History of Depression, Elevated Body Mass Index, and Waist-to-Height Ratio in Preadolescent Children

William W. Lewis-de los Angeles, MD, and Richard T. Liu, PhD

ABSTRACT

Objective: This study aimed to evaluate whether a history of depression or self-injurious thoughts and behaviors predict elevated body mass index (BMI) and elevated waist-to-height ratio in preadolescents.

Methods: Baseline data were evaluated from a large, nationally representative cohort study of 9- and 10-year-old children (unweighted n = 11,875), the Adolescent Brain and Cognitive Development study.

Results: In the weighted sample, 10.6% of children had a history of depression, 7.0% had engaged in nonsuicidal self-injury, 13.1% had experienced suicidal ideation in their lifetime, and 1.1% had a history of attempted suicide. Among the children, 34.1% had an elevated BMI in the overweight or obese range and 31.9% had a waist-to-height ratio >0.5. In multivariate analyses, history of depression was associated with elevated BMI and waist-to-height ratio. Furthermore, interactions with sex were found; girls with a history of depression were more likely to have an elevated BMI (odds ratio = 1.47, 95% confidence interval = 1.24–1.74) and elevated waist-to-height ratio (odds ratio = 1.48, 95% confidence interval = 1.18–1.86) than girls without a history of depression, but no differences were observed between boys with and without a history of depression. Self-injurious thoughts and behaviors were not associated with elevated BMI or elevated waist-to-height.

Conclusions: In this study, 9- and 10-year-old girls with a history of depression were more likely to have an elevated BMI and elevated waist-to-height ratio than girls with no history of depression. These results provide important clinical context in caring for preadolescents with a history of depression.

Key words: depression, obesity, body mass index, waist-to-height ratio, preadolescents.

INTRODUCTION

Although adults with depression have an increased risk of incident cardiometabolic disease (1,2), less direct evidence is known about depression and cardiometabolic disease in children. Obesity, an important risk factor for cardiometabolic disease, is associated with depression in adolescents. A meta-analysis of longitudinal studies by Mannan et al. (3) showed depressed adolescents to have a relative risk of being obese of 1.7, with a stronger relationship in female than in male adolescents. For preadolescents specifically, only a handful of studies have looked at depression as a predictor of elevated body mass index (BMI) (4–9). However, several of these studies featured small samples (4,5,9), and almost all focused on predicting the effects of preadolescent depression on BMI in the long term (i.e., BMI in adolescence or adulthood).

Among the large studies, Anderson et al. (6) examined depression in a mixed population of preadolescents and adolescents and its relationship to adult BMI in a US community sample. The authors found a positive relationship between early onset of childhood depression and subsequent adult BMI. Duarte et al. (8) studied mental health in male Finnish preadolescents and its correlation with BMI in young adulthood. The authors found that depressive symptoms in preadolescence were not associated with elevated BMI. Finally, Geoffroy et al. (7) studied depression and BMI at several time points in preadolescence, adolescence, and adulthood, in a large longitudinal study in the United Kingdom, finding that depression in preadolescence did not predict subsequent obesity.

The mixed findings from these studies suggest that there may be a relationship between depression in early childhood and elevated BMI adulthood, but this relationship is incompletely characterized, and it also remains unclear whether this association already manifests in childhood. From a clinical standpoint, understanding the relationship between a history of depression and elevated BMI in childhood is essential, as elevated BMI in preadolescents is a strong risk factor for adult obesity and cardiovascular disease (10,11). Thus, the existence of such an association in preadolescence would suggest the need for additional research regarding the timing and directionality of increased cardiometabolic risk in preadolescents with a history of depression. Furthermore, waist-to-height ratio is known to be related to cardiometabolic risk in preadolescent children, but its relationship to depression has not been described (12–15).

ABCD = Adolescent Brain and Cognitive Development, **BMI** = body mass index, **CI** = confidence interval, **IRB** = Institutional Review Board, **OR** = odds ratio, **SSRI** = selective serotonin reuptake inhibitor

From the Department of Pediatrics (Lewis-de los Angeles), Warren Alpert Medical School of Brown University, Providence; Department of Pediatrics, Emma Pendleton Bradley Hospital (Lewis-de los Angeles), Riverside, Rhode Island; Department of Psychiatry (Liu), Harvard Medical School; and Department of Psychiatry (Liu), Massachusetts General Hospital, Boston, Massachusetts.

Address correspondence to William W. Lewis-de los Angeles, MD, Bradley Hospital, 1011 Veterans Memorial Parkway, Riverside, RI 02915. E-mail: williamldlapeds@gmail.com

Received for publication July 13, 2020; revision received February 8, 2021.

DOI: 10.1097/PSY.0000000000000982

Similarly, no studies have examined the association between self-injurious thoughts and behaviors (i.e., suicidal ideation, suicide attempts, and nonsuicidal self-injury) and elevated BMI in preadolescents. Addressing the lack of studies on preteen suicide has recently been identified as a priority by the National Institute of Mental Health (16). In adolescents and adults, there have been mixed results when looking at these self-injurious thoughts and behaviors and in relation to elevated BMI. In one study, adolescents with obesity were more likely to report suicidal ideation than those of normal weight, although they were not more likely to attempt suicide (17). In contrast, adult women with obesity in the Nurse's Health Study II were more likely to die by suicide (18). A cross-sectional study of Dutch adolescents also found an association between obesity and suicidal thoughts and attempts (19).

The Adolescent Brain and Cognitive Development (ABCD) study includes more than 11,000 children, all 9 and 10 years of age, with data on depression diagnosis, suicidal ideation and attempts, and nonsuicidal self-injury. These data give a unique opportunity to study the relationship between elevated BMI, waist-to-height ratio, and history of depression in a nationally representative population of preadolescents (20).

Consistent with prior studies of adolescents (3), we hypothesized that a history of depression would predict known cardiometabolic risk factors in preadolescents: elevated waist-to-height ratio and elevated BMI. Similarly, we hypothesized that self-injurious thoughts and behaviors (including suicidal ideation, suicide attempts, and nonsuicidal self-injury) would also be associated with overweight and obesity as well as elevated waist-to-height ratio in preadolescents.

METHODS

Participants

Baseline data from the ABCD study included children aged 9 to 10 years (unweighted n = 11,875). Participants were recruited from 21 sites, with particular effort made to ensure diversity of sociodemographics in the recruited population. The areas from which the ABCD study sites enrolled patients included approximately 20% of the total US population (21). The data for the ABCD Data Release 2.0 were collected in 2016 to 2018 at 21 different sites across the country. Please see Garavan et al. (20) for a detailed description of recruitment procedures (including eligibility), efforts to address potential sources of bias, and discussion of the study size. Exclusion criteria for the ABCD study included known substance use disorder, moderate or severe intellectual disability, major neurologic disease, history of traumatic brain injury, significant vision, hearing, or sensorimotor impairments that cannot be corrected, birth before 28 weeks' gestation, birth weight less than 1200 g, complications requiring more than 1-month admission at birth, and contraindication to magnetic resonance imaging scanning (22).

Procedures

History of depression diagnosis, suicidal ideation, suicide attempts, and nonsuicidal self-injury were evaluated with child and caregiver completion, respectively, of the computerized version of the Kiddie Schedule for Affective Disorders and Schizophrenia for *Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition* (KSADS-COMP) (23,24). Children met the criteria for these outcomes if endorsed by either parent or child report. As noted previously in a prior study from the ABCD study, agreement between parent and child report was low (25). Only those individuals who had past depression/self-injury–associated thoughts and behaviors were identified as positive.

Height was measured at the baseline visit with a stadiometer. Height was defined as the average standing height, measured from at least two measurements. Weight was measured at the baseline visit with a balance scale. Weight was defined as the average weight from at least two measurements. BMI was calculated based on the standard formula and compared with reference charts for age and sex (https://www.cdc.gov/healthyweight/bmi/calculator.html) to calculate the BMI percentile. Calculations were performed based on these standard charts with the childsds package in RStudio (version 1.2.5033; RStudio, Inc., Boston, Massachusetts; childsds version 0.7.4). Underweight was defined as <5th percentile; normal weight, 5th to less than 85th percentile; overweight, 85th to less than 95th percentile; and obesity, 95th percentile and higher. Patients were subsequently placed in two categories: overweight or obese ("elevated BMI"), or not overweight or obese.

Waist circumference was measured a single time by a trained research assistant. Waist-to-height ratio was calculated as waist circumference divided by height, and patients were placed in two categories: waist-to-height ratio greater than 0.5, and waist-to-height ratio less than or equal to 0.5, based on the known increase in cardiometabolic risk related to an elevated waist-to-height ratio (13–15).

Families reported annual combined income in one of the following categories: <$5000, $5000–$11,999, $12,000–$15,999, $16,000–$24,999, $25,000–$34,999, $35,000–$49,999, $50,000–$74,999, $75,000–$99,999, $100,000–$199,999, and >$200,000.

Parents reported child demographics, including sex at birth, race, and ethnicity. Ethnicity was considered separately from race using a parent report of Hispanic ethnicity (for children of any race).

Medications were determined from a parent report of any medications given in the past 2 weeks. Three categories were assessed, based on medications commonly given in this age group that may also affect BMI (26–29) and/or waist circumference. Patients were categorized as either taking or not taking a medication from each of the following categories: selective serotonin reuptake inhibitors (SSRIs), stimulants (e.g., methylphenidate, amphetamine), and atypical antipsychotics.

A measure of childhood trauma was extracted from the KSADS-COMP posttraumatic stress disorder questions answered by parents. We looked at seven possible categories of childhood trauma: serious accident, fire, community disaster, community violence, family violence, sexual assault, and unexpected family death. We created a binary variable to explore childhood trauma: no exposure to childhood trauma or exposure to one or more type of childhood trauma.

For pubertal development, we calculated a composite pubertal development category ranging from 1 to 5 by summing relevant parent-reported measures of pubertal development, based on reported sex at birth. A category of 1 was defined as prepuberty, 2 as early puberty, 3 as mid puberty, 4 as late puberty, and 5 as postpuberty (30).

For physical activity, we examined number of days with at least 60 minutes of aerobic activity per week, as reported by study participants. We created a binary variable: 3 or fewer days of aerobic exercise per week, or 4 or more days of aerobic exercise per week.

Statistical Analysis

We included all children from the baseline ABCD data set in the analysis. Using the Survey package in RStudio (version 1.2.5033; RStudio, Inc.; Survey package version 4.0), we weighted the ABCD data to match the nationally representative American Community Survey. The ABCD study group was matched to the nationally representative American Community Survey on shared demographics including age, sex, race/ethnicity, family income, family composition (parental marriage status, household size), parent employment status, and census region. Full details of the matching and resulting propensity weights are described elsewhere (21). Site ID was also included as a level in the survey design.

Pearson χ^2 analyses were performed with RStudio and the svychisq function (version 1.2.5033; RStudio, Inc.; Survey package version 4.0)

for categorical variables, assessing history of depression, suicidal ideation, nonsuicidal self-injury, and suicide attempts, respectively, in relation to obesity/overweight and waist-to-height ratio. We assessed the relationship between each predictor variable as reported by either parent or child and obesity/overweight. We also assessed the relationship between each depression-associated variable as reported by either parent or child and waist-to-height ratio.

History of depression, suicidal ideation, nonsuicidal self-injury, and suicide were then examined in multivariate models with the same criterion variables. Participants with any missing data were excluded. Specifically, the Survey package in RStudio and svyglm function (RStudio version 1.2.5033; RStudio, Inc.; Survey package version 4.0) were used to perform a multivariate logistic regression analysis with weighting as described previously, with elevated BMI as the criterion variable. Based on prior studies of overweight and obesity, including one of the prior releases of the ABCD study (29), we adjusted for demographic variables (including sex at birth, race, ethnicity, and family income) and medication use (stimulants, SSRIs, and atypical antipsychotics) in these multivariate analyses. We also adjusted for related variables known to affect the risk of elevated BMI (history of childhood trauma, pubertal development category, and aerobic physical activity). This multivariate logistic regression was repeated with waist-to-height ratio >0.5 as the criterion variable. In addition, for each multivariate analysis, we tested for the presence of interactions between the predictor variables and biological sex.

Institutional Review Board

The institutional review board (IRB) at the University of California, San Diego, oversees the ABCD study. The IRB at Lifespan evaluated our use of de-identified data from the ABCD study, and it was determined to be IRB exempt.

RESULTS

Descriptive analyses are presented in Table 1. For demographics, sex at birth included 51.2% male and 48.8% female. The children in the weighted sample were 67.1% White, 14.6% Black, 4.1% Asian or Pacific Islander, and 1.0% Native American, and 7.7% reported multiple races and 5.5% other race. Twenty-four percent reported Hispanic ethnicity. The percentage of children at each family income level is listed in Table 1. For cardiometabolic measures, 34.1% of children had an elevated BMI in the overweight or obese range, with 18.3% obese and 15.8% overweight. Less than half (31.9%) of the children had an elevated waist-to-height ratio >0.5. For medications, 1.6% of children had taken an SSRI in the past 2 weeks, 6.9% had taken a stimulant, and 0.5% had taken an atypical antipsychotic. Based on the report of either the child or the parent, 10.6% of children had a history of depression, 7.0% had engaged in nonsuicidal self-injury, 13.1% had experienced any suicidal ideation in their lifetime, and 1.1% had a history of attempted suicide.

For univariate analyses, a history of depression was significantly associated with BMI category ($p < .001$), with depressed patients more likely to have an elevated BMI. There was no significant association between any of the following and elevated BMI: history of nonsuicidal self-injury, history of suicidal ideation, and history of suicide attempt (Table 2).

Similarly, in univariate analyses, a history of depression was significantly associated with waist-to-height ratio >0.5 ($p < .001$), with participants with a history of depression more likely to have an elevated waist-to-height ratio. There was no significant association between any of the following and elevated waist-to-height ratio: history of nonsuicidal self-injury, history of suicidal ideation, and history of suicide attempt (Table 2).

A logistic regression was conducted with elevated BMI as the dependent variable and history of depression as the independent variable, while adjusting for sex at birth, race, ethnicity, combined family income, medication use (SSRIs, stimulants, or atypical

TABLE 1. Descriptives for the Weighted Sample (11,875 Total Participants)

Cardiometabolic risk factors	
Overweight or obese	34.1%
Waist-to-height >0.5	31.9%
History of mental illness	
History of depression	10.6%
Nonsuicidal self-injury	7.0%
Any suicidal ideation	13.1%
Suicide attempt	1.1%
Annual household income	
<$5000	4.5%
$5000–$11,999	4.8%
$12,000–$15,999	3.3%
$16,000–$24,999	6.5%
$25,000–$34,999	7.2%
$35,000–$49,999	12.0%
$50,000–$74,999	17.7%
$75,000–$99,999	13.6%
$100,000–$199,999	22.9%
>$200,000	7.5%
Sex at birth	
Female	48.8%
Male	51.2%
Parent-reported race	
White	67.1%
Black	14.6%
Asian/Pacific Islander	4.1%
Native American	1.0%
Multiple	7.7%
Other	5.5%
Ethnicity	
Hispanic	24.0%
Medication use: past 2 wk	
SSRI	1.6%
Stimulant	6.9%
Atypical antipsychotic	0.5%
Pubertal development category	
Category 1	26.5%
Category 2	38.3%
Category 3	32.2%
Category 4	2.8%
Category 5	0.2%
History of childhood trauma	37.6%
>3 d/wk of aerobic exercise	45.9%

SSRI = selective serotonin reuptake inhibitor.

TABLE 2. Univariate Analyses of History of Depression, Suicidal Ideation, Suicide Attempts, and Nonsuicidal Self-Injury in Relation to Overweight/Obesity and Waist-to-Height Ratio

Univariate Analyses		
	χ^2	*p*
χ^2 Test with overweight/obesity		
History of depression	25.3	<.001
Nonsuicidal self-injury	0.3	.59
Suicide attempt	2.7	.12
Any suicidal ideation	0.2	.69
χ^2 Test with waist-to-height ratio		
History of depression	18.1	<.001
Nonsuicidal self-injury	0.1	.72
Suicide attempt	1.8	.19
Any suicidal ideation	0.1	.80

antipsychotics), history of childhood trauma, pubertal development category, and weekly aerobic activity. A total of 8249 participants had complete data for all relevant variables and were included in the analysis. There was a significant interaction between history of depression and sex at birth (Table 3). In particular, girls with a history of depression were more likely to have elevated BMI compared with girls with no history of depression (odds ratio [OR] = 1.47, 95% confidence interval [CI] = 1.24–1.74, $p < .001$), but boys with a history of depression did not differ from those without in terms of elevated BMI (OR = 1.01, 95% CI = 0.81–1.26, $p = .92$). Boys with no history of depression were more likely than girls with no history of depression to have an elevated BMI (OR = 1.37, 95% CI = 1.21–1.54, $p < .001$), but boys with a history of depression did not differ from girls with a history of depression in terms of elevated BMI (OR = 0.94, 95% CI = 0.73–1.20, $p = .63$).

A similar logistic regression was conducted with elevated waist-to-height ratio as the dependent variable and history of depression as the independent variable, while adjusting for sex at birth, race, ethnicity, combined family income, medication use, history of childhood trauma, pubertal development category, and weekly aerobic activity. A total of 8249 participants had complete data for all relevant variables and were included in the analysis. A similar significant interaction was observed between a history of depression and sex at birth (Table 4). Girls with a history of depression were more likely to have an elevated waist-to-height ratio than girls with no history of depression (OR = 1.48, 95% CI = 1.18–1.86, $p = .002$); boys with a history of depression were not more likely than boys with no history of depression to have an elevated waist-to-height ratio (OR = 0.98, 95% CI = 0.94–1.14, $p = .79$). Boys with no history of depression were more likely than girls with no history of depression to have an elevated waist-to-height ratio (OR = 1.20, 95% CI = 1.05–1.36, $p = .01$). Boys with a history of depression were likely to have elevated waist-to-height ratio similar to girls with a history of depression (OR = 0.79, 95% CI = 0.57–1.10, $p = .18$).

Similar separate logistic regression analyses were performed with elevated BMI and elevated waist-to-height ratio as the dependent variables and suicidal ideation, nonsuicidal self-injury, and suicide attempt as the independent variables, while adjusting for sex at birth, race, ethnicity, combined family income, medication use, history of childhood trauma, pubertal development category, and weekly aerobic activity. There was no significant relationship identified (data not shown).

DISCUSSION

To our knowledge, the current study represents the first evaluation of history of depression as a predictor of multiple cardiometabolic risk factors in a nationally representative sample of preadolescents. Our study is also the first to explore the relationship between self-injury–associated thoughts and behaviors and cardiometabolic risk factors in this age group.

TABLE 3. Multivariate Logistic Regression Predicting Elevated BMI (Overweight or Obesity; Includes 8249 Participants With Complete Data)

Predictor	OR (95% CI)	*p*
History of depression	1.47 (1.24–1.74)	<.001
Male sex	1.37 (1.21–1.54)	<.001
History of depression by male sex	0.69 (0.53–0.89)	.009
Race (reference category is White)		
Asian or Pacific Islander	1.09 (0.72–1.65)	.94
Black	1.75 (1.43–2.14)	<.001
Native American	2.19 (1.26–3.79)	.01
Mixed	1.08 (0.92–1.27)	.36
Other	0.98 (0.74–1.30)	.46
Ethnicity		
Hispanic	1.93 (1.68–2.21)	<.001
Psychotropic medication		
Uses SSRI	1.37 (0.89–2.12)	.17
Uses atypical antipsychotic	1.75 (0.88–3.51)	.13
Uses stimulant	0.55 (0.42–0.72)	<.001
Household income (reference group is >$200,000)		
<$5000	3.17 (2.37–4.25)	<.001
$5000–$11,999	3.25 (2.42–4.37)	<.001
$12,000–$15,999	2.83 (2.02–3.96)	<.001
$16,000–$24,999	2.98 (2.29–3.89)	<.001
$25,000–$34,999	2.36 (1.87–2.98)	<.001
$35,000–$49,999	2.32 (1.84–2.92)	<.001
$50,000–$74,999	1.94 (1.61–2.34)	<.001
$75,000–$99,999	1.66 (1.32–2.13)	<.001
$100,000–$199,999	1.36 (1.14–1.62)	.002
Pubertal development category (reference is category 1)		
Category 2	1.31 (1.15–1.49)	<0.001
Category 3	1.68 (1.45–1.94)	<0.001
Category 4	2.70 (1.86–3.91)	<0.001
Category 5	6.41 (2.34–17.50)	<0.001
History of childhood trauma	0.91 (0.82–1.00)	0.07
>3 d/wk of aerobic activity	0.91 (0.80–1.04)	0.18

BMI = body mass index; OR = odds ratio; CI = confidence interval; SSRI = selective serotonin reuptake inhibitor.

TABLE 4. Multivariate Logistic Regression Predicting Elevated Waist-to-Height Ratio (Includes 8249 Participants With Complete Data)

Predictor	OR (95% CI)	*p*
History of depression	1.48 (1.18–1.86)	.002
Male sex	1.20 (1.05–1.36)	.01
History of depression by male sex	0.66 (0.49–0.90)	.01
Race (reference category is White)		
Asian or Pacific Islander	1.17 (0.74–1.85)	.51
Black	1.29 (1.09–1.52)	.007
Native American	1.73 (1.19–2.54)	.01
Mixed	0.83 (0.68–1.00)	.07
Other	0.87 (0.59–1.28)	.48
Ethnicity		
Hispanic	2.32 (1.96–2.74)	<.001
Psychotropic medication		
Uses SSRI	1.17 (0.66–2.08)	.59
Uses atypical antipsychotic	1.34 (0.67–2.70)	.13
Uses stimulant	0.63 (0.48–0.84)	.004
Household income (reference group is >$200,000)		
<$5,000	3.88 (2.58–5.84)	<.001
$5000–$11,999	3.22 (2.45–4.22)	<.001
$12,000–$15,999	3.47 (2.26–5.32)	<.001
$16,000–$24,999	2.93 (2.10–4.09)	<.001
$25,000–$34,999	2.56 (1.87–3.51)	<.001
$35,000–$49,999	2.12 (1.50–3.01)	<.001
$50,000–$74,999	1.86 (1.48–2.34)	<.001
$75,000–$99,999	1.81 (1.41–2.31)	<.001
$100,000–$199,999	1.33 (1.15–1.53)	<.001
Pubertal development category (reference is category 1)		
Category 2	1.28 (1.13–1.46)	<.001
Category 3	1.47 (1.28–1.68)	<.001
Category 4	1.83 (1.28–2.62)	.003
Category 5	3.62 (1.43–9.15)	.01
History of childhood trauma	0.94 (0.87–1.02)	.18
>3 d/wk of aerobic activity	0.89 (0.80–0.99)	.04

OR = odds ratio; CI = confidence interval; SSRI = selective serotonin reuptake inhibitor.

Our results indicate a sex-specific relationship between history of depression and cardiometabolic risk factors in preadolescent children aged 9 and 10 years. The major findings are that girls with a history of depression have an increased risk of elevated BMI and elevated waist-to-height ratio as compared with girls with no history of depression. There was no difference in rate of elevated BMI or elevated waist-to-height ratio in boys with a history of depression as compared with boys with no history of depression.

Our findings extend the relationship between depression and elevated BMI to preadolescent girls; Mannan et al. (3) showed a stronger relationship between depression and elevated BMI in adolescent girls than adolescent boys. These findings also add to our understanding of how a history of depression relates to BMI and waist-to-height ratio in preadolescents, important markers of metabolic health. Elevated waist-to-height ratio may better predict cardiovascular disease risk than elevated BMI (13–15).

These findings represent an important initial step toward elucidating an association with implications for early intervention. By looking at past (rather than current) depression in relation to current BMI and waist-to-height ratio, the study offers unique information in preadolescents. Although we cannot determine if girls in our study were already overweight at the time of their depression diagnosis, the findings have clinically meaningful implications. There are two main possibilities: a) if the girls did not have an elevated BMI at the time of their past depression diagnosis, it would imply that depression temporally predicts elevated BMI with important implications for clinical follow-up, and b) if the girls did have an elevated BMI at the time of their past diagnosis of depression, it would imply that depression temporally predicts chronicity of/long-term overweight status in childhood, a finding that too is clinically important. Thus, our findings have clinical implications regardless of overweight status at the time of depression diagnosis and highlight the need for future research to evaluate which of the aforementioned possibilities is empirically supported.

In contrast to our findings on history of depression, children with a history of nonsuicidal self-injury, suicidal ideation, or suicide attempts did not have an increased risk of elevated BMI or elevated waist-to-height ratio. Some studies of adolescents and adults have shown associations between these self-injurious thoughts and behaviors and elevated BMI. It is not clear why the association was not seen in our study. It may be that there is a time lag, with elevated BMI related to these thoughts and behaviors in preadolescence developing in adolescence or adulthood. Alternatively, elevated BMI in older populations may be related to persistence or onset of these thoughts and behaviors during adolescence or adulthood. There is also the possibility that risk may be limited to specific populations (17–19).

Our results must be interpreted within the context of the study's limitations. One limitation was an inability to assess severity and duration of depression, leaving us unable to look for a dose-response relationship. Although we did control for known confounders, it is possible that other unmeasured factors relate to both a history of depression and cardiometabolic risk factors in this population. Another limitation relates to applicability of the results: the study does include a large and nationally representative population, but it may not be applicable to non-US populations or specific subpopulations within the United States that were not well represented in our study. A final limitation is the analysis of only a single time point looking at both a history of depression and cardiometabolic risk factors; it would therefore be important for the observed findings to be replicated in a longitudinal sample to clarify the temporal and directional nature of the association between history of depression and the cardiometabolic risk factors seen in this study.

In future studies, it will be important to further explore sex differences in the adolescent population and see how these change over time, especially given the relative absence of sex differences in depression in preadolescence is followed by a marked sex difference starting in adolescence (31). Finally, further exploring potential mediating factors like stigma (32), childhood maltreatment (33–37), and shared genetic markers (38–41) are essential to further understand the relationship between depression and cardiometabolic risk.

Conclusions

Girls aged 9 and 10 years with a history of depression were more likely to have elevated BMI and elevated waist-to-height ratio than girls with no history of depression. To our knowledge, this is the first study to identify a contemporaneous association between a history of depression and elevated BMI/waist-to-height ratio in preadolescents. The results of this study provide important clinical context to help pediatricians care for preadolescents with a history of depression, which represented more than 10% of the population in this nationally representative study.

Data used in the preparation of this article were obtained from the Adolescent Brain Cognitive Development (ABCD) study (https://abcdstudy.org), held in the National Institute of Mental Health Data Archive. This is a multisite, longitudinal study designed to recruit more than 10,000 children aged 9 to 10 years and follow them up more than 10 years into early adulthood. The ABCD study is supported by the National Institutes of Health and additional federal partners under award numbers U01DA041022, U01DA041028, U01DA041048, U01DA041089, U01DA041106, U01DA041117, U01DA041120, U01DA041134, U01DA041148, U01DA041156, U01DA041174, U24DA041123, U24DA041147, U01DA041093, and U01DA041025. A full list of supporters is available at https://abcdstudy.org/federal-partners.html. A listing of participating sites and a complete listing of the study investigators can be found at https://abcdstudy.org/scientists/workgroups/. ABCD consortium investigators designed and implemented the study and/or provided data but did not necessarily participate in analysis or writing of this report. This manuscript reflects the views of the authors and may not reflect the opinions or views of the National Institutes of Health or ABCD consortium investigators. The ABCD data used in this report came from ABCD Data Release 2.0 (http://dx.doi.org/10.15154/1503209).

Source of Funding and Conflicts of Interest: Preparation of this article was supported in part by the National Institute of Mental Health of the National Institutes of Health under award numbers RF1MH120830, R01MH101138, and R01MH115905 (R.T.L.). The content is solely the responsibility of the authors and does not necessarily represent the official views of the funding agencies. The authors have no conflicts of interest relevant to this article to disclose.

Author Contributions: L.-d.l.A. and R.T.L. conceptualized and designed the study, drafted the initial manuscript, performed data analysis, and approved the final manuscript as submitted.

REFERENCES

1. Martin DJ, Ul-Haq Z, Nicholl BI, Cullen B, Evans J, Gill JM, Roberts B, Gallacher J, Mackay D, McIntosh A, Hotopf M, Craddock N, Deary IJ, Pell JP, Smith DJ. Cardiometabolic disease and features of depression and bipolar disorder: population-based, cross-sectional study. Br J Psychiatry 2016;208:343–51.
2. Scott KM. Depression, anxiety and incident cardiometabolic diseases. Curr Opin Psychiatry 2014;27:289–93.
3. Mannan M, Mamun A, Doi S, Clavarino A. Prospective associations between depression and obesity for adolescent males and females—a systematic review and meta-analysis of longitudinal studies. PLoS One 2016;11:e0157240.
4. Dockray S, Susman EJ, Dorn LD. Depression, cortisol reactivity, and obesity in childhood and adolescence. J Adolesc Health 2009;45:344–50.
5. Pine DS, Goldstein RB, Wolk S, Weissman MM. The association between childhood depression and adulthood body mass index. Pediatrics 2001;107:1049–56.
6. Anderson SE, Cohen P, Naumova EN, Must A. Association of depression and anxiety disorders with weight change in a prospective community-based study of children followed up into adulthood. Arch Pediatr Adolesc Med 2006;160:285–91.
7. Geoffroy MC, Li L, Power C. Depressive symptoms and body mass index: co-morbidity and direction of association in a British birth cohort followed over 50 years. Psychol Med 2014;44:2641–52.
8. Duarte CS, Sourander A, Nikolakaros G, Pihlajamaki H, Helenius H, Piha J, Kumpulainen K, Moilanen I, Tamminen T, Almqvist F, Must A. Child mental health problems and obesity in early adulthood. J Pediatr 2010;156:93–7.
9. Lynch T, Azuero A, Lochman JE, Park NJ, Turner-Henson A, Rice M. The influence of psychological stress, depressive symptoms, and cortisol on body mass and central adiposity in 10- to-12-year-old children. J Pediatr Nurs 2019;44:42–9.
10. Franks PW, Hanson RL, Knowler WC, Sievers ML, Bennett PH, Looker HC. Childhood obesity, other cardiovascular risk factors, and premature death. N Engl J Med 2010;362:485–93.
11. Gunnell DJ, Frankel SJ, Nanchahal K, Peters TJ, Davey Smith G. Childhood obesity and adult cardiovascular mortality: a 57-y follow-up study based on the Boyd Orr cohort. Am J Clin Nutr 1998;67:1111–8.
12. Yan W, Wang X, Yao H, Dai J, Zheng Y, Yang X, Yibulayin X, Cui J. Waist-to-height ratio and BMI predict different cardiovascular risk factors in Chinese children. Diabetes Care 2006;29:2760–1.
13. Savva SC, Tornaritis M, Savva ME, Kourides Y, Panagi A, Silikiotou N, Georgiou C, Kafatos A. Waist circumference and waist-to-height ratio are better predictors of cardiovascular disease risk factors in children than body mass index. Int J Obes Relat Metab Disord 2000;24:1453–8.
14. Kahn HS, Imperatore G, Cheng YJ. A population-based comparison of BMI percentiles and waist-to-height ratio for identifying cardiovascular risk in youth. J Pediatr 2005;146:482–8.
15. Maffeis C, Banzato C, Talamini G, Obesity Study Group of the Italian Society of Pediatric Endocrinology and Diabetology. Waist-to-height ratio, a useful index to identify high metabolic risk in overweight children. J Pediatr 2008;152:207–13.
16. Identifying Research Priorities in Child Suicide Risk. NIMH Event Summaries. 2019. Available at: https://www.nimh.nih.gov/news/events/2019/identifying-research-priorities-in-child-suicide-risk.shtml. Accessed May 4, 2020.
17. Zeller MH, Reiter-Purtill J, Jenkins TM, Ratcliff MB. Adolescent suicidal behavior across the excess weight status spectrum. Obesity 2013;21:1039–45.
18. Van Dam RM, Willett WC, Manson JAE, Hu FB. The relationship between overweight in adolescence and premature death in women. Ann Intern Med 2006;145:91–7.
19. Van Wijnen LG, Boluijt PR, Hoeven-Mulder HB, Bemelmans WJ, Wendel-Vos GC. Weight status, psychological health, suicidal thoughts, and suicide attempts in dutch adolescents: results from the 2003 E-MOVO project. Obesity (Silver Spring) 2010;18:1059–61.
20. Garavan H, Bartsch H, Conway K, Decastro A, Goldstein RZ, Heeringa S, Jernigan T, Potter A, Thompson W, Zahs D. Recruiting the ABCD sample: design considerations and procedures. Dev Cogn Neurosci 2018;32:16–22.
21. Heeringa SG, Berglund PA. A guide for population-based analysis of the Adolescent Brain Cognitive Development (ABCD) study baseline data. bioRxiv 2020.
22. Rapuano KM, Laurent JS, Hagler DJ Jr., Hatton SN, Thompson WK, Jernigan TL, Dale AM, Casey BJ, Watts R. Nucleus accumbens cytoarchitecture predicts weight gain in children. Proc Natl Acad Sci U S A 2020;117:26977–84.
23. Townsend L, Kobak K, Kearney C, Milham M, Andreotti C, Escalera J, Alexander L, Gill MK, Birmaher B, Sylvester R, Rice D, Deep A, Kaufman J. Development of three web-based computerized versions of the kiddie schedule for affective disorders and schizophrenia child psychiatric diagnostic interview: preliminary validity data. J Am Acad Child Adolesc Psychiatry 2020;59:309–25.
24. Barch DM, Albaugh MD, Avenevoli S, Chang L, Clark DB, Glantz MD, Hudziak JJ, Jernigan TL, Tapert SF, Yurgelun-Todd D, Alia-Klein N, Potter AS, Paulus MP, Prouty D, Zucker RA, Sher KJ. Demographic, physical and mental health assessments in the Adolescent Brain and Cognitive Development study: rationale and description. Dev Cogn Neurosci 2018;32:55–66.
25. Janiri D, Sani G, De Rossi P, Piras F, Banaj N, Ciullo V, Simonetti A, Arciniegas DB, Spalletta G. Hippocampal subfield volumes and childhood trauma in bipolar disorders. J Affect Disord 2019;253:35–43.
26. Reekie J, Hosking SP, Prakash C, Kao KT, Juonala M, Sabin MA. The effect of antidepressants and antipsychotics on weight gain in children and adolescents. Obes Rev 2015;16:566–80.
27. Schwartz BS, Glass TA, Pollak J, Hirsch AG, Bailey-Davis L, Moran TH, Bandeen-Roche K. Depression, its comorbidities and treatment, and childhood body mass index trajectories. Obesity 2016;24:2585–92.
28. Schwartz BS, Bailey-Davis L, Bandeen-Roche K, Pollak J, Hirsch AG, Nau C, Liu AY, Glass TA. Attention deficit disorder, stimulant use, and childhood body mass index trajectory. Pediatrics 2014;133:668–76.
29. Gray JC, Schvey NA, Tanofsky-Kraff M. Demographic, psychological, behavioral, and cognitive correlates of BMI in youth: findings from the Adolescent Brain Cognitive Development (ABCD) study. Psychol Med 2020;50:1539–47.
30. Petersen AC, Crockett L, Richards M, Boxer A. A self-report measure of pubertal status: reliability, validity, and initial norms. J Youth Adolesc 1988;17:117–33.
31. Hankin BL, Abramson LY, Moffitt TE, Silva PA, McGee R, Angell KE. Development of depression from preadolescence to young adulthood: emerging

gender differences in a 10-year longitudinal study. J Abnorm Psychol 1998; 107:128–40.
32. Stevens SD, Herbozo S, Morrell HER, Schaefer LM, Thompson JK. Adult and childhood weight influence body image and depression through weight stigmatization. J Health Psychol 2017;22:1084–93.
33. O'Neill A, Beck K, Chae D, Dyer T, He X, Lee S. The pathway from childhood maltreatment to adulthood obesity: the role of mediation by adolescent depressive symptoms and BMI. J Adolesc 2018;67:22–30.
34. Sacks RM, Takemoto E, Andrea S, Dieckmann NF, Bauer KW, Boone-Heinonen J. Childhood maltreatment and BMI trajectory: the mediating role of depression. Am J Prev Med 2017;53:625–33.
35. Richardson AS, Dietz WH, Gordon-Larsen P. The association between childhood sexual and physical abuse with incident adult severe obesity across 13 years of the National Longitudinal Study of Adolescent Health. Pediatr Obes 2014;9:351–61.
36. Shin SH, Miller DP. A longitudinal examination of childhood maltreatment and adolescent obesity: results from the National Longitudinal Study of Adolescent Health (AddHealth) study. Child Abuse Negl 2012;36:84–94.
37. Danese A, Tan M. Childhood maltreatment and obesity: systematic review and meta-analysis. Mol Psychiatry 2014;19:544–54.
38. Afari N, Noonan C, Goldberg J, Roy-Byrne P, Schur E, Golnari G, Buchwald D. Depression and obesity: do shared genes explain the relationship? Depress Anxiety 2010;27:799–806.
39. Amare AT, Schubert KO, Klingler-Hoffmann M, Cohen-Woods S, Baune BT. The genetic overlap between mood disorders and cardiometabolic diseases: a systematic review of genome wide and candidate gene studies. Transl Psychiatry 2017;7:e1007.
40. Milaneschi Y, Lamers F, Peyrot WJ, Baune BT, Breen G, Dehghan A, Forstner AJ, Grabe HJ, Homuth G, Kan C, Lewis C, Mullins N, Nauck M, Pistis G, Preisig M, Rivera M, Rietschel M, Streit F, Strohmaier J, Teumer A, Van Der Auwera S, Wray NR, Boomsma DI, Penninx BWJH, CHARGE Inflammation Working Group and the Major Depressive Disorder Working Group of the Psychiatric Genomics Consortium. Genetic association of major depression with atypical features and obesity-related immunometabolic dysregulations. JAMA Psychiatry 2017;74:1214–25.
41. Bahrami S, Steen NE, Shadrin A, O'Connell K, Frei O, Bettella F, Wirgenes KV, Krull F, Fan CC, Dale AM, Smeland OB, Djurovic S, Andreassen OA. Shared genetic loci between body mass index and major psychiatric disorders: a genome-wide association study. JAMA Psychiat 2020;77:503–12.