

Original Paper

Racial Variation in the Association between Childhood Depression and Frontal Pole Volume among American Children

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Abstract

Background: Major Depressive Disorder (MDD) is associated with an altered structure and function of the prefrontal cortex (PFC). There is more to find out about how this association differs among diverse racial groups. **Aim:** This study was performed to investigate racial differences in the association between MDD and frontal pole volume in 9/10-year-old children in the U.S. **Materials and methods:** This cross-sectional study used the Adolescent Brain Cognitive Development (ABCD) study. Then an analytical sample included 10185 American children between the ages of 9 and 10. The independent variable was current MDD, measured using K-SADS. The primary outcome was frontal pole volume, measured using the structural Magnetic Resonance Imaging (sMRI). Race was the moderator. Mixed-effects regression models were used for data analysis. **Results:** In the overall sample, MDD was associated with a smaller frontal pole volume among children. Race showed a statistically significant interaction with MDD on children's frontal pole volume, indicating stronger effects on White children compared to Black children. **Conclusion:** The inverse association between MDD and frontal pole volume is steeper in Black than White American children. White American children with and without MDD show more similar frontal pole volume, while Black children with and without MDD differ more when it comes to the frontal pole volume. It is unknown whether or not the stronger association between frontal pole volume and MDD in Black children is due to a poor access to treatment or to a higher chronicity of MDD in Black communities.

Keywords

depression, frontal pole volume, population groups, prefrontal cortex, frontal pole, cerebral cortex

1. Introduction

Extensive animal (Nashed, Seidlitz, Frey, & Singh, 2015) and human (Grimm et al., 2008) research has shown that the prefrontal cortex (PFC) is a key brain region to affect regulation and emotion processing. A large body of research has also shown that an altered function (Masuda et al., 2017) and structure (Lu et al., 2019) of the PFC is linked to mood disorders such as major depressive disorder (MDD) and bipolar disorder (BD). A structural (Kozel et al., 2011) and functional (Grimm et al., 2008) alteration of PFC is consistently shown in children, youth, adults, and older adults with MDD. Similarly, an altered PFC function (Geller, Grisaru, Abarbanel, Lemberg, & Belmaker, 1997) and structure (Kozel et al., 2011) is linked to MDD severity and treatment response. In addition to that, children with MDD also show similar abnormalities in the function and structure of the PFC (Marrus et al., 2015; Zhang et al., 2020). These studies suggest that an altered PFC function and structure are among the main pathological features of MDD (Taki et al., 2005). Medial PFC (mPFC) is especially vulnerable to stress exposure (Treadway et al., 2015). In fact, stress-related morphometric changes in PFC are in line with the stress-sensitization theory of MDD (Treadway et al., 2015).

Morphological changes in PFC are well-known in MDD (Treadway et al., 2015). Multiple studies have shown volumetric reductions in mPFC among patients with MDD (Treadway et al., 2015). A structural Magnetic Resonance Imaging (sMRI) of regional gray matter volume of 34 subjects with subthreshold depression and 109 age-matched nondepressed controls showed that among males, individuals with subthreshold depression have smaller volumes of the medial part of bilateral frontal lobes and the right precentral gyrus when compared to normal controls. The same results, however, could not be found in females. The study suggested that even community-dwelling individuals with subthreshold depression show a bilateral volume reduction of PFC; a finding that is well established for patients with MDD (Taki et al., 2005). In a study of 103 medication-free patients with MDD and control subjects, sMRI was performed to examine the relationships between the number of prior MDD episodes, current stress, and cortical thickness. A greater number of prior depressive episodes but not current depressive diagnosis was associated with cortical thinning of the left mPFC. A higher number of prior episodes was also associated with a reduced volume in the dentate gyrus (Treadway et al., 2015). Although considerable research suggests that social, clinical, and behavioral correlates of MDD differ for White and Black individuals (Assari, 2016, 2017b, 2017c, 2018a, 2018b, 2019; Assari & Lankarani, 2016a, 2016b; Assari, Moazen-Zadeh, Lankarani, & Micol-Foster, 2016; Assari, Watkins, & Caldwell, 2015; Carter & Assari, 2016; Cobb & Assari, 2019; Evans, Cobb, Smith, Bazargan, & Assari, 2019), we are not aware of any previous studies that have explored racial differences in the association between PFC morphometry and MDD.

1.1 Aims

The current study was performed with two aims. The first aim was to test the association between current MDD and frontal pole volume in a national sample of 9/10-year-old American children (general population). The second aim was to compare racial groups of American children as for the association

between current MDD and frontal pole volume. While MDD is expected to be associated with smaller frontal pole volume (Hypothesis 1), this effect is expected to be more salient on Black than White children (Hypothesis 2). A stronger association between current MDD and PFC morphometry in Black than White children is based on our previous observation on higher severity of MDD in Black than White individuals (Assari, 2019; Assari & Moazen-Zadeh, 2016a, 2016b; Williams et al., 2007).

2. Materials and Methods

2.1 Design and Setting

With a cross-sectional design, this study applied a secondary analysis of data from the Adolescent Brain Cognitive Development (ABCD) study (Alcohol Research: Current Reviews Editorial, 2018; Casey et al., 2018; Karcher, O'Brien, Kandala, & Barch, 2019; Lisdahl et al., 2018; Luciana et al., 2018). The ABCD is a national brain development study of American children (Alcohol Research: Current Reviews Editorial, 2018; Auchter et al., 2018).

2.2 Sample and Sampling

The ABCD participants were sampled from 21 sites in multiple cities across different states in the US. The ABCD sample is mainly enrolled through the U.S. school system. The ABCD sampling strategy applied a careful design of pre-adolescents sampling across various sites (ABCD; Alcohol Research: Current Reviews Editorial, 2018; Asaad & Bjarkam, 2019; Auchter et al., 2018; Beauchaine, 2020; Buscemi et al., 2018; Casey et al., 2018; Dick et al., 2019a, 2019b, 2019c; Exuperio et al., 2019; Feldstein Ewing et al., 2018; Fine et al., 2019; Gray, Schvey, & Tanofsky-Kraff, 2019; Hoffman, Howlett, Breslin, & Dowling, 2018; Lisdahl et al., 2018; Lynch et al., 2019; Michelini et al., 2019; Werneck et al., 2018). To ensure that the ABCD sample is representative, the ABCD has used a weight (propensity score). Using weights, the final ABCD results are generalizable to the U.S., and the weighted participants are a close approximation of national sociodemographic, sex, and racial factors. A full description of the ABCD sample and sampling is published here (Garavan et al., 2018).

2.3 Analytical Sample

This study included 10185 9/10-year-old children who had data on our study variables, including negative urgency. Children from any race or ethnicity were included. No additional eligibility criteria were considered.

2.4 Measures and Measurements

Frontal pole volume. The frontal pole volume was measured using the sMRI. The ABCD imaging modalities are well described here (Hagler et al., 2019). All participating children in the ABCD study completed a high-resolution T1-weighted structural MRI scan (1-mm isotropic voxels) with any of the following scanners: Philips Healthcare (Andover, Massachusetts), GE Healthcare (Waukesha, Wisconsin), or Siemens Healthcare (Erlangen, Germany) (Casey et al., 2018). All the structural MRI data were processed using FreeSurfer version 5.3.0 (B. Fischl, Sereno, & Dale, 1999; Vargas, Damme, & Mittal, 2020), in line with the standard processing pipelines (Casey et al., 2018). The process included the

removal of nonbrain tissue, the segmentation of gray and white matter (Bruce Fischl et al., 2002) and the parcellation of the cerebral cortex (Bruce Fischl et al., 2004). Every scan session underwent a radiological review. An extended quality control protocol was implemented, which included a visual inspection of T1 images and FreeSurfer outputs for an acceptable quality (Hagler Jr et al., 2019). Any MRI imaging that did not pass the quality control was excluded. The cortical parcellation in this study was based on the Desikan-Killiany Atlas (Hagler Jr et al., 2019). Region of interest in this study was frontal pole. In this analysis, we used the volumetric data provided by the ABCD data. Figure 1 shows the distribution of the outcome in this study.

Race. Race, identified by parents, was a categorical variable with the following levels: Black, Asian, Other/Mixed race, and White (reference group). This variable was the effect modifier.

Current depression. Current MDD was measured using the depression module of the Kiddie Schedule for Affective Disorders and Schizophrenia (K-SADS) tool (Orvaschel, Puig-Antich, Chambers, Tabrizi, & Johnson, 1982; Puig-Antich & Chambers, 1978; Townsend et al., 2020). K-SADS, a structured and screening interview tool, is one the most widely used diagnostic tools of psychiatric disorders in children (Chambers et al., 1985; Orvaschel et al., 1982). K-SADS generates DSM-5 5 (KSADS-5) diagnosis of MDD and other psychiatric disorders (Kim et al., 2004). The child was interviewed for the past and present history of MDD in child's depression as well as depression-related symptoms. Our outcome, current MDD, was treated as a categorical/dichotomous outcome with 0 for absence and 1 for presence of current MDD.

Parental educational attainment. Parental educational attainment was a five-level categorical variable. Responses included 1 = less than high school diploma; 2 = high school diploma or GED; 3 = some college; 4 = college degree; and 5 = some graduate education.

Parental marital status. The household's marital status was a dichotomous variable: married = 1 and non-married = 0. Family structure and marital status of the parents are shown to predict children's negative urgency (Rhoades, Greenberg, Lanza, & Blair, 2011).

Family income. Family income was a three-level categorical variable. The item used to measure parental educational attainment was: "What is your total combined parental educational attainment for the past 12 months? This should include income (before taxes and deductions) from all sources, wages, rent from properties, social security, disability and veteran's benefits, unemployment benefits, workman". Levels were 1= less than \$50,000; 2 = \$50,000 to \$99,000; 3 = \$100,000 or more.

Ethnicity. Ethnicity, self-identified by the parents, was 1 for Hispanics and 0 for non-Hispanics (reference category).

Age. Age was measured in months and was a continuous measure.

Sex. Sex, 1 for males and 0 for females, was a dichotomous variable.

2.5 Data Analysis

This analysis was performed in the Data Analysis and Exploration Portal (DEAP), National Data Archive (NDA), National Institutes of Health (NIH). DEAP is specifically designed for analysis of the ABCD

data and uses R software for performing data analysis. Participants were nested within families who were nested within 21 sites. As such, our models should correct for non-independence of our observations. We applied mixed (random) effect models that allowed adjusting for the data's nested nature.

To describe our sample, we reported mean (SD) for continuous variables, frequencies and percentages for categorical variables in the pooled sample and by race. We used Chi-square or ANOVA for bivariate analysis. Two mixed-effects multivariable models were performed. In both of these models, frontal pole cortical volume was the outcome, race was the moderator, current MDD was the predictor, and covariates (sex, ethnicity, age, household income, parental education, and family structure), as well as site and family ID were the control variables. *Model 1 (no interaction)* was estimated in the absence of any interaction terms. *Model 2* (the interaction model) added interaction terms between race and current MDD. Appendix 1 shows the formula used for *Model 1* and *Model 2* in the DEAP system. Regression coefficient (b), SE, and p-values were reported for each model. Appendix 2 also shows the results of testing assumptions.

2.6 Ethical Aspect

For this study, we used a fully de-identified data set. As such, the study was exempted from a full review Institutional Review Board (IRB). However, the main study protocol, the ABCD, was approved by the IRB at the University of California, San Diego (UCSD), and several other institutions. Participants signed consent or assent depending on their age (Auchter et al., 2018).

3. Results

Table 1 depicts the summary statistics of the pooled sample and by race. The current analysis was performed on 10185, 9/10-year-old children from which 6784 were White (unweighted 66.6; weighted 69.4), 1472 were Black (unweighted 14.5%; weighted 13.3%), 219 were Asian (unweighted 2.2%; weighted 3.6%), and 1710 were other/mixed race (unweighted 16.8%; weighted 13.7%).

Table 1. Descriptive Data Overall and by Race

Level	All		White		Black		Asian		Other/Mixed		p	
	un weighted	weighted	un weighted	weighted	un weighted	weighted	un weighted	weighted	un weighted	weighted	un weighted	weighted
N	10185		6784		1472		219		1710			
Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)		
Age (Months)	118.97 (7.47)	119.23(7.48)	119.03 (7.49)	119.29(7.49)	118.98 (7.23)	119.26(7.23)	119.35 (7.82)	119.73(7.83)	118.68 (7.52)	118.75(7.59)	0.302	0.130
Left Frontal Pole Volume (mm3)	970.41 (189.71)	966.77(191.29)	989.81 (189.43)	983.90(190.30)	916.70 (184.03)	914.06(185.51)	936.09 (169.29)	938.00(167.90)	944.09 (185.51)	938.69(194.12)	< 0.001	< 0.001
MDD	0.02 (0.15)	0.03(0.16)	0.02 (0.14)	0.02(0.15)	0.03 (0.18)	0.03(0.18)	0.02 (0.13)	0.01(0.11)	0.02 (0.15)	0.03(0.16)	0.020	0.069
n(%)	%		n(%)	%	n(%)	%	n(%)	%	n(%)	%		

Sex												
Female	4858 (47.7)	(48.8)	3191 (47.0)	(48.1)	729 (49.5)	(50.7)	111 (50.7)	(51.2)	827 (48.4)	(50.1)	0.236	0.308
Male	5327 (52.3)	(51.2)	3593 (53.0)	(51.9)	743 (50.5)	(49.3)	108 (49.3)	(48.8)	883 (51.6)	(49.9)		
Parental Education												
< HS Diploma	368 (3.6)	(4.6)	143 (2.1)	(2.9)	114 (7.7)	(9.0)	5 (2.3)	(2.1)	106 (6.2)	(9.3)	< 0.001	< 0.001
HS Diploma/GED	844 (8.3)	(9.9)	322 (4.7)	(6.4)	333 (22.6)	(25.1)	3 (1.4)	(1.6)	186 (10.9)	(15.1)		
Some College	2616 (25.7)	(30.0)	1434 (21.1)	(26.8)	588 (39.9)	(41.6)	18 (8.2)	(8.9)	576 (33.7)	(40.4)		
Bachelor	2688 (26.4)	(24.9)	2014 (29.7)	(28.2)	220 (14.9)	(13.2)	57 (26.0)	(27.3)	397 (23.2)	(18.9)		
Post Graduate Degree	3669 (36.0)	(30.6)	2871 (42.3)	(35.7)	217 (14.7)	(11.1)	136 (62.1)	(60.1)	445 (26.0)	(16.4)		
Household Income												
< 50K	2921 (28.7)	(38.2)	1241 (18.3)	(28.8)	969 (65.8)	(74.7)	34 (15.5)	(19.4)	677 (39.6)	(55.2)	< 0.001	< 0.001
> =100K	4334 (42.6)	(30.4)	3471 (51.2)	(36.7)	174 (11.8)	(6.1)	132 (60.3)	(49.8)	557 (32.6)	(17.2)		
> =50K & < 100K	2930 (28.8)	(31.4)	2072 (30.5)	(34.5)	329 (22.4)	(19.2)	53 (24.2)	(30.8)	476 (27.8)	(27.5)		
Married Family												
No	3094 (30.4)	(37.2)	1392 (20.5)	(28.8)	1029 (69.9)	(76.7)	33 (15.1)	(15.9)	640 (37.4)	(46.9)	< 0.001	< 0.001
Yes	7091 (69.6)	(62.8)	5392 (79.5)	(71.2)	443 (30.1)	(23.3)	186 (84.9)	(84.1)	1070 (62.6)	(53.1)		
Hispanic												
No	8259 (81.1)	(77.6)	5633 (83.0)	(80.1)	1398 (95.0)	(92.4)	200 (91.3)	(95.2)	1028 (60.1)	(45.7)	< 0.001	< 0.001
Yes	1926 (18.9)	(22.4)	1151 (17.0)	(19.9)	74 (5.0)	(7.6)	19 (8.7)	(4.8)	682 (39.9)	(54.3)		

MDD: Major Depressive Disorder

Table 2 and Table 3 summarizes our mixed-method regression model that adjusted for the nested nature of the data. These models were in the overall (pooled) sample. *Model 1* (Main Effect Model) did show a significant inverse association between current MDD and frontal pole volume in the pooled sample. *Model 2* (Interaction Effect Model) also showed a significant interaction between race and current MDD on frontal pole volume in the pooled sample.

Table 2. Percentage of the Variance of the Outcome Explained by Models

	Effect Size	Effect Size
N	10185	10185
R-squared	0.06702	0.06786
ΔR -squared	0.00061 (0.06%)	0.01171 (1.17%)

Table 3. Summary of the Results of Our Models

	Model 1			Model 2		
	df	F	p-value	df	F	p-value
MDD	1*	6.24	0.012	1	2.02	0.155
Age	1***	31.32	< 0.001	1***	31.36	< 0.001
Sex	1***	318.19	< 0.001	1***	319.59	< 0.001
Parental Education	4**	3.71	0.005	4**	3.77	0.004
Household income	2*	3.29	0.037	2*	3.31	0.036
Race	3***	34.98	< 0.001	3***	32.83	< 0.001
Married Family	1	0.65	0.421	1	0.65	0.4195
Hispanic	1***	73.54	< 0.001	1***	74.03	< 0.001
MDD x Race				3*	3.04	0.028

MDD: Major Depressive Disorder

*P < 0.05

**P < 0.01

***P < 0.001

Table 4 summarizes regression coefficients in our two mixed-method regression models that adjusted for the nested nature of the data. These models were in the overall (pooled) sample. *Model 1* showed an inverse association between current MDD and frontal pole volume in the pooled sample. *Model 2* (Interaction Model) showed a significant interaction term between race and current MDD on frontal pole volume in the pooled sample, suggesting a stronger inverse association between the two for Black than White children.

Table 4. Regression Coefficients in Our Models

	Model 1			Model 2		
	b	SE	p	B	SE	p
MDD	-29.13*	11.66	0.013	-20.62	14.50	0.155
Age (Month)	-1.35***	0.24	< 0.001	-1.35***	0.24	< 0.001
Sex (Male)	66.46***	3.73	< 0.001	66.59***	3.73	< 0.001
Parental Education (HS Diploma/GED)	3.16	11.51	0.784	4.40	11.52	0.702
Parental Education (Some College)	4.78	10.48	0.648	5.56	10.49	0.596
Parental Education (Bachelor)	15.54	11.19	0.165	16.70	11.20	0.136
Parental Education (Post Graduate Degree)	26.60*	11.38	0.019	27.56*	11.39	0.016
Household income (> =50K & < 100K)	11.35*	5.74	0.048	16.81*	6.61	0.011
Household income (> =100K)	16.73*	6.61	0.011	11.26*	5.73	0.050

Race (Black)	-58.71	6.48	< 0.001	-56.31***	6.55	< 0.001
Race (Asian)	-58.51	11.62	< 0.001	-60.33***	11.71	< 0.001
Race (Other/Mixed)	-21.36	5.91	< 0.001	-21.90***	5.97	< 0.001
Race (Black) x MDD	-	-	-	-70.04*	29.71	0.018
Race (Asian) x MDD	-	-	-	114.00	91.52	0.213
Race (Other/Mixed) x MDD	-	-	-	27.37	34.27	0.425

MDD: Major Depressive Disorder

*P < 0.05

**P < 0.01

***P < 0.001

Figure 1 shows an inverse association between current MDD and frontal pole volume in the pooled sample. Figure 2 shows that the inverse association between current MDD and frontal pole volume is steeper in Black than White sample.

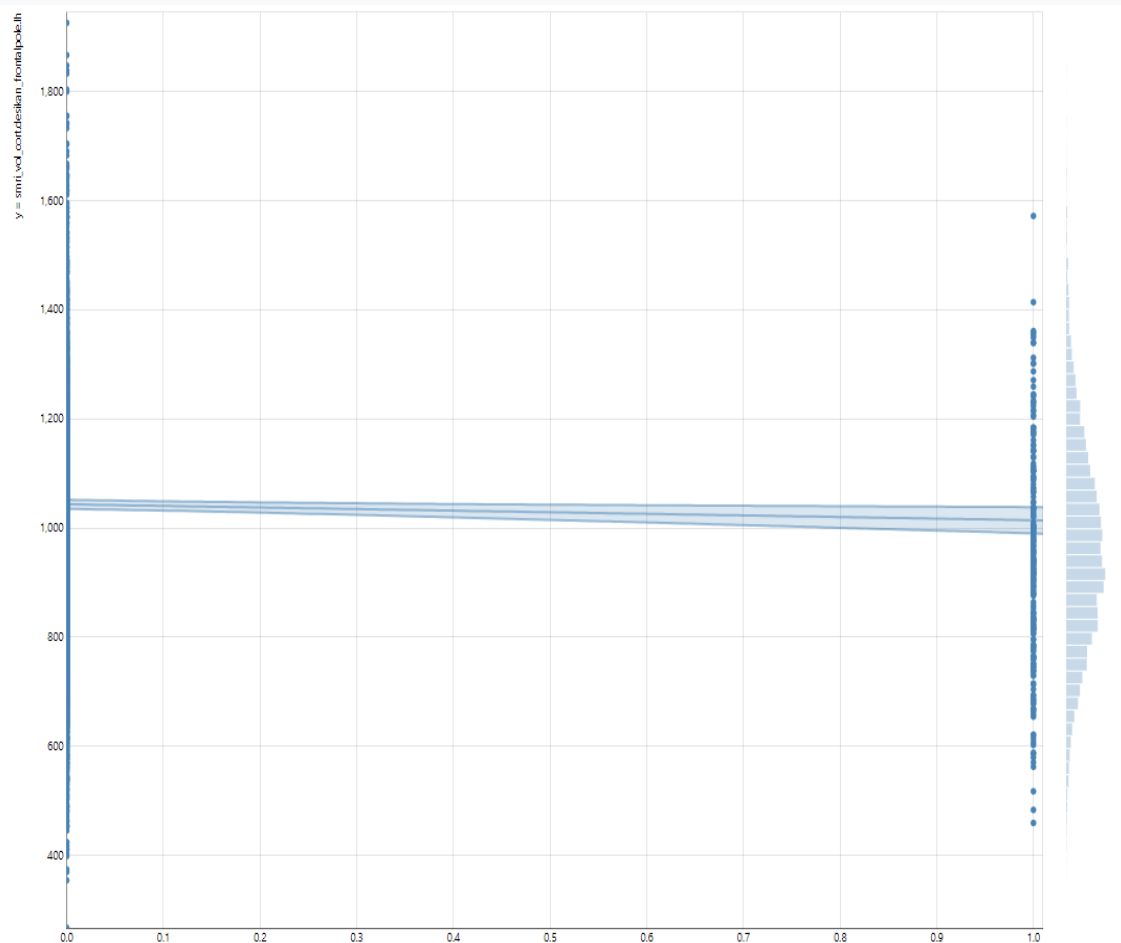


Figure 1. Association between Major Depressive Disorder (MDD) and Frontal Pole Volume Overall

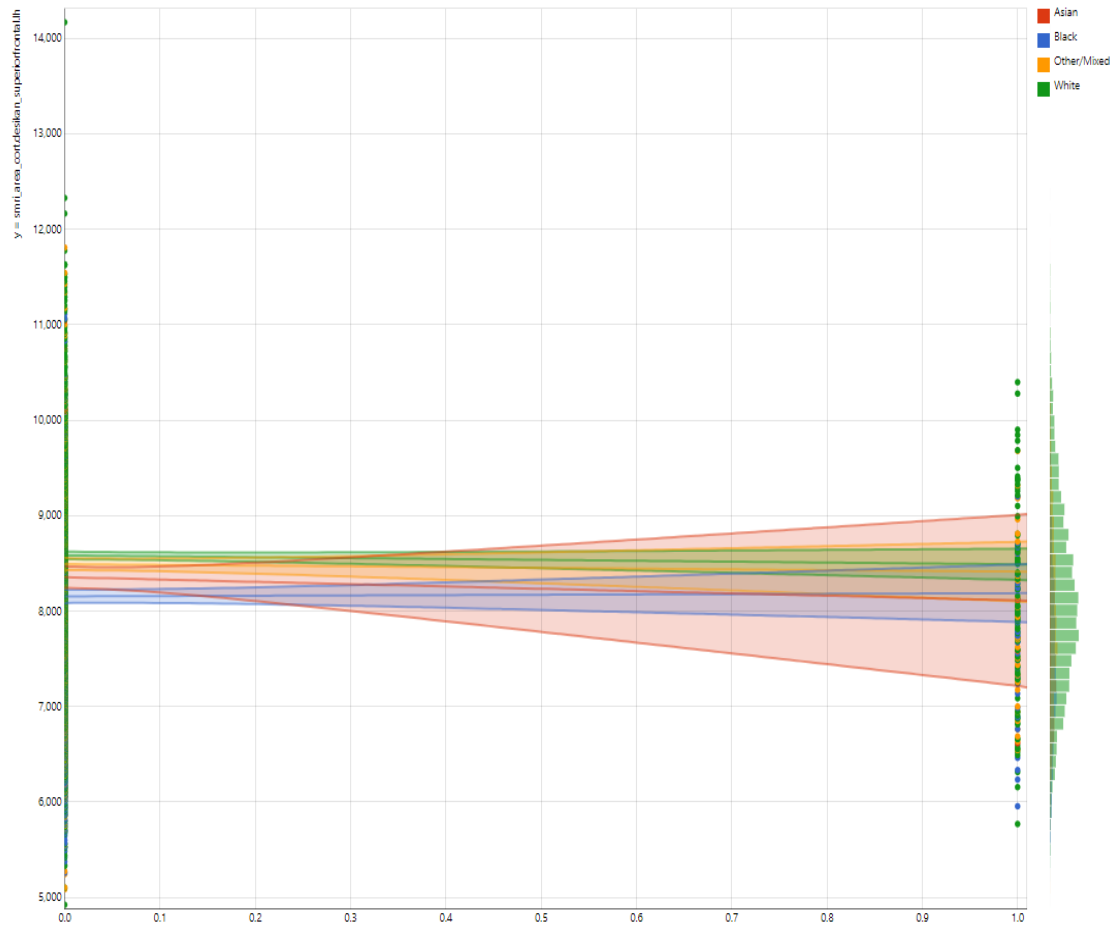


Figure 2. Association between Major Depressive Disorder (MDD) and Frontal Pole Volume by Child Race

4. Discussion

Our findings showed that current MDD is associated with a reduced frontal pole volume; however, the link between current MDD and frontal pole volume in American children depends on race. That is, the link between depression and frontal pole volume is more salient in Black than White children.

Past research has shown racial differences in correlates of depression in children, adults, and older adults (Assari, 2014, 2017b, 2017c, 2018b; S. Assari, Nikahd, Malekahmadi, Lankarani, & Zamanian, 2016; Carter & Assari, 2016; Lankarani & Assari, 2017; Watkins, Assari, & Johnson-Lawrence, 2015). For example, depression shows weaker SES correlates in Black than White families (Assari, 2017c, 2018b; Assari, Gibbons, & Simons, 2018; Assari, Nikahd, et al., 2016). There are also some studies showing a positive association between SES and depression in Black communities (Assari, 2017a, 2017c, 2020; Hudson, Bullard, et al., 2012; Hudson, Neighbors, Geronimus, & Jackson, 2012, 2016; Hudson, Puterman, Bibbins-Domingo, Matthews, & Adler, 2013).

Some research has shown that depression is associated with more depressive symptoms in Blacks than Whites (Assari, 2019; Assari & Moazen-Zadeh, 2016a, 2016b; Evans et al., 2019; Moazen-Zadeh &

Assari, 2016). Williams and colleagues have shown that depression is associated with a lower chance of treatment and more recent experience of depression in Black than White people (Williams et al., 2007). That means depression tends to be more chronic in Black than White people (Williams et al., 2007). This is in line with a worse treatment access and acceptability of Blacks than Whites (Ayalon, Arian, Linkins, Lynch, & Estes, 2007; Bailey, Blackmon, & Stevens, 2009; Nestor, Cheek, & Liu, 2016; Ward & Mengesha, 2013). Finally, the stigma is very high against depression in Black communities (Watkins, Abelson, & Jefferson, 2013).

Even more severe depression, which is associated with suicidality, shows differential correlates by race. In multiple studies, SES and race interact, with SES showing weaker effects on depression and associated suicide in Blacks than Whites. This means a diminished protective effect of SES indicators on depression and associated suicide in Black than White people, including adults and adolescents. As a result, Black middle class children remain at a high risk while middle-class White families show a lower risk (Assari, Boyce, Bazargan, & Caldwell, 2020). Many studies show racial variation in correlates of depression and associated suicide (Assari, 2015, 2018c, 2018d; Assari, Lankarani, & Lankarani, 2013; Assari, Moghani Lankarani, & Caldwell, 2017; Assari et al., 2019). Discrimination is a significant predictor of depression and associated suicide in Black (Assari et al., 2017) children and adults; however, the role of discrimination as a risk factor of psychopathology is smaller in Whites.

This study is not without methodological limitations. The first limitation is a cross sectional. We only measured current depression and did not include data on the history of depression, anxiety, and other psychiatric disorders. We also did not include data on the history of depression treatment, number of depressive episodes, severity of symptoms, or chronic stress. We also did not measure other factors such as supportive parenting and family context. The sample was not random as a result; we cannot generalize the results to all US children. However, we used the ABCD propensity score to maximize the comparability of racial groups and also the generalizability of results. Our sample size was also imbalanced, with the largest sample in White, and the smallest in Asian children. Despite the limitations listed above, our study is among the first to explore racial variation of the link between MDD and cortical morphometry. Another strength of this study was using a large national diverse sample of children.

Our result has implications for clinical practice as well as research regarding children's MDD. Researchers who study brain morphometric aspects of depression may not reduce race to a control variable. Race may have a direct effect, but also alters the correlates of PFC morphometry and depression. The results may help the tailor depression treatment or the diagnosis among racially diverse groups of children. PFC volume may differently reflect emotion regulation, affect, trauma, and depression in Black and White children. Similarly, MDD treatment response may be differently measured in terms of PFC volume change.

More research is needed on the heterogeneity of psychiatric diagnoses such as MDD and brain morphometry. It is still unknown why the MDD – PFC volume link is more prominent in Black than White children. This may be because depression tends to remain untreated and stress is more common in

Black than White communities, and Black children are not an exception to this rule. Thus, research should investigate whether severity and chronicity of MDD and access to treatment explains the observed difference in the MDD – PFC connections.

5. Conclusions

Racial groups of children differ in the magnitude of the link between current depression (MDD) and frontal pole volume. This means, considering that MDD shows a strong association with reduced frontal pole volume in Black children, depression is showing a weakened association with frontal pole volume in White children. The result is of interest as PFC morphometry in general and frontal pole volume in particular are believed to be linked to the outcomes of childhood depression.

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Appendix 1. Model Formula

Model 1

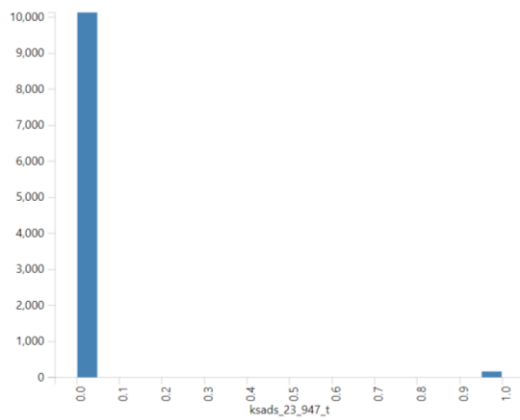
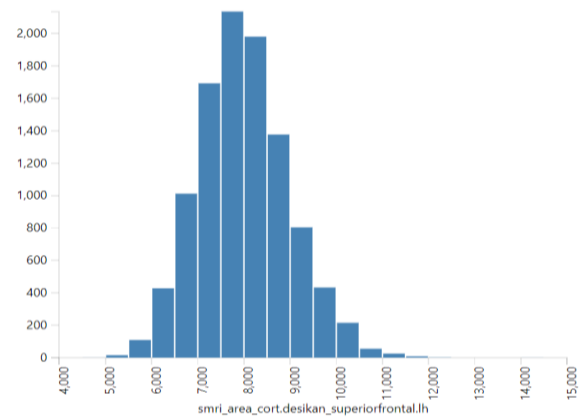
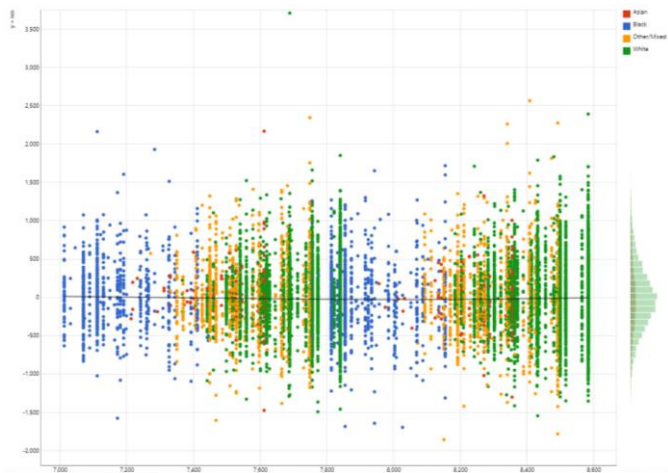
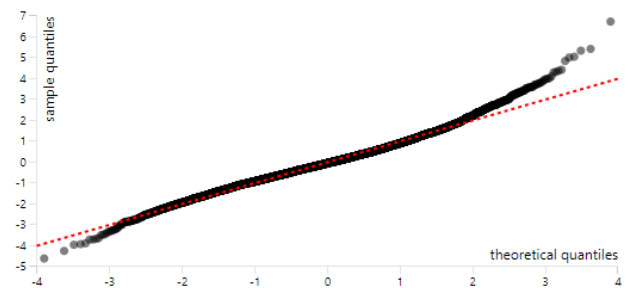
smri_vol_cort.desikan_frontalpole.lh ~ ksads_1_1_t + age + sex + high.educ.bl + household.income.bl + race.4level + married.bl + hisp

Random: ~(1|rel_family_id)

Model 2

smri_vol_cort.desikan_frontalpole.lh ~ ksads_1_1_t + age + sex + high.educ.bl + household.income.bl + race.4level + married.bl + hisp + ksads_1_1_t * race.4level

Random: ~(1|rel_family_id)

Appendix 2. Distribution of the Predictor (a), Outcome (b), Residuals (c) and Quantiles (d)**(a) predictor****(b) outcome****(c) residuals****(d) quantiles**