Effect of Vitamin D Supplementation on Language Development in Children with Attention Deficit-Hyperactivity Disorder

Original Article

Doaa Saeed El Shanshory, Mohamed El-Sayed Darwish, Ahmed Mohamed Hassan and Shaimaa Mohamed Serag El Deen

Department of Phoniatrics, Faculty of Medicine, Tanta University, Tanta, Egypt.

ABSTRACT

Background: Vitamin D is important for the brain development, especially during the prenatal and early neonatal period. We aimed to study the vitamin D supplementation effect on behavior and language development, as an adjuvant therapy to the usual protocol of treatment, in attention deficit hyperactivity disorder (ADHD) children.

Patients and Methods: This case- control prospective interventional study was carried out on 30 children aged from 3 to 7 years old, both sexes diagnosed with and delayed language development. Patients were divided into two equal groups: Group 1: Case group, and group 2: Control group. All patients were undergone general examination, vocal tract examination, history taking, ear and nose examination, auditory perceptual assessment of voice and speech, the conners parent rating scale, the modified preschool language scale -4 (PLS4) and the Egyptian Arabic Pragmatic Language Test (EAPLT).

Results: There was significant improvement in cases before compared to cases after, and control before and control after regarding inattention, hyperactivity, and psychosomatic problems. At the study end, a significant decrease was found in cases after contrasted to control after regarding inattention, and psychosomatic problems. Concerning the scores of the language assessment, there was significant increase in cases after compared to cases before, and control after and control before regarding all scores of the PLS4, and EAPLT ($P < 0.05$).

Conclusion: Vitamin D supplementation could be combined with behavioural modification therapy and language therapy for much more alleviation of ADHD symptoms and enhancing language development in ADHD children with language delay.

Key Words: Attention deficit-hyperactivity disorder, Language development, Supplementation, Vitamin D.

Received: 28 October 2024, **Accepted:** 10 January 2025.

Corresponding Author: Doaa Saeed El Shanshory, MSc, Department of Phoniatrics, Faculty of Medicine, Tanta University, Tanta, Egypt. **Tel.:** +20 10 93071858, **E-mail**: do3aasa3eed22@gmail.com

ISSN: 2090-0740, 2025 Vol.26, No.26

INTRODUCTION

Attention deficit hyperactivity disorder (ADHD) is recognized as the most prevalent psychiatric disorder among school-aged children[1]. The global ADHD prevalence is estimated to be between 5.9 and 7.1%, and its upward trajectory is concerning[2].

It is the result of a environmental and genetic factors combination, and the symptoms of the condition are inconsistent among patients[3]. It is distinguished by the elevated presence levels of hyperactivity, impulsivity, and inattention, which impede daily functioning[4].

ADHD children are believed to be at a threefold increased developing comorbid language difficulties risk, which include deficiencies in their expressive, receptive, and pragmatic language capacity[5].

Although language impairment is not a cardinal ADHD feature, there is a strong correlation between ADHD and a language deficits variety, such as issues with coherence, non-verbal communication, and semantics, pragmatic language use[6]. It is intriguing that children who exhibit a persistent hyperactive-inattentive developmental trajectory are more likely to experience persistent social communication deficits, as opposed to the reverse[7].

Language is also a challenge for children with ADHD, particularly in terms of pragmatics and structural aspects[8]. Structural language skills are fundamental language skills that are essential for the production of well-formed sentences and the comprehension of vocabulary, morphosyntax, and phonology[9].

The relationship between ADHD and language has also been empirically examined. There is evidence that ADHD is linked to structural and speech language difficulties, with suggestions that the speech onset for ADHD children occurs faintly later than that of typically developing (TD) children[9].

Pragmatics is one language-related aspect that is garnering more attention in the context of ADHD. Although

DOI: 10.21608/ejentas.2025.331920.1791

pragmatic language is defined in a multitude of ways, there is a general agreement that pragmatics encompasses the social application of language. The overarching pragmatic language construct could be deconstructed into constituent parts, such as the conversions maintenance, initiation, and termination, the content and tone adaptation of spoken messages to encounter the listener's needs, and the production of coherent narratives[10].

Consequently, for decades, there has been research on the potential of dietary modifications to alleviate symptoms in ADHD children[11]. There are two categories of dietary modifications that have been proposed as potential treatments for ADHD in children: dietary interventions that eliminate certain nutrients, dietary interventions, and elimination diets that increase the specific nutrients intake[12].

Vitamin D is believed to be crucial for brain development, particularly during the prenatal and early neonatal period[13]. It was determined that vitamin D is indispensable for brain development through various mechanisms, and that the structure and function of the brain are influenced by its absence during early fetal life and childhood[14].

We aimed to study the vitamin D supplementation effect on behaviour and language development, as an adjuvant therapy to the usual protocol of treatment, in children with ADHD.

PATIENTS AND METHODS:

This Case- control prospective interventional study was done on 30 children aged from 3 to 7 years old, both sexes, diagnosed with ADHD (the diagnosis of ADHD was based on 5th edition (DSM-5TM) for ADHD and conners parent rating scale (CPRS)) and delayed language development (the diagnosis was based on the PLS4 and the EAPLT).

The study was conducted from January 2022 to June 2022 with the approval of the Ethical Committee of Tanta University Hospitals in Tanta, Egypt (Approval code: 35127/12/21). The patients' relatives provided written consent that was informed.

Exclusion criteria were children with other psychological problems other than ADHD, renal or hepatic diseases, who are managed by any other protocol of treatment of ADHD, any other causes of delayed language development and who have received calcium or vitamin D supplementation during the preceding 6 months.

Patients were divided into two equal groups: Group 1: Case group, and group 2: Control group.

All patients were subjected to: history taking, general examination, vocal tract examination, ear and nose examination, auditory perceptual assessment of voice and speech, and laboratory investigations were done to rule out renal and hepatic diseases. The two groups were managed by language therapy and behavioral modification therapy for 6 months. The case group, additionally, received the maximal prophylactic dose of vitamin D supplementation (1000 IU).

Clinical diagnostic aids

Conners' Rating Scale in Arabic: The scale comprises ten questions that evaluate the severity of ADHD on a four-point Likert scale and identify ADHD. The total score is between 0 and 30. A child is diagnosed with ADHD if their score exceeds 15[15].

The Arabic version of the PLS4 evaluates the child's language development and assigns three language ages: the receptive, expressive, and total language ages, as determined by the child's responses to the test items[16].

Stanford Binnet Intelligence Scale (5^{th} Arabic version)[17]. The Standardized EAPLT: It evaluates verbal, paralinguistic, and nonverbal abilities. The child's total score and scores in each subset of the EAPLT were calculated at the 5th and 95^{th} percentiles, depending on their chronological age. The 5^{th} percentile rank suggests that the child has acquired the skill, while the 95^{th} percentile rank suggests that the child has mastered it. Pragmatic language delay was indicated by scores below the fifth percentile rank[18].

Statistical analysis

SPSS v28 (IBM Inc., Chicago, IL, USA) was employed to conduct the statistical analysis. The mean and standard deviation (SD) of quantitative variables were presented and contrasted between the two groups utilizing an unpaired Student's t-test. Qualitative variables were analysed utilizing the Chi-square or Fisher's exact test when appropriate and were presented as frequency and (%). Statistical significance was indicated as a two-tailed *P value* that was < 0.05.

RESULTS:

Age and sex showed insignificant difference between both groups. (Table 1)

Concerning scores of the conners test, there was significant increase in cases before compared to cases after, and control before and control after regarding inattention, hyperactivity, and psychosomatic problems ($P < 0.05$), while insignificant difference regarding opposition between both groups. At the end of the study, a significant reduction was found in cases after contrasted to control after regarding inattention, and psychosomatic problems ($P= 0.001, 0.008$, respectively), but opposition,

and hyperactivity were insignificantly different between both groups. (Table 2)

Concerning the scores of the PLS4, there was significant increase in cases after compared to cases before, and control after and control before regarding all scores of the PLS4 (total age of language, receptive age of language, and expressive age of language) ($P < 0.05$). At the end of the study, there was significant increase in cases after compared to control after regarding receptive age of language ($P < 0.26$), while no significant difference regarding total age of language, and expressive age of language between both groups. (Table 3)

Table 4 shows a significant elevation in cases after in comparison with cases before, and control after in comparison with control before regarding all scores of the EAPLT ($P < 0.05$), and at the end of the study there were no significant differences between cases and control after regarding all scores of the EAPLT except pragmatic factors differ significantly ($P= 0.012$).

Table 1: Comparison between the case group and the control group regarding demographic data

		Case group (n=15)	Control group (n=15)	*P*
Age (years)		5.02 ± 1.16	4.94 ± 0.97	0.839
Sex	Male	11 (73.3%)	10 (66.6%)	0.666
	Female	4 (26.6%)	5 (33.3%)	

Data are presented as mean ± SD or frequency (%).

Table 2: Comparison the scores of the conners test between control group and the cases group before, after and at the end of the study

Case group	Cases before (n=15)	Cases after (n=15)	*P*
Opposition	62.20 ± 8.45	58.40 ± 6.95	0.189
Inattention	63.33 ± 7.36	49.93 ± 4.06	0.001*
Hyperactivity	70.73 ± 11.88	59.27 ± 5.54	0.011*
Psychosomatic problems	60.87 ± 9.73	47.67 ± 5.22	0.001*
Control group	Control before (n=15)	Control after (n=15)	*P*
Opposition	62.20 ± 8.45	59.93 ± 7.93	0.480
Inattention	63.20 ± 7.50	56.20 ± 5.09	0.006*
Hyperactivity	70.80 ± 11.85	61.80 ± 6.64	0.016*
Psychosomatic problems	60.93 ± 9.61	53.67 ± 6.22	0.020*
At the end of the study	Case After (n=15)	Control After (n=15)	*P*
Opposition	58.40 ± 6.95	59.93 ± 7.93	0.578
Inattention	49.93 ± 4.06	56.20 ± 5.09	0.001*
Hyperactivity	59.27 ± 5.54	61.80 ± 6.64	0.266
Psychosomatic problems	47.67 ± 5.22	53.67 ± 6.22	0.008*

Data are presented as mean ± SD. *: significant as *p value<0.05*.

Table 3: Comparison the scores of the PLS4 between control group and the cases group before, after and at the end of the study

Case group	Cases before (n=15)	Cases after (n=15)	*P*
Total age of language	5.01 ± 1.05	5.84 ± 1.04	0.038*
Receptive age of language	4.86 ± 1.08	6.11 ± 0.72	0.001*
Expressive age of language	5.16 ± 1.02	5.93 ± 0.88	0.034*
Control group	Control before (n=15)	Control after (n=15)	*P*
Total age of language	4.81 ± 0.95	5.77 ± 0.68	0.039*
Receptive age of language	4.72 ± 0.98	5.47 ± 0.79	0.029*
Expressive age of language	4.93 ± 0.89	5.81 ± 0.79	0.036*
At the end of the study	Case After (n=15)	Control After (n=15)	*P*
Total age of language	5.84 ± 1.04	5.77 ± 0.68	0.834
Receptive age of language	6.11 ± 0.72	5.47 ± 0.79	0.026*
Expressive age of language	5.93 ± 0.88	5.81 ± 0.79	0.696

Data are presented as mean ± SD. PLS4: Preschool language scale 4th edition. *: significant as *p value<0.05*.

Table 4: Comparison the scores of the EAPLT between control group and the cases group before, after and at the end of the study

Case group		Cases before (n=15)	Cases after (n=15)	*P*
Nonverbal aspects		5.40 ± 1.12	8.07 ± 1.10	0.002*
Para linguistic aspects		5.93 ± 0.80	7.93 ± 1.22	0.003*
Inference		3.67 ± 1.11	6.73 ± 2.22	0.010*
Narratives	Story retelling	17.53 ± 2.29	21.60 ± 2.41	0.011*
	Story telling	7.33 ± 1.35	11.13 ± 2.50	0.005*
Answering WH Question		13.67 ± 1.18	17.87 ± 2.13	0.001*
Pragmatic functions		2.67 ±0 .49	4.27 ± 1.22	0.012*
Pragmatic factors		8.13 ± 1.06	11.13 ± 2.20	0.015*
Total score		64.33 ± 7.04	86.67 ± 11.69	0.001*
Control group		Control before (n=15)	Control after (n=15)	*P*
Nonverbal aspects		4.60 ± 1.35	7.13 ± 1.85	0.021*
Para linguistic aspects		5.40 ± 1.06	7.20 ± 1.15	0.018*
Inference		3.58 ± 1.31	5.47 ± 1.85	0.034*
Narratives	Story retelling	15.87 ± 2.85	19.20 ± 1.97	0.012*
	Story telling	8.33 ± 2.23	10.20 ± 1.82	0.037*
Answering WH Question		13.75 ± 1.50	16.67 ± 2.47	0.015*
Pragmatic functions		2.67 ± 0.62	3.80 ± 1.01	0.005*
Pragmatic factors		6.67 ± 1.18	9.07 ± 1.98	0.012*
Total score		60.87 ± 4.47	79.20 ± 11.95	0.001*
At the end of the study		Cases after (n=15)	Control after (n=15)	*P*
Nonverbal aspects		8.07 ± 1.10	7.13 ± 1.85	0.104
Para linguistic aspects		7.93 ± 1.22	7.20 ± 1.15	0.101
Inference		6.73 ± 2.22	5.47 ± 1.85	0.100
Narratives	Story retelling	21.60 ± 2.41	19.20 ± 1.97	0.085
	Story telling	11.13 ± 2.50	10.20 ± 1.82	0.253
Answering WH Question		17.87 ± 2.13	16.67 ± 2.47	0.165
Pragmatic functions		4.27 ± 1.22	3.80 ± 1.01	0.265
Pragmatic factors		11.13 ± 2.20	9.07 ± 1.98	0.012*
Total score		86.67 ± 11.69	79.20 ± 11.95	0.095

Data are presented as mean ± SD. EAPLT: Egyptian Arabic Pragmatic Language test. *: significant as *p value<0.05*.

DISCUSSION

ADHD is a neurodevelopmental disorder that is distinguished by behavioral hyperactivity/impulsivity and inattention symptoms that are inconsistent with the child's developmental stage and have a significant effect on the child's social, academic, and behavioral functioning[19].

The case group (supplemented group) exhibited a significant decrease in symptoms of inattention and psychosomatic problems contrasted to the control group (non-supplemented group) by the conclusion of the study, as evidenced by the Conner's Test. The symptoms of ADHD are purportedly alleviated by vitamin D by modulating neurotransmitters for example; norepinephrine, dopamine, and acetylcholine[20].

There was a significant decrease in the symptoms of inattention, hyperactivity and psychosomatic problems in the two studied groups. These results are expected with the behavioural modification therapy. Whereas with vitamin D supplementation in the case group, the symptoms of inattention and psychosomatic problems had decreased with high significance. Contrary to our expectations, the domain of opposition showed no-significant improvement in either group. This could be attributed to some underlying causes that couldn't be eliminated during the period of the study such as having a chaotic family life, childhood abuse and maltreatment and peer rejection resulting from the pre-existing bad impressions of those children with ADHD.

An additional critical factor is that opposition, which is a purely psychological issue, is not affected

by the brain-related effects of vitamin D, such as attention, hyperactivity, and psychosomatic disorders, which could be targeted by vitamin D as brain centers. This study also targeted attention and hyperactivity with BMT, while opposition necessitates psychiatric management in addition to family therapy, which were not addressed in this study. Our findings are substantially consistent with those of Elshorbagy *et al*.[21] who demonstrated that the conceptual level, hyperactivity, impulsivity, opposition, and inattention were significantly enhanced in the case group compared to the control group.

Additionally, this enhancement in opposition may be demonstrated through behavioral modification therapy that emphasizes opposition. Additionally, it is impossible to implement the effects of methylphenidate.

A randomized double-blind placebo-controlled trial has also substantiated the efficacy of vitamin D supplementation in ADHD by Mohammadpour *et al*.[22] who investigated the impact of vitamin D supplementation as an adjunctive therapy to methylphenidate on sixty-two children with ADHD, aged five to twelve. In addition to methylphenidate, they were randomly assigned to one of two groups and received either 2000 IU of vitamin D or a placebo. The study reported a reduction in evening symptoms of ADHD, including difficulty in completing homework, excessive running, inattentiveness in task completion, and preparing for sleep, as measured by the WPREMB scale (Weekly Parent Ratings of Evening and Morning Behaviour scale). This was observed after 8 weeks of adjunctive therapy.

The study indicated a reduction in evening ADHD symptoms, including difficulty in excessive running, completing homework, inattentiveness in task completion, and preparing for sleep, as measured by the WPREMB scale (Weekly Parent Ratings of Evening and Morning Behaviour scale). This was observed afterward 8 weeks of adjunctive therapy[23].

Despite the short duration in this trial, vitamin D supplementation could pay off. This may be due to receiving a dose of 2000 IU which is the double of the dose used in our study.

Discussing the results of the PLS4, there was a significant improvement in the receptive age of language in the case group over the control group, while non-significant improvement was detected neither in the expressive nor the receptive age of language in the cases over the controls.

Significant improvements were detected in the total age of language, the receptive age of language and the expressive age of language in the two studied groups by the end of the study and the improvement in the receptive age of language in the supplemented group rose to a high significant level. This could be attributed to the high significant improvement in the level of attention that in its turn improves the comprehension abilities with subsequent improvements in the receptive aspect of language. Taking into consideration that the receptive language develops and improves at an earlier pace than the expressive one, the latter could improve in subsequent evaluations after extra time. To the best of our knowledge, this is the first study that aimed to assess the vitamin D supplementation impact on language development in children.

Whitehouse *et al*.[24] conducted a study that demonstrated substantial linear trends between language impairment at 5 and 10 years of age and the quartiles of maternal vitamin D levels. In contrast, Beauchet *et al*.[25] conducted a randomised controlled trials systematic review to create the proof regarding the vitamin D supplementation effects on cognitive performance in adults. The review did not aid a role for vitamin D supplementation in improving cognition in adults.

Pointing to the results of EAPLS with comparing the follow up results of the two studied groups, significant enhancement was detected in the case group over the control group regarding the item of pragmatic factors. Pragmatic factors being assessed by the EAPLT, included two subitems: (How do you feel if?) and (Identifying good and bad manners), and both are related-in one way or another- to the improvement obtained in the behavior. Studies concerned with this point -to our knowledge- are lacking.

On the other hand, the rest of the items of the test did not improve significantly in the cases over the controls, because pragmatics in general require longer periods of time to develop. This is because pragmatics are considered high brain functions.

Contrary to these obtained results, Pettersen *et al*,[26] studied the vitamin D supplementation effect on verbal fluency in one hundred and forty-two healthy adults, and concluded that supratherapeutic vitamin D levels may be optimal for verbal fluency.

Some justifications for this contrast include the difference in the targeted age, the presumption that vitamin D is normal in Pettersen's study and deficient in ours, and the maximal prophylactic dose in our study versus the supratherapeutic dose in Pettersen's.

After reviewing the follow-up results of the two studied groups in terms of behavior (as evidenced by the Conner's Test) and language (as evidenced by the PLS4 and EAPLT), it is evident that vitamin

D supplementation plays a significant role in the alleviation of certain ADHD symptoms, particularly inattention and psychosomatic issues. Nevertheless, its contribution to the improvement of language is limited to specific aspects of language, specifically those that fall within its structural or functional domains.

Limitations: The small size of this study is one of the factors of limitation. Also, the Conners' Parent Rating Scale is not an objective method for measuring the child's behaviour, but a parental perception reflection. The short duration of the study is another limitation since the expressive and the pragmatic aspects of language require longer duration to develop and mature. The irregular compliance of the children either in the sessions or in receiving vitamin D supplementation could be considered. In addition, children in this study were recruited only from our phoniatric outpatient clinic, the matter that hindered dealing with children with stronger ADHD symptoms as in those who visit psychiatric clinics. Lastly, the upper limit of age which did not allow for better evaluation of the pragmatics.

CONCLUSION

Vitamin D supplementation could be combined with behavioral modification therapy and language therapy for much more alleviation of ADHD symptoms and enhancing language development in ADHD children with language delay.

CONFLICT OF INTEREST

There are no conflicts of interest.

REFERENCES

1. Samadi M, Gholami F, Seyedi M, Jalali M, Effatpanah M, Yekaninejad MS, *et al*. Effect of Vitamin D Supplementation on Inflammatory Biomarkers in School-Aged Children with Attention Deficit Hyperactivity Disorder. Int J Clin Pract. 2022;2022.

2. Nazeer N, Rohanachandra Y, Prathapan S. Prevalence of ADHD in Primary School Children, in Colombo District, Sri Lanka. J Atten Disord. 2022;26:1130-8.

3. Sonuga-Barke EJ, Becker SP, Bölte S, Castellanos FX, Franke B, Newcorn JH, *et al*. Annual Research Review: Perspectives on progress in ADHD science–from characterization to cause. J Child Psychol Psychiatry. 2023;64:506-32.

4. Virring A, Lambek R, Jennum PJ, Møller LR, Thomsen PH. Sleep problems and daily functioning in children with ADHD: An investigation of the role of impairment, ADHD presentations, and psychiatric comorbidity. J Atten Disord. 2017;21:731-40.

5. Korrel H, Mueller KL, Silk T, Anderson V, Sciberras E. Research Review: Language problems in children with Attention-Deficit Hyperactivity Disorder–a systematic meta-analytic review. J Child Psychol Psychiatry. 2017;58:640-54.

6. Randell R, Somerville-Brown L, Chen W. How relevant is higher-order language deficit (HOLD) to children with complex presentations of attention-deficit hyperactivity disorder? ADHD Attention Deficit and Hyperactivity Disorders. 2019;11:325-32.

7. Krakowski AD, Szatmari P, Crosbie J, Schachar R, Duku E, Georgiades S, *et al*. Latent Structure of Combined Autistic and ADHD Symptoms in Clinical and General Population Samples: A Scoping Review. Frontiers in Psychiatry. 2021;12:2388.

8. Korrel H, Mueller KL, Silk T, Anderson V, Sciberras E. Research Review: Language problems in children with Attention-Deficit Hyperactivity Disorder–a systematic meta-analytic review. Journal of Child Psychology and Psychiatry. 2017;58:640-54.

9. Vassiliu C, Mouzaki A, Antoniou F, Ralli AM, Diamanti V, Papaioannou S, *et al*. Development of Structural and Pragmatic Language Skills in Children With Attention-Deficit/Hyperactivity Disorder. Communication Disorders Quarterly. 2022:15257401221114062.

10. Carruthers S, Taylor L, Sadiq H, Tripp G. The profile of pragmatic language impairments in children with ADHD: A systematic review. Dev Psychopathol. 2021;77:1-23.

11. Borge TC, Biele G, Papadopoulou E, Andersen LF, Jacka F, Eggesbø M, *et al*. The associations between maternal and child diet quality and child ADHD–findings from a large Norwegian pregnancy cohort study. BMC psychiatry. 2021;21:1-14.

12. Lange KW, Nakamura Y, Reissmann A. Diet and food in attention-deficit hyperactivity disorder. J Future Foods. 2022;2:112-8.

13. Lange KW, Hauser J, Lange KM, Makulska-Gertruda E, Nakamura Y, Reissmann A, *et al*. The role of nutritional supplements in the treatment of

ADHD: what the evidence says. Curr Psychiatry Rep. 2017;19:1-9.

14. Eyles DW, Burne TH, McGrath JJ. Vitamin D, effects on brain development, adult brain function and the links between low levels of vitamin D and neuropsychiatric disease. Front Neuroendocrinol. 2013;34:47-64.

15. El-Dafrawy M, Mahfouz R, Ragab L, editors. Reliability and validity study of a rating scale for ADHD in Egyptian children and adolescents. 3rd International Egyptian Congress of Psychiatry; 1990.

16. Abou Hassiba A, El-Sady S, El-Shobary A, Gamal El-din N, Ibrahiem A, Oweys A. Standardization, translation and modification of the Preschool Language Scale-4 [Unpublished MD thesis]. Ain Shams Med J. 2011;12:610-3.

17. Melika L. Stanford Binet intelligence scale (4th Arabic version). J Child Psychol Psychiatry. 1998;70:180-6.

18. Khodeir MS, Hegazi MA, Saleh MM. Development and standardization of a test for pragmatic language skills in Egyptian Arabic: The Egyptian Arabic Pragmatic Language Test (EAPLT). Folia Phoniatr Logop. 2018;69:209-18.

19. Voeller KK. Attention-deficit hyperactivity disorder (ADHD). JCN. 2004;19:798-814.

20. Poudineh M, Parvin S, Omidali M, Nikzad F, Mohammadyari F, Sadeghi Poor Ranjbar F, *et al*. The Effects of Vitamin Therapy on ASD and ADHD: A Narrative Review. CNS & Neurological Disorders-Drug Targets (Formerly Current Drug Targets-CNS & Neurological Disorders). 2023;22:711-35.

21. Elshorbagy HH, Barseem NF, Abdelghani WE, Suliman HAI, Al-Shokary AH, Abdulsamea SE, *et al*. Impact of vitamin D supplementation on attention-deficit hyperactivity disorder in children. Ann Pharmacother. 2018;52:623-31.

22. Mohammadpour N, Jazayeri S, Tehrani-Doost M, Djalali M, Hosseini M, Effatpanah M, *et al*. Effect of vitamin D supplementation as adjunctive therapy to methylphenidate on ADHD symptoms: A randomized, double blind, placebo-controlled trial. Nutr Neurosci. 2018;21:202-9.

23. Mohammadpour N, Jazayeri S, Tehrani-Doost M, Djalali M, Hosseini M, Effatpanah M, *et al*. Effect of vitamin D supplementation as adjunctive therapy to methylphenidate on ADHD symptoms: A randomized, double blind, placebo-controlled trial. Nutritional neuroscience. 2018;21:202-9.

24. Whitehouse AJ, Holt BJ, Serralha M, Holt PG, Kusel MM, Hart PH. Maternal serum vitamin D levels during pregnancy and offspring neurocognitive development. Pediatrics. 2012;129:485-93.

25. Beauchet O, Cooper-Brown LA, Allali G. Vitamin D supplementation and cognition in adults: a systematic review of randomized controlled trials. CNS drugs. 2021;35:1249-64.

26. Pettersen JA. Vitamin D and executive functioning: are higher levels better? journal of clinical and experimental neuropsychology. 2016;38:467-77.