Int Clin Neurosci J. 2025;12:e7 Original Article

doi: 10.22037/icnj.v12iContinuous.50704

The Relationship Between Vitamin D Serum Levels and Prognosis in Ischemic Stroke Patients

Arvin Mohammad Valipour, Surena Nazarbaghi, Rezvan Norouzzadeh*

Department of Neurology, School of Medicine, Urmia University of Medical Sciences, Urmia, Iran

Abstract

Background: Vitamin D has potential protective effects against neurovascular damage, including stroke. This study investigated the relationship between serum vitamin D level and the prognosis of patients with ischemic stroke.

Methods: This prospective observational study included 95 ischemic stroke patients admitted to Imam Khomeini Hospital in Urmia, with stroke diagnosis confirmed by clinical presentation and CT scan. Upon admission, the severity of neurological deficit was assessed using the National Institutes of Health Stroke Scale (NIHSS). Functional outcomes were subsequently evaluated by the Modified Rankin Scale (mRS) at discharge and at three months post-stroke. Serum vitamin D levels (ng/mL) were measured within the first 24 hours of hospitalization.

Results: Of the 95 included patients, 51 (53.7%) were men and 44 (46.3%) were women, with a mean age of 68.6±14.8 years. The mean serum vitamin D level was 26.07±15.7 ng/mL. The mean NIHSS score was 11.69±11.39; stroke severity distribution was 32.6% mild, 41.1% moderate, 4.2% moderate to severe, and 22.1% severe. The mean mRS score was 2.98±1.48, indicating varied functional outcomes: 23.2% with no obvious disability, 17.9% partial, 17.9% moderate, 18.9% relatively severe, and 22.1% severe disability. Regression analysis revealed a significant inverse relationship between serum vitamin D levels and both NIHSS and mRS scores, such that lower vitamin D levels were associated with higher scores on both scales.

Conclusion: A significant relationship was observed between serum vitamin D levels and ischemic stroke severity and prognosis. Lower serum vitamin D levels were associated with higher stroke severity and a poorer prognosis compared to adequate levels.

Keywords: Ischemic Stroke; Vitamin D; Diagnosis; Prognosis.

Received: October 26, 2025, **Accepted:** December 28, 2025, **Published online:** November 15, 2026

Citation: Valipour AM, Nazarbaghi S, Norouzzadeh R. The Relationship Between Vitamin D Serum Levels and Prognosis in Ischemic Stroke Patients. Int Clin Neurosci J. 2025;12:e7.

Introduction

Ischemic stroke, a global health concern affecting individuals across all demographics,[1] is a major contributor to mortality and the leading cause of disability in those over 45 years.[2,3] Its sequelae, including motor impairment, social activity limitations, and depression, pose significant challenges, particularly for older people.[4] Accounting for 80% of all strokes, ischemic events result from cerebral ischemia lasting more than a few seconds, leading to glycogen depletion and the manifestation of neurological symptoms.[5] While conventional risk factors like hypertension, diabetes, and smoking are well-documented, a growing body of evidence now highlights vitamin D deficiency as a potentially critical factor in stroke pathogenesis and subsequent patient outcomes.[6, 7]

Vitamin D, recognized primarily as a steroid hormone crucial for the homeostatic regulation of inorganic ions,[8] is more accurately described as a hormone or hormonal precursor due to its endogenous synthesis capabilities under specific biological conditions.[9] Optimal serum vitamin D levels are positively correlated with enhanced cardiovascular health, notably contributing to a reduced risk of stroke.[10] Conversely, vitamin D deficiency is frequently identified as a comorbidity in various conditions, including acute ischemic stroke, neurodevelopmental disorders, intellectual disability, and cardiovascular risk, and is independently associated with elevated mortality.[11] Furthermore, prior research has established a link between vitamin D deficiency and a range of neurological disorders, such as Alzheimer's disease, Parkinson's disease, and multiple sclerosis.[12]

Recent research exploring the relationship between vitamin D and stroke risk has yielded inconsistent findings.[13] While a recent meta-analysis indicated a 62% increased stroke risk in individuals with lower serum vitamin D levels,[14] other studies have reported no significant association between vitamin D deficiency or elevated serum levels and stroke risk.[15, 16] Environmental factors also appear to play a role, with individuals residing in regions with reduced sunlight

***Correspondence to:** Rezvan Norouzzadeh, Email: rez1_nr@yahoo.com

© 2025 The Author(s). This is an open access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

exposure demonstrating a 56% higher stroke risk. At the same time, greater vitamin D intake is associated with a decreased risk of both stroke and cognitive impairments.[17] The elevated prevalence of osteoporosis in post-stroke patients, coupled with the identification of vitamin D receptors and alpha 1-hydroxylase activity within the brain, underscores the rationale for further investigation into the connection between vitamin D status and stroke.[17] Given these conflicting results in the contemporary literature concerning serum vitamin D levels and stroke risk, the present study sought to specifically examine the relationship between serum vitamin D levels and the prognosis of patients experiencing ischemic stroke.

Materials and Methods

This prospective observational study investigated stroke patients admitted to the neurology ward of Imam Khomeini Hospital in Urmia, Iran, between 2022 and 2023.

Inclusion criteria comprised patients hospitalized for a first-ever ischemic stroke, confirmed by both neurological diagnosis and brain imaging. Written informed consent was obtained from all participants at the study's inception. Exclusion criteria included pre-existing malabsorption diseases, a diagnosis of cancer or liver cirrhosis, hemorrhagic stroke, and the use of vitamin D supplements within the three months before admission.

Ischemic stroke diagnosis was established through clinical presentation and neurological examination, with confirmation via non-contrast brain computed tomography (CT) scans. Upon admission, patients' neurological deficits were assessed using the National Institutes of Health Stroke Scale (NIHSS).[18] Functional outcomes were subsequently evaluated at hospital discharge and at three months post-stroke using the Modified Rankin Scale (mRS).[19] The NIHSS, comprising 11 elements, quantifies specific neurological abilities on a scale of 0 (normal) to 4 (completely impaired), yielding a maximum score of 42. The mRS is a widely utilized instrument for assessing post-stroke functional outcome, ranging from 0 (no symptoms) to 6 (death), with higher scores denoting greater disability. This scale effectively evaluates a patient's capacity for activities of daily living, such as eating, dressing, and mobility. It is recognized for its strong inter-rater reliability and validity in both clinical practice and research.

Serum vitamin D levels (ng/mL) were quantified from blood samples collected within the first 24 hours of hospitalization using "Pishgaman Sanjesh Isatis" laboratory kits. The measurement employed an Enzyme-Linked Immunosorbent Assay (ELISA) using a specific "Anti-Vitamin D" monoclonal antibody that targets a unique antigenic determinant of the vitamin D molecule. Following the assessment of NIHSS and mRS scores, individual patient prognosis and the probability of mortality and disability were determined. Subsequently, patient prognoses were comparatively analyzed based on their measured serum vitamin D levels. For classification, serum 25(OH)D levels were defined as deficient (≤20 ng/mL), insufficient (21−29 ng/mL), or normal (≥30 ng/mL).[20] The relationship between these levels and stroke prognosis was then analyzed.

Sample size method

The sample size of 95 patients was determined using a specific formula, based on a mean vitamin D level of 9.9±7.1 ng/mL in stroke patients, as reported by Wajda et al.[21]

$$n = \frac{z^2_{1-\frac{\alpha}{2}} \times S^2}{d^2}$$

Statistical analysis

The data were statistically analyzed using SPSS version 23. Descriptive statistics were presented as frequency (percentage) and mean ± standard deviation. A paired t-test was used to compare functional outcomes (mRS scores) at hospital discharge and at 3-month follow-up. Linear regression analysis was conducted to evaluate the relationship between serum Vitamin D levels (independent variable) and stroke severity/prognosis (dependent variables: NIHSS and mRS). The adjusted beta coefficients were calculated by including age and gender as covariates in the model. A P-value < 0.05 was considered significant.

Results

The study cohort comprised 95 patients (51 men, 46.3% women), with a mean age of 68.6±14.8 years (range: 36-93 years). The mean serum vitamin D level was 26.07±15.7 ng/mL (range: 3-62.3 ng/mL). Mean NIHSS and mRS scores were 11.69±11.39 and 2.98±1.48, respectively (Table 1).

Table 1. Mean and standard deviation of the clinical quantitative variables.

Variable	Mean	SD	Min	Max	Median
Age (Year)	68.6	14.8	36	93	71
Vitamin D serum level, ng/ml	26.07	15.7	3	62.3	29.9
NIHSS score	11.69	11.39	2	39	6
mRS	2.98	1.48	1	5	3

Stroke severity, categorized by the NIHSS, showed that 31 patients (32.6%) had mild stroke, 39 (41.1%) moderate, 4 (4.2%) moderate-to-severe, and 21 (22.1%) severe (Table 2). Functional outcomes, assessed by mRS, varied across time points. At hospital discharge, 22 patients (23.2%) exhibited no obvious disability despite symptoms, 17 (17.9%) had partial disability, 17 (17.9%) had moderate disability, 18 (18.9%) had relatively severe disability, and 21 (22.1%) had severe disability. At the 3-month follow-up, an improvement was observed: 39 patients (41.1%) had no obvious disability, 23 (24.2%) had partial disability, 4 (4.2%) had moderate disability, and 29 (30.5%) had relatively severe disability, with no patients experiencing severe disability (Table 2).

A paired t-test revealed a significant difference ($P<0.05$) in mRS scores between baseline and the 3-month follow-up, correlating with serum vitamin D levels in ischemic stroke patients. Specifically, patients with adequate vitamin D levels showed a substantially greater reduction in mRS scores at the 3-month follow-up, indicating a more favorable prognosis

Table 2. Classification of the mRS score at the hospital.

Score	mRS classification, N (%)				
	Lack of obvious disability despite symptoms	Partial disability	Moderate disability	Relatively severe disability	Severe disability
At hospital	22 (23.2)	17 (17.9)	17 (17.9)	18 (18.9)	21 (22.1)
After 3 months	39 (41.1)	23 (24.2)	4 (4.2)	29 (30.5)	0 (029)
	NIHSS classification, N (%)				
	Mild	Moderate	Moderate to severe	Severe	Mild
At admission	31 (32.6)	39 (41.1)	4 (4.2)	21 (22.1)	31 (32.6)

compared with those with lower vitamin D levels (Table 3).

Linear regression analysis demonstrated a significant relationship between serum vitamin D levels and both NIHSS and mRS scores in patients with ischemic stroke. Specifically, lower vitamin D levels were associated with higher scores on both the NIHSS and mRS, indicating greater neurological deficit severity and poorer functional outcomes (Table 4).

Table 3. Comparison of the mean vitamin D serum levels.

Variables		Vitamin D serum level		t	P value
		Mean	SD		
mRS score	At hospital	2.98	1.48	8.698	<0.001
	At 3-month follow-up	2.24	1.27		

Table 4. Linear regression to predict vitamin D levels using NIHSS and MRS criteria.

Variable	Adjusted beta coefficient	Unadjusted beta coefficient	Standard error	t	P value
NIHSS	-0.42	-0.58	0.22	-2.60	0.01
MRS	-0.89	-9.48	1.72	-5.46	<0.001

Discussion

The pervasive issue of vitamin D deficiency is a significant concern due to its established links with various conditions, including cardiovascular, musculoskeletal, infectious, autoimmune, and malignant diseases.[1] Furthermore, recent population-based studies consistently highlight vitamin D deficiency as a predictor of future stroke events.[22] Against this background, the present study aimed to specifically investigate the relationship between serum vitamin D levels and the prognosis of patients experiencing ischemic stroke.

Acknowledging age as a robust predictor of stroke survival, we considered that any detrimental effects of low vitamin D might be negligible in elderly populations.[23] This aligns with Daubail et al.'s[24] finding of no significant association between 25-OH D levels and 1-year mortality in patients aged ≥75 years. In our study, the mean age of stroke patients was 68.6±14.8 years (range: 36-93 years), with a sex distribution of 53.7% men and 46.3% women. This mean age is consistent with other research indicating that stroke onset occurs approximately 15 years earlier in low-income compared to high-income countries.[25] A prospective clinical study by Markišić et al.[26] involving 50 patients with first-ever ischemic stroke, investigating the relationship between early functional outcomes and serum vitamin D levels during rehabilitation, reported a slightly older mean age of 71.9±11.3 years (range: 45-90 years) than our cohort. It is important to note that vitamin D levels typically decline with age, particularly after 60 years, due to reduced dermal synthesis. Additionally, the Markišić et al. Study[26] had a female predominance (56% women, 44% men), contrasting with the male predominance observed in the current study.

Our study found a significant association between serum vitamin D levels and both NIHSS and mRS scores in patients with ischemic stroke. This suggests a broader role for vitamin D in ischemic stroke pathophysiology and prognosis, extending beyond its traditional involvement in bone health to influence neurovascular and neurological outcomes.[27] Specifically, patients with lower vitamin D levels exhibited higher (worse) scores on both the NIHSS and mRS. Furthermore, a significant improvement in mRS scores was observed between baseline and three months post-stroke among patients with adequate serum vitamin D levels. These individuals demonstrated a greater reduction in mRS scores and consequently a more favorable prognosis compared to patients with lower vitamin D levels. The sustained improvement observed in patients with adequate vitamin D levels three months after stroke onset, relative to their baseline, underscores the potential relationship between vitamin D status and recovery. These findings collectively augment the accumulating evidence supporting a crucial role for vitamin D status in stroke pathophysiology and functional recovery.

Our findings are consistent with an expanding body of research that links vitamin D deficiency to adverse neurological outcomes. Numerous epidemiological studies have reported an inverse relationship between vitamin D levels and both stroke incidence and severity. For example, a 5-year follow-up study by Zeng et al.[28] demonstrated that a vitamin D level below 38.4 nmol/L was associated with poor long-term functional outcomes in patients with arterial ischemic stroke, suggesting a novel prognostic indicator. Similarly, Barnard et al.[29] presented population-based evidence associating vitamin D deficiency with cardiovascular disease, obesity, dementia, and increased mortality risk. Furthermore, Daubail et al.[24] reported a strong correlation between vitamin D levels at the 3-month follow-up and stroke outcomes, noting that patients with serum vitamin D levels <25.7 nmol/L at discharge had a poorer prognosis than those with levels >25.7 nmol/L.

Regarding functional outcomes, Borowicz et al.31 investigated the impact of vitamin D on post-stroke recovery

in 159 patients, observing that low vitamin D levels were associated with poorer overall functional outcomes. Their research further suggests that vitamin D3 supplementation positively influences functional outcomes during rehabilitation, potentially by enhancing neuroplasticity and recovery. Mechanistically, vitamin D directly contributes to maintaining intravascular function and regulating inflammatory activity within the vascular wall.[31] Indirectly, it modulates renin production via the renin-angiotensin-aldosterone system pathway, thereby reducing blood pressure.[32] In our study, we observed a significant association between vitamin D status and stroke severity, with higher severity noted in vitamin D-deficient patients compared to those with sufficient levels. This aligns with previous research indicating a modest association between low 25(OH) D levels and ischemic stroke risk.[11,33] Furthermore, our findings are consistent with the meta-analysis by Brøndum-Jacobsen et al.,[34] which demonstrated a significant inverse relationship between symptomatic ischemic stroke incidence and plasma 25-hydroxyvitamin D concentration. Similar to our investigation, other studies have substantiated the role of vitamin D in predicting short-term stroke outcomes, wherein lower vitamin D levels consistently correlate with worse patient prognoses.[35]

The consistent findings across multiple studies, including the present one, reinforce the clinical significance of vitamin D status in ischemic stroke. Consequently, screening for and addressing vitamin D deficiency in stroke patients could become an integral component of comprehensive stroke management. Early assessment of serum vitamin D levels upon admission may serve as a valuable prognostic indicator, facilitating patient risk stratification and potentially informing more intensive rehabilitation strategies for those found to be deficient. As vitamin D deficiency is both widespread and amenable to treatment, this represents a relatively straightforward intervention with the potential to enhance neurological recovery and mitigate long-term disability. However, the exact role and optimal efficacy of vitamin D supplementation in the acute phase of stroke necessitate further rigorous clinical trials.

Limitation of study

This study possesses several limitations. Its cross-sectional design inherently precludes establishing a causal relationship between vitamin D deficiency and stroke outcomes. The relatively small sample size may also constrain the generalizability of our findings. Furthermore, we did not evaluate long-term outcomes or the potential impact of vitamin D supplementation on post-stroke recovery.

Despite these limitations, our results, aligning with prior research, suggest that vitamin D status could be a crucial determinant of stroke prognosis. Future investigations should prioritize large-scale, prospective studies to more thoroughly clarify the relationship between vitamin D levels and stroke outcomes. Moreover, randomized controlled trials are essential to determine whether vitamin D supplementation can improve stroke outcomes and to warrant its integration into standard stroke care protocols.

Conclusion

This study reported a significant inverse relationship between serum vitamin D levels and both NIHSS and mRS scores in ischemic stroke patients, indicating that lower vitamin D levels were associated with greater neurological deficit severity and poorer functional outcomes. Furthermore, a significant improvement in mRS scores was observed over the 3-month follow-up period among patients with adequate vitamin D levels. These individuals demonstrated a more pronounced reduction in mRS scores than those with low or decreased vitamin D levels, suggesting a potential association between adequate vitamin D levels and favorable functional recovery post-stroke.

Acknowledgments

The authors would like to express their gratitude to the clinical research development unit of Imam Khomeini Hospital, Urmia University of Medical Sciences, for English editing.

Ethical consideration

The study protocol was strictly conducted in accordance with the principles of the Declaration of Helsinki. The study received formal approval from the Ethics Committee of Urmia University of Medical Sciences (Approval ID: IR.UMSU.REC.1399.094).

Competing Interests

The authors declare no conflict of interest.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

1. Borowicz W, Ptaszkowski K, Ptaszkowska L, Rosińczuk J, Murawska-Ciałowicz E. Association Between Serum Vitamin D Levels and Physical Outcomes of Patients Who Underwent Rehabilitation Following Ischemic Stroke. Med Sci Monit. 2023;29:e940115. doi: 10.12659/MSM.940115
2. Talebi A, Amirabadizadeh A, Nakhaee S, Ahmadi Z, Mousavi-Mirzaei SM. Cerebrovascular disease: how serum phosphorus, vitamin D, and uric acid levels contribute to the ischemic stroke. BMC Neurol. 2020;20(1):116. doi: 10.1186/s12883-020-01686-4
3. Siotto M, Santoro M, Aprile I. Vitamin D and rehabilitation after stroke: Status of art. Applied Sciences. 2020;10(6):1973. doi: 10.3390/app10061973
4. Heidarinejad Z, Kavosi A, Mousapour H, Daryabor MR, Radfard M, Abdolshahi A. Data on evaluation of AQI for different season in Kerman, Iran, 2015. Data Brief. 2018;20:1917-23. doi: 10.1016/j.dib.2018.08.216
5. Della-Morte D, Guadagni F, Palmirotta R, Testa G, Caso V, Paciaroni M, et al. Genetics of ischemic stroke, stroke-related risk factors, stroke precursors and treatments. Pharmacogenomics. 2012;13(5):595-613. doi: 10.2217/pgs.12.14
6. Acampa M, Lazzerini PE, Guideri F, Tassi R, Martini G. Ischemic Stroke after Heart Transplantation. J Stroke. 2016;18(2):157-68. doi: 10.5853/jos.2015.01599
7. Boehme AK, Esenwa C, Elkind MS. Stroke Risk Factors, Genetics, and Prevention. Circ Res. 2017;120(3):472-95. doi: 10.1161/CIRCRESAHA.116.308398
8. Masoudian N, Samaie S A, Darzi S, Ghooshchian M, Ziari A. The Relationship between Serum Vitamin D Level, Ischemic Stroke Severity and Lesion Volume in Ischemic Stroke Patients in Iran, 2019: An Analytic Cross-sectional Study. Journal of chemical health risk. 2020;10(3):225-

32. doi:10.22034/jchr.2020.1890656.1089
9. Voiculescu V M, Nelson Twakor A, Jerpelea N, Pantea Stoian A. Vitamin D: Beyond Traditional Roles—Insights into Its Biochemical Pathways and Physiological Impacts. Nutrients. 2020;17(5):803. https://doi.org/10.3390/nu17050803
10. Yarlagadda K, Ma N, Doré S. Vitamin D and Stroke: Effects on Incidence, Severity, and Outcome and the Potential Benefits of Supplementation. Front Neurol. 2020 Jun 10;11:384. doi: 10.3389/fneur.2020.00384
11. Alfieri DF, Lehmann MF, Oliveira SR, Flauzino T, Delongui F, de Araújo MC, et al. Vitamin D deficiency is associated with acute ischemic stroke, C-reactive protein, and short-term outcome. Metab Brain Dis. 2017;32(2):493-502. doi: 10.1007/s11011-016-9939-2
12. Savran Z, Baltaci SB, Aladag T, Mogulkoc R, Baltaci AK. Vitamin D and Neurodegenerative Diseases Such as Multiple Sclerosis (MS), Parkinson's Disease (PD), Alzheimer's Disease (AD), and Amyotrophic Lateral Sclerosis (ALS): A Review of Current Literature. Curr Nutr Rep. 2025;14(1):77. doi: 10.1007/s13668-025-00663-y
13. Wang L, Li S, Sanika GHA, Zhao J, Zhang H, Zhao L, Wang W. Association between Serum 25-Hydroxyvitamin D Level and Stroke Risk: An Analysis Based on the National Health and Nutrition Examination Survey. Behav Neurol. 2021;2021:5457881. doi: 10.1155/2021/5457881
14. Ji W, Zhou H, Wang S, Cheng L, Fang Y. Low Serum Levels of 25-Hydroxyvitamin D Are Associated with Stroke Recurrence and Poor Functional Outcomes in Patients with Ischemic Stroke. J Nutr Health Aging. 2017;21(8):892-6. doi: 10.1007/s12603-016-0846-3
15. Berghout B P, Fani L, Heshmatollah A, Koudstaal P J, Ikram M A, Zillikens M C, et al. Vitamin D status and risk of stroke: the Rotterdam study. Stroke. 2019; 50(9):2293-8. doi: 10.1161/STROKEAHA.119.025449
16. Menesgere A, Giridhar V, Bota R, Ravindranath V. Role of Vitamin D on cognitive performance among healthy volunteers of SANSCOG cohort. Clinical Nutrition Open Science. 2022;44:1-8.
17. Uluduz D, Adil MM, Rahim B, Gilani WI, Rahman HA, Gilani SI, et al. Vitamin D deficiency and osteoporosis in stroke survivors: an analysis of National Health and Nutritional Examination Survey (NHANES). J Vasc Interv Neurol. 2014;7(1):23-8. PMID: 24920985; PMCID: PMC4051901.
18. Kwah LK, Diong J. National Institutes of Health Stroke Scale (NIHSS). J Physiother. 2014;60(1):61. doi: 10.1016/j.jphys.2013.12.012
19. Quinn TJ, Dawson J, Walters MR, Lees KR. Reliability of the modified Rankin Scale: a systematic review. Stroke. 2009;40(10):3393-5. doi: 10.1161/STROKEAHA.109.557256
20. Abdehgah AG, Monshizadeh A, Tehrani MM, Afhami S, Molavi B, Jafari M, et al. Relationship Between Preoperative 25-Hydroxy Vitamin D and Surgical Site Infection. J Surg Res. 2020 Jan;245:338-343. doi: 10.1016/j.jss.2019.07.036
21. Wajda J, Świat M, Owczarek AJ, Brzozowska A, Olszanecka-Glinianowicz M, Chudek J. Severity of Vitamin D Deficiency Predicts Mortality in Ischemic Stroke Patients. Dis Markers. 2019 May 2;2019:3652894. doi: 10.1155/2019/3652894
22. Kaul S, Manikinda J. Role of Vitamin D in Cerebrovascular Disease. Ann Indian Acad Neurol. 2021 Mar-Apr;24(2):142-145. doi: 10.4103/aian.AIAN_928_20
23. Aggarwal H K, Jain D, Pahuja T, Singh J, Dahiya S. Vitamin D as a Predictor of Severity and Prognosis of Acute Ischemic Stroke. Turkish Journal of Neurology. 2022;28(3): 142-147. doi:10.4274/tnd.2022.24434
24. Daubail B, Jacquin A, Guilland JC, Hervieu M, Osseby GV, Rouaud O, et al. Serum 25-hydroxyvitamin D predicts severity and prognosis in stroke patients. Eur J Neurol. 2013;20(1):57-61. doi: 10.1111/j.1468-1331.2012.03758.x
25. Rahbar MH, Medrano M, Diaz-Garelli F, Gonzalez Villaman C, Saroukhani S, Kim S, et al. Younger age of stroke in low-middle income countries is related to healthcare access and quality. Ann Clin Transl Neurol. 2022;9(3):415-27. doi: 10.1002/acn3.51507
26. Markišić M, Pavlović AM, Pavlović DM. The Impact of Homocysteine, Vitamin B12, and Vitamin D Levels on Functional Outcome after First-Ever Ischaemic Stroke. Biomed Res Int. 2017;2017:5489057. doi: 10.1155/2017/5489057
27. Marek K, Cichoń N, Saluk-Bijak J, Bijak M, Miller E. The Role of Vitamin D in Stroke Prevention and the Effects of Its Supplementation for Post-Stroke Rehabilitation: A Narrative Review. Nutrients. 2022;14(13):2761. doi: 10.3390/nu14132761
28. Zeng YY, Yuan CX, Wu MX, Cheng L, Zhou SN, Hu PL, et al. Low vitamin D levels and the long-term functional outcome of stroke up to 5 years. Brain Behav. 2021;11(10):e2244. doi: 10.1002/brb3.2244
29. Barnard K, Colón-Emeric C. Extraskeletal effects of vitamin D in older adults: cardiovascular disease, mortality, mood, and cognition. Am J Geriatr Pharmacother. 2010;8(1):4-33. doi: 10.1016/j.amjopharm.2010.02.004
30. Borowicz W, Ptaszkowska L, Małecki R, Paprocka-Borowicz M. The Effect of Vitamin D Supplementation on Functional Outcomes in Patients Undergoing Rehabilitation After an Ischemic Stroke: A Prospective, Single-Blind, Randomized, Placebo-Controlled Study. J Clin Med. 2025;14(6):1848. doi: 10.3390/jcm14061848
31. Takeda M, Yamashita T, Sasaki N, Nakajima K, Kita T, Shinohara M, et al. Oral administration of an active form of vitamin D3 (calcitriol) decreases atherosclerosis in mice by inducing regulatory T cells and immature dendritic cells with tolerogenic functions. Arterioscler Thromb Vasc Biol. 2010 Dec;30(12):2495-503. doi: 10.1161/ATVBAHA.110.215459
32. Jia J, Tao X, Tian Z, Liu J, Ye X, Zhan Y. Vitamin D receptor deficiency increases systolic blood pressure by upregulating the renin-angiotensin system and autophagy. Experimental and Therapeutic Medicine. 2022;23 (4): 314. doi: 10.3892/etm.2022.11243
33. Sun Q, Pan A, Hu FB, Manson JE, Rexrode KM. 25-Hydroxyvitamin D levels and the risk of stroke: a prospective study and meta-analysis. Stroke. 2012;43(6):1470-7. doi: 10.1161/STROKEAHA.111.636910
34. Brøndum-Jacobsen P, Nordestgaard BG, Schnohr P, Benn M. 25-hydroxyvitamin D and symptomatic ischemic stroke: an original study and meta-analysis. Ann Neurol. 2013;73(1):38-47. doi: 10.1002/ana.23738
35. Daubail B, Jacquin A, Guilland JC, Khoumri C, Aboa-Eboulé C, Giroud M, et al. Association between serum concentration of vitamin D and 1-year mortality in stroke patients. Cerebrovasc Dis. 2014;37(5):364-7. doi: 10.1159/000362534