






## SHORT REPORT

# Estimated Nutrient Intake and Association With Psychiatric and Sleep Problems in Autistic Youth in the Adolescent Brain Cognitive Development<sup>SM</sup> Study

Petya D. Radoeva<sup>1,2</sup>  | Elizabeth A. Li<sup>1,2</sup>  | Christopher H. Legere<sup>1,2</sup> | Jared M. Saletin<sup>1,2</sup>  | Noah S. Philip<sup>2,3</sup>  | Daniel P. Dickstein<sup>4</sup> 

<sup>1</sup>Emma Pendleton Bradley Hospital, East Providence, Rhode Island, USA | <sup>2</sup>Warren Alpert Medical School of Brown University, Providence, Rhode Island, USA | <sup>3</sup>VA Providence Healthcare System, Providence, Rhode Island, USA | <sup>4</sup>PediMIND Program, Psychiatry, McLean Hospital/Harvard Medical School McLean Hospital, Belmont, Massachusetts, USA

**Correspondence:** Petya D. Radoeva ([petya\\_radoeva@brown.edu](mailto:petya_radoeva@brown.edu))

**Received:** 14 January 2025 | **Revised:** 3 April 2025 | **Accepted:** 7 April 2025

**Funding:** This work was supported by the National Institute of Health and federal partners listed in <https://abcdstudy.org/about/federal-partners/>.

**Keywords:** ABCD (adolescent brain cognitive development) study | autism | CBCL (child behavior checklist) | macronutrients | micronutrients | sleep

## ABSTRACT

Autistic children often consume less varied diets, experience sleep difficulties, and have higher rates of mental health problems as compared to neurotypical peers. Yet, the direct relationship between all of these domains is not well characterized. We leveraged the Adolescent Brain Cognitive Development<sup>SM</sup> study (ABCD study) dataset to explore whether estimated levels of consumption of specific macro- and micronutrients correlated with the severity of mental health and sleep problems in autistic youth. We found that low vitamin B3, B6, C, and iron intake was associated with more severe psychiatric problems in autistic children in the ABCD cohort, though these findings did not reach statistical significance after correction for multiple comparisons. In a post hoc analysis, we found that the severity of sleep difficulties was correlated with estimated levels of Vitamins B3, B6, C, and iron intake and with the severity of anxiety/depressive symptoms and/or thought problems. Our analysis on a large number of nutrients, psychiatric symptoms, and sleep serves as an exploratory, initial analysis to identify specific nutrients and psychiatric symptoms that could be the focus of future (confirmatory) studies on the relationship between nutrition, sleep, and mental health in autistic individuals.

## 1 | Introduction

Children diagnosed with autism spectrum disorder (ASD) often consume less varied diets than neurotypical peers, which can be associated with suboptimal nutrient intake and nutritional inadequacies (Molina-Lopez et al. 2021). Furthermore, autistic youth have an increased risk of co-occurring psychiatric problems, including difficulties with sleep (Johnson and Zarrinnegar 2021). Prior work has suggested an association between iron deficiency and sleep problems (parasomnias) in

autistic children (Giambersio et al. 2023). Supplementation with a broad range of micronutrients (vitamins and minerals) in autistic individuals has been linked to improvements in core autistic symptoms, lethargy, irritability, and hyperactivity in a randomized, controlled, single-blind trial (Adams et al. 2018) (also see (Persico et al. 2025) for a recent systematic review of clinical trials in autistic individuals involving nutritional supplements). In the general population (not specifically in autistic individuals), several associations have been previously described, including between low levels of B

**Abbreviations:** ABCD, Adolescent Brain Cognitive Development; CBCL, Child Behavior Checklist; BKFS, Block Kids Food Screener; FDR, false discovery rate.

Published 2025. This article is a U.S. Government work and is in the public domain in the USA.

## Summary

- We found that estimated low levels of vitamins B3, B6, and C, and iron from foods were linked to more severe sleep and mental health problems in autistic children.
- More research on the relationship between nutrition, sleep, and mental health in autistic individuals is needed.

vitamins and depression (Mikkelsen et al. 2016), low vitamin C and depression and/or cognitive impairment (for review, see Plevin and Galletly 2020), and low iron and sleep problems (Innocenti et al. 2023).

Leveraging the Adolescent Brain Cognitive Development study (ABCD study) dataset (Jernigan et al. 2018), we studied whether the estimated nutrient intake of a wide range of specific macro- and micronutrients is associated with specific mental health and sleep problems in autistic youth. We focused on the main macronutrients (carbohydrates, protein and fat) and micronutrients including vitamins and minerals previously associated with mental health and sleep in the general population (not specifically in autistic people) (Innocenti et al. 2023; Mikkelsen et al. 2016; Plevin and Galletly 2020).

## 2 | Methods

We obtained access to the de-identified ABCD study dataset (data release 5.1) after completing an IRB application at our institution and a Data Sharing Agreement with the National Institute of Mental Health Data Archive (NDA). The ABCD study is a longitudinal, multi-site study (with 21 sites in the United States) of brain and cognitive development (Jernigan et al. 2018). The study initially enrolled children between the ages of 9 and 10 years, and the longitudinal data is accessible through the NDA. We included all participants from the ABCD study with a parent-reported ASD diagnosis and available child behavior checklist (CBCL) (Achenbach and Ruffle 2000) (a 113-item parent questionnaire assessing psychiatric symptoms over the prior 6 months) and Block Kids Food Screener (BKFS) (Hunsberger et al. 2015) (a 41-item parent questionnaire on the child's diet over the last week) data completed at the Year 2 study visit.

We conducted Shapiro–Wilk tests of normality for the CBCL subscale (eight syndromic CBCL subscale, internalizing, externalizing T-scores) and total problems T-scores, and the BKFS estimated levels of macro- and micronutrient intake (*Total protein (grams)*, *Total fat (grams)*, *Total carbohydrate (grams)*, *Thiamin (Vitamin B1) (mg)*, *Riboflavin (Vitamin B2) (mg)*, *Niacin (Vitamin B3) (mg)*, *Vitamin B6 (mg)*, *Vitamin B12 (mcg)*, *Vitamin C (mg)*, *Vitamin K (mcg)*, *Calcium (mg)*, *Phosphorus (mg)*, *Magnesium (mg)*, *Iron (mg)*, *Zinc (mg)*, *Copper (mg)*, *Sodium (mg)*, *Potassium (mg)*, *Selenium (mcg)*). Next, we correlated the CBCL and BKFS scores, for which we applied false discovery rate (FDR) correction for multiple comparisons. As part of a post hoc analysis, we computed the *CBCL Sleep Composite Score* as previously calculated (Becker et al. 2015).

**TABLE 1** | Demographics and clinical characteristics.

	<i>n</i> (%)
Gender	
Male	147 (85.0)
Female	24 (13.9)
Different	1 (0.6)
I don't know	1 (0.6)
Sex at birth	
Male	150 (86.7)
Female	23 (13.3)
Race and ethnicity <sup>a</sup>	
American Indian/Alaska Native	9 (5.2)
Asian	11 (6.4)
Native Hawaiian or Other Pacific Islander	1 (0.6)
Black or African American	36 (20.8)
White	140 (80.9)
More Than One Race	30 (17.3)
Other Race	10 (5.8)
Hispanic or Latino	27 (15.6)
	Mean (SD)
Age (Years)	12.1 (0.7)
CBCL Internalizing T-Score	54.5 (11.6)
CBCL Externalizing T-Score	49.5 (10.9)
CBCL Total Problems T-Score	54.1 (11.1)

Abbreviation: CBCL: child behavior checklist.

<sup>a</sup>Please note that an individual participant may be included in more than one category.

In an additional follow-up analysis, we calculated the relative risk associated with insufficient micronutrient intake for specific psychiatric symptoms (initially identified through the correlations analysis described above), using several steps. First, using the recommended dietary allowances for children and adolescents aged 9–13 years, we classified each participant as having either “insufficient” estimated micronutrient intake or “adequate” estimated micronutrient intake (specific cut offs: *Iron*: 8 mg; *Vitamin B3*: 12 mg; *Vitamin B6*: 1 mg; *Vitamin C*: 45 mg) (USDHHS 2021, 2022, 2023, 2024). Next, utilizing the CBCL subscale thresholds listed in the CBCL manual (Achenbach and Rescorla 2001), we grouped participants based on their CBCL subscale scores (*CBCL Anxious/Depressed* or *CBCL Thought Problems*): T-score of 64 or less → “average range” group; and T-score of 70 or above → “clinical range” group (of note, participants who had T-scores between 65 and 69 in the “borderline range” were not included in the relative risk estimation analysis). Furthermore, the *CBCL Sleep Composite Score* was not used to create categorical variables since, to the best of our knowledge, there is no specific “clinical” threshold for this score. Finally, we conducted Relative Risk analysis and Pearson's Chi-Square tests using the derived binary categorical variables.

### 3 | Results

Our analysis included 173 autistic youth, with an age range of 10–13 years (after one participant was removed due to having multiple missing responses in the BKFS) (Table 1). The majority of the variables were not normally distributed, so we conducted nonparametric (Spearman's) correlations. The following negative correlations had significant uncorrected  $p$ -values ( $p < 0.05$ ): *Vitamins B6, C, and iron vs. CBCL Anxious/Depressed T-score*; and *Vitamins B3, B6, and iron vs. CBCL Thought Problems T-score* (Table 2), though the FDR  $p$ -values did not reach statistical significance.

In an exploratory analysis (given prior reports of the association between iron deficiency and sleep difficulties) (Innocenti et al. 2023), we computed the *CBCL Sleep Composite Score* and assessed the relationship between the estimated intake of Vitamins B3, B6, C, and iron vs. sleep difficulties; and sleep difficulties vs. severity of anxiety/depressive symptoms and/or thought problems, all of which had  $p$ -values  $< 0.05$  (uncorrected, in the context of *exploratory testing*) (Table 2). In a follow-up exploratory analysis, we calculated the relative risk associated with estimated micronutrient intake and CBCL subscale T-scores identified in Table 2. The relative risk ratios are summarized in Table 3. The highest relative risk ratio was 3.053 (CI: 1.307–7.129), suggesting that children with estimated low *Vitamin C* dietary intake were approximately three times more likely to have elevated *CBCL Anxious/Depressed T-Score* (in the clinically significant range) compared to children with adequate vitamin C intake. Furthermore, children with a combination of insufficient intake for all three micronutrients (*Vitamin B6, Vitamin C, and Iron*), had a relative risk of 3.818 (CI: 1.660–8.785;  $n = 154$ ; Pearson's  $\chi^2 = 10.076$ ,  $p = 0.002$ ) for elevated *CBCL Anxious/Depressed T-Score*, whereas children with insufficient intake of *Vitamin B3, Vitamin B6 plus Iron*, had a relative risk of 1.763 (CI: 0.993–3.128;  $n = 139$ ; Pearson's  $\chi^2 = 3.661$ ,  $p = 0.056$ ) for *CBCL Thought Problems T-Score* in the clinical range.

### 4 | Discussion

In an effort to be more inclusive of co-occurring psychiatric problems and potential suboptimal nutrient intake in autistic youth, we carried out multiple statistical tests, which, after correction for multiple comparisons, did not reach statistical significance. Yet, interestingly, the micronutrients that emerged in this broad analysis (Vitamins B3, B6, C, iron) have previously been associated with sleep difficulties and/or psychiatric problems: specifically, iron—sleep (Innocenti et al. 2023); Vitamin B (including B3, and B6)—depression (Mikkelsen et al. 2016); and Vitamin C—neuropsychiatric effects (Plevin and Galletly 2020).

Notably, in our exploratory analyses, low levels of Vitamin B3, B6, C, and iron intake correlated with more severe sleep problems (negative correlations). The severity of sleep problems correlated with the severity of anxiety/depressive symptoms and thought problems in autistic youth (Table 2). Together, these results suggest a potential explanation of the observed relationships: nutritional deficiencies may contribute to sleep problems, which in turn may worsen psychiatric symptoms.

TABLE 2 | Spearman's correlations.

Variable 1	Variable 2	N	Correlation Coefficient	p-Value
BKFS Vitamin B3	CBCL Sleep Composite Score	173	−0.170*	0.025
	CBCL Anxious/Depressed T-Score	173	−0.143	0.061
	CBCL Thought Problems T-Score	173	−0.150*	0.048
BKFS Vitamin B6	CBCL Sleep Composite Score	173	−0.204**	0.007
	CBCL Anxious/Depressed T-Score	173	−0.161*	0.034
	CBCL Thought Problems T-Score	173	−0.176*	0.020
BKFS Vitamin C	CBCL Sleep Composite Score	173	−0.172*	0.023
	CBCL Anxious/Depressed T-Score	173	−0.190*	0.012
	CBCL Thought Problems T-Score	173	−0.141	0.065
BKFS Iron	CBCL Sleep Composite Score	173	−0.213**	0.005
	CBCL Anxious/Depressed T-Score	173	−0.151*	0.047
	CBCL Thought Problems T-Score	173	−0.171*	0.024
CBCL Sleep Composite Score	CBCL Anxious/Depressed T-Score	173	0.437***	<0.001
	CBCL Thought Problems T-Score	173	0.643***	<0.001

Note: Please note that the listed  $p$ -values are the original (not FDR-corrected)  $p$ -values.

Abbreviations: BKFS: block kids food screener; CBCL: child behavior checklist.

\* $p < 0.05$ .

\*\* $p < 0.01$ .

\*\*\* $p < 0.001$ .

Important limitations include that (1) the diagnosis of ASD in the dataset was established by parental report only; (2) the estimated levels of nutrient intake are based on parental recall of

**TABLE 3** | Relative risk ratios and Chi-Square tests.

Variable 1: BKFS	Variable 2: CBCL	N	Relative Risk	95% Confidence Interval (for Relative Risk)		Pearson's Chi-Square Test	
				Lower	Upper	$\chi^2$ Value	p-Value
Vitamin B3	Thought Problems T-Score	139	1.571	0.877	2.814	2.328	0.127
Vitamin B6	Anxious/Depressed T-Score	154	2.910	1.197	7.072	6.073	0.014
	Thought Problems T-Score	139	1.941	1.089	3.461	5.117	0.024
Vitamin C	Anxious/Depressed T-Score	154	3.053	1.307	7.129	7.033	0.008
Iron	Anxious/Depressed T-Score	154	2.601	1.068	6.333	4.773	0.029
	Thought Problems T-Score	139	1.725	0.969	3.073	3.432	0.064

Abbreviations: BKFS: Block Kids Food Screener; CBCL: Child Behavior Checklist.

food intake, rather than a prospective food record; (3) there is no available information on the blood levels of micronutrients. Future research could focus on overcoming these methodological limitations and could further study the relationships between micronutrient deficiencies or insufficiencies (including Vitamins B3, B6, C, and iron), sleep, and mental health problems (such as anxiety and depression) in autistic youth with a broad range of clinical severity, which could ultimately inform personalized medicine approaches. From a clinical perspective, providers could consider a broader range of symptoms (including careful assessment of nutritional status and sleep) in autistic youth presenting with anxiety and depressive symptoms.

#### Acknowledgments

K23MH128466 (PI: Dr. Petya D. Radoeva; Primary Mentor: Dr. Noah S. Philip; Co-Mentors: Dr. Daniel P. Dickstein, Dr. Sean C. L. Deoni, Dr. Jeffrey I. Hunt, Dr. Carla A. Mazefsky, and Dr. Stephen J. Sheinkopf); 1P30GM149405 (CNSF COBRE PI: Dr. Jerome N. Sanes; Pilot project PI: Dr. Petya D. Radoeva); 1P20GM139743-01 (PI: Dr. Mary A. Carskadon; support for Dr. Jared M. Saletin). The opinions expressed are those of the authors and do not represent the National Institutes of Health or the US Department of Veterans Affairs.

Please note the following (NIMH 2023): “Data and/or research tools used in the preparation of this manuscript were obtained from the National Institute of Mental Health (NIMH) Data Archive (NDA). NDA is a collaborative informatics system created by the National Institutes of Health to provide a national resource to support and accelerate research in mental health. Dataset identifier(s)”: <https://doi.org/10.15154/z563-zd24>. “This manuscript reflects the views of the authors and may not reflect the opinions or views of the NIH or of the Submitters submitting original data to NDA.” (NIMH 2023).

Furthermore, “Data used in the preparation of this article were obtained from the Adolescent Brain Cognitive Development<sup>SM</sup> (ABCD) Study (<https://abcdstudy.org>), held in the NIMH Data Archive (NDA). This is a multisite, longitudinal study designed to recruit more than 10,000 children age 9-10 and follow them over 10 years into early adulthood. The ABCD study<sup>®</sup> is supported by the National Institutes of Health and additional federal partners under award numbers U01DA041048, U01DA050989, U01DA051016, U01DA041022, U01DA051018, U01DA051037, U01DA050987, U01DA041174, U01DA041106, U01DA041117, U01DA041028, U01DA041134, U01DA050988, U01DA051039, U01DA041156, U01DA041025, U01DA041120, U01DA051038, U01DA041148, U01DA041093, U01DA041089, U24DA041123, U24DA041147. The full list of federal partners is available at <https://abcdstudy.org/about/federal-partners/>, and the listing of participating sites and

principal investigators is available at [https://abcdstudy.org/wp-content/uploads/2019/04/Consortium\\_Members.pdf](https://abcdstudy.org/wp-content/uploads/2019/04/Consortium_Members.pdf). ABCD consortium investigators designed and implemented the study and/or provided data but did not necessarily participate in the analysis or writing of this report. This manuscript reflects the views of the authors and may not reflect the opinions or views of the NIH or ABCD consortium investigators.” (NDA 2025).

“The ABCD data repository grows and changes over time. The ABCD data used in this report came from the fast track data release. The raw data are available at [https://nda.nih.gov/edit\\_collection.html?id=2573](https://nda.nih.gov/edit_collection.html?id=2573)” (NDA 2025).

#### Conflicts of Interest

The authors declare no conflicts of interest. Unrelated to the current work, in the past 3 years, N.S.P. has received clinical trial support (through VA contracts) from Wave Neuro and Neuroief Inc.; he is on the scientific advisory board for Pulvinar Neuro and is a consultant for Motif Neurotech.

#### Data Availability Statement

The data that support the findings of this study are available in National Institute of Mental Health Data Archive (NDA) at <https://doi.org/10.15154/z563-zd24>, reference number # 2313.

#### References

- Achenbach, T. M., and L. A. Rescorla. 2001. *Manual for ASEBA School-Age Forms and Profiles*. University of Vermont, Research Center for Children, Youth, & Families.
- Achenbach, T. M., and T. M. Ruffle. 2000. “The Child Behavior Checklist and Related Forms for Assessing Behavioral/Emotional Problems and Competencies.” *Pediatrics in Review* 21, no. 8: 265–271. <https://doi.org/10.1542/pir.21-8-265>.
- Adams, J. B., T. Audhya, E. Geis, et al. 2018. “Comprehensive Nutritional and Dietary Intervention for Autism Spectrum Disorder—A Randomized, Controlled 12-Month Trial.” *Nutrients* 10, no. 3: 369. <https://doi.org/10.3390/nu10030369>.
- Becker, S. P., R. R. Ramsey, and K. C. Byars. 2015. “Convergent Validity of the Child Behavior Checklist Sleep Items With Validated Sleep Measures and Sleep Disorder Diagnoses in Children and Adolescents Referred to a Sleep Disorders Center.” *Sleep Medicine* 16, no. 1: 79–86. <https://doi.org/10.1016/j.sleep.2014.09.008>.
- Giambersio, D., L. Marzulli, L. Margari, et al. 2023. “Correlations Between Sleep Features and Iron Status in Children with Neurodevelopmental Disorders: A Cross-Sectional Study.” *Journal of Clinical Medicine* 12, no. 15: 4949.

Hunsberger, M., J. O'Malley, T. Block, and J. C. Norris. 2015. "Relative Validation of Block Kids Food Screener for Dietary Assessment in Children and Adolescents." *Maternal & Child Nutrition* 11, no. 2: 260–270. <https://doi.org/10.1111/j.1740-8709.2012.00446.x>.

Innocenti, A., G. Lentini, S. Rapacchietta, et al. 2023. "The Role of Supplements and Over-The-Counter Products to Improve Sleep in Children: A Systematic Review." *International Journal of Molecular Sciences* 24, no. 9: 7821. <https://doi.org/10.3390/ijms24097821>.

Jernigan, T. L., S. A. Brown, and G. J. Dowling. 2018. "The Adolescent Brain Cognitive Development Study." *Journal of Research on Adolescence* 28, no. 1: 154–156. <https://doi.org/10.1111/jora.12374>.

Johnson, K. P., and P. Zarrinnegar. 2021. "Autism Spectrum Disorder and Sleep." *Child and Adolescent Psychiatric Clinics of North America* 30, no. 1: 195–208.

Mikkelsen, K., L. Stojanovska, and V. Apostolopoulos. 2016. "The Effects of Vitamin B in Depression." *Current Medicinal Chemistry* 23, no. 38: 4317–4337. <https://doi.org/10.2174/0929867323666160920110810>.

Molina-Lopez, J., B. Leiva-Garcia, E. Planells, and P. Planells. 2021. "Food Selectivity, Nutritional Inadequacies, and Mealtime Behavioral Problems in Children With Autism Spectrum Disorder Compared to Neurotypical Children." *International Journal of Eating Disorders* 54, no. 12: 2155–2166. <https://doi.org/10.1002/eat.23631>.

NDA. 2025. Data Usage. Retrieved April 3, 2025 from. <https://nda.nih.gov/abcd/abcd-citing>.

NIMH. 2023. Manuscript Preparation: National Institute of Mental Health. <https://nda.nih.gov/nda/manuscript-preparation#study-acknowledgements>.

Persico, A. M., L. Asta, F. Chehbani, et al. 2025. "The Pediatric Psychopharmacology of Autism Spectrum Disorder: A Systematic Review – Part II: The Future." *Progress in Neuro-Psychopharmacology & Biological Psychiatry* 136: 111176. <https://doi.org/10.1016/j.pnpbp.2024.111176>.

Plevin, D., and C. Galletly. 2020. "The Neuropsychiatric Effects of Vitamin C Deficiency: A Systematic Review." *BMC Psychiatry* 20, no. 1: 315. <https://doi.org/10.1186/s12888-020-02730-w>.

USDHHS. 2021. Vitamin C Fact Sheet for Health Professionals Retrieved April 3, 2025 from. <https://ods.od.nih.gov/factsheets/VitaminC-HealthProfessional/>.

USDHHS. 2022. Niacin Fact Sheet for Health Professionals. Retrieved April 3, 2025 from. <https://ods.od.nih.gov/factsheets/Niacin-HealthProfessional/>.

USDHHS. 2023. Vitamin B6 Fact Sheet for Health Professionals. Retrieved April 3, 2025 from. <https://ods.od.nih.gov/factsheets/VitaminB6-HealthProfessional/>.

USDHHS. 2024. Iron Fact Sheet for Health Professionals Retrieved April 3, 2025 from. <https://ods.od.nih.gov/factsheets/Iron-HealthProfessional/>.