proteins or cofactors required for nutrient transport or biological activation.

- Metformin influences intrinsic factor and calcium-dependent mechanisms of B12 uptake.
- Corticosteroids affect the metabolism of calcium and vitamin D, causing a reduction in bone mineralization.
- Chemotherapeutic agents impair pathways of folate activation.

F.Reduced Appetite or Dietary Intake

- Various appetite-suppressing drugs, opioids, and psychotropic medications may result in inadequate intake over a period of time.
- Medication causing chronic nausea or malabsorption can further exacerbate nutrient loss.

Overall, medications can disrupt nutritional status through multiple pathways, often gradually and without immediate symptoms.

Drug classes associated with Nutrient Deficiencies

A wide range of commonly prescribed medications have been linked to specific nutrient deficiencies through their effects on absorption, metabolism, excretion, or biological utilization.

Drug Class	Drugs	Nutrients affected	Mechanism	Clinical implications
Proton pump inhibitors	Omeprazole, Pantoprazole	Vitamin B12, Magnesium, Calcium, Iron[7]	Reduces gastric acid, impairs absorption	Anemia, fractures, hypomagnesemia
Anti- convulsants	Phenytoin, Carbamazepine, Phenobarbital, Valproate	Vitamin D, Folate, Vitamin B6	Hepatic enzyme induction, increases metabolism	Osteoporosis, anemia, neuropathy
Loop diuretics	Furosemide	Potassium, Magnesium, Calcium, Sodium, Thiamine	Increased renal excretion	Arrhythmia, weakness, electrolyte disturbances
Thiazide diuretics	Hydrochlorothiazide	Magnesium, Potassium	Renal electrolyte loss	Fatigue, muscle cramps

Broad- spectrum Antibiotics	Cephalosporins, Fluoroquinolones	Vitamin K, B-complex vitamins	Destruction of gut microbiota	Bleeding tendency, fatigue
Oral contraceptives	Combined OCPs	Folate, B6, B12, Magnesium, Zinc	Altered metabolism, hormone- mediated changes	Increased homocysteine, mood changes
Anti- TB drugs	Isoniazid	Vitamin B6,	Formation of inactive complexes	Peripheral neuropathy
Corticosteroids	Prednisolone, Dexamethasone	Calcium, Vitamin D, Potassium	Reduced absorption, increased excretion	Osteoporosis, muscle weakness
Antacids	Aluminum/ Magnesium antacids	Iron, Phosphate, B vitamins,	Reduced acidity and binding effects	Anemia, fatigue
Bile acid sequestrants	Cholestyramine, Colestipol	Vitamins A, D, E, K, Folate	Binding of fat- soluble vitamins	Coagulopathy, bone changes
Chemotherapeutic s	Methotrexate, 5-fluorouracil	Folate, Thiamine	Inhibition of folate pathways	Anemia, mucositis
Metformin	Metformin ER/IR	Vitamin B12	Impaired calcium dependent ileal absorption	Neuropathy, anemia

Recognition of these relationships allows the clinician to predict deficiencies, appropriately screen patients, and intervene early to avoid unfavorable outcomes.

3. High Risk Population with Emphasis on Palliative Care Patients

Physiological, metabolic, and pharmacological factors can make specific vulnerable populations more prone to drug-induced nutrient deficiencies.

A. Older Adults

In palliative care settings, patients are often elderly with multiple comorbidities and are exposed to prolonged polypharmacy. These factors significantly increase the risk of drug-induced nutrient deficiencies, which may further worsen fatigue, cognitive decline, and overall quality of life.

Older adults have reduced gastric acidity, lower dietary intake, polypharmacy, and age-related malabsorption-all of which contribute to increased risk of deficiency. Medications that are commonly used in this population, including PPIs, metformin, diuretics, and antiepileptics, further compromise nutrient status. Due to cognitive impairment and/or frailty, symptoms may be masked, with deficiencies underdiagnosed.

B. Patients with chronic diseases

Such as diabetes, chronic kidney disease, inflammatory bowel disease, cardiovascular disease, and epilepsy, often require long-term drug therapy. Their underlying disease may already cause impairment to nutrient absorption, metabolism or excretion, making them highly susceptible to drug-nutrient interactions.,

C. Pregnant and Lactating women

Pregnancy increases the need for micronutrients such as folate, iron, vitamin B12, and vitamin D. Some drugs including anticonvulsants, antiretrovirals, and certain antibiotics, increase the risk of deficiency with potential adverse maternal and fetal consequences.

D. Individuals with Malabsorption Disorders

Patients with diseases that impede nutrient absorption, such as celiac disease, bariatric surgery, short bowel syndrome, or chronic diarrhea, are at increased risk of deficiencies if they are exposed to drugs that further impair nutrient absorption.,

E. Long term Medication users

Those on long-term therapies, for example, PPIs >2 years, metformin >5 years, corticosteroids, cholestyramine, and antiepileptics, risk cumulative nutrient depletion over time.,

F. Individuals with Restrictive diet

People with diets low in intrinsic B12, iron or fat-soluble vitamins will develop deficiencies more quickly when medications interfere with the absorption or metabolism of the few nutrients they get from their diet.
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G. Alcohol- dependent Individuals

Chronic use of alcohol disrupts hepatic metabolism, decreases intake, and impairs vitamin absorption. The use of concurrent medications such as isoniazid, diuretics, or antiepileptics may exacerbate nutrient depletion.

4. Clinical consequences of Drug- Induced Nutrient Depletion

Drug-induced nutrient deficiencies can cause various physiological, neurological, haematological, and metabolic complications. The severity depends on the specific nutrient affected, duration of medication use, underlying comorbidities, and patient age.[51]

A. Hematologic complications

Medications that interfere with the absorption or metabolism of vitamin B12 and folate may result in macrocytic anaemia, fatigue, pallor, glossitis, and decreased exercise tolerance. The drugs most frequently associated with deficiencies of these nutrients are methotrexate, antiepileptics, PPIs, and metformin. Iron deficiency caused by the administration of acid-suppressing therapy also leads to microcytic anaemia and a defective immune response.

B. Neurological and Neuropsychiatric complications

Vitamin B12, B6, and folate deficiencies can present with peripheral neuropathy, paresthesia, cognitive decline, depression, irritability, and in more severe cases, subacute combined degeneration of the spinal cord. Contributory factors commonly include prolonged metformin, isoniazid, and oral contraceptives.

C. Musculoskeletal complications

Drugs that interfere with the resorption of vitamin D, calcium, and magnesium may result in osteomalacia, muscle cramps, tetany, bone demineralization, and increased fracture risk. The most common cause of drug-induced osteoporosis is corticosteroid-induced calcium depletion.

D. Cardiovascular consequences

Nutrient depletion including potassium, magnesium, or thiamine may precipitate arrhythmias, hypertension, heart failure exacerbation, or impaired myocardial contractility. Diuretic-induced electrolyte loss is particularly associated with dangerous ventricular arrhythmias.

E. Gastrointestinal and Hepatic effects

Vitamin K deficiency caused by suppression of gut flora by antibiotics may present as prolonged bleeding, easy bruising, and elevated INR.[24] Deficiencies of the fat-soluble vitamins due to bile acid sequestrants or lipase inhibitors may present with steatorrhea, night blindness, or wound healing impairment.

F. Immune and Metabolic impairments

Zinc, vitamin A, and vitamin D deficiencies, caused by chronic drug intake, will precipitate impaired immune responses, enhanced risk to infection, and impaired glucose and lipid metabolism. This impact is increased in subjects with chronic diseases.

G. Reproductive and Developmental outcomes

Folate and vitamin B6 depletion associated with antiepileptics or oral contraceptives elevate the risk of neural tube defects in pregnancy. Vitamin A and D deficiencies might further compromise fetal development and maternal skeletal health.

5. Management strategies

A structured approach to risk assessment, targeted laboratory evaluations, and individualized supplementation will go a long way toward improving patient outcomes.

A.Nutritional assessment

Before the initiation of long-term therapies known to affect nutrient status, it is appropriate for clinicians to check baseline levels of important vitamins. Depending on the medication, baseline tests may involve vitamin B12, folate, vitamin D, calcium, magnesium, potassium, and iron studies.[20]

B. Laboratory monitoring

- PPIs and H2 blockers: Periodic assessment of vitamin B12, magnesium, and iron after 6–12 months of continuous use.
- Metformin: Vitamin B12 level annually, more frequently in those with symptoms or receiving acid-suppressing therapy concurrently.
- Diuretics: At the start of treatment and while adjusting the dosage, serum potassium and magnesium should be monitored.
- Corticosteroids: Regular screening for calcium, vitamin D, bone mineral density, and markers of bone turnover.
- Antiepileptics: Periodic monitoring of folate, vitamin D, and bone health.

This targeted approach reduces unnecessary testing while ensuring early detection of emerging deficiencies.

C. Dietary counselling and Lifestyle optimization

Patients should receive guidance on nutrient-rich dietary patterns to counteract medication-induced losses. Examples include increasing leafy greens for folate, lean meats for B12, and dairy or fortified foods for calcium and vitamin D, while magnesium and potassium should be derived from whole foods.[2]

D. Supplementation

Supplementation in appropriate cases, when deficiencies are identified or anticipated, prevents clinical deterioration:

- Vitamin B12: Oral or intramuscular supplementation in those with long-term PPI or metformin users.
- Vitamin D and Calcium: Routine supplementation for chronic corticosteroid therapy.
- Folate: Prophylactic folic acid in patients receiving antiepileptics or methotrexate.
- Electrolytes (K^+, Mg^{2+}): Replacement therapy in users of diuretics with risk of arrhythmias.

E. Medication review

Regular medication reconciliation helps identify and reduce unnecessary polypharmacy.[9] Deprescribing or switching to a lower-risk alternative, for instance, step-down therapy from PPIs where appropriate can substantially reduce the deficiency risk.

F. Patient education

Patient education on early deficiency symptoms such as numbness, generalized fatigue, muscle cramps, or palpitations encourages better self-monitoring and promotes timely medical evaluation.

G. Interprofessional collaboration

Integration of pharmacists, dietitians, and physicians enhances screening efficiency and ensures comprehensive care. Pharmacists can flag high-risk medications, while dietitians tailor nutrient intake plans, creating a coordinated prevention strategy.

6. Conclusion

Drug-Induced Nutrient Deficiencies are still an under-recognized but clinically significant consequence of long-term pharmacotherapy. If left unattended, such nutrient losses may manifest themselves in the form of anemia, neuropathy, bone demineralization, immune dysfunction, metabolic abnormalities, and other preventable complications.

These deficiencies, though common, often go unnoticed in routine clinical practice due to a lack of appropriate screening, especially in the more vulnerable groups of patients. Early identification through appropriate screening with targeted supplementation and ongoing monitoring can greatly reduce the risk of adverse outcomes. Clinical pharmacists, physicians, and nutrition specialists play a critical role in identifying at-risk patients and in integrating nutrient monitoring into therapeutic decision-making.

Ultimately, a better understanding of drug–nutrient interactions is required to ensure safe and optimized pharmacotherapy. The integration of nutrient assessment into routine care pathways, along with education for health professionals and the promotion of awareness for patients, can together serve to reduce the burden of drug-induced deficiencies. All these practices, when strengthened, will lead to improved health outcomes with fewer medication-related complications and offer more comprehensive patient care.

References

1. Prescott JD, Drake VJ, Stevens JF. Medications and Micronutrients: Identifying Clinically Relevant Interactions and Addressing Nutritional Needs. The Journal of Pharmacy Technology : jPT : Official Publication of the Association of Pharmacy Technicians [Internet]. 2018 Oct 1;34(5):216-30. https://doi.org/10.1177/8755122518780742 PMid:34860982 PMCid:PMC6109862

2. Mohn E, Kern H, Saltzman E, Mitmesser S, McKay D. Evidence of Drug-Nutrient Interactions with Chronic Use of Commonly Prescribed Medications: An Update. Pharmaceutics [Internet]. 2018 Mar 20;10(1):36. https://doi.org/10.3390/pharmaceutics10010036 PMid:29558445 PMCid:PMC5874849

3. M. V. C. Hernández. Nutrición en el paciente polimedicado [Internet]. Nutricion Hospitalaria. 2017 [cited 2025 Dec 4]. Available from: https://api.semanticscholar.org/CorpusID:59163458

4. White R, Ashworth A. How drug therapy can affect, threaten and compromise nutritional status. Journal of Human Nutrition and Dietetics. 2000 Apr;13(2):119-29. https://doi.org/10.1046/j.1365-277x.2000.00221.x

5. Sakaeda T, Tamon A, Kadoyama K, Okuno Y. Data Mining of the Public Version of the FDA Adverse Event Reporting System. International Journal of Medical Sciences. 2013;10(7):796-803. https://doi.org/10.7150/ijms.6048 PMid:23794943 PMCid:PMC3689877

6. Genser D. Food and Drug Interaction: Consequences for the Nutrition/Health Status. Annals of Nutrition and Metabolism. 2008;52(1):29-32. https://doi.org/10.1159/000115345 PMid:18382075

7. Lam JR, Schneider JL, Zhao W, Corley DA. Proton pump inhibitor and histamine 2 receptor antagonist use and vitamin B12 deficiency. JAMA [Internet]. 2013;310(22):2435-42. https://doi.org/10.1001/jama.2013.280490 PMid:24327038

8. Thewjitcharoen Y, Chongvoranond P, Nakasatien S, Krittiyawong S, Himathongkam T. Metformin-Associated Vitamin B12 Deficiency: An Underrecognized Complication. JCEM case reports [Internet]. 2024 Apr 1 [cited 2024 May 6];2(4):luae029. https://doi.org/10.1210/jcemcr/luae029 PMid:38623534 PMCid:PMC11017106

9. Little MO. Updates in nutrition and polypharmacy. Current Opinion in Clinical Nutrition and Metabolic Care. 2018 Jan;21(1):4-9. https://doi.org/10.1097/MCO.0000000000000425 PMid:29016367

10. Péter S, Navis G, de Borst MH, von Schacky C, van Orten-Luiten ACB, Zhernakova A, et al. Public health relevance of drug-nutrition interactions. European Journal of Nutrition. 2017 Jul 26;56(S2):23-36. https://doi.org/10.1007/s00394-017-1510-3 PMid:28748481 PMCid:PMC5559559

11. Hathcock J. Metabolic mechanisms of drug-nutrient interactions. [Internet]. Federation proceedings. 2023 [cited 2025 Dec 5]. Available from: https://api.semanticscholar.org/CorpusID:2962347

12. Genser D. Food and Drug Interaction: Consequences for the Nutrition/Health Status. Annals of Nutrition and Metabolism. 2008;52(1):29-32. https://doi.org/10.1159/000115345 PMid:18382075

13. Ito T, Jensen RT. Association of Long-Term Proton Pump Inhibitor Therapy with Bone Fractures and Effects on Absorption of Calcium, Vitamin B12, Iron, and Magnesium. Current Gastroenterology Reports [Internet]. 2010 Sep 30;12(6):448-57. https://doi.org/10.1007/s11894-010-0141-0 PMid:20882439 PMCid:PMC2974811

14. Chappell, Logan, et al. "Evaluation of Vitamin B12 Monitoring in Patients on Concomitant Metformin and Proton Pump Inhibitors." INNOVATIONS in Pharmacy, vol. 11, no. 4, 28 Oct. 2020, p. 5, https://doi.org/10.24926/iip.v11i4.3355. Accessed 24 Nov. 2020. https://doi.org/10.24926/iip.v11i4.3355 PMid:34007643 PMCid:PMC8127105

15. Sullivan DR. The clinical and nutritional implications of lipid-lowering drugs that act in the gastrointestinal tract. Current Opinion in Lipidology. 2005 Jan 12;16(1):39-45. https://doi.org/10.1097/00041433-200502000-00008 PMid:15650562

16. Maxwell JD, Hunter J, Stewart DA, Ardeman S, Williams R. Folate deficiency after anticonvulsant drugs: an effect of hepatic enzyme induction? British Medical Journal [Internet]. 1972 Jan 29 [cited 2022 Oct 23];1(5795):297-9. Available from: https://pubmed.ncbi.nlm.nih.gov/5008482/ https://doi.org/10.1136/bmj.1.5795.297 PMid:5008482 PMCid:PMC1787173

17. Mintzer S, Skidmore CT, Sperling MR. B-Vitamin deficiency in patients treated with antiepileptic drugs. Epilepsy & Behavior. 2012 Jul;24(3):341-4. https://doi.org/10.1016/j.yebeh.2012.04.132 PMid:22658435

18. Self TH, Chrisman CR, Baciewicz AM, Bronze MS. Isoniazid Drug and Food Interactions. The American Journal of the Medical Sciences [Internet]. 2016 Jan 5;317(5):304-11. https://doi.org/10.1016/S0002-9629(15)40533-6 PMid:10334118

19. Biehl JP, Vilter RW. Effect of Isoniazid on Vitamin B6 Metabolism; Its Possible Significance in Producing Isoniazid Neuritis. Experimental Biology and Medicine. 1954 Mar 1;85(3):389-92. https://doi.org/10.3181/00379727-85-20891 PMid:13167078

20. Dunn SP, Bleske B, Dorsch M, Macaulay T, Van Tassell B, Vardeny O. Nutrition and Heart Failure: Impact of Drug Therapies and Management Strategies. Nutrition in Clinical Practice. 2009 Feb;24(1):60-75. https://doi.org/10.1177/0884533608329299 PMid:19244150

21. Katta N, Balla S, Alpert MA. Does Long-Term Furosemide Therapy Cause Thiamine Deficiency in Patients with Heart Failure? A Focused Review. The American Journal of Medicine. 2016 Jul;129(7):753.e7-11. https://doi.org/10.1016/j.amjmed.2016.01.037 PMid:26899752

22. Mihai Nechifor, Catalina Mihaiela Luca, Gales C. Interactions of Antibacterial Antibiotics with Magnesium and Zinc. International journal of innovative research in medical science. 2024 Jan 20;9(01):50-8. https://doi.org/10.23958/ijirms/vol09-i01/1798

23. Zimmermann P, Curtis N. The effect of antibiotics on the composition of the intestinal microbiota - a systematic review. Journal of Infection [Internet]. 2019 Dec 1;79(6):471-89. https://doi.org/10.1016/j.jinf.2019.10.008 PMid:31629863

24. Matthaiou AM, Ioannis Tomos, Chaniotaki S, Dimitris Liakopoulos, Katerina Sakellaropoulou, Koukidou S, et al. Association of Broad-Spectrum Antibiotic Therapy and Vitamin E Supplementation with Vitamin K Deficiency-Induced Coagulopathy: A Case Report and Narrative Review of the Literature. Journal of Personalized Medicine [Internet]. 2023 Aug 31;13(9):1349-9. https://doi.org/10.3390/jpm13091349 PMid:37763117 PMCid:PMC10533186

25. Hossain KS, Amarasena S, Mayengbam S. B Vitamins and Their Roles in Gut Health. Microorganisms [Internet]. 2022 Jun 1;10(6):1168. Available from: https://www.mdpi.com/2076-2607/10/6/1168/htm https://doi.org/10.3390/microorganisms10061168 PMid:35744686 PMCid:PMC9227236

26. Kshitee Kharve, Engley AS, Paine MF, Sprowl JA. Impact of Drug-Mediated Inhibition of Intestinal Transporters on Nutrient and Endogenous Substrate Disposition...an Afterthought? Pharmaceutics. 2024 Mar 24;16(4):447-7. https://doi.org/10.3390/pharmaceutics16040447 PMid:38675109 PMCid:PMC11053474

27. Chapman LE, Darling AL, Brown JE. Association between metformin and vitamin B12 deficiency in patients with type 2 diabetes: A systematic review and meta-analysis. Diabetes & Metabolism. 2016 Nov;42(5):316-27. https://doi.org/10.1016/j.diabet.2016.03.008 PMid:27130885 PMCid:PMC11045118

28. Jones G, Sambrook PN. Drug-Induced Disorders of Bone Metabolism. Drug Safety. 1994 Jun;10(6):480-9. https://doi.org/10.2165/00002018-199410060-00006 PMid:7917076

29. Robien K. Folate During Antifolate Chemotherapy: What We Know... and Do Not Know. Nutrition in Clinical Practice. 2005 Aug;20(4):411-22. https://doi.org/10.1177/0115426505020004411 PMid:16207681

30. Athanasios Migdanis, Ioannis Migdanis, Papadopoulou SK, Laoura Hadjivasiliou, Nevena Trifonova, Villioti M, et al. Assessment of Dietary Intake and Nutritional Status of Former Opioid Users Undergoing Detoxification Process. Cureus [Internet]. 2023 Dec 6 [cited 2024 Jan 29]; https://doi.org/10.7759/cureus.50068

31. White R. Drugs and nutrition: how side effects can influence nutritional intake. Proceedings of the Nutrition Society [Internet]. 2010 Nov 1 [cited 2021 Aug 22];69(4):558-64. https://doi.org/10.1017/S0029665110001989 PMid:20678294

32. Cundy T, Mackay J. Proton pump inhibitors and severe hypomagnesaemia. Current Opinion in Gastroenterology. 2011 Mar;27(2):180-5. https://doi.org/10.1097/MOG.0b013e32833ff5d6 PMid:20856115

33. REYNOLDS EH, CHANARIN I, MILNER G, MATTHEWS DM. Anticonvulsant Therapy, Folic Acid and Vitamin B12Metabolism and Mental Symptoms. Epilepsia. 1966 Dec;7(4):261-70. https://doi.org/10.1111/j.1528-1157.1966.tb03806.x PMid:5227261

34. Pack AM. The Association between Antiepileptic Drugs and Bone Disease. Epilepsy Currents. 2003 May;3(3):91-5. https://doi.org/10.1046/j.1535-7597.2003.03306.x PMid:15309069 PMCid:PMC321183

35. Weiner ID, Wingo CS. Hypokalemia—consequences, causes, and correction. Journal of the American Society of Nephrology. 1997 Jul;8(7):1179-88. https://doi.org/10.1681/ASN.V871179 PMid:9219169

36. Hollifield JW. Potassium and magnesium abnormalities: Diuretics and arrhythmias in hypertension. The American Journal of Medicine. 1984 Nov 5;77(5):28-32. https://doi.org/10.1016/S0002-9343(84)80005-4 PMid:6496557

37. Johnson LE. Vitamin K Deficiency [Internet]. MSD Manual Professional Edition. MSD Manuals; 2024. Available from: https://www.msdmanuals.com/professional/nutritional-disorders/vitamin-deficiency-dependency-and-toxicity/vitamin-k-deficiency#Physiology_v44325747

38. Shere M, Bapat P, Nickel C, Kapur B, Koren G. Association Between Use of Oral Contraceptives and Folate Status: A Systematic Review and Meta-Analysis. Journal of obstetrics and gynaecology Canada: JOGC = Journal d'obstetrique et gynecologie du Canada: JOGC [Internet]. 2015 May 1 [cited 2021 Apr 1];37(5):430-8. https://doi.org/10.1016/S1701-2163(15)30258-9 PMid:26168104

39. Berenson AB, Rahman M. Effect of hormonal contraceptives on vitamin B12 level and the association of the latter with bone mineral density. Contraception. 2012 Nov;86(5):481-7. https://doi.org/10.1016/j.contraception.2012.02.015 PMid:22464408 PMCid:PMC3410054

40. Badrinath M, John S. Isoniazid Toxicity [Internet]. PubMed. Treasure Island (FL): StatPearls Publishing; 2020. Available from: https://www.ncbi.nlm.nih.gov/books/NBK531488/

41. Stettner M, Steinberger D, Hartmann C, Pabst T, Lidija Konta, Hans Peter Hartung, et al. Isoniazid-induced polyneuropathy in a tuberculosis patient - implication for individual risk stratification with genotyping? Brain and behavior. 2015 May 29;5(8):n/a-n/a. https://doi.org/10.1002/brb3.326 PMid:26355945 PMCid:PMC4559012

42. Jung JW, Park SY, Kim H. Drug-Induced Vitamin Deficiency. Annals of Clinical Nutrition and Metabolism. 2022 Jun 1;14(1):20-31. https://doi.org/10.15747/ACNM.2022.14.1.20

43. Long-term antacid use linked to vitamin B12 deficiency [Internet]. www.medicalnewstoday.com. 2013. Available from: https://www.medicalnewstoday.com/articles/270007

44. Shute N. Popular Antacids Increase The Risk Of B-12 Deficiency [Internet]. NPR. 2013. Available from: https://www.npr.org/sections/health-shots/2013/12/10/249975706/popular-antacids-increase-the-risk-of-b-12-deficiency

45. Bile acid sequestrant drugs (drug interactions) | Research Starters | EBSCO Research [Internet]. EBSCO. 2024. Available from: https://www.ebsco.com/research-starters/nutrition-and-dietetics/bile-acid-sequestrant-drugs-drug-interactions

46. Effect of Pre-treatment Nutritional Status, Folate and Vitamin B12 Levels on Induction Chemotherapy in Children with Acute Lymphoblastic Leukemia [Internet]. Indianpediatrics.net. 2015 [cited 2025 Dec 5].

47. Ehsan Sayedali, Ali Erdinç Yalin, Serap Yalin. Association between Metformin and Vitamin B12 Deficiency in Patients with Type 2 Diabetes. World Journal of Diabetes. 2023 May 15;14(5):585-93. https://doi.org/10.4239/wjd.v14.i5.585 PMid:37273250 PMCid:PMC10236989

48. Chong RQ, Gelissen I, Chaar B, Penm J, Cheung JM, Harnett JE. Do medicines commonly used by older adults impact their nutrient status? Exploratory Research in Clinical and Social Pharmacy [Internet]. 2021 Sep 1 [cited 2023 Jan 11];3:100067.

https://doi.org/10.1016/j.rcsop.2021.100067 PMid:35480616 PMCid:PMC9031754

49. Shahid MS, Ahmed N, Kamal Z, Nathaniel L, Singla B, Singla S, et al. A Systematic Review of Long-Term Use of Proton Pump Inhibitors (PPIs) in Older Adults on Polypharmacy: Do PPIs Deplete Nutrients? Cureus [Internet]. 2025 Aug 24 [cited 2025 Oct 5]; https://doi.org/10.7759/cureus.90888

50. Wakeman M, Archer DT. Metformin and Micronutrient Status in Type 2 Diabetes: Does Polypharmacy Involving Acid-Suppressing Medications Affect Vitamin B12 Levels? Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy. 2020 Jun;Volume 13:2093-108. https://doi.org/10.2147/DMSO.S237454 PMid:32606868 PMCid:PMC7308123

51. Mohn E, Kern H, Saltzman E, Mitmesser S, McKay D. Evidence of Drug-Nutrient Interactions with Chronic Use of Commonly Prescribed Medications: An Update. Pharmaceutics [Internet]. 2018 Mar 20;10(1):36. https://doi.org/10.3390/pharmaceutics10010036 PMid:29558445 PMCid:PMC5874849

52. Milman N, Paszkowski T, Cetin I, Castelo-Branco C. Supplementation during pregnancy: beliefs and science. Gynecological Endocrinology. 2016 Mar 9;32(7):509-16. https://doi.org/10.3109/09513590.2016.1149161 PMid:26956254

53. Overview of Malabsorption - Digestive Disorders [Internet]. MSD Manual Consumer Version. Available from: https://www.msdmanuals.com/home/digestive-disorders/malabsorption/overview-of-malabsorption

54. Montoro-Huguet MA, Belloc B, Domínguez-Cajal M. Small and Large Intestine (I): Malabsorption of Nutrients. Nutrients. 2021 Apr 11;13(4). https://doi.org/10.3390/nu13041254 PMid:33920345 PMCid:PMC8070135

55. Nutrient depletion is an often overlooked side effect of some medications [Internet]. pharmacy.msu.edu. Available from: https://pharmacy.msu.edu/resources/nutrient-depletion-is-an-often-overlooked-side-effect-of-some-medications

56. Oregon State University. Drug-Nutrient Interactions [Internet]. Linus Pauling Institute. 2021. Available from: https://lpi.oregonstate.edu/mic/drug-nutrient-interactions

57. Kiani AK, Dhuli K, Donato K, Aquilanti B, Velluti V, Matera G, et al. Main nutritional deficiencies. Journal of Preventive Medicine and Hygiene [Internet]. 2022 Oct 17;63(2 Suppl 3):E93-101.

58. Hosp C, Kendrick E. Opinion Article Examining the prevalence of nutrient deficiency in modern diets. Clin Nutr Hosp Diet [Internet]. 2024;44(3):1-02.

59. Jophlin L, Liu TY, McClain CJ. Nutritional deficiencies in alcohol use disorder/alcohol-associated liver disease. Current Opinion in Gastroenterology. 2024 Mar 1;40(2):112-7. https://doi.org/10.1097/MOG.0000000000000999 PMid:38193343

60. Podgajna M, Mielnik M, Szudy-Szczyrek A, Kuśmierczuk K, Hus M. Chronic use of PPIs as a potential cause of anemia: case reports and review of the literature. Acta Haematologica Polonica. 2020 Jun 16;51(2):108-11. https://doi.org/10.2478/ahp-2020-0020

61. Infante M, Leoni M, Caprio M, Fabbri A. Long-term metformin therapy and vitamin B12 deficiency: an association to bear in mind. World Journal of Diabetes [Internet]. 2021 Jul 15;12(7):916-31. https://doi.org/10.4239/wjd.v12.i7.916 PMid:34326945 PMCid:PMC8311483

62. M A, J JA, J SM, P J, S R N. A Review on Vitamin B12 and Iron Deficiency Anaemia Linked with Persistent Use of Gastric Acid Suppressants. International Journal of Advances in Pharmacy and Biotechnology. 2020 Dec 1;6(4):19-23. https://doi.org/10.38111/ijapb.20200604004

63. Englezou C, Liang D. Subacute combined degeneration of the spinal cord in functional vitamin B12 Deficiency states. Advances in Clinical Neuroscience & Rehabilitation. 2021;20(4):21-3. https://doi.org/10.47795/BUWP1560

64. Briani C, Dalla Torre C, Citton V, Manara R, Pompanin S, Binotto G, et al. Cobalamin Deficiency: Clinical Picture and Radiological Findings. Nutrients. 2013 Nov 15;5(11):4521-39. https://doi.org/10.3390/nu5114521 PMid:24248213 PMCid:PMC3847746

65. Reynolds EH. Folic acid, ageing, depression, and dementia. BMJ. 2002 Jun 22;324(7352):1512-5. https://doi.org/10.1136/bmj.324.7352.1512 PMid:12077044 PMCid:PMC1123448

66. Dutta D, Aggarwal A, Sharma M, Maisnam I, Ghosh S, Aggarwal S, et al. Drug-induced bone disorders: A systematic review. Indian Journal of Rheumatology. 2019;14(5):44. https://doi.org/10.4103/0973-3698.272152

67. Lukert BP. Glucocorticoid-Induced Osteoporosis: Pathogenesis and Management. Annals of Internal Medicine. 1990 Mar 1;112(5):352. https://doi.org/10.7326/0003-4819-112-5-352 PMid:2407167

68. Lim P, Jacob E. Magnesium Deficiency in Patients on Long-Term Diuretic Therapy for Heart Failure. BMJ. 1972 Sep 9;3(5827):620-2. https://doi.org/10.1136/bmj.3.5827.620 PMid:5071700 PMCid:PMC1785918

69. Andreyev DA, Veena Gopakumar, Andreyev N. Symptomatic vitamin A deficiency in a patient on long-term colesevelam. Frontline Gastroenterology. 2025 Feb 6;16(4):339-42. https://doi.org/10.1136/flgastro-2024-102919

70. Koop AH, Mousa OY, Pham LE, Corral-Hurtado JE, Pungpapong S, Keaveny AP. An Argument for Vitamin D, A, and Zinc Monitoring in Cirrhosis. Annals of Hepatology. 2018 Nov;17(6):920-32. https://doi.org/10.5604/01.3001.0012.7192 PMid:30600288

71. Reynolds EH, Green R. Valproate and folate: Congenital and developmental risks. Epilepsy & Behavior. 2020 Jul;108:107068. https://doi.org/10.1016/j.yebeh.2020.107068 PMid:32375098

72. Long AN, Atwell CL, Yoo W, Solomon SS. Vitamin B12 Deficiency Associated With Concomitant Metformin and Proton Pump Inhibitor Use. Diabetes Care. 2012 Nov 21;35(12):e84-4. https://doi.org/10.2337/dc12-0980 PMid:23173145 PMCid:PMC3507616

73. Aroda VR, Edelstein SL, Goldberg RB, Knowler WC, Marcovina SM, Orchard TJ, et al. Long-term Metformin Use and Vitamin B12 Deficiency in the Diabetes Prevention Program Outcomes Study. The Journal of Clinical Endocrinology & Metabolism [Internet]. 2016 Apr;101(4):1754-61. https://doi.org/10.1210/jc.2015-3754 PMid:26900641 PMCid:PMC4880159

74. Shenkin A. Micronutrients in Health and Disease. Postgraduate Medical Journal. 2006 Sep 1;82(971):559-67. https://doi.org/10.1136/pgmj.2006.047670 PMid:16954450 PMCid:PMC2585731

75. Heidelbaugh JJ. Proton pump inhibitors and risk of vitamin and mineral deficiency: evidence and clinical implications. Therapeutic Advances in Drug Safety [Internet]. 2013 Mar 25;4(3):125-33. https://doi.org/10.1177/2042098613482484 PMid:25083257 PMCid:PMC4110863

76. Ortet-Walker A, Ponsford A, McIntosh B. Communicating with patients using a new vitamin B12 deficiency leaflet. British Journal of Nursing. 2019 Dec 12;28(22):1450-4. https://doi.org/10.12968/bjon.2019.28.22.1450 PMid:31835933

77. 1.Dighriri IM, Mobarki MM, Alameer NA, Algethami BA, AlZahrani FA, AlHomyani IA, et al. Impact of Integrated Pharmacist-Nurse-Radiology-Dietitian Teams on Polypharmacy Patient Outcomes: A Comprehensive Analysis. Journal of Ecohumanism [Internet]. 2024 Nov 27 [cited 2025 Aug 21];3(8). https://doi.org/10.62754/joe.v3i8.4929