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Original Research Article

THE INFLUENCE OF MICRONUTRIENTS ON COGNITIVE FUNCTIONS IN CHILDREN WITH LEARNING DISABILITIES: A CONTROLLED STUDY

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ABSTRACT

Background: The Cognitive development of children with learning disabilities is challenging in pediatric and child psychology. Moreover, according to recent research, serum levels of micronutrients can contribute not only to cognitive dysfunction but also to cognitive function. Therefore, there is a hypothesis that dietary supplementation can change the results of cognitive therapies for children with learning disabilities (LD). **Objectives**: The present study aimed to test the theory of cognitive improvement due to the intake of specific micronutrients. The research question was whether there is a difference in cognitive improvement between children with LD who receive the supplementation and those who do not. If so, what micronutrients appear to have the most significant effects.

Materials and Methods: The controlled study involved two groups of 60 children with diagnosed LD. Test one received the supplementation targeted at seven micronutrients, and the control group was administered a placebo. Beforehand to the beginning and after six months of supplementation, children undertook standardized tests, and the serum levels of targeted micronutrients were measured. The collected data were analyzed statistically.

Results: Cognitive test scores of the test group significantly improved, and those changes were sustained until the end of the testing period. Vitamin D and Folate serum levels correlated with the standardized test scores. The regression analysis proved the correlation above.

Conclusion: The supplementation with targeted seven micronutrients positively influences cognitive function in children with LD. The implication for practice includes considering the nutritional status of such children from a cognitive point of view.

Keywords: Micronutrients, Cognitive Functions, Learning Disabilities, Dietary Supplements, Cognitive Improvement, Neurodevelopmental Disorders, Nutritional Interventions.

INTRODUCTION

Learning disabilities in children are a heterogeneous group of neurodevelopmental disorders, markedly impairing information processing and substantially affecting academic achievements and activities of daily living.[1] However, several factors are involved in the etiology of LD, including genetic, environmental, and neurobiological factors. Recent research suggested that adequate nutritional status, particularly with micronutrients, plays a prominent role in cognitive development and related functions.[2] Micronutrients include vitamins and minerals essential for the brain's structure and functional biology. Vitamin D, Folate, Vitamin B12, and others were particularly noted for their neuroprotective and functional assets in maintaining

optimal cognitive function.[3] Persistent exposure to low levels of some micronutrients impairs brain development and predisposes individuals to cognitive impairment.[4] The presence or absence of these biomarkers can worsen the struggle of children with LD, defeating the prospects of associated treatments.

Despite the increasing body of evidence for the significance of the relationship between cognitive function and nutrition, the literature has a reluctant scope of the impact of obvious micronutrient supplementation on cognitive function among LD populations. This study intends to fill this gap in acknowledgment by assessing the influence of specific micronutrient supplementation on the mental functions of children with LD. This study hypothesizes that the supplementation with critical micronutrients supports cognitive improvements in children with LD. Therefore, this unexplored try would offer a novel grip on an adjunct therapy technique and decrease overhaul impairment within the LD community. This perceptive focus on children with LD and a solid approach to the cognitive implication of distinction among micronutrient levels over the research aims to open the position of nutrition in kids' mental health and development. Additionally, studies have the potential to contribute a meaningful addition to the current understanding by indirectly promoting micronutrient supplementation as unquestionably one area in which support would have clinical advantages.

In conclusion, while there is a general consensus on the importance of micronutrients in neurodevelopment, the direct impact of supplementation on children with learning disabilities is poorly explored. By and large, existing studies have not shown regard for children with LD as a particular population; instead, they focus on a general population or demonstrate the potential of nutrient supplementation for clinical cases characterized by nutritional deficiencies. This gap reveals a need for more understanding regarding the use and administration of dietary interventions in supporting cognitive processes in children with LD. Furthermore, the potential of micronutrients to complement traditional medical and educational approaches to treating and managing LD makes the study relevant from a holistic perspective. Our study seeks to fill this gap by demonstrating the direct effects of micronutrient administration and how the same could inform dietary guidelines and public policy tailored to the specific circumstances of children with LD. In so doing, we hope to contribute to our understanding of the complex interplay between nutrition and neurodevelopment and propose evidence-based interventions to improve cognitive outcomes of children with LD worldwide.

Objectives

The primary focus of our research project is evaluating how micronutrient supplementation is used to target children with LDs' cognitive performance. From this standpoint, the first aim of the research is to thoroughly assess the potential effect of a set supplementation plan, which should include Vitamin D, C, B6, B12, Folate, Magnesium, and Zinc, on the cognitive test results of LD children. Since both before and after the 6-month supplementation, the test results will be systematically collected. Therefore, it will be possible to determine its contribution to the cognitive improvements. Aside from the project's primary goal, the research focuses on several secondary objectives, which should contribute to an improved understanding of the relationships between nutrition and the cognitive abilities of LD children. First, as a secondary aim, it was decided to receive the baseline micronutrient outcomes in subjects compared to an age-matched control group. This should help identify specific nutrient deficiencies in the LD population and ensure that the improvements were consistent with the original deficits. Secondly, after completing the supplementation, the data will also be analyzed to identify connections between specific nutrient consumption and its impact on certain cognitive domains, such as memory, attention, executive function, etc., on a more detailed level. The ultimate aim is to determine which elements are responsible for the most pronounced outcomes within different cognitive areas. The research also includes the third variable focus of the project since the potential variable outcomes of LD supplementation are explored based on the case of different LD demographic characteristics. By dividing the results based on age, sex, type of learning disability, or other factors, the research should provide varied and case-dependent values, which should be included for different LD planning. The outcome is expected to be an evidence-based set of micronutrient standards that should improve healthy cognitive development among LD children, as it provides a set of data suitable for use in combination with behavioral and intellectual standards.

MATERIALS AND METHODS

Study Design & Setting: This controlled, double-blind study was conducted at a pediatric research center focusing on neurodevelopmental disorders. The study lasted six months, thoroughly examining the effects of micronutrient supplements on cognitive function psychiatric disorders such as learning disabilities in children**.**

Participants: Participants were recruited from the centre's outpatient clinic, including children between 6 and 12 years old diagnosed with various learning disabilities based on DSM-5 criteria. Institutional ethical clearance for this study was obtained from the Institutional Review Board. All procedures performed in the study involving human participants were by the moral standards of the responsible committee on human experimentation

and with the Helsinki Declaration of 1975, as revised in 2000. The case group comprised 60 children diagnosed with learning disabilities, selected based on specific diagnosis, age eligibility, and agreement to participate. The control group included 60 age- and gender-matched healthy children selected from the community and recruited through health centers and schools. All controls were screened to ensure no previous record of cognitive or accelerated developmental disorders.
Screening & Diagnosis: All patients were screened based on their medical and educational reports and assessed by a multidisciplinary team. The diagnosis of learning disability was provided based on cognitive evaluations and achievement tests. Diag., Deanna Miranda, M.A., Lauren Grove, M.A.
Data Gathering: Dietary intake, medical history, and SS were collected using a structured parent interview. Cognitive functions were estimated via cognitive tests Conducted by clinical psychologists.
Sample Acquisition: Blood specimens from both groups were also collected at the study's pre- and post-intervention phases to assess initial and final macronutrient quantities.
Sample Size: The sample size was determined using a power analysis, aiming for 80% power to detect differences in cognitive test scores between the Case and Control groups with an Alpha level of 0.05.
Sample Analysis: The quantification of vitamins using HPLC and minerals was measured using atomic absorption spectroscopy, providing the needed level of quantification. Statistical Analysis: case and control data were examined and analyzed using SPSS software to estimate pre- and post-intervention. Paired t-tests and independent t-tests were used accordingly to determine within-group and between-group significance. Multiple regression was used to understand the relationship between micronutrients and cognitive response, adjusting for potential effects with a P value of <0.05.

RESULTS

Participant Characteristics: The study included 60 children diagnosed with learning disabilities as cases and 60 age- and sex-matched children as the control group. The mean age of the participants was nine years for both groups, and no significant gender differences were noted. All the children matched the distribution of the baseline variables, like socioeconomic status and health history.

Table 1: Baseline Characteristics of Participants

Characteristics	Cases (n=60)	Controls (n=60)	P-value
Age (years, mean ± SD)	9 ± 1.5	9 ± 1.4	NS
Gender (M/F)	30/30	30/30	NS
Socioeconomic Status (High/Medium/Low)	20/25/15	22/23/15	NS
Health History (Yes/No)	15/45	12/48	NS

*NS = Not Significant

Baseline Micronutrient Levels: The initial analysis showed that the children with learning disabilities demonstrated a statistically lower level of Vitamin D, Folate, and Magnesium than the control group. Vitamin B6, B12, Zinc, and Vitamin C were at normal levels but slightly lower than in the control group.

Table 2: Baseline and Post-Intervention Micronutrient Levels in Cases

Micronutrient	Baseline (mean ± SD)	Post-intervention (mean ± SD)	P-value
Vitamin D (ng/mL)	20 ± 5.6	30 ± 4.2	<0.001
Folate (ng/mL)	5.4 ± 1.2	7.8 ± 1.3	<0.001
Magnesium (mg/dL)	1.8 ± 0.2	2.1 ± 0.2	<0.001
Vitamin B6 (µg/L)	20 ± 3.5	21 ± 3.7	NS
Vitamin B12 (pg/mL)	500 ± 120	520 ± 115	NS
Zinc (µg/dL)	70 ± 10.2	72 ± 10.5	NS
Vitamin C (mg/dL)	0.8 ± 0.15	0.85 ± 0.14	NS

Cognitive Function Scores - Pre- and Post-Intervention: Based on standardized tests, cognitive functions in the form of scores were markedly lower in children with learning disabilities than in the control group at baseline. In the case group, a substantial improvement in cognitive scores was noted in most dimensions, with the memory, focus, and executive subdimensions exhibiting the following results. There was no meaningful distinction between time points in the placebo cluster in either dimension.

Table 3: Cognitive Function Scores - Pre and Post-Intervention in Cases

Cognitive Domain	Pre-Intervention (mean ± SD)	Post-intervention (mean ± SD)	P-value
Memory	70 ± 10	80 ± 9	<0.01
Attention	65 ± 15	75 ± 14	<0.01
Executive Functioning	55 ± 12	68 ± 11	<0.01

Impact of Micronutrient Supplementation: In the case group, a post-interventional analysis revealed a significant increase in the serum levels of Vitamin D, Folate, and Magnesium, all of which were at a p-value of less than 0.001. The strongest associations were identified with the changes in Vitamin D and Folate. Regression analysis revealed that those micronutrients were independently associated with the observed cognitive improvement, accounting for the effects of age, sex, and the initial cognitive scores, all $p<0.05$.

Table 4: Correlation Between Micronutrient Increases and Cognitive Improvements

Micronutrient	Cognitive Domain	Correlation Coefficient (r)	P-value
Vitamin D	Memory	0.45	<0.05
Folate	Executive Functioning	0.50	<0.05

Subgroup Analysis: Some group analyses showed guaranteed improvement of cognitive scores after micronutrient supplementation in younger patients aged 6-8. Namely, "the effect was greater for the younger subgroup" at a p-value of less than 0.05.

Table 5: Subgroup Analysis of Cognitive Improvements by Age

Age Group	Cognitive Improvement (mean score increase)	P-value
6-8 years	15 ± 5	<0.05
9-12 years	10 ± 4	NS

*NS = Not Significant

Overall, the results suggest that targeted micronutrient supplementation can improve cognitive functions among children with learning disabilities to some extent, especially among those who are Vitamin D and Folate-deficient. Therefore, this study supports evidence that nutritional intervention could be an adjuvant to traditional treatment modalities in improving cognitive outcomes among the target population.

DISCUSSION

Our study demonstrated significant improvements in cognitive functions in children with LD with micronutrient supplementation, particularly Vitamin D and Folate. The positive outcomes in memory, attention, and executive functioning were associated with the increased serum levels of supplemented nutrients. The current literature widely acknowledges the importance of nutrition on cognitive development and performance.[5] Vitamin D and Folate are vital for brain development and function. Vitamin D receptors are present all over the brain, especially in areas for memory and learning.[6] Folate aids in DNA synthesis, methylation reactions, and neurotransmitter production – essential for cognitive processes.[7] In this context, the importance of these two micronutrients is further established.

The positive impact of Vitamin D and Folate on cognitive performance observed in our study aligns with existing literature. Chen et al. found similar results regarding Vitamin D's role in brain function, pointing to Vitamin D's essentiality for cognitive processes.[8] Similarly, Ahmavaara and Ayoub pinpointed the importance of Folate in neurodevelopment and mental health.[9] Our study contradicts Sarris et al., who found only negligible cognitive effects from micronutrient supplementation. The research population might cause such a difference, the dosage amount, or the intervention's length. Additionally, our results might suggest that age might influence nutrient effectiveness since young children showed the most prominent improvements, supporting the idea that intervention at a younger age will be more beneficial.

As some age groups showed a better response to others, specifically the younger 6-8 age group, there may be a critical window in which intervention effectively influences cognitive development. The findings highlight the importance of early identification and correction of micronutrient deficiencies. Although the current study demonstrated promising results, several limitations should be addressed. The study may need a larger sample size and a shorter duration, which may affect the generalization of the findings. Another issue comes from the various types of LD. Even though this variable was controlled for, different types may have a variant response to the supplementation. We also did not control for other potentially relevant hormone levels, such as cortisol, or test other nutritional patterns, such as physical activity or diet type. Although we did not control for these variables, they may affect the cognitive outcomes of the study.

Our results suggest the need for further research with more extensive, diverse populations to assess the potential long-term improvements in cognitive function using micronutrient supplementation. Researchers should experiment with different dosages and combinations of micronutrients to identify the most optimal approach. It would also be beneficial to obtain a comprehensive nutritional intake of each participant to investigate other predictors of cognitive function in children with learning disabilities better while controlling confounding variables.

CONCLUSION

In summary, the journey of our study was to unfold the cognitive potential of micronutrient supplementation in LD children. It unfolded specific dimensions, leading to significant insights and promising therapeutic avenues. Vitamin D and Folate supplementation led to significant positive outcomes among LD children, especially in their memory, attention, and executive functioning. The significance of noting that the outcomes are strong in younger children implies a crucial period for nutritional interventions for proper cognitive development. The study builds a compelling argument for adding micronutrient supplementation into the broader LD interventions and the case for a thorough nutritional assessment and intervention as part of LD children's comprehensive care from accessible, evidence-based practices. The evidence is also helpful in informing future research, including long-term studies of the impact of supplementation, the impact of the micronutrients in the diverse LD categories, and the optimum doses and combinatorial impact that maximizes the desired outcomes from the interventions. Indeed, the journey closes more chapters than it opened as it raises more questions and demands further research. As we push forward, policymakers, healthcare officials, and educators must evaluate the relevance of child nutrition and food access in the quest for optimal growth and learning processes among children.

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