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

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ABSTRACT

Background: Emerging evidence indicates that exposure to police-related deaths is associated with negative health and wellbeing outcomes among black people. 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.

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.

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

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 (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 black people, 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 were positively associated with sleep difficulties among black adults 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 black people 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) study, a supplementary investigation 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 were 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 (Ecological Momentary

Assessment) 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 2018 population of 892,533). 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, and 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 vial back into a project-provided plastic bag and write the date and time of the collection on the outside of the bag, and to place the bag 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

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 et al. (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. 1). 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 black adults 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 within the first week after the event and the majority

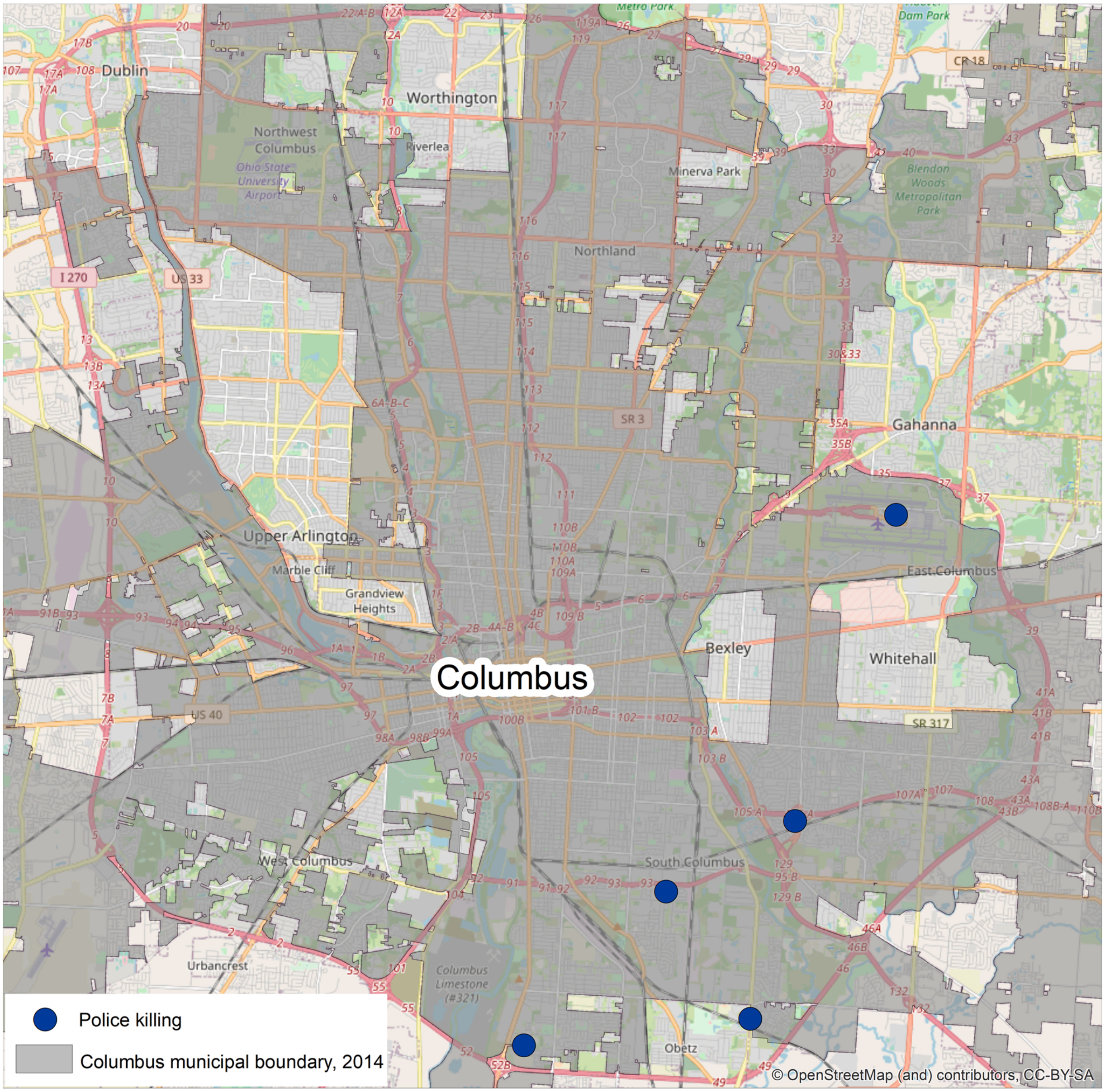

Fig. 1. Black Victims of Police-Related Deaths in Franklin County, Ohio, February 2014 – June 2015. The blue dots mark the 5 geographic locations of the 6 police-related deaths of black victims in Franklin County, Ohio, during the study period of February 2014 to June 2015. For reference, the darker 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.

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). See Fig. 2 for the distribution of PRDs and the exposure windows.

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*

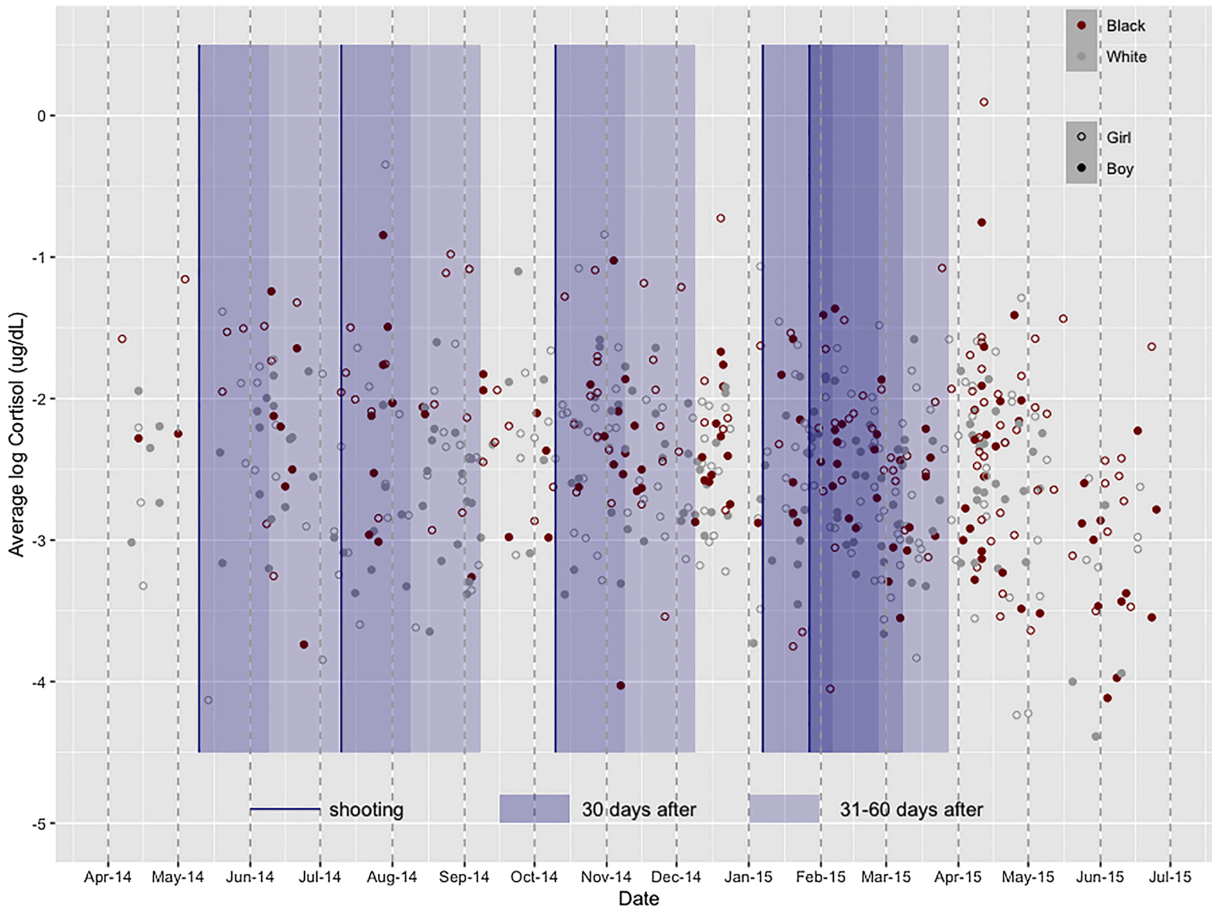

Fig. 2. Distribution of average log cortisol for black males and other youth by police-related death exposure period. Dark red dots represent black male respondents (one for each individual); gray dots represent all other respondents. The x-axis represents time, increasing from left (April 2014) to right (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.

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., 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) and individual-level covariates. Specifically, let Y_{ij} be the salivary cortisol level on day i for respondent j. We assume

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

where υ_{00} is the intercept, β_1 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; β_2 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; β_3 is the coefficient associated with the effect of time since waking, T_{ij}; β_q, $q = 4, \dots, Q$, are the coefficients associated with the effects of Q-3 additional respondent-level covariates X_{qj}, on average salivary cortisol; α_k is the kth month-year fixed effect, where $m_{(j)}$ maps the j respondent to the month/year of the respondent's first cortisol level collection and $\sum_k \alpha_k = 0$ for identifiability of the overall intercept, υ_{00}; u_{0j} is the 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

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

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

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 black people (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 curves 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 black people 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

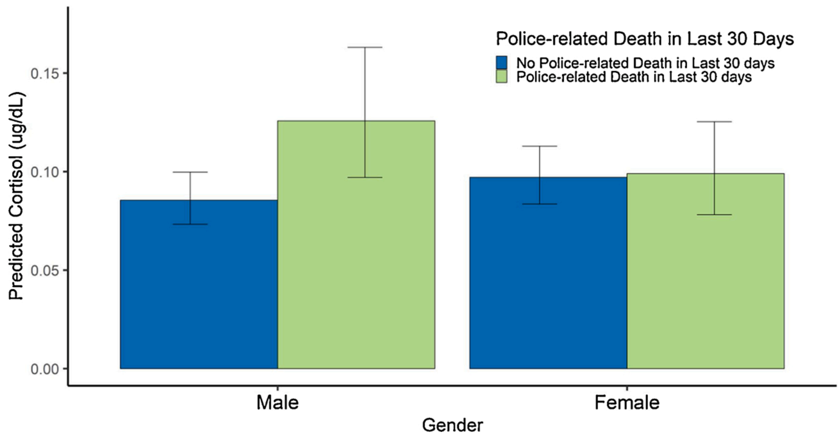

Fig. 3. Predicted average cortisol among black adolescents by gender and exposure to a police-related death in the last 30 days. The predicted average cortisol values (ug/dL) are shown for each gender and exposure combination. Higher values indicate higher average cortisol. Error bars represent 95% confidence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

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 black people, 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 Competing Interest

None.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.psyneuen.2020.104884.

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