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An abstract of
A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
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Abstract

Examining the Association Between Adverse Childhood Experiences and Ambulatory Blood Pressure in Adulthood Among Black Women in Georgia
By Ranni Tewfik

Adverse childhood experiences (ACEs) are potentially traumatic events that occur before age 18 and include witnessing or experiencing violence, abuse, or neglect in the home or community. Studies have shown that childhood adversity contributes to hypertension in adulthood, and Black American women have a heavier burden of ACEs and elevated blood pressure compared with other groups. Resting blood pressure methods have been used in most studies focusing on the association between ACEs and blood pressure, however, ambulatory blood pressure (ABP) monitoring is a more precise method and considered the gold standard. The purpose of this investigation was to investigate the relationship between ACEs and ABP in adulthood among Black women in Atlanta, Georgia, using baseline data from the Mechanisms Underlying Stress and Emotions in Heart Health (MUSE) study. To our knowledge, no studies have examined ACEs and ABP, and only one study has explored race, gender, aggregate ACEs, and elevated blood pressure. This was the first study to examine the association between cumulative ACEs and ABP, rather than resting blood pressure, and with a particular focus on Black women.

In the MUSE study, Black female adults aged 30-46 in Atlanta were enrolled from 2016 to 2019. ACEs were measured using a 10-item self-report questionnaire with subscales of abuse, neglect, and household dysfunction. The ACE composite score was categorized into four groups: no exposure, low exposure, moderate exposure, and severe exposure to ACEs. ABP was measured using a 48-hour monitoring device to record average daytime and nighttime systolic and diastolic blood pressure. The covariates used in the regression models for statistical analysis were age, education level, income level, smoking status, alcohol use status, BMI, and depression score. Logistic regression models were used to assess the association between ACE levels and the categorical measures of ABP, and linear regression models were used for the continuous measures of ABP. The results did not support the hypothesis that ACE exposure level is significantly associated with ABP. Across all comparison groups, there were no significant associations between exposure to ACEs at any level and any ABP outcome measure, even after adjusting for covariates.

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Introduction

Childhood abuse is a harmful stressor prevalent in the U.S., with 35% of adults reporting emotional abuse as a child, 18% reporting physical abuse, and 12% reporting sexual abuse, according to data from the Behavioral Risk Factor Surveillance System (CDC, 2020). Adverse childhood experiences (ACEs) include these more severe forms of abuse, but also a broader range of experiences that occur in the home prior to the age of 18 years (CDC, 2022). ACEs are defined as potentially traumatic events that occur in the first 18 years of life and include "experiencing violence, abuse, or neglect; witnessing violence in the home or community; having a family member attempt or die by suicide," as well as household problems with substance use, mental health, and overall instability (CDC, 2022). A survey conducted in 25 states showed that about three out of five adults had experienced one type of ACE (CDC, 2022). Data from the survey also indicated a heavier burden of ACEs on women and Black Americans, who are at greater risk of experiencing multiple ACEs (CDC, 2022).

A recent systematic review and meta-analysis of 96 articles showed that trauma and adverse experiences early in life, including physical, emotional, and sexual abuse, were associated not only with negative psychosocial and behavioral outcomes but also with a range of chronic illnesses in adulthood (Petruccelli et al., 2019). Individuals with adverse childhood experiences (ACEs) are more likely to develop unhealthy behaviors as adults (Hemmingsson et al., 2014) and, as a result, are more likely to have higher rates of hypertension (Stein et al., 2010), which has been associated with increased risk of coronary heart disease and stroke (Virani et al., 2021). Childhood adversity has been suggested as a contributing factor of hypertension in adulthood (Stein et al., 2010), however, with few exceptions (Su et al., 2015), most studies have focused on one or two indicators of childhood adversity and blood pressure measures later in life

(Petruccelli et al., 2019). But because ACEs are interrelated, it is important to capture a cluster of ACEs rather than looking at just one element of abuse, neglect, or violence early in life. Chapman et al. (2004) found that "a strong graded relationship was generally evident between the number of ACEs and recent and lifetime depressive disorders among men and women." Therefore, a composite ACE score to assess the cumulative effect of multiple ACEs seems to be a better measure of childhood adversity.

The burden of ACEs on blood pressure may be particularly more important to examine in Black Americans. Race, ethnicity, and other sociodemographic factors have a strong association with both ACEs (Slopen et al., 2016) and hypertension (Ostchega et al., 2020). In particular, Black Americans experience a higher prevalence of trauma in early life compared to their White counterparts (Slopen et al., 2016). Racial disparities in exposure to community violence in childhood may contribute to the higher burden of elevated blood pressure levels seen among Black Americans (Kapur et al., 2022). The impact of ACEs on hypertension in Black individuals is of major concern, as Black patients often have more severe forms of hypertension than White patients (Carson et al., 2011). Also, Black individuals are more likely to experience progression from elevated blood pressure to hypertension at a faster rate than other racial groups (Selassie et al., 2011). Yet, there have been relatively few studies that have investigated the relationship between ACEs and cardiovascular risk factors among Black Americans.

The impact of ACEs on blood pressure also may be more pronounced for women. Compared to men, women have been shown to have greater differences in blood pressure and other measures of cardiovascular function in reaction to acute psychosocial stressors, as well as slower recovery from such stressors (Kudielka et al., 2004). Moreover, being raised in adverse family conditions may be more damaging for women, given that women may be more vulnerable to interpersonal stressors than men (Cohen et al., 2019). Therefore, gender differences in acute stress reactivity and recovery and vulnerability to interpersonal stressors may contribute to increased risk of CVD in women. Previous studies have found a stronger association between childhood abuse and hypertension in women compared to men (Ford and Browning, 2014) (Suglia et al., 2014).

To the best of our knowledge, only one study has explored the interrelationships among race, gender, cumulative ACEs, and elevated blood pressure (Su et al., 2015). Su et al. (2015) conducted a longitudinal analysis of the association between exposure to multiple ACEs and blood pressure among a cohort of 97 European American men, 84 European American women, 89 African American men, and 124 African American women in Georgia. The investigators found no main effect of ACEs on average blood pressure levels, and there was no effect modification by race or gender. A notable limitation of the study was the reliance on average resting systolic (SBP) and diastolic (DBP) blood pressure to measure the outcome of interest, which is a less precise method than the gold standard: ambulatory blood pressure (ABP) monitoring (Pena-Hernandez et al., 2020).

There are several advantages to using ABP monitoring rather than other methods for measuring blood pressure, one of which is that ABP monitoring "provides a more accurate physiological description of systemic blood pressure throughout an entire 24-hour time period for patients either on or off antihypertensive drugs" (Pena-Hernandez, 2020). ABP monitoring can document daytime and nighttime blood pressure levels, 24-hour average blood pressure, and nocturnal versus diurnal change in blood pressure (Pena-Hernandez et al., 2020). Also, there are certain clinical conditions in which ABP monitoring is recommended: masked hypertension (for patients both on and off antihypertensive medications), white coat hypertension, the assessment of nighttime blood pressure (Pena-Hernandez et al., 2020). Both the United States Preventive Services Task Force (Siu, 2015) and the National Institute for Health and Care Excellence (Jones et al., 2020) recommend using ABPM as a tool to confirm hypertension in clinic practice, as the data obtained with ABP monitoring can be adjusted based on medical need (Pena-Hernandez et al., 2020).

The proposed study is designed to examine the association between ACEs and elevated blood pressure using ABP monitoring in a cohort of Black women, a group at the intersection of two vulnerable populations with regard to the burden and impact of ACEs on blood pressure. Our proposed investigation is different from the study by Su et al. (2015) because ABP monitoring is used to measure the outcome of interest rather than the traditional Dinamap method that measures average resting blood pressure. Because of the disparities in cardiometabolic health outcomes that exist among Black women and the scarcity of ACE and ABP studies in this specific gap, this project focuses on the relationship between exposure to traumatic events early in life and ABP as a proxy for cardiovascular health among Black women. Specifically, the investigation examines the association between ACEs and ABP in adulthood among Black women in Atlanta, GA, using baseline data from the MUSE study. This can help address gaps in literature centering on the relationship between ACEs and blood pressure, particularly the use of a comprehensive assessment of ACEs to measure the exposure of interest and the use of ABP monitoring to measure the outcomes of interest. The hypothesis is that ACE exposure level, assessed using an adapted CDC-Kaiser Permanente ACE questionnaire from the ACE study (Felitti et al., 1998), is significantly associated with ABP.

Methods

Participants

From December 2016 to March 2019, the Mechanisms Underlying Stress and Emotions in Heart Health (MUSE) study enrolled women in the greater metropolitan area of Atlanta, GA, who were aged 30-46 years, self-identified as Black or African American, and were premenopausal with at least one ovary. The purpose of the MUSE study was to understand the degree to which psychosocial stressors affect CVD risk. Primary recruitment for the study utilized National Opinion Research Center (NORC) sampling and screening methods so that participants represented a range of socioeconomic backgrounds. The MUSE study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline for cross-sectional studies (Vandenbroucke et al., 2007). The study procedures received approval by the Emory University Institutional Review Board. All participants provided written consent and were compensated for their time in the study.

Participants completed a standard protocol at baseline that included questionnaires and measurements of height, weight, and blood pressure, conducted at Emory University Hospital. An in-person interview was conducted to ascertain demographic, psychosocial, and behavioral characteristics. Following the standard protocol, the participants were provided an ABP device for 48-hour monitoring.

Exclusion criteria for the MUSE study included a history of CVD, pregnancy, lactation, chronic conditions linked to atherosclerosis, current psychiatric treatment, current illicit drug use, and alcohol abuse. Of the 422 eligible Black women who completed the in-person interview, 38 participants were excluded due to missing data on exposure to ACEs, ABP outcomes, or covariates of interest, resulting in a final sample of (N = 384) for the analyses.

ABP

Participants were fit with an ABP monitor and trained in proper application and removal techniques for 48-hour monitoring using a small, noninvasive device (SpaceLabs Healthcare OnTrak model 90227). The women were instructed to remove the monitor only to shower or bathe. The monitors were programmed to record SBP and DBP every 30 minutes during the day and every hour during the night. A team member in the study retrieved the ABP monitors following the 48-hour monitoring period. Blood pressure readings that were ±3 standard deviations from the participant's individual mean were deleted, and the remaining values were used to compute average daytime and nighttime SBP and DBP for each participant. Per the 2017 American College of Cardiology/American Heart Association (ACC/AHA) Guideline for the Prevention, Detection, Evaluation and Management of High BP, ambulatory hypertension was defined by SBP ≥ 130 mmHg or DBP ≥ 80 mmHg (Whelton et al., 2018).

ACEs

As in prior research (Su et al., 2015), a 10-item CDC-Kaiser Permanente ACE questionnaire adapted from the ACE study (Felitti et al., 1998) was used to measure the cumulative effect of multiple ACEs before age 18 years. Each item in the adapted questionnaire corresponds one of 10 subscales (which belong to one of three scales more broadly): abuse (emotional, physical, sexual); neglect (emotional, physical); and household dysfunction (parental separation or divorce, mother treated violently, substance abuse, mentally ill or suicidal, incarcerated household member). The affirmative responses to the dichotomous yes/no questionnaire items were computed to create a composite ACE score for each participant. For participants with missing data for ACE subscale items, imputation of the mean score of the subscale items was used for participants who completed at least 80% of the ACE subscale items. Otherwise, participants with missing data for ACE subscale items were not given a composite ACE score. The composite score was categorized into four groups: no exposure (0 ACEs), low exposure (1–2 ACEs), moderate exposure (3 ACEs), and severe exposure (≥ 4 ACEs), as was done in the study by Su et al. (2015).

Covariates

Covariates for the analyses were chosen based on those commonly used in prior studies looking at the relationship between ACEs and blood pressure outcomes (Petruccelli et al., 2019). Data on the following sociodemographic and behavioral characteristics were gathered via self-report on questionnaires: age; highest education level (high school or less, some college/occupational training, college or higher); income level (less than $35,000, $35,000 to $49,999, $50,000 to $74,999, $75,000 or more); smoking status (currently smoking or not); and alcohol use status (currently drinking alcohol or not). Baseline measurements of height and weight were used to calculate body mass index (BMI) (kg/m^2).

The 21-item Beck's Depression Inventory (BDI) was used to measure depressive symptoms (Beck et al., 1961). The summary score for BDI was classified as no depression (score < 21), borderline depression (score 21-30), moderate depression (score 31-40), or severe clinical depression (score > 40). For participants with missing data for BDI scale items, imputation of the mean score of the scale items was used for participants who completed at least 80% of the BDI scale items. Otherwise, participants with missing data for BDI scale items were not given a BDI summary score.

Statistical Analysis

Descriptive statistics were used to characterize study participants. Bivariate Pearson Correlation analysis was used to assess basic associations among ACEs, ABP outcomes, and covariates. Logistic regression models were conducted to assess the association between the ACE composite score categories (higher numbered categories indicating more total ACEs) and ambulatory hypertension (overall, daytime, nighttime) treated as categorical variables. Linear regression models were also performed to evaluate the relationship between ACE composite score categories and ambulatory blood pressure (daytime SBP, daytime DBP, nighttime SBP, nighttime DBP) treated as continuous variables. Covariates were added in a stepwise manner to measure the effect of covariate adjustment for the logistic and linear regression models: Model 1: unadjusted; Model 2: adjusted for age + highest education level + income level; Model 3: Model 2 + smoking status + alcohol use status + BMI; Model 4: Model 3 + BDI depression score. All statistical analyses were performed using SAS version 9.4. P-value < 0.05 was considered statistically significant.

<u>Results</u>

Participant Characteristics

As reported in Table 1, participants' mean (SD) age was 37.9 (4.2) (range, 30-46) years, and they represented a range of education level and income level. The mean (SD) ACE composite score was 2.8 (2.3) (range, 0-9). No exposure to ACEs was reported by 53 women (13.8%), low exposure to ACEs was reported by 161 women (41.9%), moderate exposure to ACEs was reported by 56 women (14.6%), and severe exposure to ACEs was reported by 114 women (29.7%). Women reporting severe exposure to ACEs compared to women with no exposure to ACEs were less likely to have an education level higher than high school (64 [56.1%] vs. 44 [83.0%], had lower incomes (e.g., <$50,000: 59 [53.6%] vs. 17 [33.3%]), were more likely to have a higher BMI (mean [SD], 33.3 [7.7] vs. 32.1 [7.5]), were more likely to smoke (14 [12.3%] vs. 4 [7.6%]), were less likely to use alcohol (88 [77.2%] vs. 44 [83.0%]), and were more likely to have depressive symptoms (mean [SD], 8.3 [8.4] vs. 3.5 [4.6]) (Table 1).

Women with severe exposure to ACEs compared to those with no exposure to ACEs also had a higher prevalence of ambulatory hypertension (33 [29.0%] vs. 12 [22.6%]), a higher prevalence of daytime hypertension (48 [42.1%] vs. 19 [35.9%]), a higher prevalence of nighttime hypertension (83 [72.8%] vs. 37 [69.8%]), higher daytime SBP values (122.1 [13.1] vs. 121.1 [10.3]), higher daytime DBP values (78.3 [9.2] vs. 77.5 [8.5]), higher nighttime SBP values (112.5 [12.8] vs. 111.3 [9.3]), and higher nighttime DBP values (69.2 [9.2] vs. 68.7 [8.4]) (Table 1).

Basic Associations Among ACEs, ABP Outcomes, and Covariates

ACE level was not significantly associated with any of the ABP outcomes of interest: ambulatory hypertension ($r = 0.08$; $P = 0.11$), daytime hypertension ($r = 0.08$; $P = 0.13$), nighttime hypertension ($r = 0.06$; $P = 0.28$), daytime SBP ($r = 0.05$; $P = 0.34$), daytime DBP ($r = 0.06$; $P = 0.27$), nighttime SBP ($r = 0.07$; $P = 0.19$), and nighttime DBP ($r = 0.05$; $P = 0.30$). Among the covariates, ACE level was not significantly associated with age ($r = -0.03$; $P > 0.50$), BMI ($r = 0.07$; $P = 0.19$), or smoking status ($r = 0.05$; $P = 0.32$); however, ACE level was significantly associated with education level ($r = -0.26$; $P < 0.001$), income level ($r = -0.17$; $P = 0.001$), and depression score ($r = 0.23$; $P = < 0.001$). Neither education level nor income level was significantly associated with any of the ABP outcomes of interest. Depression score was significantly associated with ambulatory hypertension ($r = 0.15$; $P = 0.005$), daytime SBP (r =

0.12; P = 0.02), and nighttime SBP (r = 0.13; P = 0.01). There were no significant associations between ACE categories (abuse, neglect, household challenges) adapted by the CDC (CDC, 2020) from the ACE study (Felitti et al., 1998) and the ABP outcomes of interest. No associations were modified by income level, where low income was defined as income less than $50,000, and high income was income of at least $50,000.

ACEs and Continuous ABP Outcomes

In unadjusted analyses (Model 1), there were no significant associations observed between women reporting severe exposure to ACEs (compared to their counterparts reporting no exposure to ACEs) and daytime SBP (β = 1.1; SE = 2.1; P = 0.60), daytime DBP (β = 0.8; SE = 1.5; P = 0.59), nighttime SBP (β = 1.2; SE = 2.0; P = 0.55), and nighttime DBP (β = 0.5; SE = 1.4; P = 0.73). Findings were similar when comparing moderate exposure to ACEs with no exposure to ACEs, as well as low exposure to no exposure. There were also no significant associations after adjusting for covariates in Models 2, 3, and 4 (Table 2).

ACEs and Categorical ABP Outcomes

In unadjusted analyses (Model 1), there were no significant associations observed between women reporting severe exposure to ACEs (compared to their counterparts reporting no exposure to ACEs) and ambulatory hypertension (OR = 1.7; 95% CI = 0.9-3.3), daytime hypertension (OR = 1.6; 95% CI = 0.9-2.8), and nighttime hypertension (OR = 1.4; 95% CI = 0.8-2.6). Findings were similar when comparing moderate exposure to ACEs with no exposure to ACEs, as well as low exposure to no exposure. There were also no significant associations after adjusting for covariates in Models 2, 3, and 4 (Table 3).

Table 1. Study sample demographics, covariates, adverse childhood experiences (ACE) composite score, and ambulatory blood pressure (ABP) outcomes by ACE level

Sample characteristic[1]	Overall N = 384	No exposure to ACEs N = 53 (13.8%)	Low exposure to ACEs N = 161 (41.9%)	Moderate exposure to ACEs N = 56 (14.6%)	Severe exposure to ACEs N = 114 (29.7%)	P-value
Age, years	37.9 (4.2)	37.8 (4.5)	38.0 (4.2)	38.2 (4.3)	37.5 (4.2)	0.82
Education level (%)						
High school or less	31.5	17.0	26.1	35.7	43.9	
Some college/ occupational training	20.6	9.4	20.5	21.4	25.4	< 0.001
College or higher	47.9	73.6	53.4	42.9	30.7	
Income level (%)						
Less than $35,000	24.7	17.7	18.8	26.8	35.5	
$35,000 to $49,999	21.2	15.7	25.6	19.6	18.2	0.03
$50,000 to $74,999	22.3	17.7	23.8	23.2	21.8	
$75,000 or more	31.8	49.0	31.9	30.4	24.6	
BMI, kg/m^2	32.6 (8.0)	32.1 (7.5)	32.1 (8.0)	33.1 (8.7)	33.3 (7.7)	0.54
Smoking (%)	10.7	7.6	9.9	12.5	12.3	0.65
Alcohol use (%)	82.8	83.0	88.2	78.6	77.2	0.17
Depression score	6.0 (6.9)	3.5 (4.6)	5.2 (6.5)	5.9 (5.1)	8.3 (8.4)	< 0.001
ACE composite score	2.8 (2.3)	0.0 (0.0)	1.5 (0.5)	3.0 (0.1)	5.8 (1.5)	< 0.001
ABP Outcomes						
Ambulatory HTN (%)	25.8	22.6	21.1	35.7	29.0	0.15
Daytime HTN (%)	37.2	35.9	32.3	42.9	42.1	0.35
Daytime SBP, mmHg	121.6 (12.4)	121.1 (10.3)	120.8 (11.7)	123.2 (14.2)	122.1 (13.1)	0.66
Daytime DBP, mmHg	77.7 (8.9)	77.5 (8.5)	77.0 (8.3)	78.7 (10.3)	78.3 (9.2)	0.61
Nighttime HTN (%)	66.4	69.8	62.1	62.5	72.8	0.28
Nighttime SBP, mmHg	111.5 (11.8)	111.3 (9.3)	110.3 (11.4)	113.0 (12.9)	112.5 (12.8)	0.38
Nighttime DBP, mmHg	68.7 (8.7)	68.7 (8.4)	67.9 (8.2)	69.9 (9.4)	69.2 (9.2)	0.45

[1] Reported as mean (standard deviation), unless otherwise indicated.
Abbreviations: kg, kilograms; m, meters; SBP, systolic blood pressure; DBP, diastolic blood pressure; HTN, hypertension; mmHg, millimeters of mercury.

Table 2. β (SE) and P-values of ACE levels[1] and continuous measures of ABP

	Low exposure to ACEs	P-value	Moderate exposure to ACEs	P-value	Severe exposure to ACEs	P-value
Daytime SBP						
Model 1[a]	-0.3 (2.0)	0.89	2.1 (2.4)	0.37	1.1 (2.1)	0.60
Model 2[b]	-0.9 (1.9)	0.63	1.0 (2.4)	0.68	-0.2 (2.1)	0.94
Model 3[c]	-0.7 (1.9)	0.70	0.8 (2.3)	0.74	-0.3 (2.1)	0.88
Model 4[d]	-1.0 (1.9)	0.61	0.5 (2.3)	0.83	-0.9 (2.1)	0.65
Daytime DBP						
Model 1[a]	-0.5 (1.4)	0.74	1.3 (1.7)	0.46	0.8 (1.5)	0.59
Model 2[b]	-0.8 (1.4)	0.56	0.6 (1.7)	0.71	0.1 (1.5)	0.93
Model 3[c]	-0.8 (1.4)	0.59	0.6 (1.7)	0.74	0.1 (1.5)	0.94
Model 4[d]	-0.8 (1.4)	0.55	0.5 (1.7)	0.79	-0.1 (1.5)	0.93
Nighttime SBP						
Model 1[a]	-1.0 (1.9)	0.58	1.7 (2.3)	0.46	1.2 (2.0)	0.55
Model 2[b]	-1.6 (1.9)	0.40	0.7 (2.3)	0.75	0.2 (2.0)	0.93
Model 3[c]	-1.3 (1.8)	0.46	0.5 (2.2)	0.81	0.0 (1.9)	0.99
Model 4[d]	-1.5 (1.8)	0.39	0.2 (2.2)	0.91	-0.6 (2.0)	0.76
Nighttime DBP						
Model 1[a]	-0.8 (1.4)	0.54	1.2 (1.7)	0.48	0.5 (1.4)	0.73
Model 2[b]	-1.1 (1.4)	0.42	0.7 (1.7)	0.66	0.1 (1.5)	0.97
Model 3[c]	-1.0 (1.4)	0.47	0.6 (1.7)	0.70	0.0 (1.5)	0.99
Model 4[d]	-1.1 (1.4)	0.42	0.5 (1.7)	0.77	-0.3 (1.5)	0.82

[1]No exposure to ACEs is the referent.
[a]Model 1: unadjusted
[b]Model 2: Model 1 + age + highest education level + income level
[c]Model 3: Model 2 + smoking status + alcohol status + BMI
[d]Model 4: Model 3 + depression score

Table 3. Odds ratios (95% CI) of ACE levels[1] and categorical measures of ABP

	Low exposure to ACEs	**Moderate exposure to ACEs**	**Severe exposure to ACEs**
Ambulatory hypertension			
Model 1[a]	1.2 (1.0-1.5)	1.4 (0.9-2.2)	1.7 (0.9-3.3)
Model 2[b]	1.1 (0.9-1.4)	1.3 (0.8-2.0)	1.5 (0.7-2.9)
Model 3[c]	1.1 (0.9-1.4)	1.3 (0.8-2.0)	1.4 (0.7-2.8)
Model 4[d]	1.1 (0.8-1.4)	1.2 (0.7-1.9)	1.2 (0.6-2.5)
Daytime hypertension			
Model 1[a]	1.2 (1.0-1.4)	1.4 (0.9-2.0)	1.6 (0.9-2.8)
Model 2[b]	1.1 (0.9-1.4)	1.3 (0.8-1.9)	1.4 (0.8-2.6)
Model 3[c]	1.1 (0.9-1.4)	1.2 (0.8-1.8)	1.4 (0.7-2.5)
Model 4[d]	1.1 (0.9-1.3)	1.2 (0.8-1.8)	1.3 (0.7-2.4)
Nighttime hypertension			
Model 1[a]	1.1 (0.9-1.4)	1.3 (0.8-1.9)	1.4 (0.8-2.6)
Model 2[b]	1.1 (0.9-1.4)	1.2 (0.8-1.9)	1.4 (0.7-2.6)
Model 3[c]	1.1 (0.9-1.4)	1.2 (0.8-1.8)	1.3 (0.7-2.5)
Model 4[d]	1.1 (0.9-1.4)	1.2 (0.8-1.8)	1.3 (0.7-2.5)

[1]No exposure to ACEs is the referent.
[a]Model 1: unadjusted
[b]Model 2: Model 1 + age + highest education level + income level
[c]Model 3: Model 2 + smoking status + alcohol status + BMI
[d]Model 4: Model 3 + depression score

Discussion

To our knowledge, this is the first study to examine the association between aggregate ACEs and ABP, rather than resting blood pressure, and with a particular focus on Black women. In this socioeconomically diverse study population of middle-aged Black women in Atlanta, we investigated the relationships between ACE exposure level (no, low, moderate, and severe exposure to ACEs) and ABP as continuous (daytime and nighttime SBP and DBP) and categorical (overall, daytime, and nighttime hypertension) outcome measures. Across all comparison groups, we observed no significant associations between exposure to ACEs at any level and any ABP outcome measure, even after adjusting for sociodemographic and behavioral covariates.

The hypothesis that we would find any significant association between ACE exposure level and ABP was not supported by the data. For the categorical outcomes, the odds ratios suggest a graded, albeit nonsignificant, relationship between ACE level and ABP across all hypertension outcomes and models, irrespective of which covariates were included in the analyses. These null results are inconsistent with prior research on ACEs and resting blood pressure. For example, of the eight studies we found examining the relationship between one or more ACEs and blood pressure in the last 15 years, only three studies reported no significant associations at all (Gooding et al., 2019) (Nikulina and Widom, 2014) (Lehman et al., 2009). The other five studies reported at least one significant association between an ACE measure and blood pressure (Kapur et al., 2022) (Schreier et al., 2019) (Su et al., 2015) (Ford and Brown, 2014) (Suglia et al., 2014). In the study most similar to ours, a cohort aged 5-38 years of 97 European American men, 84 European American women, 89 African American men, and 124 African American women, Su et al. (2015) observed interaction between ACE score and age on

SBP and DBP (significant associations were only observed after age 30), however, the main effect of ACEs on average blood pressure levels was null. Nonetheless, more research focused on ACEs and ABP monitoring is needed to either support or contradict our findings.

Consistent with prior studies (Islam et al., 2021) (Houtepen et al., 2020), reports of ACEs were associated with education level and income, such that reports of severe exposure to ACEs (i.e., four or more ACEs) were highest among women with the lowest levels of education and income. Also consistent with prior research (Gooding et al., 2019) (Chapman et al., 2004), reports of severe ACEs were associated with higher levels of depressive symptoms. However, ACEs were not significantly associated with BMI, smoking, or alcohol use in our cohort, which is inconsistent with prior studies (Gooding et al., 2019) (Su et al., 2015) (Nikulina and Widom, 2014) and a possible reason as to why we did not observe a significant relationship between ACEs and ABP. Because alcohol use and obesity have been linked with both ACEs (Lee and Chen, 2017) (Mahmood et al., 2023) and CVD (CDC, 2023), the null associations with risk factors might have impacted our results. Considerations of sample size and study power are also important in the discussion of non-significant findings, especially when subgroup analyses are involved. Whereas an overall analysis of the main effect of ACE composite score on ABP for all study participants may have yielded significant results, analyses of the smaller subgroups of exposure may have been a consequential factor in the non-significant findings due to an underpowered study design.

While prior research with significant results implemented methods with few ACE indicators (Petruccelli et al., 2019), they may have had more sensitive ACE measures than our 10-item CDC-Kaiser Permanente ACE questionnaire adapted from the ACE study (Felitti et al., 1998). The original ACE questionnaire used by Felitti et al. (1998) consisted of 17 items divided into seven subcategories: psychological abuse (2 questions), physical abuse (2 questions), sexual abuse (4 questions), substance abuse exposure (2 questions), mental illness exposure (2 questions), domestic violence exposure (4 questions), and criminal behavior exposure (1 question). The investigators found “a strong graded relationship between the breadth of exposure to abuse or household dysfunction during childhood and multiple risk factors for several of the leading causes of death in adults” (Felitti et al., 1998). Schreier et al. (2019) used the 13-item Family Environment Scale from the Risky Families Questionnaire to measure childhood environment and found that increased exposure to ACEs was significantly correlated with lower SBP and DBP among women. Similarly, Islam et al. (2021) found that higher levels of childhood trauma were associated with worse cardiovascular risk factors among lower income Black Americans using the 27-item Self-Report Short Form of the Early Trauma Inventory. Thus, future investigations using a more comprehensive measure of cumulative ACEs (i.e., more than one question for each ACE subscale) may result in more statistically significant findings, particularly in correlation analyses of ABP and ACE subscales: abuse, neglect, and household dysfunction.

Although some studies have found significant associations between ACEs and blood pressure using self-report questionnaires (Petruccelli et al., 2019), adults who have been traumatized by ACEs early in life often underreport their experiences (Hardt and Rutter, 2004). This can cause information bias and may result in invalid measures of association. Generally, self-report questionnaires like the one used in this study are inexpensive and feasible to administer, however, using multiple sources to verify the data being collected can increase validity and reduce systematic error. Bethell et al. (2017) compared methods to assess ACEs among children and families and evaluated their application in research and clinical practice.

One of the methods to assess ACEs included in the comparison review was the Yale-Vermont Adversity in Childhood Scale (Y-VACS), a 20-item questionnaire sponsored by the National Institute for Mental Health (Hudziak and Kaufman, 2014). Like the questionnaire used in our examination, Y-VACS was adapted from the CDC-Kaiser Permanente ACE questionnaire and is available in several versions, including parent-, clinician-, and self-report (Hudziak and Kaufman, 2014). We suggest future research projects look into methods like Y-VACS to measure ACE exposure utilizing multiple sources of information verification, though we recognize the likely increase in cost and time to implement such methods.

There are some limitations in our research that should be mentioned, one of which is the study design. Our data represent a cross-sectional snapshot of the ACE-ABP relationship and, therefore, cannot establish temporality or causality. Yet as ACEs occur in childhood and adolescence by definition, and poor cardiovascular health often presents later in life, it is more likely that ACEs preceded elevated blood pressure outcomes in our study. Additionally, the reliance on retrospective, self-reported information regarding ACE exposure introduces the possibility of recall bias that may distort the observed associations between ACEs and ABP. Finally, the responses from the 10-item questionnaire used to represent aggregate ACEs can encompass neither the whole spectrum of potentially traumatic experiences in early life nor all essential information to properly contextualize the experiences (e.g., age at onset).

Another limitation of this investigation is its lack of generalizability. The study population was limited to middle-aged Black women in Atlanta, GA, and although the basis for enrolling this specific demographic is justified – Black women have greater risk of experiencing multiple ACEs (CDC, 2022) and increased blood pressure (Ostchega et al., 2020) – using study results to make inferences about other races, genders, age groups, or geographic regions may not be possible. Furthermore, recruitment of participants considered socioeconomic status by design, resulting in a sample population with overrepresentation of college-educated women (48% in the study vs. 36% nationally) (Nichols and Schak, 2018).

Though the non-significant findings were unexpected, we maintain that this investigation extends prior research and addresses gaps in literature addressing the association between ACEs and blood pressure. Whereas some previous studies have looked at a limited number of ACE indicators and blood pressure measures among a non-specific demographic, this study is unique in its focus on measuring cumulative ACEs across 10 subscales in a vulnerable subpopulation (i.e., Black women) concerning the burden and impact of ACEs on blood pressure. Another novel aspect of this research is the utilization of 48-hour ABP monitoring to measure the outcomes of interest in examining the relationship between ACEs and blood pressure. The gold standard in clinical practice, ABP monitoring has been shown to be more precise and provide more information (e.g., nighttime blood pressure readings) than resting blood pressure methods (Pena-Hernandez et al., 2020).

In addition to pursuing the suggestions already discussed (more ACE studies that use ABP monitoring, sample size considerations across subgroups, and reliable and comprehensive methods for measuring ACEs), future studies should explore the modifying and mediating effects of coping behaviors in the association between ACEs and blood pressure. Very few studies have addressed the impact of coping with ACEs on adult health, and not much is known about how cumulative ACE exposure and specific ACE subgroups play into that relationship. Regarding one example of a coping mechanism, Brody et al. (2017) found that supportive parenting ameliorated the association between ACEs and prediabetes status in a cohort of 390 African Americans in rural Georgia. Another study reported that the negative effect of early traumatic stress on adult health was reduced by religious involvement factors (positive religious coping, intrinsic religiosity, forgiveness, and gratitude) among a sample of 6,533 White Americans and 3,750 Black Americans (Reinert et al., 2016). It should be noted that Black Americans attend religious services more frequently than any other race (Pew Research Center, 2023). Perhaps one explanation for the lack of significant results in this investigation is that Black women are better able to cope with traumatic experiences in childhood compared to other demographics and can maintain those positive adaptations throughout adolescence and adulthood, thereby attenuating the negative effects of ACEs on cardiovascular health. Further research is needed to test this hypothesis.

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