Original Article

Association of Metformin Use With Deficiency of Vitamin B-12 And Folate And Peripheral Neuropathy In Adults With Type 2 Diabetes Mellitus

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Abstract

Objective: This study aimed to determine the association between metformin therapy, vitamin B12 and folate deficiencies, and peripheral neuropathy in adults with type 2 diabetes mellitus (T2DM).

Methods: A cross-sectional study was conducted at the Department of Medicine, Tertiary Care Hospital, Rawalpindi, from November 2023 to April 2024. The study included 224 patients with T2DM based on distinct inclusion and exclusion criteria, with informed consent obtained from all participants. Data collection involved assessing diabetes duration, metformin usage, dosage, and the presence of peripheral neuropathy. Serum levels of vitamin B12, folate, and homocysteine were calculated during the evaluation.

Results: Individuals taking metformin tend to have lower serum vitamin B12 levels than those not using the medication. Among metformin users, 27 (69.2%) were found to have vitamin B12 deficiency, compared to 12 (30.8%) in the non-user group, indicating a significant association (p=0.00). However, no significant difference in folate levels could be determined between the groups (p = 0.55). Among participants with hyperhomocysteinemia, vitamin B12 deficiency was identified in 20 (71.4%) individuals versus 8 (28.6%), with a significant p-value of 0.02. While VPT and DN4 scores were comparable between groups, the DNS score showed statistical significance, being higher in metformin users (p = 0.03).

Conclusion: This study highlights the high incidence of vitamin B12 deficiency, a preventable condition, among metformin users in the evaluated population and its association with neuropathy. Future studies are warranted to evaluate the efficacy of oral vitamin B12 supplementation in managing peripheral neuropathy in this group. Patients with T2DM on metformin for more than 2 years should therefore be screened for vitamin B12 deficiency regularly.

Keywords: Metformin, Peripheral Neuropathy, Diabetes Mellitus type 2, Vitamin B12.

Introduction

Diabetes mellitus (DM) is a highly prevalent metabolic disorder globally, with its incidence steadily increasing. In 2014, the WHO declared that 8.5% of adults aged 18 and above were affected by diabetes. In 2019, diabetes was responsible for 1.5 million deaths, with 48% of these occurring before the age of 70. DM is a metabolic disorder associated with chronic hyperglycemia, caused by either a lack of insulin secretion, impaired insulin action, or both. There are two main types of DM. Type 1 DM is an autoimmune disease where the pancreas produces little/no insulin, requiring lifelong insulin therapy. Type 2 DM is associated with insulin resistance. It is managed with medications and sometimes insulin. Metformin, a first-line oral hypoglycemic agent, is widely used to manage Type 2 DM in adults. The diagnosis of DM is made when fasting plasma glucose is more than 126 mg/dL (7.0 mmol/L), the 2 h OGTT plasma glucose is more than 200 mg/dL (11.1 mmol/L), or the HbA1c level is higher than 6.5%, or the random plasma glucose level is higher than 200 mg/dL (11.1 mmol/L). Vitamin B12 is a crucial coenzyme for DNA synthesis and neuroprotection. However, prolonged metformin use may impair vitamin B12 absorption and alter intestinal motility.[1,2]

Although metformin is generally considered safe and effective over the long term, its use is associated with vitamin B12 deficiency, especially at higher doses (≥1500 mg/day). This deficiency is primarily attributed to metformin's effects on vitamin B12 absorption. Vitamin B12, or cobalamin, is a water-soluble vitamin predominantly derived from animal-based foods.[3] A deficiency in vitamin B12 and folate is linked to various complications, including macrocytic anaemia, progressive demyelination, peripheral neuropathy, and cardiovascular issues. Studies have suggested that metformin therapy may reduce serum levels of both vitamins.[4] Dose of metformin ≥1500 mg/day can lead to a reduction in vitamin B12 levels.[5,6]

Among diabetic patients treated with metformin, vitamin B12 deficiency is notably prevalent, affecting approximately 22% of T2DM patients and 41% of those on metformin therapy.[7,8] Folate deficiency has also been documented in these patients, with a prevalence of 34.3%. Prolonged use of metformin (≥6 months) further increases the likelihood of deficiency.[9] Assessing serum levels of vitamin B12, methylmalonic acid, and homocysteine can aid in identifying early deficiencies.[10]

Deficiencies in vitamin B12 and folate in individuals with diabetes may result in severe complications, such as megaloblastic anaemia and cognitive impairments. Consequently, annual evaluations of vitamin B12 levels are recommended for metformin users, with intramuscular vitamin B12 supplementation advised upon detecting a deficiency.[11]

Contributions:
FAS LY IM - Conception, Design
FAS AA KAS SA IM - Acquisition, Analysis, Interpretation
FAS AS SA - Drafting
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This study aimed to evaluate the prevalence of vitamin B12 and folate deficiency and peripheral neuropathy among diabetic patients treated with metformin compared to those not treated with the drug. The findings may aid in the early identification of these deficiencies, thereby mitigating associated complications through timely supplementation.

Materials And Methods

This cross-sectional study was conducted at a tertiary care hospital in Rawalpindi, Pakistan, over six months from November 2023 to April 2024. Non-probability consecutive sampling was utilised to recruit participants. The sample size, determined using the World Health Organization sample size calculator with a 95% confidence interval and a 2.1% prevalence of vitamin B12 and folate deficiency, included 224 individuals with type 2 diabetes mellitus (T2DM). Of these, 112 were metformin users, while the remaining 112 did not use metformin.

The study received ethical clearance from the Institutional Review Board, with approval reference number 468.

Patients aged 18 to 85 years, diagnosed with T2DM, and attending either inpatient or outpatient facilities were included after providing verbal consent. The participants were divided into two groups: Group 1 comprised patients with T2DM not taking metformin, whereas Group 2 included those receiving metformin monotherapy at a dose exceeding 500 mg daily.

Patients were excluded if they declined to provide verbal consent or if they were on insulin therapy in combination with metformin. Other exclusion criteria included a history of pernicious anaemia before T2DM diagnosis, malabsorption syndromes (e.g., celiac disease and inflammatory bowel disease), malnourishment, strict vegetarian or carnivore diets, active cancer, abdominal surgeries, thyroid disorders, autoimmune diseases (e.g., vitiligo, Addison's disease, and hypoparathyroidism), and pregnancy. Patients who had received oral or intramuscular vitamin B12, vitamin D, calcium, or proton-pump inhibitors within the past three months and were on methotrexate or antifolate drugs were also excluded.

A comprehensive demographic and clinical history was collected, including age, sex, blood pressure, body mass index (BMI), personal and drug history, duration and dose of metformin use, and details regarding the onset and treatment of T2DM. Data were recorded using a predesigned questionnaire. Serum vitamin B12 and folate levels were measured under sterile conditions in both groups. Serum samples of 3 ml were taken for vitamin B12 and folate levels. The Cobas e 801 automated chemistry analyser (Roche Diagnostics, Basel, Switzerland) was used to measure vitamin B12 and folate levels. Vitamin B12 deficiency was identified as a serum concentration below 200 pg/mL, whereas folate deficiency was characterized by levels below 2.5 ng/mL. Patients with low vitamin B12 levels were further tested for hyperhomocysteinemia, which was defined as levels ≥15 µmol/L, and normal levels were <15 µmol/l.

Neuropathy assessment included measurement of the vibration perception threshold (VPT) using a neurothesiometer on the big toe pulp of both feet. VPT scores were categorised as follows: < 15 V (normal), 16–25 V (intermediate), and > 25 V (abnormal). Neuropathic pain was assessed using the Douleur Neuropathique 4 (DN4) questionnaire, with scores ≥4 indicating neuropathic pain. The Diabetic Neuropathy Symptom (DNS) score was also calculated, with a score ≥1 indicating diabetic neuropathy.

Data analysis was carried out using SPSS software, version 26. Descriptive statistics for continuous variables were represented as the mean and standard deviation, while categorical data were presented as counts and percentages. To compare the differences between groups, paired t-tests, independent t-tests, and Chi-square tests were applied. A p-value of less than 0.05 was considered to indicate statistical significance.

Results

A total of 224 individuals participated in the study and were equally divided into two groups: 112 patients who were on metformin and 112 who were not.

Table 1: Comparison of Demographic and Clinical Features between Patients on Metformin and Those Not on Metformin

		Metformin Use		p-value
		`Yes n=112	`No n=112	
Age Groups	18-37 years	7 (63.6%)	4 (36.4%)	0.41
	38-57 Years	30 (44.1%)	38 (55.9%)	
	58-77 Years	69 (53.1%)	61 (46.9%)	
	78-97 Years	6 (40.0%)	9 (60.0%)	
Gender	Male	63 (51.6%)	59 (48.4%)	0.59
	Female	49 (48.0%)	53 (52.0%)	
Diabetes Duration	0-5 years	37 (44.0%)	47 (56.0%)	0.37
	6-10 years	48 (52.7%)	43 (47.3%)	
	11 years or more	27 (55.1%)	22 (44.9%)	
Systolic BP	Normal	96 (51.6%)	90 (48.4%)	0.28
	High	16 (42.1%)	22 (57.9%)	
Diastolic BP	Normal	87 (50.6%)	85 (49.4%)	0.75
	High	25 (48.1%)	27 (51.9%)	
BMI	18.5-24.9	104 (52.5%)	94 (47.5%)	0.03
	25 or more	8 (30.8%)	18 (62.9%)	
Hemoglobin	Low	29 (53.7%)	25 (46.3%)	0.53
	Normal	83 (48.8%)	87 (51.2%)	
HbA1c	6.5 to 7	13 (43.3%)	17 (56.7%)	0.63
	> 7 to 7.5	39 (55.7%)	31 (44.3%)	
	>7.6 to 8	30 (46.9%)	34 (53.1%)	
	>8	30 (50.0%)	30 (50.0%)	

The average age of the participants was 59.9 ± 11.8 years. In the metformin group, 63 (56.3%) were men, and 49 (43.8%) were women, whereas in the non-metformin group, 59 (52.7%) were men and 53 (47.3%) were women.

Vitamin B12 deficiency was notably more prevalent among patients using metformin, with 27 (69.2%) of them affected, compared to only 12 (30.8%) of those not on metformin. However, no significant difference in folate deficiency was observed between the two groups (p = 0.55). Among those with B12 deficiency, 20 (71.4%) also exhibited hyperhomocysteinemia, compared to 8 (28.6%) without it, and this association was statistically significant (p = 0.02).

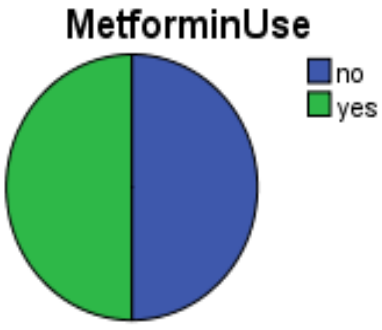
Table 2: Vitamin B12, Folate, and Homocysteine levels in Metformin users and Metformin non-users

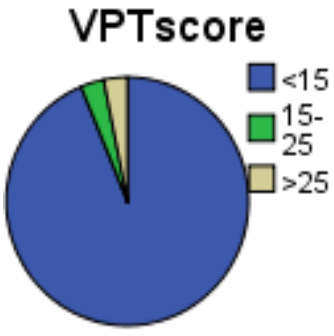
		Metformin use		
		Yes n=112	**No n=112**	
Vitamin B12 Levels	**Deficiency**	27 (69.2%)	12 (30.8%)	0.00
	Normal	85 (45.9%)	100 (54.1%)	
Folate Levels	**Deficiency**	5 (41.7%)	7 (58.3%)	0.55
	Normal	107 (50.5%)	105 (49.5%)	
Homocysteine levels	**Not done**	85 (45.9%)	100 (54.1%)	
	Raised	20 (71.4%)	8 (28.6%)	0.02
	Normal	7 (63.6%)	4 (36.4%)	

There were no significant differences in the VPT and DN4 scores between the metformin and non-metformin groups. The DNS score was significantly different between the metformin and non-metformin groups.

Table 3: Association of VPT, DNS, and DN4 scores with Vitamin B12 Deficiency

		Metformin use		p-value
		Yes n=112	No n=112	
VPT	**<15**	102 (48.6%)	108 (51.4%)	0.14
	15-25	4 (57.1%)	3 (42.9%)	
	>25	6 (85.7%)	1 (14.3%)	
DNS	**<1**	100 (48.1%)	108 (51.9%)	0.03
	≥1	12 (75.0%)	4 (25.0%)	
DN4	**<4**	104 (48.8%)	109 (51.2%)	0.12
	≥4	8 (72.7%)	3 (27.3%)	





Discussion

The global prevalence of diabetes is increasing. It was estimated to be 463 million (9.3% of adults aged 20–79 years) and is expected to increase to 700 million by 2045. Over 90% of diabetes mellitus cases are Type 2 DM. T2DM is also associated with increased healthcare costs, estimated to be $850 billion globally.[12] In 2016, 2018, and 2019, the prevalence of diabetes in Pakistan was 11.77%, 16.98%, and 17.1%, respectively. According to the International Diabetes Federation, in 2022, 26.7% of adults in Pakistan were affected by diabetes, making the total number of cases approximately 33,000,000.[13] Metformin, the first-line oral hypoglycaemic agent prescribed for type 2 diabetes mellitus (T2DM), is primarily used to manage insulin sensitivity and weight reduction. Despite its benefits, prolonged metformin use is associated with deficiencies in vitamin B12 and folate, which can lead to cognitive impairment, neuropathy, and diabetic retinopathy.[14] These deficiencies are often linked to the dose and duration of treatment, usually becoming evident after four to five years, although they have been documented as early as four months of metformin therapy. While the reduction in vitamin B12 absorption in the terminal ileum due to metformin is well-established, the precise mechanisms behind this effect are still not fully understood.[15]

The main aim of T2DM treatment is to optimise blood glucose levels to improve quality of life. Since its discovery in 1922, metformin has been a cornerstone of diabetes management, effectively reducing hepatic glucose production and improving glucose uptake by peripheral tissues, such as the muscle and liver. However, its long-term use has been linked to reduced vitamin B12 levels, with some studies also noting a slight reduction in folate levels.[16]

In a study by Miyan et al. at Baqai University, Karachi, involving 932 participants, metformin users exhibited a significantly higher prevalence of vitamin B12 deficiency (<200 pg/mL) than non-users (3.9% vs. 2.1%). Our study supports this finding, with a significantly higher proportion of metformin users (69.2%) showing vitamin B12 deficiency than 30.8% in the non-metformin group.[17] Farooq et al. also reported vitamin B12 deficiency in 11% of metformin users,[18] while Kakarlapudi et al.'s meta-analysis found significantly lower serum B12 concentrations in patients taking metformin regularly than in those not on metformin.[19]

Additionally, hyperhomocysteinemia was identified in 71.4% of patients with vitamin B12 deficiency in our study ($p = 0.02$), which aligns with findings by Yazidi et al., who also observed a positive correlation between elevated homocysteine levels and low vitamin B12 levels.[20] Rojbi et al. similarly found that metformin users had a higher likelihood of borderline-low B12 levels (356 pg/mL) ($p<0.01$), with each year of metformin use increasing the likelihood of developing B12 deficiency.[21] Wale et al. conducted a cross-sectional study and found that Vitamin B_{12} and folate deficiency were documented in 5% and 23.8% of participants on metformin dose >1500 mg/day.[22]

Peripheral neuropathy, assessed using DNS scores, was significantly more common in metformin users ($p = 0.03$) in our study. Yang et al. also reported a higher incidence of peripheral neuropathy in metformin users (84%).[23] However, some studies have reported conflicting results. For example, Rodriguez et al. found no substantial variation in vitamin B12 levels between metformin-treated patients and those not taking the drug.[24] Genc et al. also found only folic acid deficiency in metformin users.[25]

These contradictory findings emphasise the need for further studies to better understand the relationship between metformin use, vitamin B12 and folate deficiencies, and their potential impact on neuropathy and overall patient health in type 2 diabetes mellitus (T2DM).

This study investigated the complex relationship between vitamin B12 deficiency and metformin. Routine monitoring of vitamin B12 levels in patients on metformin for extended periods is important to identify and address the deficiency in its early stages. Routine supplementation can reduce the risk of adverse effects.

Several limitations of this study must be acknowledged. First, a comprehensive evaluation of diabetic peripheral neuropathy was not conducted, as the study did not include systematic assessments beyond the chosen scores. Second, the cross-sectional design precludes establishing a direct causal relationship between metformin use and deficiencies in vitamin B12 or folate. Lastly, as a single-center study, the findings may not be generalizable to the broader population of patients with T2DM who are treated with metformin. In the future, multicentre studies should be conducted to counter these limitations.

Conclusions

Understanding the multifaceted effects of metformin in T2DM management involves recognising its potential role in contributing to vitamin B12 and folate deficiencies. These deficiencies, in turn, are associated with preventable complications, such as peripheral neuropathy. Our study pinpoints the importance of regular screening and vitamin B12 supplementation in diabetic patients on metformin. Although folate deficiency appears less significant in this context, its potential impact warrants further exploration. Proactive strategies, including regular monitoring of B12 levels and appropriate supplementation, are essential for mitigating the long-term risks associated with metformin therapy.

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References

1. Tiwari A, Kumar Singh R, Satone PD, Meshram RJ. Metformin-Induced Vitamin B12 Deficiency in Patients With Type-2 Diabetes Mellitus. Cureus. 2023 Oct 26;15(10):e47771. https://doi.org/10.7759/cureus 47771.
2. Antar SA, Ashour NA, Sharaky M, Khattab M, Ashour NA, Zaid RT, et al. Diabetes mellitus: Classification, mediators, and complications; A gate to identify potential targets for the development of new effective treatments. Biomed Pharmacother. 2023 Dec;168:115734. https://doi.org/10.1016/j.biopha.2023.115734.
3. Infante M, Leoni M, Caprio M, Fabbri A. Long-term metformin therapy and vitamin B12 deficiency: An association to bear in mind. World J Diabetes. 2021 Jul 15;12(7):916-931. https://doi.org/10.4239/wjd.v12.i7.916.
4. Kanti G, Anadol-Schmitz E, Bobrov P, Strassburger K, Kahl S, Zaharia OP, et al. Vitamin B12 and Folate Concentrations in Recent-onset Type 2 Diabetes and the Effect of Metformin Treatment. J Clin Endocrinol Metab. 2020 Jun 1;105(6):dgaa150. https://doi.org/10.1210/clinem/dgaa150.

5. Sayedali E, Yalin AE, Yalin S. Association between metformin and vitamin B12 deficiency in patients with type 2 diabetes. World J Diabetes. 2023 May 15;14(5):585-593. https://doi.org/10.4239/wjd.v14.i5.585.
6. Bell DSH. Metformin-induced vitamin B12 deficiency can cause or worsen distal symmetrical, autonomic, and cardiac neuropathy in the patient with diabetes. Diabetes Obes Metab. 2022 Aug;24(8):1423-1428. https://doi.org/10.1111/dom.14734.
7. Ramzan NUH, Shahjahan K, Dhillon RA, Khan NTA, Hashmat MB, Anwer MU, Ahmed D, Afzal F, Tahir MM, Muzaffar A. Vitamin B12 Deficiency in Patients Taking Metformin: Pathogenesis and Recommendations. Cureus. 2024 Sep 3;16(9):e68550. https://doi.org/10.7759/cureus.68550.
8. Atkinson M, Gharti P, Min T. Metformin Use and Vitamin B12 Deficiency in People with Type 2 Diabetes. What Are the Risk Factors? A Mini-systematic Review. touchREV Endocrinol. 2024 Oct;20(2):42-53. https://doi.org/10.17925/EE.2024.20.2.7.
9. Wale Tesega W, Genet S, Netasan G, Tarekegn G, Girma F, Chalchisa D, et al. Assessment of serum vitamin B12 and folate levels and macrocytosis in patients with type 2 diabetes mellitus on metformin attending Tikur Anbessa Specialized Hospital, Addis Ababa, Ethiopia: A cross-sectional study. Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy. 2021;Volume 14:2011–8. https://doi.org/10.2147/dmso.s306433
10. Albai O, Timar B, Paun DL, Sima A, Roman D, Timar R. <p>metformin treatment: A potential cause of megaloblastic anemia in patients with type 2 diabetes mellitus</p>. Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy. 2020;Volume 13:3873–8. https://doi.org/10.2147/dmso.s270393
11. Batulwar PS, Anjankar A. Individuals Diagnosed With Type 2 Diabetes Mellitus and the Status of Vitamin B12 Deficiency: A Review. Cureus. 2024 Feb 27;16(2):e55103. https://doi.org/10.7759/cureus.55103.
12. Majety, Priyanka et al. "Pharmacological approaches to the prevention of type 2 diabetes mellitus." Frontiers in endocrinology vol. 14 1118848. 9 Mar. 2023, https://doi.org/10.3389/fendo.2023.1118848
13. Azeem S, Khan U, Liaquat A. The increasing rate of diabetes in Pakistan: A silent killer. Ann Med Surg (Lond). 2022 Jun 3;79:103901. https://doi.org/10.1016/j.amsu.2022.103901.
14. Patel H, McGuirk R. Vitamin B12 Deficiency: Common Questions and Answers. Am Fam Physician. 2025 Sep;112(3):294-300.
15. Didangelos T, Karlafti E, Kotzakioulafi E, Margariti E, Giannoulaki P, Batanis G, et al. Vitamin B12 Supplementation in Diabetic Neuropathy: A 1-Year, Randomized, Double-Blind, Placebo-Controlled Trial. Nutrients. 2021 Jan 27;13(2):395. https://doi.org/0.3390/nu13020395.
16. Huynh DT, Nguyen NT, Do MD. Vitamin B12 deficiency in diabetic patients treated with metformin: A cross-sectional study. PLoS One. 2024 Apr 25;19(4):e0302500. https://doi.org/10.1371/journal.pone.0302500.
17. Miyan Z, Waris N; MIBD. Association of vitamin B_{12} deficiency in people with type 2 diabetes on metformin and without metformin: a multicenter study, Karachi, Pakistan. BMJ Open Diabetes Res Care. 2020 May;8(1):e001151. https://doi.org/10.1136/bmjdrc-2019-001151.
18. Farooq MD, Tak FA, Ara F, Rashid S, Mir IA. Vitamin B12 Deficiency and Clinical Neuropathy with Metformin Use in Type 2 Diabetes. J Xenobiot. 2022 May 31;12(2):122-130. https://doi.org/10.3390/jox12020011.
19. Kakarlapudi Y, Kondabolu SK, Tehseen Z, Khemani V, J SK, Nousherwani MD, et al. Effect of Metformin on Vitamin B12 Deficiency in Patients With Type 2 Diabetes Mellitus and Factors Associated With It: A Meta-Analysis. Cureus. 2022 Dec 7;14(12):e32277. https://doi.org/10.7759/cureus.32277.
20. Yazidi M, Kamoun E, Hadj Taieb S, Rejeb O, Mahjoub S, Maryam S,et al. Vitamin B12 deficiency in long-term metformin treated type 2 diabetic patients: Prevalence and risk factors in a Tunisian population. Chronic Illn. 2023 Jun 19:17423953231184220. https://doi.org/10.1177/17423953231184220.
21. Rojbi I, Kalthoum M, Mekni S, Bouzid K, Khiari K, Ben Nacef I. Vitamin B12 levels in type 2 diabetic patients on Metformin compared to those never on Metformin: a cross sectional study in Tunisia. Tunis Med. 2023 Apr 5;101(4):433-439. English.
22. Wale Tesega W, Genet S, Natesan G, Tarekegn G, Girma F, Chalchisa D, et al. Assessment of Serum Vitamin B_{12} and Folate Levels and Macrocytosis in Patients with Type 2 Diabetes Mellitus on Metformin Attending Tikur Anbessa Specialized Hospital, Addis Ababa, Ethiopia: A Cross-Sectional Study. Diabetes Metab Syndr Obes. 2021 May 3;14:2011-2018. https://doi.org/10.2147/DMSO.S306433.
23. Yang R, Yu H, Wu J, Chen H, Wang M, Wang S, et al. Metformin treatment and risk of diabetic peripheral neuropathy in patients with type 2 diabetes mellitus in Beijing, China. Front Endocrinol (Lausanne). 2023 Feb 28;14:1082720. https://doi.org/10.3389/fendo.2023.1082720.
24. Rodríguez-Gutiérrez R, Montes-Villarreal J, Rodríguez-Velver KV, González-Velázquez C, Salcido-Montenegro A, Elizondo-Plazas A, et al. Metformin Use and Vitamin B12 Deficiency: Untangling the Association. Am J Med Sci. 2017 Aug;354(2):165-171. https://doi.org/10.1016/j.amjms.2017.04.010.
25. Genc FT, Nalbant A, Genc AC, Kaya T. Effect of a combination of gliptin and metformin on serum vitamin B12, folic acid, and ferritin levels. Rev Assoc Med Bras (1992). 2023 Oct 27;69(11):e20230641. https://doi.org/10.1590/1806-9282.20230641.