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Exposure to police-related deaths and physiological stress among urban black youth

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Highlights

- Exposure to police-related deaths is associated with negative health among blacks
- This study examined biological consequences of exposure for urban black youth
- Black boys exposed to a police-related death have higher average nightly cortisol
- No effect of police-related deaths on physiological stress levels of other youth
- Potential negative health consequences for black boys exposed to police-related deaths

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ABSTRACT

Background
Emerging evidence indicates that exposure to police-related deaths is associated with negative health and wellbeing outcomes among blacks. Yet, no study to date has directly examined the biological consequences of exposure to police-related deaths for urban black youth.

Methods and Findings
We employ unique data from the 2014-16 *Adolescent Health and Development in Context* (AHDC) study – a representative sample of youth ages 11 to 17 residing in the Columbus, OH area. A subsample of participants contributed nightly saliva samples for cortisol for up to six days, providing an opportunity to link recent exposures to police-related deaths within the residential county to physiological stress outcomes during the study period (N=585). We examine the effect of exposure to a recent police-related death in the same county on the physiological stress (nightly cortisol) levels of black youth. We find evidence of elevated average levels of nightly cortisol (by 46%) for black boys exposed to a police-related death of a black victim in the 30 days prior to the subject's cortisol collection. We find no evidence of police-related death effects on the physiological stress levels of black girls or white youth.

Conclusions
These analyses indicate that police-related deaths influence the biological functioning of black boys, with potential negative consequences for health. We consider the implications of exposure to lethal police violence among black boys for understanding racial disparities in health more broadly.

Keywords: police-related deaths, police killings, physiological stress, cortisol

1. INTRODUCTION

The health and wellbeing effects of exposure to police violence have become a focus of increasing concern in the wake of widespread adoption of aggressive policing tactics and high profile instances of the lethal use of police force (U. S. Commission on Civil Rights, 2018). Although a number of studies have focused on the individual level impact of direct police contact experiences (Geller, 2020; Sugie and Turney, 2017), an emerging literature has documented the indirect, contextual impact of policing behavior, particularly for black urban residents. These *vicarious* exposures to aggressive and lethal policing practices (Brunson and Weitzer, 2009; Geller, 2020) have been linked with compromised physical health (Sewell et al., 2020; Sewell and Jefferson, 2016), mental health (Sewell et al., 2016), and educational performance (Legewie and Fagan, 2019).

Yet, a number of questions remain regarding the pathways through which the health consequences of police behavior are channeled. Notably, the specific biological effects of aggressive policing as captured by biomarkers of physiological stress have largely been neglected (although see McFarland et al., 2018b). We consider the consequences of exposure to the most extreme form of police violence – police-related deaths – for cortisol physiology, a theoretically plausible mechanism through which reactions to police use of force might be biologically manifest. Specifically, we examine the link between exposure to temporally and spatially proximate police-related deaths and elevated cortisol levels among urban youth – a population disproportionally exposed to aggressive policing.

1.1. Police-Related Deaths, Stress, and Cortisol Reactivity Among Young Urban Blacks

Cortisol is a steroid hormone that is released continuously by the hypothalamic pituitary adrenal (HPA) axis into the circulatory system to meet environmental demands (McCarthy, 2012). Under normal conditions, cortisol release follows a circadian rhythm, but levels can increase when an acute stressor is encountered. Chronic stress occurs when individuals encounter persistent or recurrent external threats to their physical and/or psychological wellbeing (Grant et al., 2003), which can result in alterations to both the diurnal and reactivity patterns of cortisol release (Contrada and Baum, 2011).

Importantly for the goal of identifying biological effects of police-related deaths, there is an extensive body of research grounded in Lazarus and Folkman's transactional model of stress (1984) that has identified psychological triggers of the cortisol response. According to the theory, a stress response is not solely a function of the stressful stimulus, but also of one's assessment of the personal relevance of the situation (primary appraisal) as well as the perceived capacity to deal with the stressor (secondary appraisal). When an event is appraised as presenting both a threat to the self and insufficient coping options (e.g. "I do not have control over the outcome"), an individual experiences emotions and biological reactions characteristic of a stressful experience (Dickerson and Kemeny, 2004). Critically, a secondary appraisal of a lack of control can elicit a cortisol response in anticipation of the event and doesn't require one to actually experience the event (Engert et al., 2013; Paridon et al., 2017).

For black male youth in particular, heightened awareness of a police-related death of a black male in one's city likely involves stress-inducing primary and secondary appraisals. The fatality rate from police-related deaths is approximately 2.5 times higher among black males by comparison with white males based on their relative proportions of the United States population

(Cesario et al., 2018; DeGue et al., 2016; Edwards et al., 2019; Schimmack and Carlsson, 2020). Black males are also disproportionately likely to experience unwarranted police stops and unjustified use of non-lethal force (Brunson and Weitzer, 2009; Geller et al., 2014; Legewie and Fagan, 2019; Sewell et al., 2016). Among urban youth, black boys are subjected to the gateway conditions for victimization by police, including police contacts such as stop and frisk, at markedly higher rates. Black boys report significantly higher lifetime incidence of personal contact with the police (39%) compared with white (23%) and Hispanic (20%) boys (Geller, 2020). For urban black males, a police-related death of a black victim – the vast majority of whom are male – powerfully demonstrates the ongoing risk presented by law enforcement officers and discriminatory targeting more generally, elevating threat appraisals. Viewed in the context of both a history of state-administered and tolerated lethal violence (Bailey and Tolnay, 2015; Garland, 2012) and contemporary susceptibility to aggressive policing, police-related deaths of black male victims are likely to be seen as an expression of ongoing institutionalized violence directed toward black men.

Beyond the direct threat of violent victimization, police-related deaths of black victims may also serve as a forceful, personally relevant reminder that vulnerability to discrimination is a pan-institutional hazard for black men. Evidence indicates that the anticipation of discriminatory targeting across a wide range of formal and informal settings is an everyday experience for blacks, resulting in heightened vigilance in public spaces (Feagin, 1991). Consistent with these findings, Hicken et al (2013) find that elevated levels of racism-related vigilance was positively associated with sleep difficulties among blacks and completely explained the black-white disparity in this outcome. In this view, exposure to discrimination is a chronic threat the response to which may have implications for both subjective and physiological stress

(Himmelstein et al., 2015). As an instance of vicarious discrimination, police-related deaths of black victims are likely to substantially heighten more generalized racism-related vigilance among black male youth.

Awareness of a police-related death in one's vicinity is likely to be appraised as an extreme example of aggressive policing behavior over which black men have little control, potentially eliciting anticipatory stress and associated cortisol response. Extant research offers substantial evidence of elevated distrust of police and legal cynicism among urban blacks leading to heightened perceived risk of unfair treatment and unjustified targeting (Kirk and Papachristos, 2011; Sampson and Bartusch, 1998; Sewell, 2017). Qualitative evidence corroborates survey data on legal cynicism, indicating that black men often maintain an ongoing sense of vulnerability to potentially aggressive police behavior, regardless of their own actions (Smith Lee and Robinson, 2019). In this view, policing behavior is generally seen as uncontrollable, unpredictable, and potentially lethal among urban black males – impressions that likely amplify stress responses to recent police-related death events.

Although black females face substantially lower risk of lethal police violence than black men, they may nevertheless experience elevated stress responses to recent killings of black men. Black females are more likely to be killed by police than are white females (Edwards et al., 2019). Instances of lethal violence directed at black men may call attention to the heightened direct vulnerability to aggressive policing and the broader pattern of everyday and institutionally-based discrimination faced by black women and girls. Moreover, as Sewell et al (2020) note, health-related stress consequences may follow from the disproportionate representation of others who have experienced police harassment or violence in the networks of black females (Goff et al., 2016), concern over which may be elevated among black females (Hurst et al., 2005). Thus, we expect recent police-related deaths involving black victims to elicit anticipatory stress processes affecting cortisol production among black adolescent girls, but at lower levels than those exhibited by black boys.

The focus of our analysis is on the biological consequences of exposure to recent police-related deaths of black victims among black urban youth, expecting elevated physiological stress (as captured by nightly cortisol) among both black boys and girls, but more pronounced effects for the former. We also consider the effects of recent police-related deaths of black victims on white youth, expecting no observed impact on nightly cortisol. We draw on unique data from adolescents that include nightly saliva samples for cortisol over the course of 6 days, providing an opportunity to link the timing of exposure to police-related deaths with a stress biomeasure. These analyses offer the first investigation of exposure to lethal police violence and daily physiological stress among a representative sample of urban youth.

2. METHODS

2.1. Study Design

The study draws on data from two linked data collection efforts: 1) *The Adolescent Health and Development in Context (AHDC)* study – a representative cohort study that examines the impact of social and spatial environments on the behavioral and health outcomes of youth aged 11-17 years in Franklin County, Ohio (collected during 2014-2016) and 2) *The Linking Biological and Social Pathways to Adolescent Health and Wellbeing* (Bio-Social Linkages), a supplementary study which collected nightly cortisol for a subsample of 650 of the 1,405 Wave 1 (2014-2015) AHDC youth (Ford et al., 2019; Ford and Stowe, 2017; Schmeer et al., 2019). The study design and procedures were reviewed and approved by the Social and Behavioral Sciences Institutional

Review Board at Ohio State University before fieldwork began. Written parental permission and youth assent to participate in the study was obtained by trained interviewers prior to the beginning of the initial in-home interview.

The AHDC study design includes an initial Entrance Survey (face-to-face interviews and computer-assisted personal interviewing with a youth and his/her caregiver) followed by a weeklong period during which the youth carries a smartphone for EMA and GPS tracking. Finally, an Exit Survey captures additional information about the activities the youth engaged in over the course of the smartphone week (see Appendix section A.1. for additional detail on data collection procedures).

2.2. Study Location and Sample

Franklin County contains the city of Columbus – Ohio's largest city and the 14th largest city in the U.S. (estimated 2016 population of 860,090). The study area is contained within Interstate 270, the 55-mile beltway loop freeway containing the most urbanized area within the county. The study area is deliberately designed to include both the City of Columbus and wealthier suburban municipalities that border, or are contained within, the boundaries of Columbus.

2.3. Nightly Saliva Data Collection

Due to known methodological challenges in the collection of multiple daily saliva samples to measure the diurnal cortisol curve (Adam and Kumari, 2009; Halpern et al., 2012; Michels et al., 2012) and the need for minimal disruption of the everyday activity patterns of youth participants (a principal focus of the AHDC project), the study collected saliva for cortisol prior to bedtime for 6 nights total. A substantial body of research has found higher evening salivary cortisol levels as well as a blunted diurnal curve (associated with higher levels of salivary cortisol in the evening) are closely linked to psychosocial stress, risk behaviors and poor health outcomes (Doane and Adam, 2010; Huizink et al., 2009; Kumari et al., 2011; Rao et al., 2009a, 2009b; Ruttle et al., 2011; Suglia et al., 2010; Van den Bergh and Van Calster, 2009). The interviewer instructed the youth at the Entrance Survey visit on how to self-collect the nightly saliva sample via passive drool with instructions to collect the sample each night prior to bedtime. Participants were instructed to avoid eating large meals, dairy products, foods high in sugar or acidity, or drinking caffeinated beverages in the 20 minutes prior to collection. Participants were also told to avoid teeth brushing in the 20 minutes beforehand, and to rinse their mouth with water 10 minutes prior to collection. For the actual collection, they were directed to place the collection aid in their mouth, imagine favorite foods or chew softly on the collection aid, then push saliva down into the vial, repeating until the vial was full. Once the collection was complete, they were instructed to put the tube back into plastic bag and write the date and time of the collection on the outside of the bag and to place the specimen in the household freezer until the interviewer picked up the specimen at the second home visit. Each bag was identified with a unique ID number that was linked to their study record on file. Youth were prompted each evening via EMA with a reminder and instructions to collect the nightly saliva sample. The saliva samples were collected by the interviewer at the Exit Survey and then stored in a -80° C freezer until assay. Although we received nearly 95% of saliva samples requested, not all samples included information on the date and time of the sample (see 2.6. Analytic Sample below).

2.4. Dependent Variable – Physiologic Stress

Physiologic stress was measured via nightly salivary cortisol (HPA activity) levels. Prior to assay, the saliva samples were thawed completely and then vortexed and centrifuged at 1500 x g

(@3000 rpm) for 15 minutes. The saliva was then assayed for cortisol using the Salimetrics™ high sensitivity enzyme immunoassay cortisol kit. All samples from each subject were assayed at the same time, and in duplicate, with the mean calculated for analyses. Inter- and intra-assay coefficients of variation were <10% (9.7% and 8.9%, respectively). Cortisol levels are expressed in saliva as ug/dL (a continuous measure, log transformed for analysis).

2.5. Independent Variables

2.5.1. Exposure to Police-Related Deaths (PRD)

We draw on information from the Fatal Encounters database (Burghart, 2016) to measure occurrences of people who have been killed through interactions with law enforcement over the relevant period prior to and including the study dates. We include all instances of police-related deaths in the 60 days prior to the saliva collection start date for the subsample of youth included in the Bio-Social Linkages study (the first and last interview dates were April 12, 2014 and June 30, 2015). We include only those killings that occurred in Franklin County, Ohio, capturing a sufficiently proximate area to be considered relevant as an exposure space for youth and one that corresponds, roughly, to the local media market.

Fatal Encounters is a quasi-crowd-sourced database with over 20,000 observations of police-related deaths (PRDs), beginning in 2000 and spanning until present day (Burghart, 2016). While crowd-sourced data may be subject to error and missingness, 85% of data is logged by paid researchers and each observation undergoes a rigorous vetting process, including the aggregation of numerous confirmatory sources and multiple rounds of verification. Investigations into the reliability of Fatal Encounters have also produced support for its use in research. Finch and colleagues (2019) note that the data offer a more diverse array of predictors (e.g., race/ethnicity, details of death, the address of incident) and also publish data more expeditiously, often within a week of a PRD incident than most other sources of information on police-related deaths. Most importantly, the dataset identifies an incident as police-related based on journalist reports, rather than departmental or government sources, which may be subject to biasing influences during the adjudication process. In this sense, Fatal Encounters possesses a degree of objectivity that may be absent in official public sources. Because the number of police-related deaths used in the current analysis was small, the study team was able to check data provided by the Fatal Encounters database to available local media accounts of each death, corroborating key indicators (e.g., victim race/ethnicity).

Between February 2014 and June 2015, there were 7 police-related deaths in Franklin County. Of these, six victims were black and one was white. Events involving black victims occurred on May 10, July 10, and October 10 (two victims) of 2014 and January 7 and January 27 of 2015. The one incident involving a white victim occurred on March 21, 2015. All victims were male and all Franklin County incidents occurred within the AHDC study area boundary (see Fig 2). The average age of victims was 32 with a range from 18 to 42. All victims died by gunshot. We choose to include all police-related deaths of blacks whether armed or not under the assumption that designation of a particular death as “justified” by police (typically based on the alleged presence of a potentially lethal weapon) may not diminish the stress consequences of exposure to these events among black youth. Rather, these events may serve as a reminder that black men are at elevated risk of being shot by the police, regardless of whether they are armed (Ross, 2015). The Fatal Encounters database lists one PRD in this analysis as justified and the others as either unreported or pending investigation. However, in all instances, Franklin County Grand Juries declined to press charges against the officers involved.

2.5.2. The Timing of Cortisol Responses to Police-Related Deaths

We hypothesize that cortisol levels among black youth will be elevated in the short-term aftermath of exposure to a PRD in response to media (both traditional and digital sources) and social network-based communication about the event. Evidence on the duration of media coverage of, and audience reaction to, police-related deaths is limited. However, investigation of social media activity in response to violent crime more generally indicates that most activity occurs within a relatively brief period after violent events. In an analysis of Twitter data, Kounadi et al (2015) found that over 50% of tweets related to recent homicides occur with the first week after the event and the majority are posted within a month. We expect that media accounts likely seed network interaction related to the event, resulting in further dissemination. As news of a PRD event unfolds, anticipatory and associated physiological stress is likely to increase. Stress responses may be sustained over a period of weeks by a combination of ongoing media coverage, social network-based communication, and individual-level rumination and perseverative cognition (Hicken et al., 2013). Consistent with Kounadi et al, we consider the stress response during the first 30-day period after a PRD death event (see also Holman et al., 2019).

We created indicator variables capturing instances of PRDs before the beginning of the saliva data collection. Indicator variables are assigned a value of “1” if one or more PRDs occurred during a given temporal window. We constructed these indicator variables for occurrences of exposure to any PRD of a black victim in the 30 days prior to the start of the salivary data collection – the focal hypothesized period of elevated cortisol response. We also include an indicator for 31-60 days prior to salivary data collection start to capture any potential lingering impact of exposure to a PRD (results were not sensitive to the inclusion of this indicator).

2.5.3. Individual and Day-level Controls

We include measures of youth and caregiver demographic and socioeconomic characteristics. Because we are focused principally on the impact of PRD exposure among black youth, we run analyses separately by race (black and white youth). Multiracial youth (N=28) who identify as black in combination with other racial identity categories are included in the black sample. Prior analyses of AHDC data show comparably elevated average nightly cortisol levels for youth who report black alone and multiracial black youth by comparison with white youth. *Youth gender* is a dichotomous measure: female and male (reference). *Youth age* is a continuous measure. *Household income* is a four-category measure ($30,000 or less (reference); $30,001 to $60,000, $60,001 to $150,000, and greater than $150,000). *Caregiver marital status* includes four categories: married (reference), cohabitating, single, and other. *Caregiver education* is a continuous measure of educational attainment: less than a high school degree (reference category), high school degree, some college, college degree, or a graduate/professional degree. We also include relevant biological controls, including age-adjusted body mass index (*BMI z-score*), *pubertal status*, a youth self-reported sex-specific scale adapted from Petersen et al (Petersen et al., 1988), with higher scores indicating more advanced pubertal development, and *steroid use* (1=no steroid use, compared to any caregiver-reported current oral, nasal, inhaled, or topical steroid use). We include a measure of the salivary sample *time since waking* in hours at the day level.

2.6. Analytic Sample

After initial processing of salivary samples, 650 youth had at least one valid cortisol sample with non-missing date of the sample. We exclude 266 days due to a combination of short time since waking (sample collection time was less than 9 hours since waking, indicating noncompliance with the recommended timing of sample collection, unusually short waking time, or error) or samples for which time since waking is missing, resulting in 3,234 days from 642 youth available for analysis. Finally, we keep only black and non-Hispanic white respondents (samples of Asian, Hispanic, and other race/ethnicity youth were too small to analyze separately), resulting in a final sample of 2,929 days across 585 youth.

Given the repeated measure study design and evidence of missing data at the day level and the respondent level, we employed multilevel multiple imputation with chained equations using the MICE package in R (van Buuren and Groothuis-Oudshoorn, 2011). Roughly 80% of days with missing data was driven by respondent-level household income and pubertal status (the latter largely due to responses of "don't know" rather than refusal). In the analyses to follow, we compare black (N=241 youth; 1,168 cortisol days) and white youth (N=344 youth; 1,761 cortisol days). Imputations were performed separately for black and white youth.

2.7. Analytic Strategy

To estimate the effect of exposure to a PRD on average nightly salivary cortisol and account for our repeated measure study design, we employ mixed-effect linear regression models with time fixed effects. We use time fixed effects to mitigate the potential biasing effect of seasonal or other unobserved sources of temporal variability in average cortisol levels at the month level. We model average (log) salivary cortisol as a function of saliva sample collection time since waking (a day-level covariate indicated by the superscript *D*) and individual-level covariates (indicated by the superscript *I*). Specifically, let Y_{ij} be the salivary cortisol level on day *i* for respondent *j*. We assume

$$Y_{ij} = v_{00} + \beta_1^{(I)} E_j^{(30)} + \beta_2^{(I)} E_j^{(31:60)} + \beta_3^{(I)} T_{ij} + \sum_{q=4}^{Q} \beta_q^{(I)} X_{qj}^{(I)} + \alpha_{m(i,j)} + u_{0j} + e_{ij}$$

where v_{00} is the intercept, $\beta_1^{(I)}$ is the coefficient associated with the effect of $E^{(30)}$, an indicator of exposure to a PRD within the 30 days prior to the beginning of the nightly cortisol collection; $\beta_2^{(I)}$ is the coefficient associated with the effect of $E^{(31:60)}$, an indicator of exposure to a PRD within the 31 to 60 days prior to the cortisol collection; $\beta_3^{(I)}$ is the coefficient associated with the effect of time since waking on daily salivary cortisol ; $\beta_q^{(I)}, q = 4, \ldots, Q$, are the coefficients associated with the effects of *Q*-3 additional respondent-level covariates $X_{qj}^{(I)}$, on average salivary cortisol; α_k is the *k*th month-year fixed effect, where $m_{(i,j)}$ maps the *i*,*j* observation to the corresponding month/year and $\sum_q \alpha_k = 0$ for identifiability of the overall intercept, v_{00}; u_{0j} is individual-level random effect assumed to be independent and identically distributed with mean 0 and respondent-level specific variance τ^2; and e_{ij} is an independent and identically distributed error term with mean 0 and variance σ^2.

With the incorporation of month-year fixed effects, models including indicators of study participation within 30 days of a PRD event and 31-60 days after a PRD event capture the additive effects of these exposures relative to those with neither exposure *within a given calendar month.* The fixed effects approach thus ensures that the comparison period is temporally proximate.

The estimation strategy can be understood to yield causal estimates of the effect of exposure to a PRD under the assumption of no omitted confounders of treatment and outcome (e.g., factors varying within month correlated with both the timing of PRDs and youth physiological stress) and no endogenous selection into the sample. With respect to the latter, for instance, one possibility is that the occurrence of a PRD directly altered the likelihood of study participation resulting in *over*representation of physiologically stressed youth in the aftermath of the event, net of observed covariates (endogenous selection). Although it seems unlikely that changes in recruitment outcomes induced by the occurrence of a PRD would result in selection on *higher* stress levels, we nevertheless modeled the probability of exposure to a police-related death as a function of demographic, socioeconomic, and mental health-related factors by race, finding no evidence of association with interview timing (see section A.1. Supplementary Information for additional analyses of potential confounders).

All analyses were conducted in Stata SE 15.

3. RESULTS

Descriptive statistics for variables included in the analysis (by race) are provided in Table 1. The analytic sample is 42% black with an average age of 14.7 (range: 11 to 17). The mean time since waking is 13.8 hours, indicating that youth recorded taking saliva samples, on average, between 9 and 10 at night (assuming an 8AM wake-up time – roughly the mean for the sample). Logged nightly cortisol is higher for black (-2.32) vs white youth (-2.52) (t = 3.58, p < .001), consistent with prior research on race differences in physiological stress (DeSantis et al., 2015, 2007; Tackett et al., 2017). With respect to PRD exposures, 33.5% of black youth and 36.9% of white youth were exposed to a PRD within Franklin County in the 30 days prior to the start of the saliva data collection while 30.7% of black youth and 40.2% of white youth were exposed in the 31-60 days prior to the data collection. Fig 2 presents the distribution of average log nightly cortisol by race for black boys and other youth by PRD exposure timing across the study period.

Two level models of log nightly cortisol are presented in Table 2. All models include month-year fixed effects. Models 1 through 3 present models for the black sample only. Model 1 includes the day-level measure of time since waking and average effects of the PRD indicators. The effects of timing indicators can be interpreted as the effect of exposure to a given treatment, compared with youth who began data collection in the same month but outside the exposure windows. Model 1 offers no evidence of average effects of exposure to a PRD on average log nightly cortisol. Model 2 includes gender interactions with both exposure indicators. In addition to a significant and positive main effect for girls, model 2 offers evidence of a significant interaction between exposure to a PRD within 30 days prior to data collection and gender. Specifically, black boys exhibit significantly higher levels of cortisol if exposed to a PRD in the 30 days prior to saliva data collection; however, the gender interaction term is negative and of comparable magnitude to the effect observed for boys, indicating that exposure to a PRD within 30 days prior to the data collection has no effect on the salivary cortisol levels of black girls. The effect for boys is non-trivial ($\beta = .382$; $p < .01$): exposure in the last 30 days is associated with a 46% increase in average salivary cortisol (see Fig 3). Model 2 offers no evidence that black youth who began saliva data collection between 31 and 60 days after a PRD exhibit significantly different levels of salivary cortisol.

Model 3 adds demographic, health, and developmental controls that could systematically vary across respondents within month, possibly accounting for the association between exposure to a PRD and physiological stress. The model indicates that more advanced pubertal development is associated with increased cortisol, consistent with prior research (Shirtcliff et al., 2012). However, none of the remaining covariates are significantly associated with the outcome. Incorporating these covariates results in negligible change to the magnitude of the coefficient for exposure in the 30 days prior to data collection for black boys ($\beta = .386$, $p < .05$) and a modest reduction in the magnitude of the gender interaction (this effect remains statistically significant). The effect of PRD exposure in the past 30 days for boys is nontrivial in magnitude, equivalent to a .46 standard deviation increase in average nightly cortisol. The effect of exposure between 31 and 60 days prior to the data collection remains statistically insignificant in this model.

Finally, model 4 fits covariates included in model 2 to the sample of white youth with the expectation that we will observe no impact of PRDs involving black victims on these youth. This model offers no evidence of a cortisol impact of exposure to a PRD of a black victim for either gender among white youth. Only caregiver cohabiting status exhibits a statistically significant (negative) effect on average nightly cortisol. The absence of a PRD effect for white youth is consistent with expectations and prior research. We also fit pooled models with the three-way interaction between race, gender, and exposure to a PRD in the prior 30 days, revealing evidence of significant difference in the impact of this event between black and white male youth (see Appendix section A.3 (p.40) for additional discussion of findings from the pooled model including a three-way interaction).

4. DISCUSSION

Recent years have seen a number of high-profile instances of police-related deaths involving black male victims, including the killings of Michael Brown, Tamir Rice, and, most recently, George Floyd. Beyond the lethal consequences of these events for the victims themselves, mounting evidence suggests that vicarious exposure to police violence negatively impacts the wellbeing of broader communities of urban blacks (Boyd, 2018). An emerging literature focused on specific health impacts of police-related deaths suggest the potential for biological effects of these events on exposed populations (McFarland et al., 2019, 2018a, 2018b; Sewell, 2017; Sewell et al., 2016; Sewell and Jefferson, 2016). To date, however, no studies have investigated the physical health consequences of police-related deaths using biomarkers of physiological stress. We draw on unique data from the Adolescent Health and Development in Context study to estimate the effect of exposure to police-related deaths on the salivary cortisol levels of black urban adolescents, offering the first test of police-related death effects on youths' physiological health.

We find that, for black boys, exposure to a nearby (within-county) police-related death of a black victim in the 30 days prior to the beginning of the weeklong AHDC salivary data collection was associated with a statistically significant and nontrivial increase in nightly salivary cortisol levels. The effect held with the incorporation of year-month fixed effects, allowing for assessment of physiological stress effects for youth interviewed within the same month but experiencing different police-related death exposure conditions. These findings offer robust evidence of police-related death influences on the biological responses of black boys.

The implications of these findings for understanding the uniquely compromised health outcomes of black men (Young, 2018) – are significant. For example, a recent meta-analysis found evidence of an association between blunted diurnal cortisol curve and both mental and physical health outcomes (Adam et al., 2017).. Furthermore, the regularity with which police-related deaths involving black victims occur, particularly in larger metropolitan areas where blacks are concentrated, may lead to repeated exposures to lethal police violence for many black male youth. Extant research indicates that a higher cumulative exposure to adverse events over the lifetime or during sensitive developmental periods, such as adolescence, can negatively impact physical and mental health across the subsequent life course (Hughes et al., 2017; National Academies of Sciences, 2019). In addition, the observed impact of exposure to police-related deaths does not take into account the supplementary or even amplifying effect of encounters with non-lethal forms of aggressive policing and surveillance, everyday encounters with which are likely pervasive among black and Latino male youth (Rios, 2011).

Evidence of vicarious biological stress responses to police-related deaths among black male youth offers additional corroboration of the likely widespread negative health consequences of police violence (Sewell et al., 2020). Critically, successful efforts to address the ongoing use of aggressive and potentially lethal police tactics will impact not only the wellbeing of potential black victims but larger communities of urban blacks – including youth – who must navigate environments characterized by the looming threat of institutionally-based violence. An important direction for future research will be the investigation of heterogeneity in police-related death effects on biological stress and related health outcomes by levels of policing in the local context. Youth who reside or spend time in neighborhoods characterized by more prevalent police presence and more frequent unwarranted police stops and arrests may experience more pronounced anticipatory stress in response to recent police-related deaths.

We did not observe an elevated cortisol response to police-related deaths among black girls. The gendered nature of the finding is potentially inconsistent with prior research finding elevated risk of diabetes, hypertension, and obesity among women residents of neighborhoods characterized by higher levels of lethal police violence (Sewell et al., 2020). Yet, while the current analyses do not offer evidence of short-term cortisol response to recent police-related deaths among black girls, we do not assess other outcomes such as self-reported mental health (e.g., depression and subjective stress) which may independently influence longer-term health outcomes (Penninx et al., 2013). Moreover, our focus is largely on within-neighborhood changes in the cortisol response in the aftermath of police-related deaths rather than between-neighborhood differences in average cortisol levels by gender. For instance, it may be the case that girls stress responses to environments characterized by increased risk of police-related deaths exhibit a more chronic pattern where the ongoing threat of police violence exerts influence on physiological processes regardless of temporal fluctuations in actual incidents of police violence.

The study has a number of limitations. First, loss of some saliva data occurred due to missing information on sample collection times and dates, despite overall high compliance with sample collection itself. Second, the cortisol data collection focused only on nightly sample collection. Although data collection allowing for estimation of the diurnal curve over the course of the day would be preferred, this approach presents a number of data collection challenges (Halpern et al., 2012) and was not feasible in the context of the current study (focused on fine-grained everyday activity patterns and their consequences for youth wellbeing). Third, while the sample was comparatively large for the analysis of a physiological stress biomarker, sample size limitations precluded more precise analysis of shorter-term temporal windows and higher order interactions within the subsample of black youth.

Fourth, the study occurred during a potentially unusual period of national attention to police violence directed against blacks, prompted notably by the killing of Michael Brown by police officer Darren Wilson in Ferguson, Missouri on August 9 of 2014 (four months into the study period). The sustained coverage of this and subsequent events, including the killing of

Tamir Rice in Cleveland, Ohio, on November 22, 2014, could have amplified the effects of local police-related deaths for black youth. Although the potential for a period effect on the stress consequences of police violence cannot be entirely ruled out, supplementary analyses revealed no evidence of significant differences in the impact of police-related deaths before and after Ferguson and the killing of Tamir Rice. Moreover, police violence has been a historically consistent and significant source of concern for the black community (Weitzer and Tuch, 2006); the national attention to police-related deaths occurring during the study period may have had the principal effect of bringing this concern to the attention of a wider audience beyond the black community. Future analyses, however, should consider the period-effect in the aftermath of the killing of George Floyd by officer Derek Chauvin on May 25 of 2020 in Minneapolis. The uniquely intense global response to this event may have resulted in a more pronounced sensitivity to instances of police violence. Finally, these data are from a single urban area. Although a diverse context for the assessment of criminal justice system contact, we nevertheless cannot generalize our findings to urban areas more broadly.

These analyses offer novel findings on the impact of police violence on the physiological health of black youth. Concern regarding the use of lethal violence – and aggressive policing more broadly – directed at black men has taken a central place in current debates regarding the functioning of the criminal justice system. Understanding the biological consequences of these and related policing practices for the urban black community as a whole should be a focus of continued research and inform the ongoing policy discussion regarding criminal justice system reform.

Declaration of Interest

None.

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Table 1: Descriptive Statisics for Black and White Sample

	Black (241 Youth and 1,168 Days)				White (344 Youth and 1,761 Days)			
	MEAN or %	**SD**	**Min**	**Max**	**MEAN or %**	**SD**	**Min**	**Max**
Log Cortisol	-2.32	0.83	-4.66	0.59	-2.52	0.75	-4.96	0.56
Exposure to Police Killing								
Police killing 60 days prior	30.74%				40.20%			
Police killing 30 days prior	33.48%				36.91%			
Youth Characteristics								
Female	53.25%				52.92%			
Youth age	14.67	1.70	11.00	17.00	14.68	1.87	11.00	17.00
Household Income								
$30,000 or less	50.61%				17.79%			
$30,001 - 60,000	33.19%				17.50%			
$60,001 - 150,000	15.64%				43.28%			
$150,000 or more	0.56%				21.44%			
Caregiver Marital Status								
Married	35.41%				78.76%			
Cohabitating	12.71%				5.62%			
Single	36.21%				2.73%			
Other	15.66%				12.89%			
Caregiver Education								
Less than high school degree	7.73%				1.62%			
High school degree	19.65%				11.01%			
Some college	48.16%				23.08%			
College degree	18.53%				34.18%			
Graduate degree	5.92%				30.11%			
BMI (Z-score)	0.82	1.390	-3.12	5.31	0.45	1.30	-3.18	7.98
Puberty	3.02	0.692	1.00	4.00	3.08	0.73	1.00	4.00
No steroid use	85.28%				90.84%			
Time Since Waking, hours	13.80	2.11	9.00	21.75	13.85	1.96	9.00	20.50

Table 2. Multilevel Linear Regression: Daily Logged Cortisol on Police-Related Death Exposure and Controls by Race (Black (B) and White (W) Samples)

	Model 1 (B) b/(se)	**Model 2 (B) b/(se)**	**Model 3 (B) b/(se)**	**Model 4 (W) b/(se)**
Time since waking	-0.020	-0.021*	-0.024*	-0.024**
	(0.010)	(0.010)	(0.010)	(0.009)
Police killing 31-60 days prior	0.058	-0.037	-0.035	-0.155
	(0.194)	(0.190)	(0.186)	(0.113)
Police killing within 30 days prior	0.165	0.382*	0.386*	-0.012
	(0.166)	(0.183)	(0.168)	(0.133)
Female		0.373***	0.097	-0.020
		(0.112)	(0.124)	(0.104)
Police killing 31-60 days prior*Female		0.129	0.100	0.021
		(0.156)	(0.151)	(0.117)
Police killing within 30 days prior*Female		-0.437**	-0.368*	0.210
		(0.168)	(0.163)	(0.122)
Youth age			-0.005	0.020
			(0.032)	(0.029)
Income $30,000 or less			--	--
			--	--
Income $30,001-$60,000			0.014	-0.145
			(0.102)	(0.110)
Income $60,001-$150,000			-0.011	-0.159
			(0.155)	(0.097)
Income >$150,000			0.311	-0.195
			(0.204)	(0.124)
Caregiver education			0.039	0.014
			(0.046)	(0.039)
Caregiver married			--	--
			--	--
Caregiver cohabiting			0.219	-0.280*
			(0.137)	(0.136)
Caregiver single			0.121	0.136
			(0.104)	(0.177)
Caregiver other marital status			0.171	-0.173
			(0.134)	(0.101)
No steroid use			-0.065	-0.165
			(0.118)	(0.093)
BMI z-score			-0.017	-0.001
			(0.027)	(0.024)
Puberty			0.378***	0.072
			(0.095)	(0.082)
Constant	-2.163***	-2.358***	-3.422***	-2.199***
	(0.263)	(0.255)	(0.465)	(0.362)
Variance: Individual level	0.308***	0.278***	0.229***	0.206***
Variance: Residual (day level)	0.352***	0.353***	0.352***	0.317***
N (Youth)	241	241	241	344
N (Days)	1168	1168	1168	1761

* p<0.05; ** p<0.01; *** p<0.001;

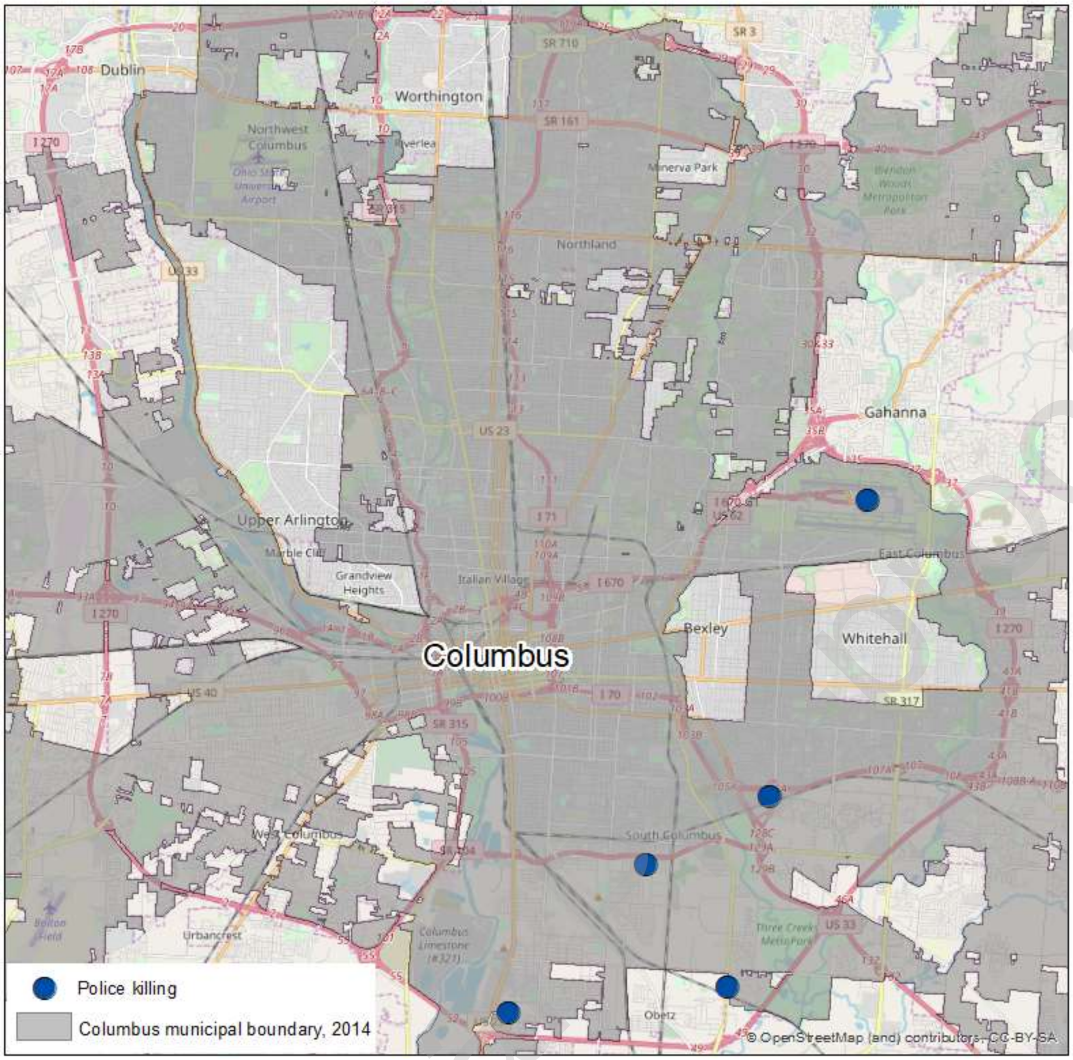

Fig 1. Black Victims of Police-Related Deaths in Franklin County, Ohio, February 2014 – June 2015. The blue dots mark the geographic locations of the 5 police-related deaths of black victims in Franklin County, Ohio, during the study period of February 2014 to June 2015. For reference, the darker shaded area represents the borders of the city of Columbus municipal boundaries in 2014. The study participants were recruited from the entire area within Interstate 270 that surrounds the central part of the city.

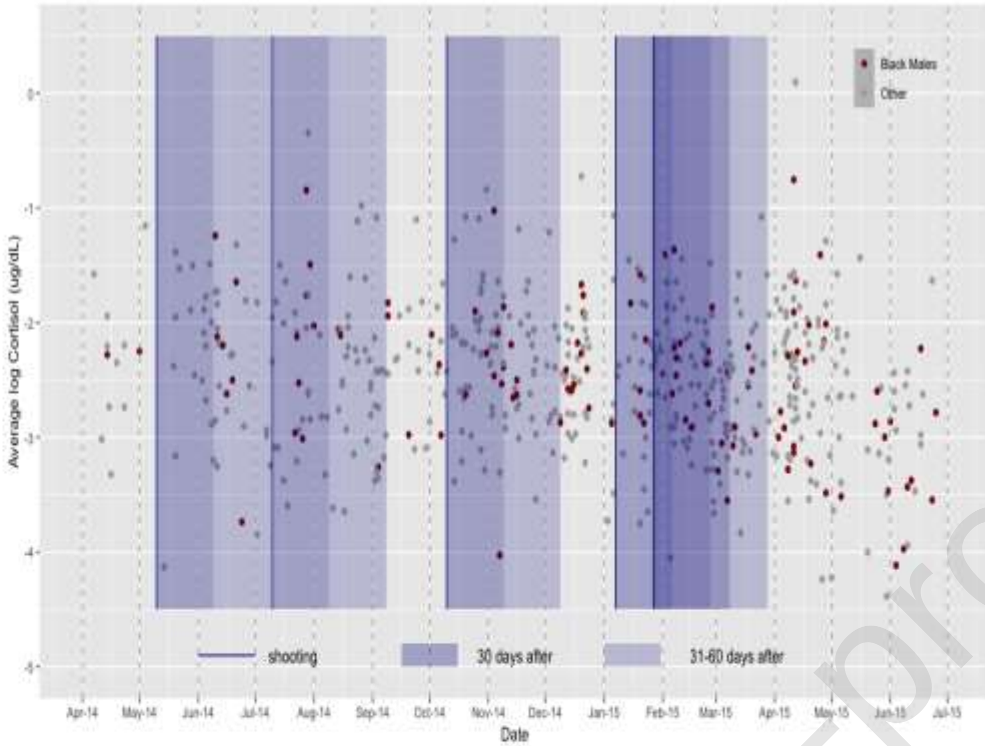

Fig 2. Distribution of average log cortisol for black males and other youth by police-related death exposure period. Dark red dots represent black male respondents (one for each individual); gray dots represent all other respondents. The x-axis represents time, increasing from left (April 2014) to right (June 2015) across the study period. Vertical dark blue lines represent the date of a police-related death. The dark blue shaded area immediately to the right of the killing covers the 30-day period immediate following a killing; the light blue shaded area covers the 31 to 60 day period after a killing. Youth participants who fall in the darker areas are exposed to a police-related death within 30 days prior to their participation in the study. Participants in the lighter areas are exposed to a police-related death in the 31 to 60 days before their participation. The y-axis is the average log cortisol (in ug/dL) for each individual, averaged across days in the study period.

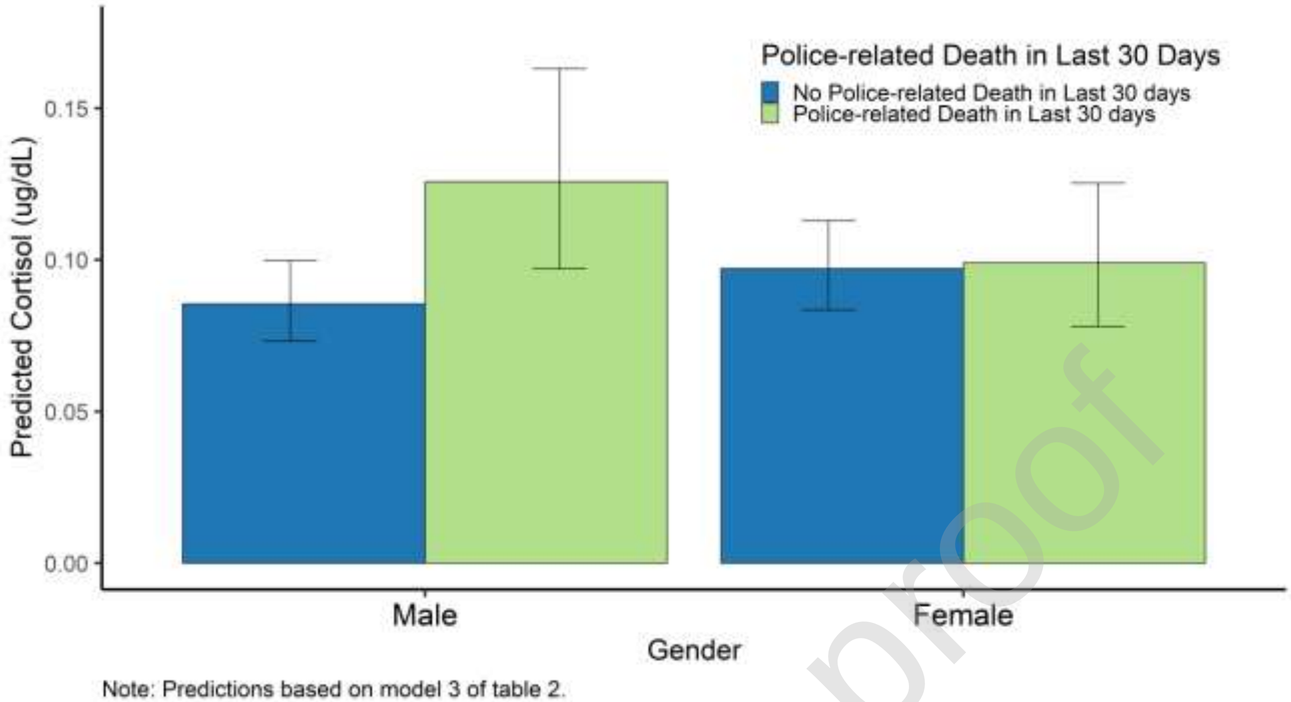

Fig 3. Predicted average cortisol among black adolescents by gender and exposure to a police-related death in the last 30 days. The predicted average cortisol values (ug/dL) are shown for each gender and exposure combination. Higher values indicate higher average cortisol. Error bars represent 95% confidence intervals of the predicted individual-level average cortisol, holding all other covariates constant at their mean.

Appendix A. Supplementary Information for “Exposure to police-related deaths and physiological stress among urban black male youth.”

A.1. The Adolescent Health and Development in Context Data

A1.1. Data Collection Procedures

The Adolescent Health and Development in Context (AHDC) study is a longitudinal, representative data collection effort focused on the consequences for health and wellbeing of everyday developmental contexts. The study was conducted in an urban and suburban area within Interstate 270 (the Franklin County outer belt including the majority of the City of Columbus as well as a number of wealthier inner suburbs). The AHDC data capture a representative sample of households with youth ages 11 to 17. The sampling frame was based on a combination of a vendor-provided list of households with high probability of meeting eligibility criteria (youth age 11 to 17 in the household with an English-speaking caregiver) and data from public school districts representing households in the study area. Sampled households were mailed a letter or post card describing the study, followed by interviewer calls to the household to solicit participation in the study. Among contacted, eligible households, one randomly selected youth and one primary caregiver were recruited to participate in the study.

The AAPOR Cooperation Rate 1– the number of completed interviews out of eligible contacted households – is 88.0%. The AAPOR Response Rate 3 – including the estimated proportion of cases with unknown eligibility that is actually eligible in the denominator – is 21.3%. Although low by historical standards, the AHDC AAPOR 3 response rate reflects recent trends afflicting social survey response rates globally (National Research Council, 2013). Low response rates affect the quality of inferences drawn from the AHDC data to the extent that the resulting sample misrepresents the target population. Supplemental Table 1 compares race/ethnic distributions for the AHDC biomeasure subsample with American Community Survey data for the study area, indicating that the AHDC racial/ethnic distribution closely approximates the target population on this key indicator. Although the proportion

Hispanic is low by comparison with the census-based estimate, AHDC inclusion criteria required an English-speaking caregiver, likely resulting in reduced proportion Hispanic in the population of inference.

Data were collected over a week-long period (see appendix figure A1). First, an *Entrance Survey* was administered to both caregivers and a focal youth covering a range of topics including demographic and socioeconomic background, household composition, family structure and marital status, employment and income, health, social support, behavior, mental/physical health, schooling, family conflict, and legal troubles. The questionnaires include separate modules on the geographic coordinates of places to which the caregiver and youth are regularly exposed (e.g., school, friends' houses, regular "hang out" locations, etc.).

The Entrance Survey was followed by a seven-day smartphone-based Geographically Explicit Ecological Momentary Assessment (GEMA; Kirchner and Shiffman, 2016) period for the youth, which combines GPS tracking and ecological momentary assessment (EMA) to examine youth perceptions, behaviors, and activity space locations across the study week. During the in-home interview, the interviewer provided a smartphone to the youth with instructions to carry the phone continuously over the course of the week. The GPS feature of the study design facilitated collection of in-the-moment data on the locations at which youth spend time through continuous tracking (with the exception of in-school hours). The phone app prioritizes spatial data from more accurate GPS satellites, logging location data every 30 seconds when connected. If no GPS satellite position has been saved in the last 10 minutes, location coordinates based on cell tower network position are collected every 60 seconds. The GPS data was uploaded to secure servers every hour during the smartphone week.

The EMA component of the study involved administration of five randomly timed mini-surveys per day over the course of the week. The EMA averages approximately 4.5 minutes in length and asks the respondent questions about their current location and activities. At the in-home interview, the youth was walked through a practice EMA. The practice round included instruction on procedures for responding to an EMA prompt, completing questions, advancing through the survey, and information on how long the youth would have to acknowledge a prompt (20 minutes) and to complete the questionnaire once logged on (an additional 20 minutes). At the first EMA prompt in the morning, youth are asked what time they woke up. If the youth does not respond to the first EMA prompt, the question on waking time is carried forward to subsequent EMAs (on that day) in order to ensure that this information is collected on each EMA day. Missing waking times were imputed based on a model including non-missing EMA responses to the waking time question, age, whether the day in question was a school day, and the interaction between age and school day. The EMA was incorporated into the salivary data collection through employing a nighttime prompt to remind youth to collect a saliva sample. EMA-based waking and saliva sample collection timing were used to construct a measure of time since waking of the saliva collection (included in the multilevel regression analyses).

At the end of the study week, the interviewer returned to the youth's home for a follow-up Exit Survey, during which the youth completed a recall-aided interactive space-time budget. Prior to administering the space-time budget, the GPS data are processed using a convex hull-based binning algorithm that summarizes data points into stationary and travel periods. The space-time budget application takes the output of the convex hull processing of the raw GPS data and displays estimated locations to the respondent. Each location is combined with labels from nearby routine location self-reports from the Entrance survey along with Google Places search results; the respondent can then report whether each stable location was associated with a routine location, a Google Places result, write in other text, or change the location coordinates as needed. The youth respondents report on up to 5 days of location data of the GEMA week. The supplementary analyses below employ these activity space exposure data to capture potential day-level exposure confounders. Specifically, the analyses employ location data from the space-time budget, geocoding coordinates from locations encountered over the 5-day period to the Census block group level. Exposures to block group census characteristics are constructed using the American Community Survey 2009-2013 five-year file.

A1.2. Additional Detail on Measures

Puberty was based on youth self-reported sex-specific scales adapted from Petersen et al. (1988) in which youth were asked to rate their change in pubertal development. Response options included “no development”, “development barely begun”, “development definitely underway”, or “development complete” with scores ranging from 1 to 4 and higher scores indicating more advanced pubertal development. Both males and females were asked to rate their development on the following: growth spurt in height, growth of pubic hair, and skin changes (pimples/acne). Males were asked to rate changes in voice and growth of facial hair whereas females were asked to rate breast growth and if they had ever menstruated, which included a yes or no response option with yes scored as a 4 and no scored as 1. The scores to the items were summed and averaged for the participants who had complete data on all 5 items; those missing a response to any item were set to missing on the scale. Analyses interacting the scale by gender revealed no evidence of a significant gender interaction. Incorporating the interaction term had virtually no impact on the magnitude or significance of the PRD exposure effects.

A.2. Assessing Robustness of the Findings

A.2.1. In addition to models examining the impact of PRDs of black victims on the cortisol responses of white youth, we also explored the robustness of the observed findings for black boys employing a number of strategies. These include supplementary analyses that 1) control for patterns of spatial exposure that may have been confounded with PRD events, 2) control for a variety of potential confounders, including exposure to other forms of violence, experiences of adverse childhood events, and risk behavior orientations, 3) drop the sample of youth who reported using steroids, and 4) include saliva samples with issues related to the timing of saliva collection.

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A.2.2. Additional Covariates

We considered the possibility of within-month confounding of interview timing with the experience of other forms of violence exposure (EtV) that may account for the observed association of PRD with cortisol levels for black boys. The AHDC data contain a wide range of EtV measures, including *exposure to severe victimization* during the youth's lifetime (if youth reported any of the following 6 items: was beaten up, attacked, robbed, shot at, shot, or sexually assaulted; mean = .12), *witnessing of severe violence* during the youth's lifetime (if youth reported any of the following 7 items: saw someone get beaten up, attacked, robbed, shot at, shot, killed, or sexually assaulted; mean = .27), *caregiver-child violence* (mean frequency of 4 items of physical aggression in the last year, rated from 0 [never/not in the last year] to 6 [more than 20 times]: shaken, hit bottom with an object, spanked, or slapped; mean = .15), and *caregiver-partner violence* (mean frequency of 7 items of physical violence in the last year including both perpetration and victimization of each item, rated from 0 [never/not in the last year] to 6 [more than 20 times]: threw something at partner, used a knife or gun on partner, punched, kicked, slammed partner against a wall, slapped partner, or kicked partner; mean = .03), and exposure to both residential *neighborhood concentrated disadvantage* and *violent crime*. Addition of these covariates to model 3 of table 2 results in comparable impact of exposure to PRD for black boys ($\beta = .36$, $p < .05$). Further incorporation of controls for the youth's report of violent behavior (lifetime count of 12 behaviors including chased, threatened, hit, beaten up, attacked, robbed, shot at, or shot someone, or been in a gang fight; mean = 1.35), delinquency (lifetime count of 14 behaviors, including items such as stolen things from a car or a store, damaged property, broke into a building, or snatched a wallet; mean = .63), and lifetime exposure to adverse events during childhood (count of 16 items across the early childhood period, including items such as parents divorced, eviction, bankruptcy, child went to live with a new caregiver, was placed in foster care, was homeless, was in a serious accident, and death of a close relative; mean = 2.1) also resulted in a comparable effect of exposure to PRDs for black boys (β=.38, $p < .05$).

We also considered the possibility of within-month confounding of interview timing with the selective participation that could potentially account for the observed association of PRD with cortisol levels for black boys. It is possible that PRD may be associated with days of the week kids collected saliva samples. If salivary cortisol varies according to the day of the week and PRD were related to participating on certain days, it is possible that our results might reflect differences in participation patterns. We tested the possibility that our results might reflect confounding between PRD and the days of the week youth participated in the study. Incorporating day of the week indicators to model 3 of table 2 resulted in a comparable effect of exposure to PRDs for black boys (β=.38, $p < .05$). We note that no statistically significant effect of day of the week on salivary cortisol was observed. Analyses including a collapsed day of the week (weekday vs weekend) measure yielded comparable results.

A.2.3. Controlling Potentially Confounded Spatial Exposure Patterns

PRDs may be associated with mobility patterns (not capture by conventional measures of residential neighborhood context alone) that lead both to greater likelihood of youth encountering higher crime and potentially stressful urban areas and increased opportunity for lethal police-citizen interactions. An obvious possibility is the increase in time spent outdoors during warmer months of the year. This seasonal trend is also associated with higher levels of crime and increases in the likelihood of interactions with the police. Longer-term seasonal confounding is not a threat to the current analyses, given use of year-month fixed effects in the analyses of nightly cortisol. However, unobserved within-month variation in mobility patterns may present a potential source of confounding (e.g., short-term weather fluctuations, sports events). The AHDC include unique data on the daily spatial exposure patterns of youth that allow for measurement of exposure to adverse socio-spatial environments and the extent to which they may account for the observed association of PRD exposure with physiological stress.

Specifically, we estimate models controlling day-level exposures to structurally disadvantaged and higher crime neighborhoods. Day-level activity space measures are calculated from data collected using the recall-aided space-time budget data provided by the youth on five days of the week-long EMA/GPS week (Boettner et al., 2019). For exposure to sociospatial adversity, we calculate mean exposure to block group characteristics across all locations during the day, weighted by time spent in minutes at each location during waking hours. *Concentrated disadvantage* is a standardized scale of the following four items: 1) the poverty rate, 2) unemployment rate, 3) the percent of households that are female-headed, and 4) the percent of households receiving cash assistance. *Residential instability* is measured with the standardized percent of residents ages one and older who moved in the last year and the percent of housing units that are renter-occupied.

In order to create a measure of exposure to crime, we use administrative data on every reported crime incident between 2014 and 2016 in Franklin County. We geocode these incidents to the block group level based on x-y coordinates. The geocoded and dated incidents were then used to create counts at the day level for each block group, resulting in a day-block group level observation file that provided the total count of crimes that occurred at block group *j* on day *t*. Using this file, we then generated a 180-

day rolling average for each block group. For example, the crime rate for block group *j* at day *t* would be equal to the sum of crimes that occurred at block group *j* between day *t* and day t–180, divided by the total population for block group *j*. We then used this 180-day rolling window to calculate time-weighted exposures to crime based on the proportion of time spent in each location in a manner similar to the census characteristic exposures.[1] The total crime rate combines violent crimes (homicide, robbery, aggravated assault and rape) and property crimes (burglary, larceny, motor vehicle theft and arson). We also investigated measures of exposure to crime in more temporally proximate periods (last 7 days, last 30 days).

In supplementary models for black youth, we added measures of time-weighted activity space exposures to structural disadvantage and crime for the sample of days including non-missing information on spatial exposures (N=726) to models otherwise including covariates comparable to those in model 3 of table 2. In models replicating model 3 of table 2 without activity space controls, the effect of exposure to a PRD in the 30 days prior to the salivary data collection on log cortisol for black boys is positive and statistically significant ($\beta = .47$, $p < .05$). The magnitude of the coefficient is somewhat elevated over that observed in the table 2. A model adding activity space covariates indicates that concentrated disadvantage is not significantly associated with nightly cortisol values. Residential instability was negatively and significantly associated with nightly cortisol while the total crime rate was positively associated with the outcome. The effect of exposure to a PRD in the 30 days prior to saliva data collection for black boys remained significant and positive in the model including activity space covariates ($\beta = .48$, $p < .05$). These analyses indicate that the effect of exposure to a PRD in the prior 30 days for black boys is robust to controls for higher risk activity space exposures at the day level.

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[1] For a large majority of cases (91%), crime rates reflected the true 180 day rates of crime. For 53 youth who began participation prior to July 2014, their exposures include crime incidents occurring, in part, after the time of interview.

A.2.4. Models Dropping Youth Who Report Steroid Use

We include the subsample of youth who reported some steroid use in the analyses presented in table 2 and control for steroid use in all models. However, corticosteroids may influence HPA axis activity and cortisol levels and cross-react with antibodies used in salivary cortisol immunoassays. We estimated a model otherwise comparable to model 3 of table 2 while dropping youth who reported any steroid use from the analysis. The effect of exposure to a PRD in the prior 30 days for black boys increases in magnitude and significance ($\beta = .53$, $p < .01$) over the estimate presented in table 2.

A.2.5. Models Including Samples with Timing of Saliva Collection Issues

Respondents were asked to collect saliva samples prior to going to sleep for the day. Main analyses (black sample) excluded 125 samples where saliva was collected within 9 hours of waking (or sample collection time and/or wake up time was missing). These samples were likely not at the end of the adolescent's day (or collected on days of unusually late wake up times). Nevertheless, we estimated models otherwise comparable to model 1-3 of table 2 while including samples that were collected within any (observed non-missing) hours of waking in the analysis (a less conservative approach compared to our main models). The effect of exposure to a PRD in the 30 days prior to saliva data collection for black boys remained significant and positive in the model including these cases where compliance was less certain ($\beta = .38$, $p < .05$ in model 2, $\beta = .42$, $p < .05$ in model 3). As an additional check, we included a measure of wake up time (in hours) in the models and found a comparable effect of exposure to PRDs for black boys ($\beta = .38$, $p < .05$ in model 2). We exclude 'wake up time' in the main models due to the fact that wake up time is itself used to calculate 'time since waking' (time since wake = sample collection time – wake up time) and is highly correlated with time since waking (r = -.71).

A.3. Alternative to Race Stratified Models

As an alternative to the race stratified models we present in the main body of the text, we pooled the samples and fit a model similar to model 3 of table 2, but included a three way interaction term (race * gender * treatment). We present the results of a pairwise comparison of all main and interacted effects resulting from these models in table A.2. These results are consistent with our featured race stratified analysis: we observed a statistically significant difference in the effect of treatment for black male youth by comparison with white male youth. We did not observe statistically significant differences in the impact of treatment between black male youth and girls of either race in the three-way interaction model, although the baseline finding of a significant and non-trivial effect of treatment for black male youth and no effect for any other sub-group held in these models.

A.4. Additional Falsification Test

We provide an additional falsification test by assessing how an indicator of whether the interview took place in the 30 days *before* a PRD relates to salivary cortisol. We fit models with similar controls to model 2 and model 3 of table 2 with an indicator of whether the interview took place in the 30 days *before* a PRD (interacted with gender). We observe no statistically significant effect being interviewed in the 30 days *before* a PRD on salivary cortisol ($\beta = .10$, and $p = .419$ in model 2; $\beta = .04$ and $p = .742$ in model 3). We also fit this same model including the indicator associated with exposure to a PRD within 30 days prior to data collection (interacted with gender). We again observed no statistically significant effect being interviewed in the 30 days *before* a PRD on salivary cortisol ($\beta = .16$, and $p = .173$ in model 2; $\beta = .11$ and $p = .379$ in model 3). The effect of exposure to a PRD in the 30 days prior to saliva data collection for black boys however remained significant and positive across models ($\beta = .40$, $p < .01$ in model 2; $\beta = .40$, $p < .01$ in model 3).

A.5. Additional Exploratory Analyses

Finally, we investigated whether youth proximity to the location of a PRD in the course of their daily routines resulted in elevated cortisol levels using information on the locations of routine activities collected at the Exit Survey interview. We found no evidence that days on which activity locations were closer to a recent PRD event within Franklin County resulted in increased cortisol levels. Additionally, we find no evidence that proximity to the location of a PRD from the youth's home address was associated with salivary cortisol. As noted, our theoretical approach rests on the assumption that exposure to the police is likely to trigger anticipatory stress in the aftermath of PRD events rather than the precise location of specific PRDs. While information on levels of police activity in the areas to which youth are exposed would allow for a test of the conditioning impact of such exposures on the cortisol response to a PRD, we lacked the statistical power to examine interactions between race, gender, treatment, and measures of potential police exposure.

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Table A.1. Comparison of Adolescent Health and Development in Context Cortisol Sub-Sample Characteristics to Estimated Population of Youth and Households

Youth Race/Ethnicity	Population Estimate	AHDC Cortisol Sample
Non-Hispanic white	48.9%	53.4%
Non-Hispanic black	38.2%	37.7%
Hispanic (any race)	8.7%	4.5%
Other	4.6%	4.4%

Note: Population estimates are derived from the American Community Survey 2012-2014 data from the IPUMS Integrated Public Use Microdata Series. We limit the ACS data to 6 public use microdata areas (PUMAs) for which the majority of the PUMA area falls within the AHDC study area of the I-270 outbelt. Youth racial composition is calculated for the entire population ages 11-17 living in the estimated study area, weighted at the individual level to account for sampling design of the ACS. Non-Hispanic black includes those who report black alone or in combination with other groups.

Table A.2. Summary of Pairwise Comparisons of Predicted Differences in Main and Interacted Effects from Three Way Interaction Between Race, Police-Related Death (PRD) Exposure, And Gender (Coefficients of Controls Not Shown)

	Contrast	SE	t	P>t
Race				
Black vs White	0.206	0.064	3.21	0.001
PRD in Past 30 Days				
Yes vs No	0.117	0.095	1.23	0.218
Race*PRD in Past 30 Days				
(White w/PRD) vs (White w/ No PRD)	0.097	0.103	0.94	0.347
(Black w/ No PRD) vs (White w/ No PRD)	0.185	0.073	2.52	0.012
(Black w/PRD) vs (White w/ No PRD)	0.332	0.124	2.68	0.007
(Black w/ No PRD) vs (White w/PRD)	0.087	0.108	0.81	0.417
(Black w/PRD) vs (White w/PRD)	0.235	0.093	2.51	0.012
(Black w/PRD) vs (Black w/ No PRD)	0.147	0.113	1.30	0.193
Gender				
Female vs Male	0.077	0.054	1.42	0.155
Race*Gender				
(White Female) vs (White Male)	0.006	0.064	0.10	0.922
(Black Male) vs (White Male)	0.110	0.076	1.45	0.146
(Black Female) vs (White Male)	0.289	0.085	3.39	0.001
(Black Male) vs (White Female)	0.104	0.084	1.24	0.217
(Black Female) vs (White Female)	0.283	0.083	3.41	0.001
(Black Female) vs (Black Male)	0.179	0.082	2.19	0.028
PRD in Past 30 Days*Gender				
(No PRD Female) vs (No PRD Male)	0.087	0.066	1.32	0.188
(PRD Male) vs (No PRD Male)	0.138	0.109	1.27	0.205
(PRD Female) vs (No PRD Male)	0.185	0.106	1.74	0.082
(PRD Male) vs (No PRD Female)	0.051	0.113	0.45	0.651
(PRD Female) vs (No PRD Female)	0.099	0.104	0.94	0.345
(PRD Female) vs (PRD Male)	0.047	0.081	0.58	0.559
Race*PRD in Past 30 Days*Gender				
(White No PRD Female) vs (White No PRD Male)	-0.053	0.082	-0.65	0.515
(White PRD Male) vs (White No PRD Male)	0.008	0.121	0.07	0.948
(White PRD Female) vs (White No PRD Male)	0.123	0.120	1.02	0.307
(Black No PRD Male) vs (White No PRD Male)	-0.005	0.087	-0.06	0.95
(White No PRD Female) vs (White No PRD Male)	0.299	0.101	2.97	0.003

(Black PRD Male) vs (White No PRD Male)	0.329	0.150	2.19	0.029
(Black PRD Female) vs (White No PRD Male)	0.280	0.146	1.92	0.055
(White PRD Male) vs (White No PRD Female)	0.061	0.124	0.50	0.619
(White PRD Female) vs (White No PRD Female)	0.176	0.119	1.48	0.139
(Black No PRD Male) vs (White No PRD Female)	0.048	0.097	0.49	0.622
(Black No PRD Female vs (White No PRD Female)	0.352	0.100	3.53	0.000
(Black PRD Male) vs (White No PRD Female)	0.382	0.154	2.48	0.013
(Black PRD Female) vs (White No PRD Female)	0.334	0.143	2.34	0.020
(White PRD Female) vs (White PRD Male)	0.115	0.095	1.20	0.228
(Black No PRD Male) vs (White PRD Male)	-0.013	0.122	-0.11	0.912
(Black No PRD Female vs (White PRD Male)	0.291	0.133	2.19	0.028
(Black PRD Male) vs (White PRD Male)	0.321	0.125	2.57	0.010
(Black PRD Female) vs (White PRD Female)	0.272	0.127	2.15	0.031
(Black No PRD Male) vs (White PRD Female)	-0.128	0.124	-1.03	0.303
(Black No PRD Female) vs (White PRD Female)	0.176	0.129	1.37	0.172
(Black PRD Male) vs (White PRD Female)	0.206	0.126	1.63	0.103
(Black PRD Female) vs (White PRD Female)	0.158	0.127	1.24	0.214
(Black No PRD Female) vs (Black No PRD Male)	0.304	0.096	3.15	0.002
(Black PRD Male) vs (Black No PRD Male)	0.334	0.141	2.37	0.018
(Black PRD Female) vs (Black No PRD Male)	0.286	0.138	2.08	0.038
(Black PRD Male) vs (Black No PRD Female)	0.030	0.148	0.20	0.840
(Black PRD Female) vs (Black No PRD Female)	-0.018	0.141	-0.13	0.896
(Black PRD Female) vs (Black PRD Male)	-0.048	0.141	-0.34	0.733

Notes: Covariate adjustment follows that of model 3 in table 2

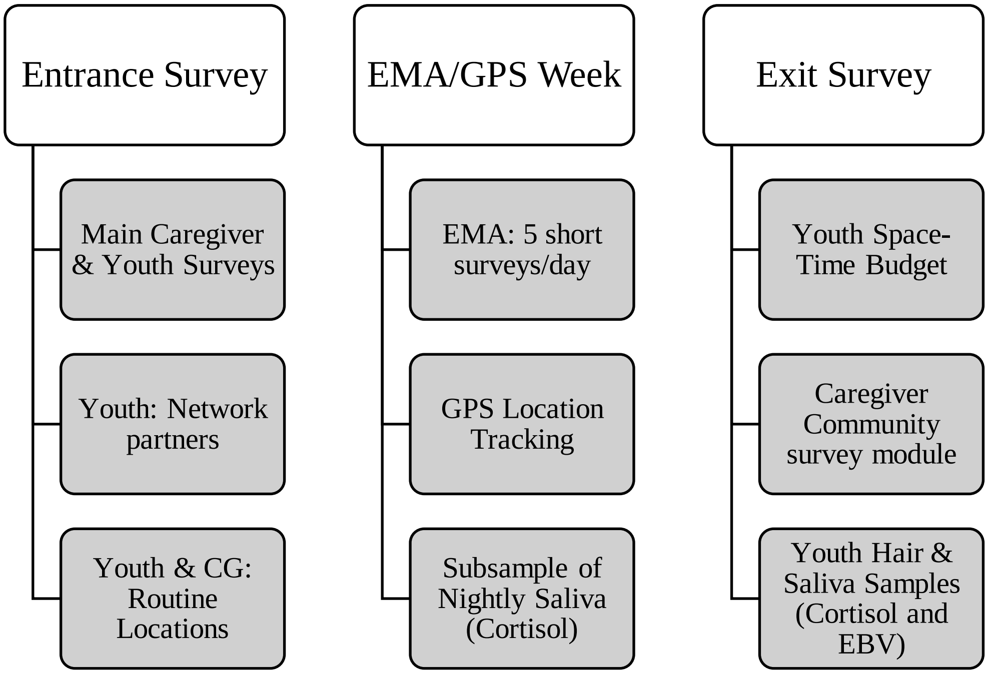

Fig A1. The Adolescent Health and Development (AHDC) and Bio-Social Linkages study design. The initial in-home Entrance Survey collects the main caregiver and youth surveys. During the Ecological Momentary Assessment (EMA)/GPS week, the respondent receives 5 short surveys per day, along with continuous GPS tracking, and nightly salivary cortisol samples. The second in-home visit, the Exit Survey, collects space-time budget information along with additional biomarkers.