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8-Year Prospective Study of Depressive Symptoms and Change in Insulin from Adolescence to Young Adulthood

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Abstract

Objective—To evaluate whether depressive symptoms predict change in fasting insulin among adolescents followed into young adulthood. We hypothesized that higher depressive symptoms would predict increased insulin and that puberty and race/ethnicity would moderate this relationship.

Methods—Data came from the Princeton School District Study, a school-based longitudinal cohort of non-Hispanic black and white adolescents (2001–2011). Depressive symptoms, fasting insulin, and body mass index (BMI) were measured at baseline (adolescence) and eight years later (young adulthood) in 685 participants. Puberty was assessed using a validated protocol measuring sex steroids and physical changes. The primary outcome was change in fasting insulin. Analyses accounted for age, sex, race, parental education, baseline insulin, BMI z, puberty, and time to follow up.

Results—At baseline, depressive symptoms were correlated with insulin ($\rho = .13, p = .001$). High baseline insulin predicted insulin change ($B = -11.50, SE = 2.30, p < .001$). Depressive symptoms also predicted insulin change, but only for pubertal adolescents ($B = -.23, SE = .11, p = .038$). This relationship was moderated by race ($p < .047$); depressive symptoms predicted insulin change only among pubertal black adolescents ($p = .030$), not whites ($p = .49$), and in the direction opposite that hypothesized ($B_{\text{blacks}} = -.51, SE = .23$). Post-hoc analyses revealed pubertal black adolescents with high depressive symptoms had the highest baseline insulin, which stayed high across the follow up period.

Conclusions—Among pubertal black adolescents, elevated depressive symptoms are associated with increased risk for sustained hyperinsulinemia from adolescence into adulthood. These youths may be particularly vulnerable for type 2 diabetes.

Keywords

depression; insulin; race/ethnicity; adolescents; young adults

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INTRODUCTION

Prevalence of type 2 diabetes, once considered a disease of older adults, is rising alarmingly among adolescents and young adults, particularly in non-Hispanic black, Hispanic and Native American populations (1–4). The rise in earlier manifestation of type 2 diabetes parallels dramatic increases in obesity prevalence in children and adolescents (5). These trends are likely related given the well-established causal link between excessive adiposity and hyperinsulinemia, an early pathophysiological step in the progression to type 2 diabetes (6–8).

In addition to traditional risk factors such as adiposity, studies of adults suggest that psychological states and traits, particularly depressive symptoms, may independently predict increased risk for type 2 diabetes (9–11). In adults, elevated depressive symptoms and major depressive disorder have both been associated with increases in fasting insulin, insulin resistance, and the onset of type 2 diabetes (12–15). However, there have been some inconsistencies in this literature, including some negative findings (16). A recent meta-analysis, for instance, found a significant but small cross-sectional association between depression and insulin resistance (17). Although adiposity may partially explain an association between depressive symptoms and hyperinsulinemia (18, 19), there is some evidence for direct effects of depressive symptoms on insulin regulation through both behavioral and neuroendocrine pathways (20–23).

From a developmental perspective, how and when depressive symptoms could affect risk for type 2 diabetes remain unclear. Adolescence is a key developmental period for both depression and hyperinsulinemia, and, thus, may be a developmental period of particular importance in this relationship. Depressive symptoms rise at the onset of adolescence (24), and major depressive disorder typically manifests in the second decade of life (25). In community samples, point prevalence estimates for clinical depression are 5–8%, with up to 20% of individuals estimated to have a major depressive episode at some point during adolescence or young adulthood (26–28). Approximately a quarter of adolescents from community studies endorse sub-threshold elevated depressive symptoms at any given point in time (29). Data from the SEARCH for Diabetes in Youth cohort indicate a particularly high prevalence of elevated depressive symptoms in adolescents with diabetes (18–27%), with the highest estimates for adolescent females and for youths with type 2, as opposed to type 1, diabetes (30). Adolescence is also notable for the increases in fasting insulin and insulin resistance that accompany puberty (31). Typically, hyperinsulinemia related to pubertal development improves by the completion of puberty, although, on average, it does not return to pre-pubertal levels, and youths at-risk for type 2 diabetes may show no recovery (31–33).

Despite these established developmental risks and their potential implications for preventive efforts, little is understood about the relationship between depressive symptoms and hyperinsulinemia during adolescence. Depressive symptoms have been shown to be positively associated with fasting insulin or insulin resistance in two cross sectional studies of adolescents (34, 35). Further, in a longitudinal study of children age 6–12 at-risk for

chronic obesity, depressive symptoms predicted worsening insulin resistance 5–6 years later (36). However, this prospective study included a select population and did not follow participants through the completion of puberty into young adulthood. Indeed, no longitudinal study exists of the relationship between depressive symptoms and insulin in the transition to adulthood.

In the current study, we sought to address this gap in the current knowledge base. We investigated the relationship between depressive symptoms and fasting insulin in a community-based longitudinal cohort study of non-Hispanic black and white adolescents followed to young adulthood. We hypothesized that higher depressive symptoms would be related to increases in fasting insulin. Further, given pubertal insulin resistance, we hypothesized that the relationship of depressive symptoms to change in fasting insulin would differ by pubertal status in adolescence. Finally, because there are well-established variations between racial/ethnic groups in fasting insulin, insulin sensitivity, and depressive symptoms (37–39), we hypothesized that race/ethnicity would also moderate the impact of depressive symptoms on fasting insulin change.

METHODS

Participants and Data Collection

These data were drawn from the Phase 2 cohort of the Princeton School District (PSD) Study, a longitudinal, school-based cohort study of cardio-metabolic risk of students enrolled in grades 5–12 in the Princeton City School District of Cincinnati, Ohio in the 2001–2002 academic year (40–42). Prior publications have evaluated the relationships of depression and BMI (e.g., 43) or socioeconomic status and insulin during adolescence/Phase 1 (e.g., 44); this manuscript represents the first publication of results from young adult follow-up/Phase 2 data, and the only paper to evaluate the relationship of depression and fasting insulin change. The study took place in two phases. Phase 1 lasted from 2001–2005 and included four assessments, approximately one year apart. Written informed consent and assent were obtained from parents/guardians and adolescents, respectively. The Institutional Review Board of Cincinnati Children's Hospital Medical Center as well as other affiliated academic institutions (Brandeis, Tufts, and Partners Human Subjects committees) approved all study procedures. Study exclusion criteria were pregnancy, regular corticosteroid treatment for asthma, or a major medical problem that would affect carbohydrate metabolism. Study visits included a physical exam for height and weight, phlebotomy, and completion of a survey that included assessment of depressive symptoms. Survey measures included in the PSD Study were not validated in participants less than 12 years of age. Therefore, initial 5th–6th graders did not receive a Phase 1 survey until they reached 7th grade. We selected the initial Phase 1 study visit at which the survey was completed as our “baseline” visit because depressive symptoms were the key predictor variable of interest in this study. Data on all key baseline measures were drawn from this visit.

In Phase 2 (2008–2011), a subset of 780 non-Hispanic black and white Phase 1 subjects completed up to two additional study visits 8–10 years after the initial Phase 1 study visit. Participants were eligible for Phase 2 if they had completed the final Phase 1 visit, had a

parent provide socio-demographic data in Phase 1, and were not pregnant, on active military duty, or incarcerated.

For the current study, we applied three additional exclusion criteria: 1) age < 18 years at initial Phase 1 visit, 2) taking insulin sensitizers (e.g., Metformin), and 3) developed diabetes over the study period ($n = 3$). Further, because only 2% of Phase 2 participants ($n = 14$) were pre-pubertal at baseline, we did not have the power to assess the impact of this pubertal stage on the depressive symptoms-insulin relationship. These participants were, therefore, also excluded, leaving a final sample size of 686 for this study.

Measures

Demographics—Birth date was provided by the school district from administrative records. Parent education, ranging from never attended school to attainment of professional training beyond a four-year college or university, was reported by a parent/guardian, who also reported education attained by her or his spouse/partner. Highest educational attainment between both parental figures was used as a proxy for the adolescents' socioeconomic status (45). Race/ethnicity and gender were self-reported in Phase 2.

Pubertal status—Pubertal status (pubertal or post-pubertal) at the baseline visit was determined using a validated algorithm that included data on serum estradiol and age of menarche for girls and serum free testosterone concentration and the stage of axillary hair for boys (40, 46).

Body mass index (BMI)—Height and weight at baseline and follow up were both obtained in duplicate by trained study staff. Participants were measured in regular attire with shoes removed. BMI was calculated as weight in kg divided by height in m^2 . In adolescence, BMI z scores for sex and age were calculated according to the Centers for Disease Control and Prevention 2000 standards (47).

Depressive symptoms—Depressive symptoms were assessed with the reliable, well-validated and widely used 20-item Center for Epidemiological Studies-Depression (CES-D) scale, which asks adolescents to describe their mood over the past week (48–50). The CES-D has demonstrated adequate test-retest reliability in adolescent samples over one month (51), and the scale has good internal reliability and moderate sensitivity and specificity (52). In primary analyses, the continuous CES-D total score was utilized. In post-hoc analyses for interpretive purposes, depressive symptoms were dichotomized by median split into low (< 13) and elevated (≥ 13) depressive symptom categories. Cutoff scores ranging from 12 to 24 have been utilized as suggestive of elevated depressive symptoms (52).

Fasting insulin—Blood was sampled from participants after a 10-hour overnight fast at baseline and follow up. Samples were collected in the morning between 7:00–9:30AM. At baseline, appointments were between 8:00–9:30AM and at follow up between 7:00–9:00AM. As described previously (44, 46), plasma insulin concentration was measured by radioimmunoassay. Change in insulin was derived by subtracting the baseline from follow up fasting insulin concentration. Preliminary analyses indicated one extreme outlier for insulin change ($-237 \mu IU/mL$; 12 SDs above the mean); this individual was excluded from

further analyses reducing the sample to $N = 685$. For regression analyses, baseline insulin was dichotomized by median split into low ($< 17.57 \mu\text{UmL}$) and high ($\geq 17.57 \mu\text{UmL}$). Cut offs of 15 or 20 μUmL have been suggested to be indicative of high fasting insulin or hyperinsulinemia, and correspond to the 90–95th percentile for 14-year-olds, the average age of our sample at baseline (53).

Statistical Analysis

Analyses were conducted using IBM SPSS Statistics 22 (Armonk, NY). Assumptions for parametric tests were evaluated. Descriptive information on the sample was generated on all key variables. Bivariate associations among baseline depressive symptoms, baseline fasting insulin, and change in fasting insulin were assessed with Spearman's ρ in the total sample and then, stratified by race/ethnicity. After evaluating bivariate associations, multiple linear regression modeling was conducted. First, a basic model was conducted in which change in insulin (the dependent variable) was regressed on the pre-determined covariables of age, sex, race (non-Hispanic white, non-Hispanic black), parental education, baseline insulin, baseline BMI z, and time to follow up. These variables were selected *a priori* for inclusion because they have been associated with depression or insulin in previous research, and we aimed to determine the association of depressive symptoms to insulin change independent of these factors. Modeling at this stage revealed significant two- and three-way interactions of puberty with race and baseline insulin. Therefore, the subsequent models were stratified by baseline pubertal status and the two-way interaction of race by baseline insulin was retained. Of note, there were no interactions with sex or parental education. Thus, the final models, stratified by baseline pubertal and post-pubertal participants, predicted change in insulin from baseline age, sex, race (non-Hispanic white, non-Hispanic black), parental education, baseline insulin, baseline BMI z, time to follow up, race by baseline insulin, baseline depressive symptoms, and race by baseline depressive symptoms. To clarify the meaning of significant race by baseline depressive symptoms interactions, model-based estimates were derived for the separate effects of baseline depressive symptoms on fasting insulin change in non-Hispanic black and white participants. We then evaluated a separate set of models accounting for baseline BMI and BMI change as opposed to baseline BMI z. These conservative analyses allowed us to determine whether any observed relationships between depressive symptoms and insulin change were potentially accounted for by or operated independently of change in BMI. Throughout, continuous variables (baseline depressive symptoms) were centered prior to entry into interaction terms.

RESULTS

Participants were a total of 685 adolescents studied initially in mean $\pm$ SD grade 9 ± 1.62 (range = 7th to 12th grade), with an average age of 14.44 ± 1.62 years (range = 12.20 to 17.99 years). Descriptive characteristics for the total sample are displayed in Table 1.

In bivariate analyses, adolescents' baseline depressive symptoms and baseline fasting insulin were positively correlated ($\rho = .13, p = .001$). When stratified by race/ethnicity, this association was significant in non-Hispanic white ($\rho = .17, p = .001$), but not among non-Hispanic black participants ($\rho = .05, p = .35$). Upon adjusting for baseline BMI z, the

baseline depressive symptoms-fasting insulin association remained significant only in white participants (partial $\rho = .09$, $p = .01$) and non-significant among black participants (partial $\rho = .04$, $p = .46$).

The time to follow up was 8.0 ± 1.4 years (range = 4 to 10); all adolescents studied at baseline were seen for a follow-up assessment. Mean change in fasting insulin between baseline and follow up was 5.0 ± 19.8 $\mu\text{IU/mL}$, and this change did not differ significantly between non-Hispanic white and black subjects ($p = 0.62$). In bivariate analyses, baseline depressive symptoms had a trend-level, inverse association with change in fasting insulin ($\rho = -.06$, $p = .09$). When stratified by race/ethnicity, this association was non-significant in white participants ($\rho = -.04$, $p = .43$) and remained a trend in black participants ($\rho = -.11$, $p = .054$). After adjustment for baseline BMI z, the partial correlation of baseline depressive symptoms and fasting insulin change was non-significant in whites (partial $r = -.01$, $p = .81$) and significant in blacks (partial $r = -.13$, $p = .02$), such that black subjects with relatively higher levels of depressive symptoms had less change in fasting insulin ~8 years later.

Table 2 displays the multiple linear regression models evaluating predictors of change in fasting insulin, stratified by baseline pubertal status. High baseline fasting insulin was the strongest predictor of fasting insulin change. For both pubertal and post-pubertal youths, those with high baseline insulin showed less increases in insulin over the follow up period ($p \leq .001$). There was a trend-level race by baseline insulin interaction in participants who were pubertal at baseline ($B = -7.82$, $SE = 4.10$, $p = .058$). This interaction indicates that pubertal black youths with high baseline insulin had significantly less change in insulin than pubertal black youths with low baseline fasting insulin or pubertal whites. This interaction was non-significant in post-pubertal participants and removed from the model in an effort to be parsimonious. The effect of depressive symptoms on insulin change was moderated by race among pubertal subjects ($p = .046$). In follow-up regression analyses stratified by race, depressive symptoms predicted lower fasting insulin change only among black participants ($B = -.51$, $SE = .23$, $p = .03$), not among white participants ($B = -.10$, $SE = .13$, $p = .43$).

To aid interpretation of this interaction, we used a median split in CES-D scores to divide the cohort into those with low or elevated depressive symptoms. We then assessed the relationship between initial and follow up fasting insulin among pubertal black and white adolescents based on this median split. At baseline, pubertal black adolescents with elevated depressive symptoms had the highest fasting insulin compared to pubertal black adolescents with low depressive symptoms or whites with either low or elevated depressive symptoms ($p = .029$). Further, pubertal black adolescents with elevated depressive symptoms showed no significant change in fasting insulin over the follow up period ($p = .50$). In contrast, pubertal black adolescents with low symptoms had significant increases in fasting insulin ($p = .011$), as did pubertal white adolescents with low depressive symptoms ($p < .001$) and pubertal white adolescents with high symptoms ($p = .001$). These increases in pubertal whites and blacks with low baseline depressive symptoms, coupled with the sustained high insulin level for pubertal blacks with baseline elevated depressive symptoms, led to similar (high) insulin levels at follow up across these four race by baseline depression subgroups of pubertal adolescents ($p = .21$). Figure 1 illustrates these relationships. An identical pattern was

observed when the fasting insulin for these groups over time was adjusted for covariates in the primary models.

To investigate if change in BMI was a possible confounder of the effects observed for depressive symptoms and race among pubertal adolescents, we performed parallel regression modeling using baseline BMI, rather than BMI z, and adding BMI change between baseline and follow up to the model. These results are displayed in Table 3. BMI change was positively associated with greater insulin change among adolescents who were pubertal at baseline ($p < .001$). The interaction of depressive symptoms by race remained significant ($p = .048$).

DISCUSSION

This study is one of the first prospective investigations of the relationship between depressive symptoms and fasting insulin in a community-based cohort of adolescents followed into young adulthood. Based on prior literature (9, 10, 36, 54), we hypothesized that initial depressive symptoms measured in adolescence would predict greater increases in fasting insulin approximately eight years later in young adulthood. While we found a relationship between depressive symptoms in adolescents and change in fasting insulin during the transition to adulthood, our findings revealed a number of intricacies in this relationship that were unexpected. First, the effect of depressive symptoms on change in fasting insulin was present only among those who were pubertal, not post-pubertal at baseline. Second, this effect was moderated by race such that the association between adolescent depressive symptoms and fasting insulin change was apparent for non-Hispanic black, but not non-Hispanic white, pubertal youths. Third, the direction of the effect of depressive symptoms on fasting insulin was paradoxical. Depressive symptoms predicted less increases in fasting insulin over the study interval among pubertal non-Hispanic black youths. Post-hoc testing suggests the explanation for the direction of this finding is that black, pubertal adolescents with elevated depressive symptoms had the highest levels of fasting insulin initially, and these levels remained stably high over the follow up period. In contrast, pubertal blacks with low depressive symptoms, as well as pubertal whites regardless of level of depressive symptoms, started out with lower fasting insulin in adolescence and showed significant increases in fasting insulin into young adulthood.

The early onset of high levels of prolonged fasting insulin among pubertal black adolescents with elevated depressive symptoms has important clinical implications for type 2 diabetes prevention. Health disparities in type 2 diabetes risk are widely recognized, with rates 77% higher among blacks relative to the United States' national average (55). Type 2 diabetes continues to be on the rise in adolescents, especially racial/ethnic minority youth (3). Compared to all other racial/ethnic groups, black youths have the second highest prevalence of type 2 diabetes (1.06 per 1000), with the highest prevalence in American Indian youths (1.20 per 1000) and much lower rates in whites (.17 per 1000) (3). While these statistics suggest that type 2 diabetes is still relatively rare in childhood and adolescence, lifetime risk for type 2 diabetes, astoundingly, is estimated to exceed 50% for black women (56). Moreover, after developing type 2 diabetes, black people are more likely to suffer from diabetes-related complications and poorer glycemic control (57, 58). The etiology of these

differences in type 2 diabetes risk and complications are poorly understood, but research points to potential socio-environmental, as opposed to genetic, differences (59). Findings from the current study suggest that depressive symptoms tied to elevated fasting insulin—originating early, in the pubertal years—possibly may be one explanatory factor. Indeed, some research indicates higher rates of adolescent/early life depression in racial/ethnic minorities compared to whites (60), and there is recent evidence that depressive symptoms may mediate the effects of childhood socioeconomic adversity on subsequent diabetes risk (61).

The effects of depressive symptoms on fasting insulin change were not observed in participants who were post-pubertal at the start of the PSD Study. These null results were surprising given that many, though not all, studies of adults show that elevated depressive symptoms or clinical depression predict worsening insulin resistance (9, 10, 17, 54). The current results suggest that depressive symptoms experienced in the midst of puberty may have particularly important implications for insulin and diabetes risk. Further research is required starting even earlier—perhaps tracking pre-pubertal youths through the onset of puberty and subsequent resolution of puberty—to disentangle the nature of this complicated relationship between depressive symptoms and fasting insulin. While the vast majority of research on depression-diabetes focuses upon adulthood, these sorts of developmental studies are crucial to illuminating the influence of depression on diabetes risk.

It is noteworthy that the effects of depression on fasting insulin for black, pubertal adolescents were observed after accounting for BMI or even BMI change. Thus, depression's relationship to fasting insulin was independent of adiposity. A number of physiological mechanisms associated with stress, such as inflammation and dysregulation of the hypothalamic-pituitary-adrenal axis (20, 21), have been proposed to potentially account for the influence of depression on cardiometabolic disease, independent of energy balance. However, future research explicitly testing these factors as mediators is essential.

Findings of the current study are limited by reliance on several measurements prioritizing feasibility in large community samples. We relied upon self-report of depressive symptoms, fasting insulin as opposed to more sophisticated measures of insulin sensitivity, and estimated puberty based upon hormones and self-reported physical changes, rather than Tanner staging. Although these measures are all validated, care should be exercised in generalizing the findings to youth with clinical depression, and additional work is required to understand to what extent depressive symptoms may influence insulin resistance or even insulin secretion. Another shortcoming is the utilization of BMI indices as opposed to more accurate measures of excess or central adiposity, and thus, additional research clarifying the depression-insulin association independent of adiposity, assessed, for instance, via magnetic resonance imaging or dual energy x-ray absorptiometry, is needed. Further, a growing body of research using ecological momentary assessment tools indicates that there is significant intraindividual, daily fluctuations in mood states during adolescence, which are not captured by traditional survey measures of depressive symptoms, and which could be relevant to understanding the potential impact on insulin dynamics (62). Survey measures of depression also do not distinguish between individuals prone to overeating versus undereating, or hypersomnia versus insomnia, which may be quite relevant for determining metabolic risk.

Future research dissecting these more complex elements of depressive symptomatology in relationship to metabolic health in adolescents and young adults is strongly warranted. Additionally, because we analyzed two measurements spread widely apart (~eight years), it was not possible to elucidate the effects of pubertal development and depressive symptoms on insulin trajectories, which may yield further information. Although the effects were after accounting for sex, age, and parental education, additional factors warrant study as potential confounders or mediators, including other socioeconomic indicators such as unemployment or family stability, low birth weight, as well health behaviors such as smoking, eating behaviors, and exercise. Finally, although prospective, the data are correlational, prohibiting the ability to make causal inferences. Although depressive symptoms theoretically may influence fasting insulin, only experimental manipulations of depressive symptoms can address questions pertaining to causality.

The limitations of these data are balanced by significant strengths. We utilized a large population-based community cohort study that followed adolescents over a long interval into young adulthood, and collected information on relevant medications and diagnoses, as well as objective measurements of BMI and fasting blood samples. Our results highlight the complexity of the relationships among social, psychological and physiological risks for type 2 diabetes and provide a bird's eye view on how depressive symptoms during adolescence may affect fasting insulin and consequently, subsequent type 2 diabetes risk. The findings shed light on a subgroup—pubertal, black adolescents with elevated depressive symptoms—whose increased risk for hyperinsulinemia and, perhaps, eventual development of type 2 diabetes was heretofore unrecognized.

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Acronyms

BMI	body mass index
CES-D	Center for Epidemiological Studies-Depression Scale
PSD	Princeton School District

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FIGURE 1.

Post-hoc analyses to interpret how race moderates the relationship between baseline depressive symptoms and fasting insulin change among adolescents who were pubertal at baseline. Values displayed are unadjusted means for fasting insulin at each time point for pubertal participants categorized into four groups based on race/ethnicity (non-Hispanic black versus non-Hispanic white) and depressive symptoms (low or elevated based on CES-D score below versus equal to or above the median). *P* values are from Kruskal-Wallis analysis of variance tests.

TABLE 1

Descriptive information of participant characteristics

	% (n)
Female	55.8 (382)
Non-Hispanic black	43.4 (297)
Baseline pubertal	49.1 (336)

	Mean $\pm$ SD, Range	
	Baseline	Follow-up
Age (y)	14.44 $\pm$ 1.62, 12.20–17.99	22.48 $\pm$ 2.56, 18.00–27.26
BMI (kg/m ²)	23.52 $\pm$ 5.51, 14.82–53.67	27.37 $\pm$ 7.29, 16.48–68.32
BMI z-score	0.77 $\pm$ 0.96, –2.11–2.92	---
Insulin (μ U/mL)	21.41 $\pm$ 15.43, 1.20–137.53	26.44 $\pm$ 17.51, 5.82–159.60
Insulin (μ U/mL)	---	5.03 $\pm$ 19.76, –99.87–124.27
Depressive symptoms	13.84 $\pm$ 8.39, 0–50	---

BMI = body mass index.

TABLE 2

Multiple linear regression models predicting fasting insulin change among participants stratified by pubertal status at baseline

Predictors	Insulin (μIU/mL)			
	Baseline Pubertal (n = 336)	Baseline Post-Pubertal (n = 349)		
Black	3.06	2.94	3.49	2.26
Baseline high insulin	-8.25**	2.70	-11.07***	2.32
Black x baseline high insulin	-7.82 [†]	4.10	---	---
Baseline BMI z-score	-.12	1.14	2.33 [†]	1.25
Baseline depressive symptoms	-.07	.14	.10	.18
Black x baseline depressive symptoms	-.47*	.23	-.20	.28
Model R ²	.144***		.076**	

Models include adjustment for sex, baseline age, parental education, and length of follow up. The non-Hispanic black x baseline high fasting insulin interaction was not significant among post-pubertal subjects and is not included in models for this subgroup. Unstandardized coefficients (B) and standard errors (SE) presented.

p < .001.

**
p < .01.

*
p < .05.

[†]
p < .10.

TABLE 3

Multiple linear regression models predicting fasting insulin change and adjusting for change in BMI among participants who were pubertal at baseline

Predictors	Insulin ($\mu\text{IU/mL}$)	
	B	SE
Black	1.97	2.61
Baseline high insulin	-8.88***	2.39
Black x baseline high insulin	-6.67 [†]	3.64
Baseline BMI (kg/m^2)	-.21	.21
BMI (kg/m^2)	2.04***	.21
Baseline depressive symptoms	-.03	.13
Black x baseline depressive symptoms	-.41*	.21
Model R ²	.332***	

All models include adjustment for sex, baseline age, parental education and length of follow up. Unstandardized coefficients (B) and standard errors (SE) presented.

 $p < .001$.

*
 $p < .05$.

[†]
 $p < .10$.

n = 336.