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Research paper

Adherence to the Mediterranean Dietary Approaches to Stop Hypertension Intervention for Neurodegenerative Delay (MIND) diet and trajectories of depressive symptomatology in youth

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ABSTRACT

Background: The rising prevalence of youth depression underscores the need to identify modifiable factors for prevention and intervention. This study aims to investigate the protective role of Mediterranean-DASH Intervention for Neurodegenerative Delay (MIND) diet on depressive symptoms in adolescents.
Methods: Participants were identified from the Adolescent Brain Cognitive Development study. Adherence to the MIND diet was measured by the Child Nutrition Assessment or the Block Kids Food Screener. Depressive symptoms were measured annually using the Child Behavior Checklist's depression subscale. We utilized regression analyses and cross-lagged panel modeling (CLPM) to examine longitudinal associations. Additional analyses adjusted for polygenic risk scores for depression, and changes in Body Mass Index (BMI) and waist-to-height ratio.
Results: Of the 8459 children (52.3 % male; mean age 10.9 [SD, 0.6] years), 2338 (27.6 %) demonstrated high MIND diet adherence, while 2120 (25.1 %) showed low adherence. High adherence was prospectively associated with reduced depressive symptoms (adjusted β, −0.64, 95 % CI, −0.73 to −0.55; $p < 0.001$) and 46 % lower odds of clinically relevant depression (adjusted odds ratio, 0.54, 95 % CI, 0.39 to 0.75; $p < 0.001$) at two-year follow-up. CLPM analyses showed significant cross-lag paths from MIND diet scores to less depressive symptoms across three time points. These associations persisted independently of changes in BMI and waist-to-height ratios, and were not significantly moderated by genetic predisposition to depression.
Conclusions: Higher adherence to the MIND dietary pattern was longitudinally associated with decreased risk of depressive symptoms in adolescents. Promoting MIND diet may represent a promising strategy for depression prevention in adolescent populations.

1. Introduction

Depression is a leading cause of worldwide disability, exhibiting a rising prevalence and high recurrence rates (Malhi and Mann, 2018). Adolescent-onset depression are commonly accompanied by pronounced functional impairments, including additional psychiatric, somatic comorbidities, and more likely recurrent episodes (Tse et al., 2023). Recent epidemiological data suggest a concerning upward trend in youth depression rates, necessitating identification of modifiable risk factors for prevention and intervention (Kieling et al., 2024).

Dietary patterns have emerged as critical modulators of depression risk, with robust evidence supporting the protective effects of the Mediterranean diet (Shafiei et al., 2023; Camprodon-Boadas et al., 2024; Fabiano et al., 2024). Evidence shows that the Mediterranean diet serves as an effective adjunctive therapeutic approach for alleviating depressive symptoms, showing potential advantages over Western and

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ketogenic diet (Swainson et al., 2023). However, this dietary pattern's strict requirements, particularly its restricted food choices, present significant adherence challenges for children and adolescents (Obeid et al., 2022). The Mediterranean-DASH Intervention for Neurodegenerative Delay (MIND) diet represents a more flexible approach, combining key elements from the Mediterranean and Dietary Approaches to Stop Hypertension (DASH) diets while expanding food choices, designed to emphasize foods potentially protective against cognitive decline (Fox et al., 2022). The MIND diet expands protein options beyond the Mediterranean diet's emphasis on seafood, while preserving key neuroprotective nutrients such as flavonoids, folate, and omega-3 fatty acids (Fox et al., 2022). These dietary components have been demonstrated to protect the brain and affect depression mainly through their antioxidant and anti-inflammatory properties (Marx et al., 2021). Studies examining the MIND diet's impact on depression in adults have yielded mixed results, potentially due to cohort heterogeneity and varying depression etiologies across different age groups (Fresán et al., 2019; Salari-Moghaddam et al., 2019). Notably, adolescence represents a critical period for both the establishment of dietary habits and the onset of depressive disorders. Although cumulative evidence indicates that healthy dietary patterns, such as the Mediterranean diet, may serve as beneficial strategies for both preventing and treating depression in adolescents, longitudinal and clinical studies in this age group are still limited (Orlando et al., 2022; Zielińska et al., 2022), and the potential protective effects of the MIND diet have yet to be explored.

This study leveraged longitudinal data from the Adolescent Brain Cognitive Development (ABCD) Study, a prospective cohort of over 10,000 children across the United States. We aimed to investigate whether adherence to the MIND diet is protective of depressive symptoms in adolescents. We rigorously evaluated prospective associations between MIND diet adherence and depressive symptom trajectories through multi-wave dietary assessments, and explored potential mechanisms underlying dietary influences on adolescent mental health.

2. Methods

2.1. Study population

This study utilized data from Release 5.1 of the ABCD Study, a large-scale longitudinal cohort comprising approximately 20 % of the U.S. population within the target age demographic (Garavan et al., 2018; Volkow et al., 2018). The ABCD Study enrolled a total of 11,876 children between 9 and 11 years of age through school systems across 21 research sites in the United States between 2016 and 2018, with ongoing annual follow-ups. Our analytical sample included participants with complete data for both the Child Behavior Checklist (CBCL) and Food Frequency Questionnaire across the initial three years of follow-up. All participants and their guardians provided informed consent.

2.2. Measures

2.2.1. MIND diet

Dietary assessment utilized two instruments across the study period. During the first-year follow-up, parents completed the Child Nutrition Assessment (CNA), an adapted version of the MIND diet questionnaire. The original MIND diet questionnaire evaluates consumption frequency across 15 food categories: whole grains, vegetables, leafy greens, berries, nuts, poultry, legumes, fish, wine, olive oil, fast food, fried foods, pastries, confectionery, butter, and cheese. The CNA adaptation employed in the ABCD study excluded the wine category, resulting in 14 food categories (Table S1). Responses were binary-coded (yes = 1, no = 0) and summed to established a score indicating adherence to MIND diet (range, 0 to 14). Adherence to MIND diet was trichotomized as low (0–6), moderate (7–9), and high (10–14) using established cut-points derived from tertiles in population (Nagata et al., 2024).

For the second- and third-year follow-up, dietary habits were collected using the Block Kids Food Screener (BKFS), reported by either children or their parents. Given the BKFS structure, the MIND score was modified to include 10 food categories, omitting 5 categories (Table S2). Responses to these ten dietary items were binary-coded (yes = 1, no = 0) and summed to represent the adherence to MIND diet. The score ranged from 1 to 6 in this cohort. The distributions of BKFS scores across waves were detailed in Table S3. The MIND diet scores across various time points showed moderate and comparable correlation coefficients (first- and second-year, r = 0.22; second- and third-year, r = 0.34; Table S4). For the BKFS-derived MIND score, we also trichotomized the study population by the tertiles as low (0–2), moderate (3–4), and high (5–6) at each follow-up.

2.2.2. Depressive symptom

Depressive symptoms were evaluated annually through parental reports using the CBCL. The CBCL is a widely used measure of youth emotional and behavioural problems including 120 questions rating on three-point Likert scale: 0 (not true), 1 (somewhat/sometimes true), and 2 (very/often true). A composite score for depression was calculated by summing all relevant questions, according to the manual of the CBCL (Diagnostic and Statistical Manual of Mental Disorders [Fifth Edition]-oriented scales; Table S5). Higher scores indicate more depressive symptoms (Stewart et al., 2024). In addition, the age- and sex-adjusted T-score ≥ 70 was corresponding to higher than the 98th percentile in the general population, thus defined as depression. We also examined a similar CBCL-derived score of withdrawn/depressed symptom, to assess the robustness of our results.

2.2.3. Polygenic risk score for depression

Genotype data from the ABCD Study were sourced from saliva or blood specimens using the Affymetrix NIDA Smoke Screen Array (Baurley et al., 2016). A subset of 5807 individuals of European descent were selected based on genetic lineage. Quality control and imputation were conducted using PLINK v1.90 (Purcell et al., 2007), Michigan Imputation Server (Das et al., 2016), and Eagle v2.4, resulting in 4673 samples for analysis. To construct PRS for depressive symptoms, we incorporated data from the genome-wide analyses of depressive symptoms (n = 161,460) of European ancestry (Okbay et al., 2016), using a continuous shrinkage with a global shrinkage prior of 0.01 (Ge et al., 2019). The PRS were trichotomized into tertiles, designated as low, moderate risk, and high risk.

2.3. Covariates

We consider the following covariates as confounders: age at assessment, sex (male, or female), race/ethnicity (White, Black, Hispanic, Asian, or other), family annual income (<$35,000, $35,000 ~ $75,000, $75,000 ~ $100,000, or ≥ $100,000), Body Mass Index (BMI, kg/m^2) at assessment, parental average education year, and pubertal score at assessment. The pubertal score was the average of self- and parent-reported score on a scale from 1 (prepuberty) to 5 (post puberty). BMI was converted into sex and age-specific z-scores in accordance with Centers for Disease Control and Prevention (CDC) growth curves (Ogden et al., 2023). For variables with substantial missing data at certain follow-ups (specifically, BMI at third follow-up), values were carried forward from the most recent previous assessment. The waist-to-height ratio has been proposed as a simple and effective adiposity metric to assess central obesity widely applied to paediatric populations (Zong et al., 2023).

2.4. Statistical analysis

Chi-square test and *t*-test were performed to compare demographic characteristics among children at different level of adhering to the MIND diet. To investigate the correlation between MIND score and depression, we applied mixed-effect regressions to account for the nested structure

of family and site. Linear regression was applied for continuous outcomes, including depressive symptom scores, while logistic regression was applied for bivariate outcomes, including depression. We applied cross-lagged panel model (CLPM) to investigate the bidirectional longitudinal associations between MIND score and depressive symptoms. CLPM is specifically designed to evaluate temporal relationships and reciprocal influences between repeatedly measured variables. Specifically, the CLPM evaluates bidirectional temporal dynamics through three components: 1) autoregressive effects: model stability of variables across waves (e.g., depression at Wave 1 - > Wave 2); 2) synchronous covariances: capture within-wave correlations between variables (e.g., depression and MIND diet at Wave 1); 3) cross-lagged effects: test predictive relationships between variables across waves (e.g., MIND diet at Wave 1 - > depression at Wave 2), supporting temporal precedence. Significance was assessed at $p < 0.05$ (two-tailed). The goodness-of-fit was measured and compared by log-likelihood, chi-square, Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA) and Standardized Root Mean Square Residual (SRMR). To explore the potential influence of overweight on the relationship between MIND diet scores and depressive symptoms, we conducted stratified sensitivity analyses based on whether BMI exceeded the 85th percentile (p85) and the additionally adjusting for waist-to-height ratio at assignment. In sensitivity analyses, imputation of missing BMI of the third-year follow-up was conducted by the average of the second and fourth-year follow-ups, followed by the conduct of sensitivity analyses. Multiple testing corrections were implemented with distinct approaches across analytical frameworks: Holm-Bonferroni correction (controlling family-wise error rate, FWER) was applied to longitudinal analyses examining temporal associations, whereas Benjamini-Hochberg (BH) correction (controlling false discovery rate, FDR) was employed for cross-sectional comparisons to balance stringency with exploratory discovery.

We performed all analyses using R software version 4.2.2. CLPM model was performed by package lavaan (version 0.6-17). Mixed models were fitted with the package lme4 (version 1.1-35.3). Missing values were imputed by chained equations with package mice (version 3.16.0).

3. Results

A total of 8459 children had complete data of both the CBCL and dietary assessment questionnaires across three annual follow-ups. The mean (SD) age of participants was 10.9 (0.6) years at first follow-up, 12.0 (0.7) years at second follow-up, and 12.9 (0.6) years at third follow-up. Participants were categorized based on their MIND diet scores at the first follow-up. MIND diet adherence scores were significantly higher among female participants and those of Hispanic ethnicity (Table 1). Family income appeared to be higher among the moderate adherence group. Throughout the follow-up period, obesity measures were comparable among the three groups. The pubertal scores were comparable in the second-year follow-up, though a higher level in the high adherence group was observed at the first and third follow-ups.

The mean depressive score in the low MIND diet adherence group was 1.87 (SD, 2.49) at the first-year follow-up, compared to 1.30 (SD, 2.03) in the moderate group and 0.94 (SD, 1.75) in the high adherence group. Using T-score ≥ 70 to define depression, the rates of depression were 5.4 %, 2.8 %, and 2.1 % in the low, moderate, and high adherence group, respectively (Table S6). The high MIND diet adherence group was associated with a 0.74-point lower depressive score compared to the low adherence group, adjusting for age, sex, race, family income, parental education level, puberty status, and BMI (adjusted β, −0.74, 95 % CI, −0.84 to −0.65, Cohen's d, 0.44; Fig. 1). Likewise, the group with high adherence to the MIND diet exhibited a 60 % reduction in the odds of depression compared to low adherence (adjusted OR, 0.40, 95 % CI, 0.27 to 0.58; Fig. 2). The results were consistent after multiple testing correction. The moderate adherence group exhibited consistent and less prominent associations. Consistent cross-sectional associations were

Table 1
Demographics of the study population, categorized by their adherence to MIND diet.

Variables	MIND<7 (N = 2120)	7 ≤ MIND ≤ 9 (N = 4001)	MIND ≥ 10 (N = 2338)	P value
Age, mean (SD), years				
The first follow-up	10.9 (0.6)	10.9 (0.6)	10.9 (0.6)	0.15
The second follow-up	12.0 (0.7)	12.0 (0.7)	12.0 (0.7)	0.15
The third follow-up	12.9 (0.6)	12.9 (0.6)	12.9 (0.6)	0.79
Biological sex, male (%)	1150 (54.2)	2115 (52.9)	1163 (49.7)	0.007
Race (%)				<0.001
White	1197 (56.5)	2429 (60.7)	1115 (47.7)	
Black	314 (14.8)	388 (9.7)	316 (13.5)	
Hispanic	337 (15.9)	706 (17.6)	601 (25.7)	
Asian	46 (2.2)	71 (1.8)	58 (2.5)	
Other	226 (10.7)	407 (10.2)	248 (10.6)	
Body Mass Index (kg/m^2)				
The first follow-up	19.6 (4.62)	19.6 (4.62)	19.6 (4.62)	0.47
The second follow-up	21.2 (5.70)	20.3 (4.52)	20.5 (4.84)	0.32
The third follow-up	22.0 (6.28)	21.7 (5.37)	22.4 (5.94)	0.23
Waist-to-height ratio				
The first follow-up	0.19 (0.03)	0.19 (0.03)	0.19 (0.03)	0.47
The second follow-up	0.19 (0.03)	0.19 (0.03)	0.19 (0.03)	0.03
The third follow-up	0.20 (0.04)	0.19 (0.03)	0.19 (0.04)	0.61
Family income (%)				<0.001
<$35,000	386 (18.2)	511 (12.8)	442 (18.9)	
$35,000–$75,000	494 (23.3)	785 (19.6)	435 (18.6)	
$75,000–$100,000	329 (15.5)	591 (14.8)	295 (12.6)	
≧$100,000	776 (36.6)	1879 (47.0)	975 (41.7)	
Parental average education year				<0.001
Mean (SD)	15.6 (2.00)	16.0 (1.95)	15.7 (2.24)	
Puberty status (mean (SD))				
The first follow-up	2.10 (0.92)	2.09 (0.90)	2.13 (0.0.93)	0.005
The second follow-up	2.60 (1.08)	2.54 (1.06)	2.62 (1.06)	0.16
The third follow-up	3.07 (1.04)	3.05 (1.04)	3.14 (1.00)	0.04
PRS for depression[a]				0.03
Low	289 (13.6 %)	646 (30.5 %)	252 (10.8 %)	
Moderate	289 (13.6 %)	596 (28.1 %)	302 (12.9 %)	
High	329 (15.5 %)	593 (27.9 %)	269 (11.5 %)	

MIND, the Mediterranean dietary approaches to stop hypertension intervention for neurodegenerative delay; PRS, polygenic risk score.
The aggregate percentile distribution did not reach 100 % owing to the presence of missing observations. Proportion of missing values: age at first-year follow-up, N = 1; age at second-year follow-up, N = 1; age at third-year follow-up, N = 1; BMI at first-year follow-up, N = 75; BMI at second-year follow-up, N = 1249; BMI at third-year follow-up, N = 6763; waist-to-height ratio at first-year follow-up, N = 68; waist-to-height ratio at second-year follow-up, N = 1277; waist-to-height ratio at third-year follow-up, N = 6771; family income at recruitment, N = 561; parental average education year, N = 1485; puberty status at first-year follow-up, N = 193; puberty status at second-year follow-up, N = 399; puberty status at third-year follow-up, N = 467; PRS for depression, N = 4894.
[a] Due to the impact of race/ethnicity on PRS, we only calculated PRS in White individuals.

Time of MIND	Time of CBCL	Subgroup of MIND	Mean (SD)	Adjusted β (95%CI)	Cohen's d	p value	Adjusted p value
Wave 1	Wave 1	Low	1.87 (2.49)	0.00 (ref)	Ref		
		Moderate	1.30 (2.03)	-0.40 (-0.48 to -0.32)	0.26	<0.001	<0.001
		High	0.94 (1.75)	-0.74 (-0.84 to -0.65)	0.44	<0.001	<0.001
Wave 2	Wave 2	Low	1.60 (2.34)	0.00 (ref)	Ref		
		Moderate	1.38 (2.16)	-0.15 (-0.22 to -0.08)	0.10	<0.001	<0.001
		High	1.35 (2.13)	-0.16 (-0.28 to -0.05)	0.11	0.004	0.004
Wave 3	Wave 3	Low	1.83 (2.59)	0.00 (ref)	Ref		
		Moderate	1.59 (2.45)	-0.14 (-0.20 to -0.07)	0.10	<0.001	<0.001
		High	1.33 (2.12)	-0.26 (-0.37 to -0.14)	0.20	<0.001	<0.001
Wave 1	Wave 2	Low	1.88 (2.48)	0.00 (ref)	Ref		
		Moderate	1.45 (2.22)	-0.26 (-0.34 to -0.18)	0.19	<0.001	<0.001
		High	1.07 (1.92)	-0.56 (-0.65 to -0.47)	0.37	<0.001	<0.001
Wave 1	Wave 3	Low	2.12 (2.70)	0.00 (ref)	Ref		
		Moderate	1.69 (2.51)	-0.26 (-0.33 to -0.18)	0.17	<0.001	<0.001
		High	1.21 (2.31)	-0.64 (-0.73 to -0.55)	0.36	<0.001	<0.001
Wave 2	Wave 3	Low	1.81 (2.58)	0.00 (ref)	Ref		
		Moderate	1.58 (2.43)	-0.15 (-0.22 to -0.09)	0.09	<0.001	<0.001
		High	1.54 (2.40)	-0.19 (-0.31 to -0.08)	0.11	<0.001	<0.001

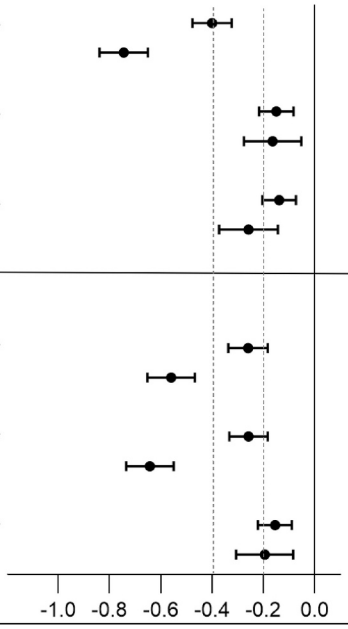

Fig. 1. Cross-sectional and longitudinal associations between adherence to MIND diet and depression symptom score.
All analyses were adjusted for age at assessment, sex, race/ethnicity, family annual income, Body Mass Index at assessment, parental average education year, and pubertal score at assessment. The adjusted p-values were calculated using the Holm-Bonferroni method for longitudinal analyses and Benjamini-Hochberg method for cross-sectional comparisons.
MIND, the Mediterranean dietary approaches to stop hypertension intervention for neurodegenerative delay; PRS, polygenic risk score; CBCL, the Child Behavior Checklist.

Time of MIND	Time of CBCL	Subgroup of MIND	N (%)	Odds Ratio (95%CI)	p value	Adjusted p value
Wave 1	Wave 1	Low	114 (5.4%)	1.00 (ref)		
		Moderate	113 (2.8%)	0.56 (0.41 to 0.75)	<0.001	<0.001
		High	49 (2.1%)	0.40 (0.27 to 0.58)	<0.001	<0.001
Wave 2	Wave 2	Low	119 (3.8%)	1.00 (ref)		
		Moderate	134 (3.9%)	0.78 (0.59 to 1.04)	0.07	0.07
		High	20 (2.3%)	0.61 (0.35 to 1.04)	0.07	0.07
Wave 3	Wave 3	Low	156 (4.5%)	1.00 (ref)		
		Moderate	149 (3.6%)	0.80 (0.62 to 1.02)	0.07	0.07
		High	12 (1.5%)	0.33 (0.17 to 0.62)	<0.001	0.001
Wave 1	Wave 2	Low	95 (4.5%)	1.00 (ref)		
		Moderate	120 (3.0%)	0.70 (0.52 to 0.96)	0.03	0.11
		High	58 (2.5%)	0.58 (0.40 to 0.84)	0.004	0.02
Wave 1	Wave 3	Low	104 (4.9%)	1.00 (ref)		
		Moderate	151 (3.8%)	0.78 (0.60 to 1.01)	0.06	0.19
		High	62 (2.7%)	0.54 (0.39 to 0.75)	<0.001	0.001
Wave 2	Wave 3	Low	131 (4.2%)	1.00 (ref)		
		Moderate	161 (3.6%)	0.85 (0.67 to 1.08)	0.19	0.19
		High	25 (2.9%)	0.68 (0.44 to 1.05)	0.09	0.19

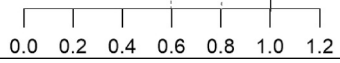

Fig. 2. Cross-sectional and longitudinal associations between adherence to MIND diet and clinical depression.
All analyses were adjusted for age at assessment, sex, race/ethnicity, family annual income, Body Mass Index at assessment, parental average education year, and pubertal score at assessment. The adjusted p-values were calculated using the Holm-Bonferroni method for longitudinal analyses and Benjamini-Hochberg method for cross-sectional comparisons.
MIND, the Mediterranean dietary approaches to stop hypertension intervention for neurodegenerative delay; PRS, polygenic risk score; CBCL, the Child Behavior Checklist.

observed when utilizing the withdraw depression scale as the outcome measure (Tables S7–8).

Longitudinally, high MIND diet adherence at the first follow-up was predictive of lower depressive scores at both second and third follow-ups, compared to the low adherence group (adjusted β for the second follow-up, −0.56, 95 % CI, −0.65 to −0.47, Cohen's d, 0.37; adjusted β for the third follow-up, −0.64, 95 % CI, −0.73 to −0.55, Cohen's d, 0.36; Fig. 1). Likewise, the high MIND diet adherence group was associated with a lower odd of depression (Fig. 2). The results were consistent after multiple testing correction. Similar results were found between MIND score at the second follow-up and depressive score at the third follow-up (Figs. 1, 2). Additionally adjusting for the depression symptom at the time of MIND yielded consistent results (Tables S9–10). Similar longitudinal associations were consistently observed when using withdraw depression scale as outcome (Tables S7–8) To further understand the role of BMI and waist-to-height ratio, the analyses stratified by BMI exceeding the p85 and with additional adjustment for waist-to-height ratio yielded consistent cross-sectional and longitudinal results (Tables S11–13).

To determine the temporal relationship between MIND diet and depression score, we applied CLPM and the model showed moderate to good model fit (Table S14). We found that high MIND diet adherence was longitudinally associated with lower depression score (Fig. 3). Specifically, there were significant cross-lagged effects of the MIND diet on subsequent depression symptoms (Wave 1- > 2: $\beta = -0.02$, $p = 0.009$; Wave 2- > 3: $\beta = -0.02$, $p = 0.01$), whereas only a single reverse pathway from depression at Wave 2 to MIND adherence at Wave 3 reached significance ($\beta = -0.05$, $p < 0.001$). Concurrent negative correlations were evident at Wave 1 ($\beta = -0.15$, $p < 0.001$) and Wave 2 ($\beta = -0.02$, $p = 0.02$), but attenuated to non-significance by Wave 3 ($\beta = -0.01$, $p = 0.14$).

To investigate the role of genetic predisposition to depression, we included 3565 White children in analyses of PRS for depression symptoms. Categorizing the children by the tertiles of PRS for depression symptoms, we observed generally consistent cross-sectional and longitudinal association between adherence to MIND diet and lower depressive symptoms across PRS groups (Table S15). The risk estimates exhibited variations across comparisons, indicating limited evidence of moderation. Moreover, additionally adjusting for PRS for depression symptoms in the CLPM resulted in similar risk estimates of cross-lag paths (Fig. S1).

4. Discussion

In this large prospective cohort of adolescents, we found a robust longitudinal association of adherence to MIND diet with lower depressive symptoms and lower likelihood of having clinically significant depression at 1- and 2-year follow-up. MIND diet adherence demonstrated a dose-dependent relationship with depressive symptoms, where higher adherence levels predicted progressively lower symptom severity at follow-up assessments. These associations persisted independently of changes in BMI and waist-to-height ratios, and were not significantly moderated by genetic predisposition to depression.

Prior research on MIND diet and depression has focused primarily on adults. Only one study included participants under age 18 (n = 19), but did not report outcomes specific to this adolescent subgroup (Ma et al., 2023). In adults, one randomized trial showed that the MIND diet improved depressive symptoms among obese or overweight women with polycystic ovary syndrome (Kabiri et al., 2024). Previous cohort studies have yielded inconsistent results, likely due to methodological limitations including cross-sectional designs and heterogeneous study populations spanning different age groups and body mass indices (Cherian et al., 2021; Wang et al., 2023; Kabiri et al., 2024; Fresán et al., 2019; Barkhordari et al., 2022; Kamrani et al., 2024; Seifollahi et al., 2024). Adolescence represents a critical period for both dietary habit formation and depression onset, yet research has not examined the potential protective effects of the MIND diet during this developmental stage. To our knowledge, we provide the first empirical evidence suggesting a potential protective effect of the MIND diet against depression in adolescents using a longitudinal design.

The MIND diet incorporates key components of the Mediterranean diet, which has been shown to reduce depressive symptoms in both adolescents and adults (Camprodon-Boadas et al., 2024). Both diets emphasize high intake of plants and complete protein, which provides elevated levels of polyphenols and polyunsaturated fatty acids - compounds that may improve depression through suppressing inflammatory pathways (Dinan et al., 2019). Our finding aligns with established research showing that healthier dietary patterns correlate with decreased depressive symptoms. The MIND diet offers greater adherence potential for children and adolescents compared to the Mediterranean diet. For example, the MIND diet places a greater emphasis on the consumption of green leafy vegetables and berries, which are rich in fiber and thus can produce a higher amount of prebiotics (Barnes et al., 2023). These characteristics make the MIND diet particularly promising for enhancing mental health outcomes, including depression reduction, among children and adolescents (Yang et al., 2024).

MIND diet is effective in weight control (Akbar et al., 2023). Previous studies suggested that adherence to the MIND diet may improve cognitive outcomes by reversing obesity-related brain alterations (Arjmand et al., 2022). However, our study showed a significant association with depressive symptoms even adjusting for BMI or waist-to-height ratio at each follow-up, suggesting that obesity-related factors

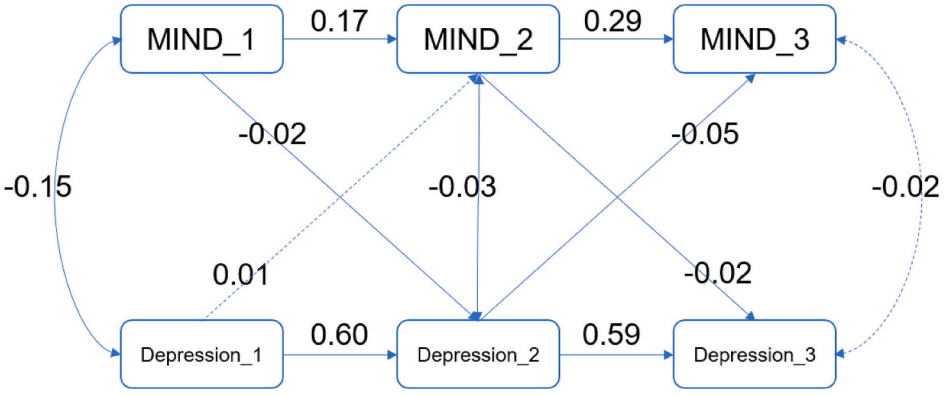

Fig. 3. CLPM of MIND and depression symptom score.
All analyses were adjusted for age at assessment, sex, race/ethnicity, family annual income, Body Mass Index at assessment, parental average education year, and pubertal score at assessment.
CLPM, cross-lagged panel model; MIND, the Mediterranean dietary approaches to stop hypertension intervention for neurodegenerative delay.

play a limited mediating role in the diet's effects on depressive symptoms. BMI and waist-to-height ratio are crude adiposity proxies that fail to capture ectopic fat distribution or metabolic dysfunction in normal-weight individuals. The MIND diet's anti-inflammatory components may act directly on neuroimmune pathways rather than through systemic adiposity changes (Milaneschi et al., 2021).

Genetic factors play a significant role in the development of depression among adolescents (Bakken et al., 2024). In investigating the role of genetic predisposition of depressive symptoms, we found limited evidence that the PRS moderated the association between MIND diet adherence and depressive symptoms. This suggests that the MIND diet's protective effects may operate independently of genetic predisposition, highlighting its potential as a universally applicable modifiable factor for depression prevention.

Our study possesses several strengths. First, our longitudinal design and comprehensive series of analyses yielded robust results, enhancing the reliability of our findings. Second, this study is the first to investigate the protective role of the MIND diet against depressive symptoms specifically in adolescents. Third, the racial diversity of the ABCD study sample increases the generalizability of our findings across different populations.

Our findings should be interpreted with caution due to some limitations. First, the MIND diet assessments at waves 2 and 3 utilized questionnaires that were not specifically designed for MIND diet evaluation and lacked certain components. However, the questionnaires captured key dietary elements, and we demonstrated significant correlations between wave 1 (using standard MIND diet items) and wave 2 scores, aligning with previous research. Second, the absence of biological assessment data, particularly inflammatory biomarkers (e.g., C-reactive protein, Interleukin-6) in the ABCD dataset, represents a limitation, as it precludes the investigation of potential underlying mechanisms, such as chronic inflammation. Finally, the mechanisms of action linking diet with health outcomes are complex and multifaceted, which could include social and cultural factors. Though we controlled for several potential confounders in our analyses, future studies should incorporate a broader range of social and cultural factors that may influence these relationships.

5. Conclusion

Adhering to MIND diet was associated with less depressive symptoms risk over 2 years in children and adolescents. Our findings suggest that promoting MIND diet adherence may represent a promising strategy for depression prevention in adolescent populations.

CRediT authorship contribution statement

Yiwei Pu: Writing – original draft, Visualization, Validation, Software, Investigation, Formal analysis, Data curation. **Hangyu Tan:** Writing – original draft, Visualization, Data curation, Conceptualization. **Runqi Huang:** Software, Formal analysis. **Wenchong Du:** Resources, Methodology. **Qiang Luo:** Writing – review & editing, Resources, Project administration, Methodology. **Tai Ren:** Writing – review & editing, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization. **Fei Li:** Writing – review & editing, Supervision, Resources, Project administration, Funding acquisition, Conceptualization.

Ethics approval and consent to participate

In the ABCD study, all procedures were approved by a central Institutional Review Board (IRB) at the University of California, San Diego, and in some cases by individual site IRBs (e.g., Washington University in St. Louis) (https://www.sciencedirect.com/science/article/pii/S1878929317300622). Parents or guardians provided written informed consent after the procedures had been fully explained and children assented before participation in the study.

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Role of the funder/sponsor

The funders had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

Declaration of competing interest

None reported.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jad.2025.03.087.

Data availability

Data are publicly released on an annual basis through the National Institute of Mental Health (NIMH) data archive (NDA, https://nda.nih.gov/abcd). The ABCD study are openly available to qualified researchers for free. Access can be requested at https://nda.nih.

gov/abcd/request-access. The data that support the findings of this study are openly available in the ABCD Dataset Data Release 5.1. An NDA study has been created for the data used in this report and code for the replication of analyses conducted in the manuscript can be retrieved under the doi: 10.15154/d21c-1r22.

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