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Community Violence Exposure, Sleep Disruption, and Insulin Resistance in Low-Income Urban Adolescents

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Abstract

Background Exposure to violence, which is experienced at disproportionally higher levels by black versus white youth, is associated with disruptions in sleep and elevated cardiovascular risk. Further, poor sleep hygiene is associated with insulin resistance. However, research to date examining disruptions in sleep and cardiovascular risk in African-American adolescents has not taken the impact of exposure to violence into account, nor considered how gender might affect patterns of association. The present study addressed this gap by testing a path model linking exposure to community violence, sleep disruption, and insulin resistance in a sample of African-American adolescents and evaluating model fit across gender.

Method African-American adolescents ($N = 107$; 56% female; $M_{age} = 14.29$, $SD = 1.17$) completed structured interviews at home and provided a blood sample after fasting overnight.

Results The model fit connecting exposure to violence with sleep disruption and insulin resistance, adjusting for depressive symptoms and body mass index z score, was excellent. Multiple group analysis indicated gender differences in model fit. Path analysis revealed significant positive associations between exposure to violence and sleep disruption and sleep disruption and insulin resistance for females but not males.

Conclusion These data indicate that low-income, urban African-American female adolescents who witness violence and experience sleep disruptions may already be at elevated risk for health problems compared with their male counterparts. Additional research should attempt to replicate and explicate the underlying reasons for the gender differences observed here, with the goal of improving health and disrupting the path leading to health disparities.

Keywords Insulin resistance · Sleep problems · Violence exposure · Gender differences · African-American · Adolescents

Introduction

Evidence suggests that exposure to violence during adolescence increases cardiovascular risk into adulthood [1]. A recent study that examined racial disparities in violent victimization, and health consequences associated with violence exposure during childhood by black youth and young adults, found that black adolescents and young adults were at risk for the most physically harmful forms of violence compared with whites [2]. Mounting evidence suggests that this exposure to violence contributes to health disparities, particularly with regard to sleep disruption and cardiovascular risk [2–4]. However, research to date linking disruptions in sleep and cardiovascular risk in African-American adolescents has not taken the impact of exposure to violence into account. Adolescents who are exposed to violence experience more disrupted sleep, including problems falling asleep, staying asleep, and staying awake during the day [5–7]. These associations remain after adjusting for known correlates such as depressive symptoms and intrusive thoughts. In otherwise healthy

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adolescents, insufficient sleep is associated with alterations in HOMA-IR indicative of insulin resistance, the strongest predictor of type 2 diabetes risk [8–10]. In a narrative review of 23 studies, evidence generally supports that both objective and subjective reports of disruptions in sleep are associated with insulin resistance in children and adolescents [11]. Among African-American adolescents specifically, sleep disruption is strongly associated with obesity and insulin resistance [12]. Further, Van Cauter's review [13] found consistent evidence that sleep disruptions result in decreased insulin sensitivity, independent of changes in adiposity. Another review correlated compromised sleep with insulin resistance as well as other predictors of cardiovascular risk including dyslipidemia and hypertension [14].

In summary, there is evidence that violence exposure during adolescence is associated with disruptions in sleep, which in turn increase risk for insulin resistance. These associations are more likely to be evident in African-American compared with white youth, as African-American youth have higher rates of exposure to violence. Additionally, within the African-American community, there is evidence that girls and women may be at particularly high risk for cardiovascular health disparities. In a recent *American Psychologist* article on *Reducing disparities and achieving equity in African American women's health*, Belgrave and Abrams [15] noted that African-American women, relative to women in other racial/ethnic groups, fare worse on nearly every health indicator with cardiovascular disease being the leading cause of death in women over the age of 20. Further, these cardiovascular health disparities begin in adolescence [16].

Building on this work, as well as on the need for research on mechanisms linking stressors during adolescence with processes that lead to compromised health, the present study tested a path model linking exposure to community violence, sleep disruptions, and insulin resistance in a sample of low-income, urban, African-American adolescents. Given concerns that health risks for African-American women may emerge early [15], the study also examined gender differences in patterns of associations between our study constructs. Indirect associations between exposure to community violence and insulin resistance via compromised sleep were hypothesized. Specifically, positive associations between violence exposure and sleep disruption, and positive associations between sleep disruption and insulin resistance were anticipated. Depressive symptoms were controlled to adjust for the contribution of depression on violence exposure and sleep, and body mass index z score (BMIz) was controlled to adjust for contributions to insulin resistance.

Methods

Recruitment and Data Collection

The Institutional Review Board at the authors' university approved the study. Parents or legal guardians provided written informed consent for their children to participate, and adolescents provided written assent prior to the start of any data collection. Participants were recruited from health clinics and fairs in local housing communities in low-income urban areas of central Virginia, USA, as well as by word of mouth. All African-American, biological, mother-adolescent dyads, who were living together in a low-income urban community, and had a household income 125% or less above the federal poverty line ($30,750), were eligible for inclusion. There were no other exclusion criteria. All study data were collected between August 2013 and December 2015.

After determining eligibility, two trained interviewers visited the participants' home. Mothers and adolescents completed the home interview portion of the study separately. Data collection involved standardized questionnaires programmed into laptops using computer-assisted survey software (CAPI, Sawtooth Software, Inc.). Research assistants read questions aloud and recorded responses directly into the computer. Visual aids were used so participants could follow along with the survey questions. At the end of this visit, the health assessment visit was scheduled. Funding supported obtaining laboratory measures on 54 dyads of the total sample. The first 54 families who agreed to the blood draw and who could be scheduled for a health assessment within 2 weeks of their initial survey assessment provided the blood samples. For the health assessment, a research assistant trained in phlebotomy visited the home between 7:00 and 10:00 a.m. to collect a health history, anthropomorphic measures (height, weight, blood pressure), and 12 ml of blood for fasting laboratory measures. Blood samples were labeled, immediately stored on ice, and delivered to the laboratory for analysis directly following the visit. Families were compensated $100 ($50 each to the mother and adolescent) for their time in gift cards and received the results of their biological assessments to share with their healthcare providers.

Measures

Sociodemographic Variables Sociodemographic variables, reported by mothers, included adolescent age, adolescent gender, annual household income, maternal education (highest level of education achieved), and family structure.

Health History Data regarding prior diagnosis of disorders of glucose metabolism including types 1 and 2 diabetes, polycystic ovarian syndrome, and obstructive sleep apnea were collected. Data on medications that could affect sleep or glucose metabolism also were collected.

Community Violence Exposure Violence witnessed in the previous year was self-reported with 20 items from the Survey of Children's Exposure to Violence [17]. Designed to cover a wide range of exposures, this measure includes items ranging

from drug activity to knife attacks and murder. Response options include 1 (never), 2 (1–2 times), 3 (3–5 times), 4 (6–9 times), 5 (10–19 times), and 6 (20 or more times). Items were summed to create a total score, with higher scores reflecting greater exposure to violence. A meta-analysis on violence exposure and mental health outcomes indicated that this measure is the most frequently used tool to assess youth's exposure to community violence and it appears to have good predictive validity [18]. Cronbach alpha in the present study was .92.

Sleep Disruption Adolescents completed the 10-item Sleep/Wake Behavior Problems Scale [19] to index erratic sleep-wake behaviors (e.g., "extremely hard time falling asleep") over the previous 2 weeks. Response options ranged from 1 (never) to 5 (every day or every night). Items were summed to create a total sleep-wake behavior problems score, with higher values indicating more disrupted sleep. Cronbach alpha in the present study was .77. This measure has been used extensively with a broad range of adolescent samples and evidences excellent predictive validity [20].

Insulin Resistance Glucose and insulin levels were assessed by the clinical pathology laboratory using well-established procedures. Insulin resistance was assessed with fasting blood glucose (mg/dL) and insulin (mg/dL) using the homeostatic model assessment of insulin resistance (HOMA-IR) (fasting glucose × insulin/405), which has been validated in adolescents [8], and provides a more sensitive measure of evolving insulin resistance than either fasting glucose or insulin levels alone [10]. HOMA-IR greater than 2.6 is associated with increased cardiometabolic risk in adolescents [21].

Control Variables: Depressive Symptoms Adolescents reported their depressive symptoms with the 27-item Children's Depression Inventory (CDI; [22]), which measures cognitive, affective, and behavioral symptoms of depression in school-aged children and adolescents experienced in the previous 2 weeks. Each item consists of three statements graded in order of increasing severity, ranging from 0 (absence of symptoms) to 2 (definite symptoms). Youth select the sentence that best describes them for the past 2 weeks. A total depressive symptom score was calculated by summing all the items. The CDI has good sensitivity and specificity as well as relatively high test–retest reliability and internal consistency [22]. Cronbach alpha in the current study was .83.

Body Mass Index *z* Score (BMIz) Weight was measured in kg using a portable medical grade scale. Height was measured in cm with a tape measure. BMIz score was calculated using a commercially available program that considers weight, height, gender, date of birth, and age at the time of clinical measurements (https://zscore.research.chop.edu/index.php). BMIz score was used as a control variable rather than BMI because BMI is quite variable during adolescence.

Data Analysis

First, *t* tests were used to compare adolescents with and without valid blood samples on questionnaire measures and BMIz. Next, descriptive information on and correlations among the study constructs by gender was calculated. Third, path analysis within Mplus [23] was used to assess the primary hypotheses. The fit of the model was assessed using the χ^2 value, the comparative fit index (CFI), and the root mean square error of approximation (RMSEA). Values of 0.90 or above for the CFI [24] and 0.08 or below for the RMSEA [25] indicated that the model adequately fit the data. Gender differences in relation between variables for this model were tested using multiple group analyses. An unconstrained model where the path coefficients were allowed to vary by gender was compared with a constrained model where path coefficients were set to be equal across gender. The fit for the unconstrained and constrained models were evaluated by examining differences in the models based on the CFI, RMSEA, and the Bayesian information criterion (BIC). Finally, a sensitivity analysis was conducted by dichotomizing youth's HOMA-IR values into lower versus higher cardiometabolic risk and computing a model predicting this categorical outcome. The predictors (violence exposure and sleep disruption) and control variables (depressive symptoms and BMIz scores) in this model were identical to those in the previous model.

Results

Participants

Participants included 107 African-American adolescents who were part of a larger study of mother-adolescent dyads focused on health and resilience in teens. Adolescents (56% female) were 13 to 17 years old ($M = 14.29$, $SD = 1.17$). None had been diagnosed with disorders or were taking medications that affect glucose metabolism or sleep. Family structure varied, but in the majority of participating households, the mother had never married (55%). A quarter of the households had mothers who were married or cohabitating (25%), 12% were separated, 5% were divorced, and 3% were widowed. Maternal education was low, with 32% of the sample having less than a high school education, 29% having a high school diploma or general education diploma (GED), 19% completing some college, 16% earning an associate's or vocational degree, and 4% completing a bachelor's degree or higher. Median annual household income after taxes was $ 10,452–$15,600.

Comparisons of adolescents with and without valid blood samples revealed no significant differences on the level of

violence witnessed, $t(102) = -.04$, $p = .97$, sleep disruption, $t(103) = 1.13$, $p = .26$, depressive symptoms, $t(102) = .19$, $p = .85$, or BMIz score, $t(97) = .05$, $p = .96$. Thus, there do not appear to be systematic differences among adolescents with and without blood samples on the other key variables in the model. Table 1 presents descriptive information on the study variables, and Table 2 presents Pearson correlations among study constructs by gender. As seen in Table 2, for both genders, witnessing violence was positively and significantly associated with sleep disruption. Additionally, for both genders, sleep disruption and depressive symptoms were positively and significantly associated. However, sleep disruption was only significantly associated with insulin resistance in females.

Associations between exposure to violence, sleep disruption, and insulin resistance were tested in a multivariate context using path analysis. Overall, model fit was good, $N = 97$; χ^2 (4) = 4.12, $p = .39$; RMSEA = .017 90% CI(0, .155); CFI = .998; SRMR = .049. In the overall model, the paths from violence exposure to disrupted sleep and from disrupted sleep to insulin resistance each were positive and significant. Multiple group analysis revealed a lower sample size adjusted BIC value for the unconstrained compared with the constrained model (1549.69 versus 1554.47), a lower RMSEA (.076 versus .120), a higher CFI (.968 versus .867), and a lower SRMR (.083 versus .155). For these reasons, it was determined that the unconstrained model was preferred over the constrained model, indicating that the path coefficients in the model differed for males and females. Figure 1 presents the standardized path coefficients for the unconstrained model, with values for females in front of the diagonal, and values for males behind the diagonal. Consistent with the univariate analyses, sleep disruption was only associated with insulin resistance as assessed by HOMA-IR in females.

A sensitivity analysis then was conducted by dichotomizing youth's HOMA-IR values into lower versus higher cardiometabolic risk using a cutoff value of 2.6, based on the clinical literature [21]. Twenty-three percent of the sample had HOMA-IR scores equal to or greater than 2.6, placing them at elevated cardiometabolic risk. Univariate analyses revealed that this percentage did not differ across gender, Chi-square (1) = 0.74, $p = .49$; or by age, $t(45) = 0.96$, $p = .34$. However, youth within the higher category of HOMA-IR risk relative to youth in the lower risk category had more disrupted sleep, $t(43) = -2.19$, $p = .03$ (Ms = 25.36 [SD = 6.70] & 20.36 [SD = 6.55]), more symptoms of depression, $t(43) = -2.62$, $p = .01$. (Ms = 12.97 [SD = 8.47] & 7.09 [SD = 5.72]), higher BMIz scores, $t(45) = -2.81$, $p = .007$, (Ms = 1.56 [SD = 1.20] & 0.28 [SD = 1.36]), and marginally more exposure to violence, $t(43) = -1.79$, $p = .08$ (Ms = 45.00 [SD = 21.03] & 35.32 [SD = 13.47]).

As with the previous analysis, associations between exposure to violence, sleep disruption, and insulin resistance were tested in a multivariate context using path analysis. The difference between this model and the previous model was that the insulin resistance outcome in this model was categorical. Overall, model fit was good, $N = 97$; χ^2 (4) = 2.97, $p = .56$; RMSEA = 0 90% CI (0, .134); CFI = 1.0; SRMR = .059. In the overall model, the paths from violence exposure to sleep disruption and from sleep disruption to insulin resistance risk each were positive and significant. Further, the covariate depressive symptoms were positively associated with both violence exposure and sleep disruption, and the covariate BMIz score was positively associated with insulin resistance risk. As with the prior analyses, there was a significant positive association between sleep disruption and insulin resistance risk for females ($r = .42$, $p = .03$) and a non-significant negative association for males ($r = -.19$, $p = .49$).

Discussion

To better understand the roots of health disparities in adulthood, this study examined a path model linking exposure to community violence, sleep disruption, and insulin resistance in a sample of low-income urban adolescents. Depressive symptoms were controlled given the robust associations with both exposure to violence and sleep disruption, and body mass

Table 1 Descriptive information on the study variables by gender

Variables	Males			Females		
	M	SD	Range	*M*	SD	Range
1 Adolescent age	14.19	1.14	13–17	14.37	1.21	13–17
2 Violence seen	37.36	14.44	20–83	37.83	16.32	22–99
3 Sleep disruption	21.88	6.88	12–38.57	22.99	7.45	11–42
4 Depressive symptoms	6.83	5.19	0–22	10.11	6.59	0–32
5 BMI *z* score	.23	1.74	−7.22 to 2.77	0.85	1.38	−3.59—2.79
6 Insulin resistance	1.54	1.10	0–3.70	2.27	1.51	0–5.27

Table 2 Correlations among study variables by gender

Variables	1	2	3	4	5	6
1 Adolescent age	–	− .18	− .01	.13	− .15	− .17
2 Violence seen	.10	–	.52***	.41***	.10	.54***
3 Sleep disruption	.06	.38**	–	.40**	.12	.51**
4 Depressive symptoms	.03	.22	.49***	–	.11	.30
5 BMI *z* score	− .24	− .12	0	− .05	–	.19
6 Insulin resistance	− .08	− .01	.16	.31	.79***	–

Correlations for females are above the diagonal and correlations for males are below the diagonal

**$p < .01$; ***$p < .001$

index (using *z* scores) was controlled given known associations with insulin resistance [10]. Gender differences in model fit were examined. The results align with prior reviews showing the negative health impacts of exposure to community violence during childhood and adolescence [3], as well as with a review linking disruptions in sleep to insulin resistance [13]. Interestingly, the link between disruptions in sleep and insulin resistance was confined to females in our sample, highlighting the message conveyed in Belgrave's and Abrams' [15] work.

The association between disruptions in sleep and insulin resistance and type 2 diabetes risk in children and adolescents has been well established [11, 26]; our study replicates these findings among a sample of disadvantaged African-American youth. However, contrary to previous studies [27], we found stronger associations between sleep disruption and insulin resistance for females versus males. Additional studies are needed to further elucidate for whom associations between sleep disruption and insulin resistance apply, and the potential factors associated with such differences. Diversity in samples, including the level of background stressors to which adolescents were exposed, age, and race/ethnicity, and controls included in the models could help to explain some of the differential findings.

Limitations of this study include the cross-sectional design, which limits our ability to make statements about temporal ordering of variables; the correlational nature of the work, which does not allow us to make statements about causal associations among our constructs; and the reliance on adolescents' subjective self-reports of violence exposure and sleep disruption, although that is quite common in the literature. Pubertal status, menstrual history, pregnancy, and lactation were not assessed and could affect insulin resistance assessment. Further, the use of a tape measure for height assessment could have resulted in measurement error. Nevertheless, this study investigated an important topic, assessed a difficult to recruit sample, used well-validated measures, and tested gender differences, which are all strengths. Additionally, our measure of sleep disruption encompassed both sleep duration and sleep patterns. This is a strength given prior studies suggest that sleep irregularity may be stronger predictor of risk than sleep duration alone [28].

In terms of future research, scholars might consider including sleep duration and habits with actigraphy to augment self-reports of sleep disruption, and corroborating self-reports of witnessed violence with police data or other objective indicators of exposure to enhance data quality. Additionally, exploring both psychological and biological explanations for the observed gender differences between sleep disruptions and insulin resistance would be important to investigate, given the role insulin resistance plays in health [29].

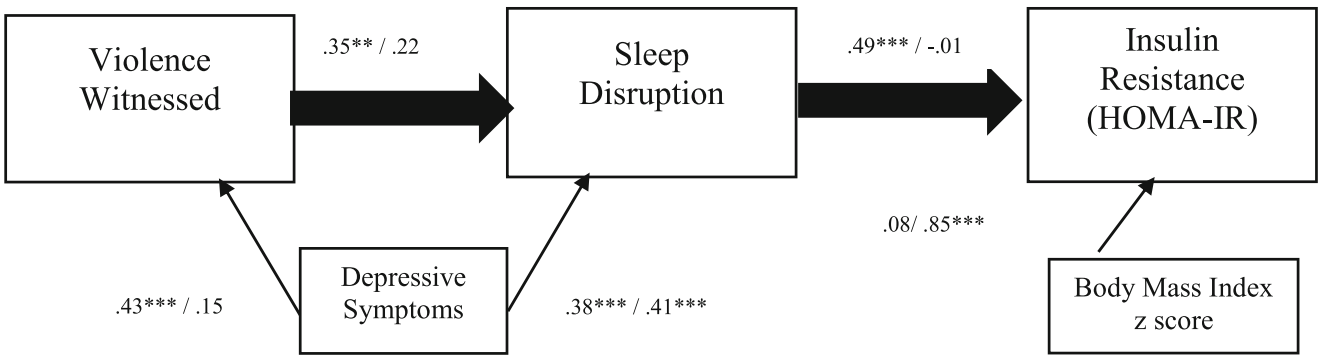

Fig. 1 Relations between community violence witnessed in the previous year, sleep disruption, and insulin resistance, adjusting for depressive symptoms and body mass index *z* score (BMIz), by gender. Standardized beta weights are presented in the figure. Values in front of the diagonal are for females; values behind the diagonal are for males. **$p < .01$; ***$p < .001$

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Compliance with Ethical Standards

Ethical Approval All procedures performed involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Ethical approval to conduct the study was obtained from the authors' university.

Informed Consent Written informed consent or assent (as appropriate) was obtained from all individual participants included in the study.

Conflict of Interest The authors declare that they have no conflicts of interest.

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