



Skin-deep Resilience and Early Adolescence: Neighborhood Disadvantage, Executive Functioning, and Pubertal Development in Minority Youth

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Abstract

Skin-deep resilience, in which youth overcome adversity and achieve success in psychological and academic domains but at a cost to their physiological well-being, has been documented in late adolescence and adulthood. However, its potential to emerge at earlier developmental stages is unknown. To address this gap, secondary data analyses were executed using waves 1 and 2 of the Adolescent Brain Cognitive Development study ($n = 7712$; ages 9–10 years at baseline [mean: 9.92; $SD = 0.63$]; 47.1% female; 66.1% White, 13.4% Black, and 20.6% Hispanic). The results indicated high levels of executive functioning were associated with improved psychological and behavioral outcomes at one-year follow-up. However, for racial and ethnic minority (i.e., Black or Hispanic) youth from disadvantaged neighborhoods, high levels of executive functioning were also associated with accelerated pubertal development. No significant interaction was observed among White youth. The findings suggest the skin-deep resilience pattern may be evident in early adolescence.

Keywords Adolescence · Race · Disadvantage · Puberty · Resilience

Introduction

In the last decade, findings related to skin-deep resilience have highlighted the hidden physiological toll that some minority youth experience in their efforts to overcome adversity and achieve success. To date, support for this phenomenon has been primarily documented in samples composed of individuals in late adolescence and early adulthood (for exception, see Ehrlich et al., 2023). Consequently, the potential for skin-deep resilience to emerge at earlier developmental stages is largely unknown. To help inform this gap in the literature, the current study examined associations among neighborhood disadvantage, executive functioning, and pubertal development from a nationwide sample of youth in early adolescence.

Compared to their White counterparts in the United States, racial and ethnic minority youth are more likely to experience numerous stressors that impinge on their development (Finkelstein et al., 2007; B. Miller & Taylor, 2012). Despite the hardships these youth encounter from stressors such as racial discrimination, neighborhood disadvantage, and socioeconomic risk, many racial and ethnic minority children demonstrate high levels of academic achievement and self-regulation as well as low levels of behavioral and emotional problems (Brody et al., 2012). These youth are commonly characterized as resilient, as they evince positive adaptation and have seemingly ‘beaten the odds’ despite the risks they encountered.

However, a growing literature has begun to question this thinking, suggesting that this resilience may only be “skin-deep” for disadvantaged minority youth. As a result, disadvantaged youth of color who achieve success by external metrics are also characterized by heightened allostatic load, a composite of risk factors for cardiometabolic disease (Brody et al., 2013). These patterns suggest a scenario where minority youth who demonstrate resilience in domains of academic achievement, psychological well-being, and behavioral health have not entirely avoided the consequences of adversity; as

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they go about beating the odds, the process exacts a toll on their allostatic systems.

In the last decade, numerous empirical studies have supported this skin-deep resilience phenomenon (for review, see Chen et al., 2022). For instance, youth of color from low-SES neighborhoods that attended college reported lower levels of substance use but also possessed higher levels of allostatic load compared to youth from low-income neighborhoods who did not make it to college and compared to those in college from high-income neighborhoods (Chen et al., 2015). In another study, individuals who demonstrated high levels of behavioral “striving” during adolescence had, at age 29, a higher likelihood of college graduation, greater personal income, and fewer symptoms of depression. However, among Black participants only, those high-striving adolescents raised in the most disadvantaged families also had a greater likelihood of developing type 2 diabetes (Brody, Yu, Miller, et al., 2016). A study of monozygotic twins subjected the skin-deep resilience notion to a more rigorous evaluation by controlling for genetic and familial influences. This study found that, among all twins, conscientiousness – a personality trait associated with striving, persistence, and economic mobility – was associated with higher educational attainment, fewer depressive symptoms, and less problematic alcohol use. However, among low-SES twin pairs, the twin with higher conscientiousness evinced more low-grade inflammation in adulthood relative to their (less conscientious) twin (Chen et al., 2020). Other studies have documented findings consistent with skin-deep resilience patterns with respect to outcomes of immune cell aging (G. E. Miller et al., 2015), metabolic syndrome (Duggan et al., 2019), and respiratory infection (G. E. Miller et al., 2016).

To date, however, nearly all of the findings on skin-deep resilience have originated from samples of individuals whose health outcomes were measured in late adolescence or adulthood (e.g., Brody et al., 2013; Duggan et al., 2019). Consequently, whether this phenomenon is evident at earlier developmental stages is largely (if not entirely) unknown. In essence, are seemingly ‘resilient’ youth, despite outward indicators of success, achieving this success at a cost to their long-term health in ways that are evident even in late childhood and early adolescence? Insights into this question can inform both developmental and health disparities literature by documenting how early in development this physiological wear-and-tear is occurring, and in response, potential early efforts to help mitigate such effects.

Answering such a question, however, is quite challenging as many of the aforementioned health indicators of skin-deep resilience (e.g., allostatic load, inflammation, chronic disease) lack substantial variability at earlier developmental stages. Consequently, to assess skin-deep resilience at younger ages, it is necessary to identify a physical health-related outcome that provides a clear marker of change occurring ‘beneath the skin’ at this developmental state. To that end, the current study

considers accelerated pubertal development as one possible outcome that could provide novel insights into skin-deep resilience among early adolescents. Rates of pubertal change exhibit meaningful and quantifiable differences among early adolescents, and earlier pubertal onset appears as an established risk factor for negative outcomes in multiple domains, including physical health (e.g., higher insulin levels, cardio-metabolic risk; Day et al., 2015).

Various factors have been identified to date as contributing to early pubertal timing, including strong evidence for the effect of harsh rearing environments associated with family and neighborhood disadvantage (Sun et al., 2017). Notably, both early pubertal timing as well as faster pubertal tempo stemming from these challenging environments are thought to result from the wear and tear on the developing child’s stress response systems (Joos et al., 2018), a similar process hypothesized to underlie the skin-deep resilience pattern and its outcomes such as allostatic load and cellular aging (Brody, Yu, & Beach, 2016). Thus, as scholars have observed, earlier pubertal timing and faster pubertal tempo may each be a manifestation of a more general acceleration of aging, with alterations in the developing hypothalamic-pituitary-adrenal (HPA) axis providing a mechanism through which stressful life events operate to influence earlier puberty as well as cellular aging (Joos et al., 2018). In light of this conceptual overlap, accelerated pubertal development may be a sensitive outcome for evaluating the skin-deep resilience pattern among pre- and early adolescent youth living in more disadvantaged neighborhoods.

This divergence between mental and physical health outcomes occurs in minority youth who possess high levels of self-regulation, determination, and persistence. Previous studies focused on skin-deep resilience have operationalized this construct using various indices including self-control (Brody et al., 2013), conscientiousness (Duggan et al., 2019), and striving (Brody, Yu, Miller, et al., 2016). Theoretically, all of these constructs (which commonly are assessed via self-report surveys) are founded upon executive functioning (e.g., Forbes et al., 2014) which relies on a network of brain regions including the prefrontal cortex (PFC) of the brain (Menon & D’Esposito, 2022). Executive functioning, in brief, describes a set of higher-order processes that contribute to the regulation of cognition in relation to planning, problem-solving, and goal-directed actions (Diamond, 2013);¹ all of these actions are common tenets associated with ‘striving’ youth that appear with skin-

¹ In the child development literature, there is a well-established pathway among maturation over time, increased executive functioning, and more complex cognitive coping and emotion regulation. Rather than attempting to further elucidate this developmental pathway, executive functioning was examined in the current study as a means to identify a behaviorally-assessed neurocognitive construct with phenotypic expressions of high self-regulation and persistence.

deep resilience. Prior research also indicates executive functioning to be a key contributor to academic success among lower SES, racial minority youth (Nesbitt et al., 2013).

Executive functioning can be assessed using various neuropsychological tests known to activate PFC brain regions involved in such functions (Luciana et al., 2018). Neuropsychological testing is a more direct assessment of executive function that advantageously eliminates sources of potential measurement error in self-report surveys such as response bias (Paulhus, 1991). With the vast majority of skin-deep resilience studies having employed self-report measures, the current study was designed to extend research by providing one of the first studies to employ executive functioning derived from neuropsychological testing as an underlying indicator of individuals' conscientiousness and self-control.

Current Study

Although the skin-deep resilience has been well-documented in late adolescence, little research has examined whether this phenomenon is evident among disadvantaged youth of color at an earlier developmental stage (i.e., early adolescence). To this end, this current study investigated the associations between neighborhood disadvantage, executive functioning, and accelerated pubertal development from a nationwide sample of youth in early adolescence. It was hypothesized that high levels of executive functioning in racial and ethnic minority youth would promote psychological and behavioral well-being (i.e., less rule breaking behaviors, social problems, conduct disorder, and depressive symptoms) over a one-year period. Although advantageous for psychological and behavioral outcomes, it was also hypothesized that high levels of executive functioning would be associated with accelerated pubertal development for youth residing in more disadvantaged neighborhoods. For White youth, no interaction between neighborhood disadvantage and executive functioning for accelerated pubertal development was expected. Main effects of executive functioning and neighborhood disadvantage for psychological and behavioral outcomes were still hypothesized to appear for White youth.

Methods

Participants & Procedures

Participants in the current study originate from the ongoing ABCD study, which recruited approximately 11,000 youth and their parents/guardians across 21 sites in the United

States (Garavan et al., 2018; Volkow et al., 2018). Pre-adolescents (ages 9–10 years) were recruited using a stratified probability sampling of elementary schools at the recruitment sites to approximate the variation in age, sex, ethnicity, socioeconomic status (household income), and urbanicity of the United States and to minimize systematic bias in sampling. A total of 21 different research centers distributed throughout the nation served as data collection sites. Youth were recruited by materials sent to homes of 3rd, 4th, and/or 5th grade students distributed through lists provided by public and private schools. Interested families completed a brief telephone screening, and eligible families were enrolled. Data collected activities occurred at ABCD research centers. More detailed descriptions of the motivation for the ABCD Study (Volkow et al., 2018) and its recruitment and sampling procedures (Garavan et al., 2018) are described elsewhere.

The current study includes baseline (9–10 years old) and 1-year follow-up assessment time points of the ABCD Study. Data are drawn from NIMH Data Archive release 4.0 of the ABCD Study. The final sample size in the current study was 7712 participants (47.1% female; 66.1% White, 13.4% Black, and 20.6% Hispanic), which represented all individuals with no missing data on study variables and that were not multiracial (see Supplemental Table 1 for comparisons of those included in the analyzed sample and those excluded). Median household income was between \$75,000–\$99,999 (with 7.8% reporting less than \$15,999 and 11.7% reporting \$200,000 or more). The vast majority (97%) were born in the United States. Parental consent and child assent were obtained from all participants and approved by institutional review boards at each data collection site.

Measures

Accelerated pubertal development

Accelerated pubertal development was assessed with the 5-item Pubertal Development Scale (PDS) completed by the youth and their parent/guardian at baseline and the one-year follow-up. The scale includes three gender-general items (i.e., growth spurt, changes in skin, hair growth) and two gender-specific items (e.g., facial hair growth, voice change [boys]; breast development, menarche [girls]). Response options range from 1 (*no development*) to 4 (*development already completed*). Mean scores for each individual were computed. Parent and youth scores ($r = 0.43$ [baseline] and 0.65 [1 year follow-up], both $p < 0.001$) were then averaged, in line with existing practices in the literature (Owens et al., 2021; Petrican et al., 2021). At each wave, an index of accelerated pubertal development was computed by regressing PDS score onto chronological age in years of the

youth. Thus, a positive residual score indicated accelerated biological aging relative to chronological age (Colich et al., 2020; Petrican et al., 2021; Sumner et al., 2019). Cronbach's alpha was 0.73 (baseline) and 0.82 (year 1 follow-up).

Psychological and behavioral outcomes

Youth outcomes in psychological and behavioral domains were assessed at baseline and one-year follow-up from parent reports of four subscales of the Child Behavior Checklist (CBCL) (Achenbach & Edelbrock, 1991). These four subscales assessed the following domains: rule breaking behaviors (17 items; e.g., lying or cheating; steals at home or outside home), social problems (11 items; e.g., clings to adults or too dependent; complains of loneliness), conduct disorder (17 items; e.g., gets in many fights; threatens people), and depressive symptoms (13 items; e.g., there is very little they enjoy; feels worthless or inferior). All the CBCL subscales were log-transformed given their skewed distribution.

Neighborhood disadvantage

Neighborhood socioeconomic disadvantage was determined using the neighborhood area deprivation index (ADI) (Singh, 2003) using the family home address (and associated census tract) provided at baseline assessment. The neighborhood ADI uses data from 17 factors in areas such as employment (e.g., percentage of employed persons >16 years old in white collar occupations), income (e.g., percentage of families below the poverty level), education (percentage of population >25 years old with <9 years of education), and housing equality housing equality (e.g., median home value, percentage of owner-occupied housing units). The ADI calculates a ranking of neighborhood by socioeconomic disadvantage as a national percentile (Kind et al., 2014; Singh, 2003). Higher values indicate greater neighborhood disadvantage.

Executive functioning

Youth executive functioning score at baseline was computed by summing scores across four executive function tasks in the National Institute of Health Toolbox (NIHTBX). The four tasks (and the domains they target) were: Flanker (Cognitive Control/Attention), List Sorting Working Memory Test (Working Memory; Categorization; Information Processing), Dimensional Change Card Sort (Flexible thinking; concept formation; set shifting), and Pattern Comparison Processing Speed (Processing Speed; Information Processing). Cronbach's alpha was 0.65. Detailed information about each of these tasks, how each

task was executed, and how scores were recorded has been summarized in other ABCD publications (Luciana et al., 2018).

Family SES risk index

Family socioeconomic status was included as a control variable given prior research emphasizing its inclusion in research examining neighborhood effects on pubertal development (Sun et al., 2017) and neighborhood effects on skin-deep resilience (Chen et al., 2015). An index of family socioeconomic risk was computed using four dichotomized indicators provided by the parent at baseline. A score of 1 was assigned to each of the following: family poverty status, highest parent education less than high school graduate, single-parent status, and both parents' unemployment status. Items were summed such that higher scores indicated greater family SES risk, similar to other research (Brody et al., 2014).

Plan of Analysis

Analyses were conducted in two stages. The first set of analyses sought to confirm the predictive utility of the executive functioning composite for change in 'above the skin' outcomes in racial minority youth. For this, the study examined whether executive functioning was associated with improvements in psychological and behavioral outcomes over a one-year period among early adolescents.

The second set of analyses focused on testing the skin-deep resilience hypothesis. This model tested main effects of neighborhood disadvantage and executive functioning (both terms standardized) as well as the two-way interaction term of neighborhood disadvantage \times executive functioning for the pubertal development index at one-year follow-up. Covariates included baseline pubertal development index, gender, and family SES risk index. Separate regression models were run for Black or Hispanic youth and for White youth, consistent with prior research (Chen et al., 2020). Significant interactions were plotted at ± 1 Standard Deviation (SD) of neighborhood disadvantage and executive functioning. To provide additional detail into skin-deep resilience among this population, exploratory analyses were conducted to investigate (a) the moderating role of gender via a three-way interaction and (b) results for Non-Hispanic Black youth and Hispanic youth separately.

All the analyses were run in SPSS (version 25), using generalized estimating equation with robust standard errors. Family was specified as a clustering variable to account for nonindependence of observations among parents and children nested within families.

Table 1 Descriptive Statistics and Comparison between Non-Hispanic White sample and Black and Hispanic samples

Characteristics	Entire sample (<i>N</i> = 7712)	Subsample comparison		<i>p</i> -value ^a
	<i>n</i> (%) or Mean (<i>SD</i>)	Non-Hispanic White (<i>N</i> = 5096)	Black and Hispanic (<i>N</i> = 2616)	
Male	4079 (52.9%)	2731 (53.6%)	1348 (51.5%)	0.087
Age, months	119.00 (7.51)	119.17 (7.56)	118.68 (7.38)	0.006
Family SES risk index	0.42 (0.72)	0.21 (0.49)	0.83 (0.90)	<0.001
Neighborhood ADI	38.76 (25.73)	32.66 (21.25)	50.66 (29.29)	<0.001
NIHTBX executive function	373.32 (31.22)	378.34 (28.86)	363.53 (33.27)	<0.001
Pubertal development index	−0.08 (2.13)	−0.47 (1.85)	0.70 (2.41)	<0.001
Pubertal development index (Year 1)	−0.07 (257)	−0.49 (2.41)	0.75 (2.69)	<0.001

All measures reported at baseline unless noted. Pubertal development index values at baseline ranged from 1 to 19 (of a potential scale range of 1 to 20), with a mean of 8.85 and median value of 8.50. ^a*p*-value determined from *T*-test for continuous and ordinal variables; chi-square cross-tab for binary variables

Results

Descriptive Statistics and Racial Comparisons

Table 1 presents descriptive statistics and racial differences in study variables (see Supplemental Table 2 for correlations). Racial differences were evident in multiple variables, with mean values indicating that Black or Hispanic youth had higher levels of family SES risk, greater neighborhood disadvantage, and lower levels of executive functioning, compared to non-Hispanic White youth. Black or Hispanic youth reported more pubertal development compared to White youth at baseline and one-year follow-up.

Executive Functioning and Change in Psychological and Behavioral Outcomes

Direct effects of executive functioning on changes in racial minority youth' psychological and behavioral outcomes are reported in Table 2. Results indicated that racial minority youth with higher levels of executive functioning at baseline reported decreased rule breaking behaviors ($b = -0.01$; 95% CI $[-0.019, -0.000]$, $p = 0.044$), social problems ($b = -0.01$; 95% CI $[-0.023, -0.003]$, $p = 0.013$), and conduct disorder at a one-year follow-up ($b = -0.01$; 95% CI $[-0.022, -0.003]$, $p = 0.010$). Thus, executive functioning was associated with positive development across a range of behavioral outcomes for racial and ethnic minority youth. With the exception of predictors for conduct disorder, few other covariates included in the models demonstrated significant effects on psychological and behavioral outcomes.

The right portion of Table 2 contains results for similar models involving White youth. Executive functioning at baseline was associated with lower levels of conduct

problems; no significant effects appeared for executive functioning predicting change in the other three behavioral outcomes under investigation.

Accelerated Pubertal Development Status and the Skin-Deep Resilience Hypothesis

The second set of analyses examined the skin-deep resilience hypothesis – that accelerated pubertal development at one-year follow-up would be most evident in youth from disadvantaged neighborhoods with high levels of executive functioning. Table 3 presents the results for these analyses. For main effects, neighborhood disadvantage and being female were positively associated with accelerated pubertal development in both groups; family SES risk index was also associated with accelerated pubertal development among White youth. Concerning the moderation effects of focal interest in this study, a significant interaction between neighborhood disadvantage and executive functioning appeared for analyses involving Black or Hispanic youth ($b = 0.131$, 95 % CI $[0.050, 0.211]$, $p = 0.001$). This interaction, however, was not significant for analyses involving the sample of White youth.²

² The three-way interaction of Neighborhood ADI × NIHTBX executive functioning × Black/Hispanic predicting accelerated pubertal development was significant ($b = 0.117$, $p = 0.013$), further supporting the ethnic/racial differences examined in this model. In addition, the interaction of Neighborhood ADI × NIHTBX executive functioning retained statistical significant even after controlling for family conflict (as reported by parents and by child). Models testing the interaction of family conflict × NIHTBX executive functioning and of family SES risk × NIHTBX executive functioning for pubertal development were not significant (interaction involving family conflict parent report: $b = 0.043$, $p = 0.28$; family conflict youth report: $b = 0.007$, $p = 0.86$; and family SES risk: $b = 0.043$, $p = 0.30$).

Table 2 Neighborhood Area Deprivation Index (ADI) and NIH Tool Box Executive Function (NIHTBX) with CBCL Outcomes

Predictors (baseline)	Black or Hispanic Youth				White Youth			
	Rule Breaking Behaviors (Year 1 Follow-Up)		Social Problems (Year 1 Follow-Up)		Rule Breaking Behaviors (Year 1 Follow-Up)		Social Problems (Year 1 Follow-Up)	
	<i>b</i>	[95% CI]	<i>b</i>	[95% CI]	<i>b</i>	[95% CI]	<i>b</i>	[95% CI]
1. Sex, male	0.028**	[0.011, 0.046]	−0.003	[−0.021, 0.015]	0.028***	[0.017, 0.039]	−0.001	[−0.013, 0.011]
2. Age	0.009*	[0.000, 0.018]	−0.001	[−0.011, 0.008]	0.001	[−0.005, 0.007]	−0.006	[−0.012, 0.000]
3. CBCL variable ^a	0.176***	[0.167, 0.185]	0.191***	[0.182, 0.200]	0.161***	[0.154, 0.167]	0.191***	[0.185, 0.198]
4. Family SES risk index	0.009	[0.000, 0.018]	0.002	[−0.008, 0.012]	0.020***	[0.013, 0.026]	0.015***	[0.008, 0.022]
5. Neighborhood ADI	0.009	[0.000, 0.018]	0.000	[−0.010, 0.010]	0.006*	[0.000, 0.012]	−0.000	[−0.006, 0.006]
6. NIHTBX exec. function	−0.009*	[−0.019, −0.000]	−0.013*	[−0.023, −0.003]	−0.002	[−0.008, 0.004]	−0.008*	[−0.015, −0.001]

Predictors	Conduct Disorder (Year 1 Follow-Up)		Depressive Symptoms (Year 1 Follow-Up)		Conduct Disorder (Year 1 Follow-up)		Depressive Symptoms (Year 1 Follow-Up)	
	<i>b</i>	[95% CI]	<i>b</i>	[95% CI]	<i>b</i>	[95% CI]	<i>b</i>	[95% CI]
	1. Sex, male	0.024**	[0.006, 0.041]	0.001	[−0.018, 0.020]	0.022***	[0.011, 0.034]	0.015*
2. Age	0.014**	[0.006, 0.023]	0.005	[−0.005, 0.014]	0.001	[−0.004, 0.007]	−0.003	[−0.010, 0.004]
3. CBCL variable	0.195***	[0.185, 0.205]	0.179***	[0.169, 0.189]	0.181***	[0.174, 0.188]	0.184***	[0.177, 0.190]
4. Family SES risk index	0.010*	[0.001, 0.019]	0.001	[−0.009, 0.011]	0.021***	[0.014, 0.027]	0.012**	[0.004, 0.019]
5. Neighborhood ADI	0.010*	[0.000, 0.020]	−0.006	[−0.016, 0.004]	0.005	[−0.001, 0.011]	0.008*	[0.002, 0.015]
6. NIHTBX exec. function	−0.013*	[−0.022, −0.003]	−0.004	[−0.014, 0.006]	−0.003	[−0.010, 0.003]	−0.001	[−0.008, 0.006]

N = 2612; *b* = unstandardized regression coefficient; CI = confidence interval. ^a The same CBCL variable is utilized at baseline (as a predictor) as the CBCL variable at Year 1; i.e., for rule breaking behaviors, the predictor is baseline rule breaking behaviors

p* < 0.05. *p* < 0.01. ****p* < 0.001

To more clearly interpret this significant interaction found in Black or Hispanic youth, the association between neighborhood disadvantage and accelerated pubertal development was plotted at low and high levels of executive functioning. These results, depicted in Fig. 1, were consistent with the skin-deep resilience pattern. Thus, for Black or Hispanic participants with higher executive functioning, residing in a more disadvantaged neighborhoods was associated with a greater likelihood of accelerated pubertal development (simple slope: $b = 0.29$, $SE = 0.06$, $p < 0.001$). For racial minority youth with low levels of executive functioning, neighborhood disadvantage was not associated with elevated risk for accelerated pubertal development (simple slope: $b = 0.03$, $SE = 0.06$, $p = 0.64$). Thus, the results support the skin-deep resilience pattern in which accelerated pubertal development was most evident among Black or Hispanic youth who lived in disadvantaged neighborhoods and possessed high levels of executive functioning.

Exploratory analyses examining the moderating effect of gender for this skin-deep resilience pattern were not significant for the Black or Hispanic sample ($b = 0.122$, $p = 0.139$) or the White sample ($b = 0.065$, $p = 0.194$). Additional exploratory analyses that disaggregated data for

Black youth and for Hispanic youth indicated findings that continued to trend in similar directions for both groups (See Supplemental Tables 3–5). With respect to statistical significance, a significant neighborhood disadvantage \times executive functioning interaction predicting pubertal development was observed with Black ($b = 0.205$, $p = 0.002$) but not Hispanic ($b = 0.072$, $p = 0.175$) youth. In addition, for Hispanic youth, executive functioning was found to significantly predict social problems ($b = -0.016$, $p = 0.012$) and conduct disorder ($b = -0.013$, $p = 0.035$); no main effects of executive functioning were observed with Black youth psychological and behavioral outcomes.

Discussion

The skin-deep resilience phenomenon has substantial implications for child development and efforts to promote well-being – both psychologically and physiologically – for disadvantaged youth. This phenomenon has been well-documented in late adolescence, but much less is known regarding whether it is evident at earlier developmental stages. From a diverse sample of 7712 youth participating in the ABCD study, findings from the current study

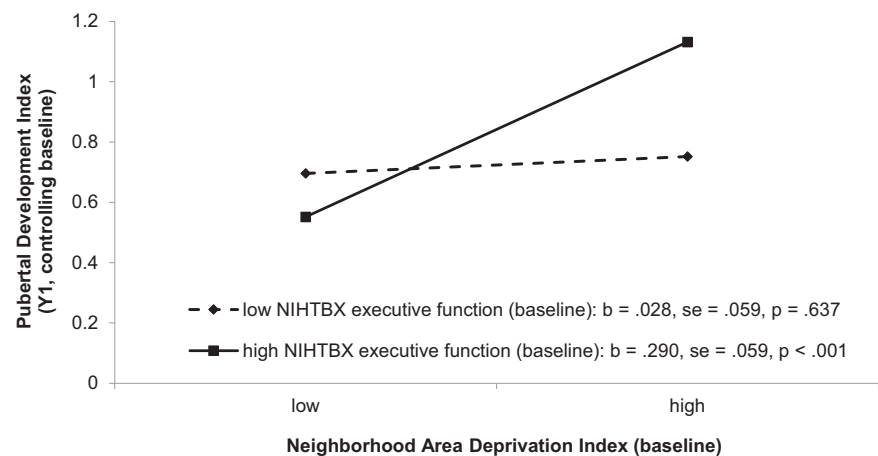
Table 3 Interactions of Neighborhood Area Deprivation Index (ADI) and NIH Tool Box Executive Function (NIHTBX) with Pubertal Development Index

Predictors	Pubertal Development Index (Year 1 Follow-Up)			
	Black & Hispanic (<i>N</i> = 2616)		White (<i>N</i> = 5096)	
	<i>b</i>	[95% CI]	<i>b</i>	[95% CI]
1. Sex, male	−1.318***	[−1.478, −1.159]	−1.270***	[−1.365, −1.175]
2. Pubertal development index (baseline)	1.488***	[1.400, 1.576]	1.458***	[1.407, 1.508]
3. Family SES risk index (baseline)	−0.029	[−0.112, 0.054]	0.051*	[0.001, 0.102]
4. Neighborhood ADI (baseline)	0.159***	[0.076, 0.243]	0.067**	[0.018, 0.116]
5. NIHTBX executive function (baseline)	0.059	[−0.021, 0.138]	−0.041	[−0.086, 0.005]
6. Neighborhood ADI × NIHTBX executive function	0.131**	[0.050, 0.211]	−0.005	[−0.053, 0.043]

b = unstandardized regression coefficient; CI = confidence interval

p* < 0.05. *p* < 0.01. ****p* < 0.001

Fig. 1 Pubertal development as a function of neighborhood disadvantage and executive functioning among Black and Hispanic youth (*N* = 2,616)



provided support for the skin-deep resilience pattern in early adolescence.

Consistent with prior research with youth of color (Johnson et al., 2022; Sulik et al., 2015), executive functioning was prospectively associated with positive ‘outward’ adjustment (e.g., reduced rule breaking, conduct disorder) at one-year follow-up. However, among youth of color growing up in disadvantaged neighborhoods, those youth with higher levels of executive functioning showed accelerated pubertal development over the same one-year time period. This divergence between outcomes suggests the possibility that high levels of executive functioning, although beneficial for behavioral outcomes, has unanticipated consequences of pubertal development of youth at the onset of adolescence.

The resilience literature is replete with studies that emphasize high levels of planful self-regulation and self-control as a key characteristic of youth who demonstrate resilience in academic and behavioral domains (Nesbitt et al., 2013; Sulik et al., 2015). However, current findings and other skin-deep resilience studies provide an important qualification to this literature by highlighting the unique

interaction between socioeconomic disadvantage and high self-regulation in ways that forecast worsened physical health outcomes for youth of color (Brody et al., 2013; Chen et al., 2022). Current findings highlight how this pattern can emerge even when using neuropsychological testing as a means to measure self-regulation (in the form of executive functioning), a measurement approach few, if any, prior studies of skin-deep resilience have utilized.

These findings contribute new insights for the literature on skin-deep resilience as well as broader health disparities. Prior research indicates that youth of color who develop skin-deep resilience are characterized by elevated levels of glucocorticoids and catecholamines, hormonal end products that results from frequent activation of the stress response system (Brody et al., 2013; Chen et al., 2015). Developmental scholars have also suggested that earlier pubertal maturation may be indicative of a more general acceleration of aging (Joos et al., 2018), an acceleration that is thought to occur in part from wear and tear on the same stress response system. Current study findings are consistent with both literatures, documenting the heightened risk for accelerated pubertal development among youth of color that live in

disadvantaged neighborhoods and exhibit high levels of executive functioning, a precursor of planful, self-regulated behavior.

The skin-deep resilience pattern in the current study was observed for Black or Hispanic youth, but not White youth. This finding is consistent with the majority of research to date on this topic that has documented the skin-deep resilience pattern in samples of Black youth only (Brody, Yu, Miller, et al., 2016; G. E. Miller et al., 2016) or in samples of Black, Hispanic, and White in which significant interaction effects appear for Black and Hispanic, but not White, youth (Gaydosh et al., 2018). That said, some studies have observed worse health outcomes for all individuals of lower socioeconomic status, regardless of race (Chen et al., 2020; G. E. Miller et al., 2020), suggesting a complexity to the interactions among race, disadvantage, and self-control in predicting health outcomes. Consistent with this noted complexity, findings from exploratory analyses indicated some differences in statistical significance with disaggregated data for Black and Hispanic youth. Prior research with older samples (spanning adolescence and young adulthood) that separately analyzed Black and Hispanic samples found evidence for skin-deep resilience in each group (Gaydosh et al., 2018), lending support for general trend in findings observed in the current study and its younger sample. The current results, as well as those of prior findings, highlight how marginalized youth of color, although possessing certain similarities, are by no means monolithic, with unique histories, current experiences of hardship, and differential exposure to risk factors (e.g., neighborhood disadvantage) that influence the nature and means by which the skin-deep phenomenon may appear in youth of color across developmental stages. As others have noted, continued research at the intersection of social class and race/ethnicity is needed for skin-deep resilience (Chen et al., 2022).

Study findings emphasize the importance of considering ways to support high-achieving minority youth from disadvantaged neighborhoods in ways that foster their development above and beneath the skin. In addition to screening for early indicators of skin-deep resilience and accelerated aging in medical settings, programmatic and clinical work with these youth may need to ensure a focus that extends beyond developing youth's capacity for self-regulation, planning, and grit. Providing strong family support for these youth, well-known to promote academic and behavioral well-being, may also prove beneficial for youth's physical health (Brody, Yu, Chen, et al., 2016).

Various limitations of the study merit consideration. First, because families began the study when youth were ages 9–10, it was not possible to examine the extent to which stressors at even earlier developmental stages may contribute findings. Second, neighborhood disadvantage is a multi-faceted construct, and further research could benefit from considering

both subjective assessments of neighborhood conditions and more precise objective assessments apart from census tracts (whose boundaries are somewhat arbitrary and may not align with how individuals define their neighborhood). Third, accelerated pubertal development provides one potential indicator of the physiological cost associated with skin-deep resilience but lacks direct clinical health endpoints at older ages. Future research to identify other markers of biological weathering with meaningful variability in early adolescence remains needed (see Ehrlich et al., 2023 for example). Fourth, the time period of early adolescence represents a period of pronounced growth and change cognitively, biologically, and socially. Consequently, the interplay between constructs such as executive functioning, pubertal development, and social behavior are complex and not mutually exclusive. The current study is one attempt to consider this complexity and posit one means of their associations for youth from different racial and ethnic groups.

Conclusion

The phenomenon of skin-deep resilience, well-documented in late adolescence, remains less understood in earlier developmental stages despite its significant implications for the psychological and physiological well-being of minority youth. Results from the current study indicate that youth of color (i.e., Black or Hispanic) from disadvantaged backgrounds with high levels of executive functioning fare well in behavioral domains in early adolescence. However, the opposite pattern appeared for their physical health, as evidenced by accelerated pubertal development. Thus, for these youth, maintaining high levels of executive functioning, a precursor of self-regulated behavior, may act as a “double-edged sword,” facilitating behavioral adjustment while undermining physical health.

Data Availability

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 NIH or ABCD consortium investigators. The datasets generated and/or analyzed during the current study are available in the ABCD Data Repository, <https://nda.nih.gov/abcd/>.

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Authors' Contributions A.B. participated in the design of the study and drafted the manuscript; T.Y. performed the data analyses and participated in the interpretation of the data; Q.G. helped to draft the

manuscript; E.C. participated in the interpretation of the data and helped to draft the manuscript; G.M. participated in the interpretation of the data and helped to draft the manuscript; G.B. conceived the study and participated in the design of the study and interpretation of the data. All authors read and approved the final manuscript.

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Compliance with Ethical Standards

Conflict of Interest The authors declare no competing interests.

Ethical Approval Centralized institutional review board approval was obtained from the University of California, San Diego.

Informed Consent Written informed consent and assent were obtained from the parent/guardian and the child, respectively, to participate in the ABCD study.

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