Associations between an educational attainment polygenic score with educational attainment in an African American sample

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Abstract

Polygenic propensity for educational attainment has been associated with higher education attendance, academic achievement and criminal offending in predominantly European samples; however, less is known about whether this polygenic propensity is associated with these outcomes among African Americans. Using an educational attainment polygenic score (EA PGS), the present study examined whether this score was associated with post-secondary education, academic achievement and criminal offending in an urban, African American sample. Three cohorts of participants (N = 1050; 43.9% male) were initially recruited for an elementary school-based universal prevention trial in a Mid-Atlantic city and followed into young adulthood. Standardized tests of reading and math achievement were administered in first grade. At age 20, participants reported on their level of education attained, and records of incarceration were obtained from Maryland's Criminal Justice Information System. In young adulthood, DNA was collected and extracted from blood or buccal swabs and genotyped. An EA PGS was created using results from a large-scale genome-wide association study on educational attainment. A higher EA PGS was associated with a greater log odds of post-secondary education. The EA PGS was not associated with reading achievement, although a significant relationship was found with math achievement in the third cohort. These findings contribute to the dearth of molecular genetics work conducted in African American samples and highlight that polygenic propensity for educational attainment is associated with higher education attendance.

Keywords

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1 | INTRODUCTION

Substantial advances in molecular genetics technology and increased sample sizes have allowed researchers to examine polygenic contributions to phenotypes, correlates and outcomes associated with educational attainment (ie, number of years of schooling).[1] However, most of the research in this area has included individuals of European descent, although there are a few exceptions.[2–4] This is a significant issue as it is unclear whether and to what extent findings from genome-wide association studies (GWAS) involving individuals of European ancestry apply to individuals of different ancestral backgrounds given differences in allele frequencies and linkage disequilibrium (LD) structure across ancestry groups.[5]

In light of the limited study of genetic influences on educational attainment in African American samples, the primary question we sought to address in the present study was whether an educational attainment polygenic score (EA PGS) derived from a GWAS of individuals of European ancestry is associated with higher education status in an African American sample. The second question we explored was whether the relationship between polygenic propensity for educational attainment is associated with academic achievement and criminal offending. Our third question centered on whether sex differences exist in the relationship between polygenic propensity for educational attainment and the outcomes described above.

1.1 | Educational attainment polygenic propensity and associations with higher education

In samples of predominantly European descent, higher polygenic propensity for educational attainment is positively associated with higher education attendance.[6–8] Individuals with a higher polygenic propensity for educational attainment may be more likely to seek out challenging academic endeavors which may promote their learning and academic options, possibly because they possess greater cognitive faculties and/or have a greater motivation to academically excel.[9] As such, these individuals may have greater scholastic aspirations and be more likely to seek out educational opportunities beyond high school. Across studies, the variance accounted for by polygenic contributions for educational attainment and higher education has ranged from 2% to 13%.[2,4,10] Variability in the variance accounted for by the EA PGS across studies may be due to differences in the sizes of the discovery samples, with smaller discovery samples yielding less robust effect sizes.

The association between polygenic propensity for educational attainment and higher education is often reduced in admixed populations such as African Americans. For example, in a large-scale GWAS conducted by Lee et al,[4] an EA PGS accounted for 11% to 13% of the variance in years of schooling among European descent individuals compared with 1.6% of the variance among socioeconomically diverse individuals of African descent (net attenuation ~85%). Other work conducted by Belsky et al[2] found that an EA PGS accounted for a similar level of variance in educational attainment among individuals of European heritage, with a significant reduction in the variance accounted for among individuals of African heritage with diverse socioeconomic standing. Although these studies suggest that

polygenic contributions to educational attainment and post-secondary education status are reduced when considering socioeconomically diverse African American populations, it is unclear whether these findings would apply to a low-income, African American sample. Environmental experiences such as poverty, racial discrimination and attending under-resourced schools may influence whether genetic propensity for educational attainment confers benefits for achievement and college attendance[11,12]; thus, an examination of these relationships is warranted.

1.2 | Educational attainment polygenic propensity and associations with achievement

Polygenic propensity for educational attainment may also relate to academic achievement (ie, standardized test performance or grades), although there is a paucity of work in this area relative to research linking polygenic load for educational attainment to higher education status. Greater polygenic propensity for educational attainment has been linked to a number of cognitive, behavioral and emotional characteristics including higher cognitive aptitude, self-control, and interpersonal skills in childhood (ie, communication and cooperativeness), which may increase the likelihood of individuals performing well academically.[6] Individuals with these qualities may also exhibit higher levels of academic self-efficacy and be better equipped to excel when faced with academic challenges in an educational setting.

GWAS that have examined associations between polygenic propensity for educational attainment and academic achievement (eg, standardized test performance) in samples of European ancestry have showed significant variability in the variance accounted for by these genetic contributions, which have ranged from 2% to 9%.[6,7] Consistent with the variability observed in the effect sizes of higher education, a number of factors such as sample size and measurement of academic achievement may contribute to inconsistent findings across studies. While some studies have found positive associations between polygenic propensity for educational attainment and academic achievement among individuals of European ancestry, no studies to our knowledge have examined these associations among African Americans.

1.3 | Educational attainment polygenic propensity and associations with criminal offending

Polygenic propensity for educational attainment may also influence criminal offending, although there is a scarcity of work in this area. There are, however, a number of reasons to expect that polygenic propensity for educational attainment may relate to criminal behavior. A substantial body of literature has linked phenotypic educational attainment to crime and there are a number of theories that have been offered to explain the relationship between these constructs. Consistent with a theory offered by Werner and Smith,[13] the failure to graduate from high school represents a significant turning point that may set the stage for increased involvement in criminal activity.[14–17] This idea is consistent with the literature that individuals who graduate high school are less likely to engage in criminal acts compared with individuals who drop out of high school.[14,18] The decision to stay in school may allow students to develop knowledge and skills that open up work or educational opportunities and thus, minimize the likelihood of youth engaging in criminal behavior. In contrast to this perspective, social control theory suggests that decreased attachment to prosocial institutions

such as school may increase the likelihood of school dropout and subsequent delinquent behavior.[19]

Despite some differences between the theoretical paradigms that attempt to explain criminal behavior, these viewpoints similarly maintain that criminality is largely a product of cumulative disadvantage.[20] Indeed, it is thought that disadvantage increases the likelihood of negative experiences and decreased interest in school, which in turn, augments the likelihood of antisocial behaviors. Engagement in delinquency may elicit negative responses from authority figures (eg, parents, teachers) which may reduce one's attachment to school, resulting in further disengagement and increased risk for antisocial activities.[20] Thus, educational attainment and criminal activity may influence each other in a bidirectional, reciprocal manner.

While a number of theories and empirical evidence suggest a relationship between phenotypic educational attainment and criminal offending, less is known about whether polygenic propensity for educational attainment is associated with criminal behavior. To our knowledge, only one study has examined polygenic propensity for educational attainment and criminal justice involvement. In particular, Wertz et al[21] found that lower polygenic propensity for educational attainment was negatively associated with criminal offending among adults of European ancestry, with polygenic propensity for educational attainment accounting for 1.2% of the variance in this outcome. However, it is unclear whether these findings are relevant to a low-income, African American sample.

1.4 | Sex differences in the EA PGS and outcomes

An additional gap in the literature is the failure to consider sex differences that may arise when considering associations between polygenic propensity for educational attainment, academic achievement and criminal offending among African American populations. Differences in phenotypic academic achievement have been observed among males and females which may be partly due to differences in socialization, differences in expectations for males and females, and discrimination.[22–24] Across the literature, findings indicate that females are more likely to attend higher education institutions[25,26] and perform better in English language arts compared with males in early childhood[27,28]; however, findings are mixed regarding whether there are sex differences in mathematics achievement.[28] Other work shows that males are generally more likely to engage in risk-taking behaviors, delinquency, and experience more school expulsions relative to females.[29]

In terms of work that has examined sex differences in the relationship between polygenic propensity for educational attainment and higher education in samples of predominantly European heritage, limited evidence of sex differences has been found.[4,30] Wertz et al[21] found that the relationship between polygenic propensity for educational attainment and criminal offending was not influenced by participant sex among individuals of European descent. Despite the lack of evidence regarding sex differences between polygenic propensity for educational attainment and higher education and crime, there are a number of reasons to expect that sex differences may arise when considering these constructs. For example, some work suggests that school removal rates are higher among African American boys relative to African American girls.[31] Higher levels of suspensions and expulsions

among African American males may reduce the likelihood of their genetic propensity for educational attainment being realized compared with their peers. Thus, an examination of sex differences when considering genetic propensity for educational attainment, achievement and criminal offending is warranted.

1.5 | The current study

We sought to examine whether polygenic propensity for educational attainment (assessed via a genome-wide polygenic score) is associated with post-secondary education, academic achievement, and criminal offending among inner-city, African American young adults. Grounded in past scholarship that has identified a positive relationship between an EA PGS and higher education among individuals of European ancestry,[2,4] we expected that the direction of effects would be the same, but the strength of effects observed would be attenuated (75%–85% reduction in R^2). We also expected that there would be a greater reduction in the variance accounted for by the EA PGS in achievement and criminal offending compared with higher education given that achievement and criminal offending were not the outcomes from which the PGS was based on. We expected to observe sex differences regarding the relationship between the EA PGS and higher education, achievement and criminal offending; however, given the dearth of work in this area, we did not have specific hypotheses.

2 | MATERIALS AND METHODS

2.1 | Participants

The study's analytic sample was drawn from three cohorts of participants in a series of randomized controlled trials of elementary school-based universal preventive interventions targeting early aggression and academic achievement. The trials were carried out within a single urban school district in a Mid-Atlantic region of the United States when children were in first grade. In terms of exclusion criteria, children had to attend one of the participating schools, be in first grade, and be in a mainstream as opposed to a self-contained special education classroom. The interventions employed in the first two cohorts (first trial) are described in Dolan[32] whereas Ialongo et al[33] describes the interventions employed in the third cohort (second trial). Although the targets of the interventions were the same in the first and second trials, the nature of the interventions varied. Across all three cohorts, the interventions were administered universally or classroom-wide and participants were followed from first grade to young adulthood. The interventions have been associated with increased academic achievement, an increased likelihood of attending college, and decreased delinquency in adulthood.[32–34] The trials and follow-up studies were approved by a University Institutional Review Board and participants provided informant consent as adults and assent prior to the age of 18.

Three-thousand and one-hundred and nine individuals were available for recruitment in first grade across the three cohorts, of which 1344 participants had genome-wide assays and completed measures regarding their educational attainment at age 20. In line with our focus on genetic associations with educational attainment, standardized achievement and criminal offending among African Americans, we restricted the sample to individuals who identified

as African American (n = 1050). Participant demographic information for the analytic sample is outlined in Table 1.

With respect to differences in first grade demographic characteristics between the analytic sample (ie, 1050 participants in cohorts 1, 2 and 3) and those not assessed at age 20 and/or those who did not provide DNA, the only significant difference (P 0.05) was that the analytic sample had a significantly greater proportion of females than the original study sample (analytic sample, 56.6% vs whole sample, 44.6%). There were no significant differences with respect to participants who received an intervention (analytic sample, 51.9% vs whole sample, 48.9%).

2.2 | Measures

2.2.1 | Participant demographic information—At age 20, participants reported on their income. To help contextualize the sample, we report caregiver level of education, income and marital status when participants were in first grade which can be found in Table 1.

2.2.2 | Post-secondary education—At age 20, participants reported on the number of years of education they completed, and degrees attained. From these responses, a dichotomous variable was created to reflect individuals that had a high school education or generalized education degree or less (coded as 0) and individuals that reported attending a post-secondary education institution (eg, vocational school, college/university) (coded as 1).

2.2.3 | Early childhood academic achievement—In cohorts 1 and 2, the California Achievement Test (CAT)[35] was used to assess early childhood achievement in the fall of first grade. The CAT is one of the most frequently used standardized achievement batteries and includes both verbal (reading, spelling and language) and quantitative (computation, concepts and applications) subtests. Reading and math composite scores were used to index reading and math achievement. The CAT has shown concurrent validity with McCarthy's Scales of Children's Abilities General Cognitive Index,[36] and convergent validity with the Kaufman Adolescent and Adult Intelligence Test (KAIT) and the Weschler Intelligence Scale for Children-Third Edition (WISC-III).[37]

In cohort 3, the Comprehensive Test of Basic Skills (CTBS)[38] was used to measure academic achievement in the fall of first grade. Like the CAT, the CTBS is a common assessment used to measure scholastic achievement. Subtests in the CTBS cover both verbal (word analysis, vocabulary, comprehension, spelling and language mechanics and expression) and quantitative topics (computation, concepts and applications). Like the CAT, two composite scores were provided to reflect reading and mathematics ability. Higher scores reflect higher academic achievement. The CTBS has shown convergent validity with other achievement tests (eg, Academic Performance Rating Scale [APRS]) and concurrent validity with teacher ratings of inattention and aggression.[39,40]

2.2.4 | Criminal justice system involvement—When participants were 20 years old, records of incarceration status were obtained via Maryland's Criminal Justice Information System. We created a dichotomous variable to reflect whether participants had no adult

record (coded as 0) or an adult record (coded as 1). See Table 1 for ns and percentage of the sample with an adult criminal record.

2.3 | Educational attainment polygenic score discovery sample

We used the discovery sample results from a mega GWAS conducted recently by Lee et al.[4] This GWAS included 1.1 million individuals pooled from a large number of samples, such as the Netherlands Twin Registry, Finnish Twin Cohort, Swedish Twin Registry, the Avon Longitudinal Study of Parents and Children, the UK Biobank and 23andme.[4] The authors conducted a sample size weighted meta-analysis of single nucleotide polymorphisms (SNPs) that were associated with years of schooling completed, measured continuously. We used the discovery sample results that were available from the Social Science and Genetics Consortium and our PGS was based on summary statistics derived from 500 000 individuals, which excluded results from 23andme given that they are not publicly available.

2.4 | DNA and genotyping

In young adulthood, DNA was extracted from blood or buccal swab samples and was genotyped using Affymetrix 6.0[41] microarrays comprising 1 million SNPs across the genome. Standard quality control steps were implemented to ensure accurate genotypes were included in subsequent analyses. Subjects with >5% missing genotype data were removed. SNPs were also removed from further analysis when they had a minor allele frequency <0.01, missingness >0.05 or departures from Hardy-Weinberg equilibrium at $P < 0.0001$.[42] These steps were performed using PLINK 2.0.[43] Genotypes were imputed to the 1000 Genomes Phase 3 reference panel[44] using IMPUTE2[45] pre-phasing performed in SHAPEIT.[46] Resulting variants imputed with an INFO (quality) score <0.8 were removed. Uncertainty adjusted dosage data, instead of called alleles, were used to generate the polygenic score.

When exploring genetic associations, it is important to identify and control for population stratification or genetic differences between subpopulations so that any significant associations observed are not confounded by ancestry.[47] We used principal components (PCs) analysis in PLINK 2.0 to create the population stratification control variables.[48] This process uses an orthogonal transformation to reduce the multi-dimensional genome-wide SNP data into a smaller number of genetic ancestry PCs. We used all the available measured SNPs (roughly 900 000) to generate these components. Although these were not a priori identified ancestry information markers, it has been shown that "randomly" selected SNPs perform equally as well.[49] We identified 10 PCs that sufficiently accounted for population stratification in our sample.

2.5 | PGS generation

Using the discovery GWAS for educational attainment,[4] our GWA panel contained 741 174 (26.3%) directly genotyped SNPs from this list. After imputation, 2 554 305 (90.5%) SNPs from the discovery dataset were available in the current sample. Palindromic (A/T or C/G) SNPs were excluded, as methods for properly orienting multiple datasets are error-prone. Mean imputation was performed for missing genotypes and alleles were weighted by the effect sizes from the discovery GWAS. LDPred, a method that includes direct modeling of

LD, was used to generate our EA PGS.[50] In this approach, the posterior mean effect size in a target sample is estimated based on the LD pattern in the target sample, as well as the LD pattern and effect sizes in the discovery sample. The EA discovery GWAS summary statistics and a local European ancestry sample derived from our study (N = 336) was used to estimate LD parameters in our African American sample. PGS were reestimated using reweighted raw scores drawn from the entire genome, without P-value thresholding. The EA PGS was regressed on the 10 principle components described above and standardized (M = 0, SD = 1). The residualized, standardized EA PGS was used in all the analyses.

2.6 | Statistical analyses

Bivariate correlations and descriptive statistics were conducted to investigate the relations among the predictor and dependent variables using SPSS Version 25.[51] The demographic and participant variables were coded as follows: (female = 0, male = 1; no intervention = 0, received an intervention = 1). Linear regressions were run to investigate the main effects of the EA PGS and participant sex on early childhood achievement. Logistic regressions were conducted for young adult outcomes (ie, post-secondary education and criminal justice involvement) given that these variables are binary. When examining outcomes that were assessed post-intervention (ie, post-secondary education and criminal justice involvement), we controlled for intervention status given that participation in these interventions has been predictive of positive educational outcomes and decreased delinquency in adulthood.[32–34] In regression analyses where participant sex was a significant predictor ($P < 0.05$) of the outcomes, we report stratified effect sizes and confidence intervals (CIs) for males and females. We also present the linear probability models derived from these analyses which were plotted using ggplot in R.[52,53] All analyses included the EA PGS that was regressed on the 10 genetic ancestry PCs.

3 | RESULTS

Bivariate correlations, means, SDs and ns are presented in Table 2. A greater proportion of (a) females reported post-secondary education than males ($\chi^2(1) = 14.65$, $P < 0.005$, $\varphi = 0.12$), and (b) males were more likely to have a criminal record than females ($\chi^2(1) = 98.39$, $P < 0.005$, $\varphi = 0.31$). No other sex differences were observed. Results from the primary analyses are presented below.

3.1 | Post-secondary education

As indicated in Table 3, the EA PGS was positively associated with the log odds of post-secondary education (odds ratio [OR] = 1.31, 95% CI = 1.14–1.50, $P < 0.005$) and accounted for 1.30% of the variance in this outcome. Participant sex also predicted the log odds of pursuing post-secondary education such that females were more likely to report having post-secondary education relative to males (OR = 1.74, 95% CI = 1.32–2.29, $P < 0.005$). The EA PGS was similarly associated with higher education among females (OR = 1.32, 95% CI = 1.11–1.58, $P = 0.002$) and males (OR = 1.29, 95% CI = 1.04–1.60, $P = 0.018$). See Figure 1A for the linear probabilities of obtaining higher education among males and females based on participant EA PGS.

3.2 | Academic achievement

As shown in Table 3, the EA PGS was positively associated with CTBS mathematics test performance in the third cohort (B = 11.58, P = 0.020) with 1.40% of the variance accounted for; however, the EA PGS was not associated with performance on the CTBS reading test (B = 4.55, P = 0.232) in the third cohort, or the CAT mathematics test (B = 1.59, P = 0.192), and CAT reading test (B = 1.95, P = 0.170) in the first and second cohorts (R^2 range = 0.30%−0.40%). Participant sex was not associated with performance on the CAT or CTBS reading and math achievement tests; thus, we did not examine whether the EA PGS was associated differently with achievement based on participant sex.

3.3 | Criminal justice system involvement

The EA PGS showed a negative, trend-level association with criminal record status (OR = 0.87, 95% CI = 0.76–1.00, P = 0.057) and accounted for 0.30% of the variance in this outcome (Table 3). Participant sex predicted the log odds of criminal offending such that females were less likely than males to have a criminal record (OR = 0.25, 95% CI = 0.19–0.33, P < 0.005). The EA PGS was not associated with criminal offending among females (OR = 0.94, 95% CI = 0.77–1.16, P = 0.564), although there was a significant association observed among males (OR = 0.82, 95% CI = 0.67–0.99, P = 0.041) such that males with a higher EA PGS were less likely to have a criminal record compared to males with a lower EA PGS. See Figure 1B for the linear probabilities of having a criminal record among males and females based on participant EA PGS.

4 | DISCUSSION

Advances in quantitative genetic methods in the last decade have allowed for the study of polygenic contributions to educational attainment. Although previous studies have showed polygenic influences on educational attainment among individuals of European descent,[6,9] there is a scarcity of work that has considered whether genetic factors related to educational attainment are associated with higher education attendance among urban, African Americans. In the United States, African Americans who reside in urban communities are disproportionately affected by poverty and are often exposed to substandard schools that put them at risk for reduced educational attainment.[54] This raises the question of whether the relationship between polygenic propensity for educational attainment and higher education may be attenuated due to such factors, as well as the mismatch between the predominant ethnicity of the discovery sample and the target sample in terms of allele frequency differences and LD structure. Using an African American, low-income sample, we aimed to replicate existing work that has established a relationship between polygenic propensity for educational attainment and higher education in predominantly European, socioeconomically diverse samples. We also sought to extend the literature by considering whether polygenic propensity for educational attainment is related to achievement and criminal offending.

Consistent with previous findings that have documented a link between polygenic propensity for educational attainment and post-secondary education with an attenuation in the variance observed in African American samples,[4,6,55] a greater polygenic propensity for educational attainment was associated with attending a higher education institution and accounted for

1.30% of the variance in this outcome. Higher polygenic propensity for educational attainment has been extensively linked to higher cognitive faculties and executive functioning.[6,7,56] Youth higher in this genetic propensity may be at an advantage in an educational context, as academic challenges may come easier and they may be more likely to persist when faced with academic obstacles. Youth with a higher EA PGS may also exhibit higher levels of academic self-efficacy and be more likely to have a positive outlook regarding their ability to succeed in a post-secondary education environment and accordingly pursue these options. The level of attenuation in the variance accounted for by the EA PGS on higher education observed in our sample may be due to cross-ancestry comparisons or the fact that very few participants endorsed attending a higher education institution; thus, we may have been underpowered to detect an effect similar to what has been observed in socioeconomically diverse samples of European ancestry. Studies of much larger and socioeconomically diverse samples of African Americans are needed to confirm and expand upon the results reported pressented here. Future work should also examine whether phenotypes (eg, executive functioning, self-control) and environmental experiences (eg, parenting quality, trauma exposure) influence the relationship between polygenic propensity for educational attainment and higher education.

There was some evidence that a higher EA PGS was positively associated with academic achievement in first grade with significant effects observed for math achievement in the third cohort. The lack of robust associations between the EA PGS and academic achievement may be because academic achievement was measured in early childhood, a developmental period during which the importance of genetic influences on intelligence is lower compared to young adulthood.[6,57] Indeed, although the same genetic variants are implicated in academic achievement across the developmental course, it is thought that as youth become older, they seek out environments and experiences that reflect their genetic propensities and increase the manifestation of a given phenotype.[57] Another important factor that may explain the reduction in the variance accounted for is the low socioeconomic nature of our sample. A number of twin and family-based studies have indicated that the shared environment accounts for a much greater amount of variance in scholastic aptitude than genetics among individuals in low socioeconomic status (SES) environments.[11,12,58] However, among individuals in more affluent families, genetics often accounts for a substantially greater amount of variance in scholastic aptitude than context.[11,12,58] Thus, the observed reduction in the variance accounted for in this outcome, as well as educational attainment, may be because of the socioeconomic status of our sample.

Polygenic propensity for educational attainment showed a negative, trend-level association with criminal offending and accounted for less than 0.50% of the variance in criminal offending. This finding is consistent with limited work indicating that higher polygenic propensity for educational attainment was negatively associated with having a criminal justice record with a very small amount of variance accounted for.[21] Individuals with lower cognitive ability may be more likely to engage in criminal behavior, potentially because they may experience executive function deficits, such as a decreased ability to problem solve, engage in self-control and anticipate the consequences of their actions.[59,60] Consistent with social control theory and Werner and Smith's contention that high school graduation is a turning point for youth, excelling academically and graduating from secondary school may

confer youth with greater opportunities and choices that deter them from engaging in delinquency or criminal activities. The decreased amount of variance observed in our sample regarding the EA PGS-criminal involvement association compared with that of Wertz et al.[13] may also be because of cross-ancestry differences, as well the fact that the GWAS from which the EA PGS derived was focused on educational attainment. However, as noted previously, the sample included individuals from an urban region that may have experienced higher levels of disadvantage and violence, racial discrimination and potentially fewer economic and social resources; these experiences may have a stronger effect on criminal offending in our sample compared with genetic propensity for educational attainment.

No sex differences were observed regarding the relationship between the EA PGS and higher education status and achievement. This is consistent with work that has found that participant sex did not influence the relationship between polygenic propensity for education attainment and higher education in samples of predominantly European heritage.[4,21,30] However, we found that a higher EA PGS was negatively associated with criminal offending among males, but not females, conflicting with findings reported by Wertz et al.[21] who found no sex differences in polygenic propensity for educational attainment and criminal offending. The sex differences observed may be largely driven by differences in incarceration rates among males and females, socialization, expectations for males and females, and the effect of contextual factors (eg, peers) among males compared with females.[22,23] Future work should explore whether academic expectations and social contextual factors influence the relationship between polygenic propensity for educational attainment and criminal offending among males and females.

While our results highlight that the genetic architecture of educational attainment is associated with higher education, caution should be taken regarding the interpretation of these findings. First, the effect sizes for the significant relationships observed were very small in magnitude. The consideration of contextual influences with genetic factors often accounts for a greater proportion of the variance in behaviors, underscoring the importance of the environment in fostering or hindering adjustment. While our work is a first step in identifying whether polygenic propensity for educational attainment is associated with higher education status in non-European samples, our results do not imply a causal relationship between genes and behavior. In support of this idea, recent work indicates that parents' polygenic propensity for educational attainment influences their children's educational attainment through parents (a) transmitting their own genetics to their children, and (b) shaping the environments in which their children grow up in.[2,61] In terms of the former, recent work by Belsky et al[2] found that individuals with a higher EA PGS tended to have higher levels of education and occupational status and come from socioeconomically advantaged families. It has been posited that parents' genetics may influence the likelihood of children's academic success, although higher levels of wealth and greater access to resources might also explain this relationship. In terms of the latter, recent work supports the importance of the caregiving environment in fostering or hindering children's educational attainment. For example, Bates et al[62] examined whether parents' genetic propensity for educational attainment affected their children's educational attainment, while taking into account genetic relatedness between parents and their children. The authors found that parents' genetic propensity for educational attainment was positively associated with

children's educational attainment when taking into account nontransmitted alleles, highlighting that parents with a higher EA PGS may create an environment that fosters their children's learning potential.[61,62] A next step in our work is to examine causal pathways that might be associated with higher education status.

An additional limitation was that we created a PGS for educational attainment that was derived from a GWAS that included individuals of predominantly European ancestry. As noted previously, prediction from GWAS is most accurate when the ancestry of the discovery sample matches the ancestry of the target sample. Indeed, there is often a substantial reduction in the variance accounted for in phenotypes considered in non-European ancestry samples,[4,50] and in some cases, directional inconsistencies between PGS-phenotype associations have been observed.[5] While this may be the case, we found in the current study that there was a positive association between the EA PGS and higher education reflecting results from the discovery sample, and the level of attenuation observed in the current study parallels other studies that have examined PGS-phenotype associations in admixed samples.[2,4] As Martin et al[5] point out, approaches that better account for LD and differences in allele frequencies are needed to maximize the predictive power of PGS to groups that are of a different ancestry than discovery samples.

In sum, the present study sought to evaluate whether polygenic propensity for educational attainment is associated with education outcomes and criminal offending in a low-income, African American sample. Findings suggest that a higher polygenic propensity for educational attainment is positively associated with post-secondary education and showed a positive association with mathematics performance—albeit in one of the three cohorts studied. While the charged national history tying educational attainment to socioeconomic status and racial identity makes this area of study particularly sensitive, this work helps elucidate pathways that are involved in a multitude of outcomes and may contribute to the limited body of social genomics research that has incorporated African Americans.

Funding information

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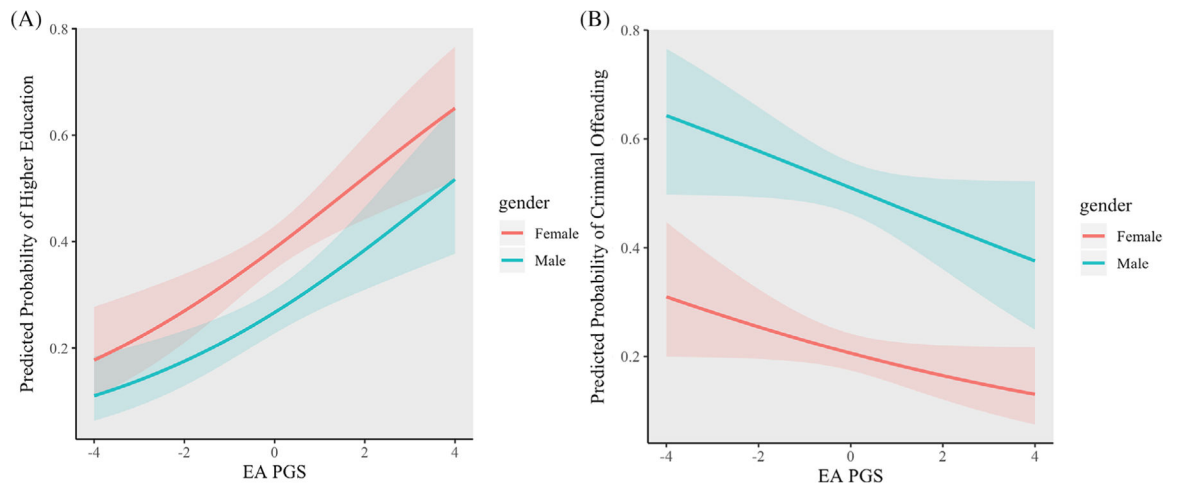
FIGURE 1.

Probability of (A) higher education and (B) criminal offending based on participants' EA PGS and gender adjusted for intervention status. The EA PGS included in the analyses was regressed on the 10 genetic ancestry principal components

TABLE 1

Characteristics of the analytic sample (ie, cohorts 1, 2 and 3)

Characteristic	n (%)
Young adult sex	
Male	461 (43.9)
Female	589 (56.1)
Intervention status	
Yes	545 (51.9)
No	505 (48.1)
Young adult income	
<$10 000	579 (72.0)
$10 000 to $20 000	127 (15.8)
$20 000 to $35 000	82 (10.2)
>$35 000	16 (1.9)
Young adult criminal record	
Yes	343 (33.7)
No	675 (66.3)
Young adult education	
<High school diploma	269 (25.9)
High school diploma only	332 (32.0)
GED only	85 (8.2)
>High school diploma or GED	352 (33.9)
Young adult cohort identification	
Cohort 1	345 (32.9)
Cohort 2	295 (28.1)
Cohort 3	410 (39.0
Caregiver marital status	
Single	118 (13.1)
Married	298 (33.0)
Separated/divorced	176 19.5)
Widowed	49 (5.4)
Never married	263 (29.1
Caregiver education	
High school diploma	620 68.7)
>High school diploma	283 (31.3)
Caregiver income	
<$5000	105 (12.8)
$5000 to $10 000	159 (19.4)
$10 000 to $20 000	203 (24.8)
$20 000 to $30 000	130 (15.9)
$30 000 to $40 000	109 (13.3)
>$40 000	114 (13.9)

Abbreviation: GED, generalized education degree.

TABLE 2

Bivariate correlations, means, SDs, ranges, and n's of study variables

Variable	1	2	3	4	5	6	7
1. EA PGS[a]	--						
2. CAT reading performance[b]	0.06	--					
3. CAT math performance[b]	0.06	0.57**	--				
4. CTBS reading performance[c]	0.06	N/A	N/A	--			
5. CTBS math performance[c]	0.12*	N/A	N/A	0.65**	--		
6. Post-secondary education	0.12**	0.26**	0.24**	0.26**	0.16**	---	
7. Criminal justice involvement	−0.05	−0.05	−0.10*	−0.11*	−0.14	−0.27**	--
M	0.00	260.45	288.89	453.38	435.96	--	--
SD	1.00	33.58	28.32	65.40	86.85	--	--
Range	−3.45–2.81	153–344	216–495	229–632	158–678	0–1	0–1
n	1010	597	584	330	337	1038	1018

Abbreviation: N/A, not applicable.

[a] The EA PGS included in the analyses was regressed on the 10 genetic ancestry principal components.

[b] The CAT tests were administered to cohorts 1 and 2.

[c] The CTBS tests were administered to cohort 3.

*
$P < 0.05$;

**
$P < 0.01$.

TABLE 3

Summary of regression analyses predicting young adult outcomes and early childhood achievement from the EA PGS

Young adult outcomes	OR (95% CI)	P-value	R^2
Post-secondary education[b]			4.3%
Sex	1.74 (1.32–2.29)	<0.005	
Intervention status	0.57 (0.44–0.75)	<0.005	
EA PGS	1.31 (1.14–1.50)	<0.005	
Criminal justice involvement[b]			10.4%
Sex	0.25 (0.19–0.33)	<0.005	
Intervention status	1.59 (1.20–2.11)	0.001	
EA PGS	0.87 (0.76–1.00)	0.057	

Early childhood achievement	B (SE)	β	P-value	R^2
CAT reading test performance[c]				1.0%
Sex	−5.68 (2.89)	−0.08	0.050	
EA PGS	1.95 (1.42)	0.06	0.170	
CAT math test performance[c]				0.3%
Sex	−0.52 (2.48)	−0.01	0.833	
EA PGS	1.59 (1.22)	0.06	0.192	
CTBS reading test performance*				0.6%
Sex	−6.09 (7.35)	−0.05	0.408	
EA PGS	4.55 (3.80)	0.07	0.232	
CTBS math test performance*				2.4%
Sex	−17.46 (9.52)	−0.10	0.067	
EA PGS	11.58 (4.96)	0.13	0.020	

The EA PGS included in the analyses was regressed on the 10 genetic ancestry principal components.

[a] Post-secondary education status and criminal justice involvement data were available for cohorts 1, 2 and 3.

[b] The CAT tests were administered to cohorts 1 and 2.

[c] The CTBS tests were administered to cohort 3.