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The impact of perceived intensity and frequency of police work occupational stressors on the cortisol awakening response (CAR): Findings from the BCOPS study

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ABSTRACT

Police officers encounter unpredictable, evolving, and escalating stressful demands in their work. Utilizing the Spielberger Police Stress Survey (60-item instrument for assessing specific conditions or events considered to be stressors in police work), the present study examined the association of the top five highly rated and bottom five least rated work stressors among police officers with their awakening cortisol pattern. Participants were police officers enrolled in the Buffalo Cardio-Metabolic Occupational Police Stress (BCOPS) study (n = 338). For each group, the total stress index (product of rating and frequency of the stressor) was calculated. Participants collected saliva by means of Salivettes at four time points: on awakening, 15, 30 and 45 min after waking to examine the cortisol awakening response (CAR). Saliva samples were analyzed for free cortisol concentrations. A slope reflecting the awakening pattern of cortisol over time was estimated by fitting a linear regression model relating cortisol in log-scale to time of collection. The slope served as the outcome variable. Analysis of covariance, regression, and repeated measures models were used to determine if there was an association of the stress index with the waking cortisol pattern. There was a significant negative linear association between total stress index of the five highest stressful events and slope of the awakening cortisol regression line (trend p-value = 0.0024). As the stress index increased, the pattern of the awakening cortisol regression line tended to flatten. Officers with a zero stress index showed a steep and steady increase in cortisol from baseline (which is often observed) while officers with a moderate or high stress index showed a dampened or flatter response over time. Conversely, the total stress index of the five least rated events was not significantly associated with the awakening cortisol pattern. The study suggests that police events or conditions considered highly stressful by the officers may be associated with disturbances of the typical awakening cortisol pattern. The results are consistent with previous research where chronic exposure to stressors is associated with a diminished awakening cortisol response pattern.

1. Introduction

Over the course of what may ultimately be a decades long career police officers are repeatedly exposed to conditions and incidents unique to their job that they may perceive and respond to as stressful (North et al., 2002; Paton, 2005; Paton et al., 2009). With little or no warning, officers may find themselves responding to events ranging from domestic disturbances to involvement in complex, evolving natural disasters or acts of terrorism. Events at the more challenging end of the critical incident spectrum (e.g., terrorist acts,

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shootings, assaults) result in officers encountering, over periods of several days or weeks, unpredictable, evolving, and escalating demands (Paton and Violanti, 2007). Further, the burden of societal responsibility and strict legal norms are placed on officers as they deal with these demands. One may surmise that police officers are often in a state of psychological inflexibility faced with a multitude of difficult and challenging work demands.

1.1. Perceived stress and biological change

In general, the perception of an event or condition as a stressor triggers the response of several biological systems to aid the body in dealing with the stressor. Primary among them is the hypothalamic-pituitary-adrenal (HPA) axis which responds to a stressor by releasing cortisol, the species-specific hormone in man from the adrenal gland. The cortisol response is frequently used as a biomarker of HPA axis status or function. The axis acts in a classic negative feed-back fashion where the circulating cortisol acts to “shut-off” the signals that trigger the response allowing a return to homeostasis. The return to homeostasis confers stability to the system through change or allostasis (McEwen, 1998, 2007, 2008; McEwen and Wingfield, 2003). It seems intuitive that, repeated or sustained activation of the HPA axis may cause an increase in the allostatic load, the unwanted “wear-and-tear” on the system that occurs with the need to constantly respond to various stressors. The constant adaptation of the HPA axis to various demands may ultimately result in pathological function of the HPA axis where the response is exaggerated or minimal. This alteration in the response of HPA axis may be reflected in the pattern of the cortisol secretion or the amount of the hormone. For example, in a non-compromised functioning of HPA axis the CAR is characterized by a pronounced peak in cortisol shortly after awakening which gradually diminishes over the next 30 to 40 min. Here, we hypothesized that the constant need for police officers to respond to a variety of stressors may compromise the functioning of HPA axis and be reflected in a disturbed CAR pattern.

To our knowledge, no recent study has examined the effect of the perceived *intensity of stressors* and the frequency of occurrence in police work on the CAR pattern. We hypothesize in the present study that the perceived intensity of specific police work stressors as most stressful (high) or least stressful (low) will have a differential effect on the awakening cortisol patterns among police officers.

2. Materials and methods

2.1. Study population

Study participants for the current analyses were officers enrolled in the Buffalo Cardio-Metabolic Occupational Police Stress (BCOPS) study. The BCOPS study was a cross-sectional study aimed at investigating the associations of occupational stressors experienced in police work with the psychological and physiological health of police officers. A total of 710 police officers who worked at the Buffalo Police Department in New York were invited to participate in the BCOPS study; 464 (65.4%) officers agreed to participate and were examined during the period of June 4, 2004 to October 2, 2009. No specific inclusion criteria were indicated for the study, only that participants be sworn police officers and willing to participate. Comparisons of available demographic variables (sex, age, and police rank) showed no significant differences between participants and non-participants. A written informed consent was collected from each participant. Data collection was performed at The Center for Preventive Medicine, State University of New York at Buffalo. The study was approved by the Internal Review Board of the State University of New York at Buffalo, and the National Institute for Occupational Safety and Health (NIOSH) Human Subjects Review Board (IRB).

2.2. Police stressor measure

Evaluation of various incidents and conditions as possible stressors experienced in police work were assessed by the study participants using the Spielberger Police Stress Survey. The Spielberger Police Stress Survey is a 60-item instrument for assessing the possible stressors in police work (Spielberger et al., 1981). For each item, the officer rates the perceived stressfulness of experiencing the event on a scale from 0 to 100 (0 = no stress, 100 = maximum stress). The officer also provides the frequency of occurrence of each event over the past month (total occurrences in past month) and past year (total occurrences in past year). The instrument has three subscales: *administrative and organizational pressure* (23 items), which includes satisfaction with departmental policies and procedures, performance, fairness of rewards, and the judicial system; *physical and psychological threat* (24 items), which includes dangerous situations and experiences such as killing someone in the line of duty; and *lack of support* (13 items), which includes political pressures and relationships with supervisor and coworkers. The subscales have acceptable internal consistency (Cronbach's alpha > 0.90).

Of the 60 items, the five highest and five lowest rated stressful events were selected by ranking each item using the mean rating of stressfulness from all officers. For each of the 10 selected items (the 5 most stressful and the 5 least stressful), a stress index was derived by multiplying the rating of stressfulness by the corresponding frequency of occurrence in the past month (stress index = rating × occurrence). The stress index is therefore a weighted average of frequency of occurrence where the ratings of stressfulness were used as weights. For each group (top five and bottom five), the total stress index was calculated by summing the stress indices of the five events that belong within each group. The total stress index for the top five most stressful events (herein called the “major stress index”) and the total stress index for the bottom five least stressful events (herein called “minor stress index”) served as the primary exposure variables of interest (measure of police stress) for the current analyses.

2.3. Salivary cortisol measures

To assess the salivary CAR pattern, subjects were instructed to collect saliva samples immediately after awakening, and 15, 30, and 45 min thereafter. The saliva samples were collected during a single day and occurred the day after the clinic examination. Officers were provided with Salivettes (Sarstedt, USA), a commercially available collection device consisting of a dental roll and a centrifuge tube, for the collection of saliva samples. Participants were asked to refrain from taking stimulant medication, smoking, eating and drinking, and brushing their teeth before completing salivary sampling to avoid contamination of saliva with food or blood caused my micro-injuries of the oral cavity. At the designated collection time, the officers removed the dental roll from the centrifuge tube and placed it in their mouth for approximately two minutes allowing for saturation of the roll. The roll was then returned to the tube and samples were returned to the clinic and subsequently sent to the laboratory of DBM. Upon delivery the tubes were centrifuged to provide a non-viscous saliva sample for assay of cortisol. Samples were maintained at −20 °C until sent to the Technical University of Dresden for analysis of cortisol by a commercially available chemiluminescence immunoassay (IBL, Hamburg, Germany). The four cortisol values from the saliva samples and the corresponding times of collection were used to estimate a slope reflecting the awakening pattern over time and served as the outcome measure of interest in the current analyses.

2.4. Assessment of covariates

Questionnaires were administered to collect demographic and lifestyle characteristics including age, gender, race/ethnicity, years of police service, police rank, years of education, marital status, smoking status, and alcohol consumption. Height and weight were measured with shoes removed and recorded to the nearest half centimeter and rounded up to the nearest quarter of a pound, respectively. Height and weight were converted to meters and kilograms, respectively. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared.

2.5. Statistical analysis

Of the 464 BCOPS study participants, only officers with complete data on the exposure variables of interest (major and minor stress indices), and cortisol values from the four waking saliva samples and their corresponding times of collection were used for statistical analyses (n = 338).The possible association between the stress indices (exposure variable) and the awakening cortisol pattern (outcome variable) was examined using two methods (analysis of covariance and repeated measures analysis). Due to the skewed nature of the cortisol concentration in the awakening saliva samples, values were log-transformed prior to analyses in both statistical approaches. Analysis of covariance was used to compare mean slopes of regression lines fitted to the waking cortisol pattern across tertiles of the stress indices. A slope reflecting the awakening pattern of cortisol over time was first estimated by fitting a simple linear regression model for each participant, where the cortisol values (in log-scale) were regressed on time of collection.

The slope served as the outcome variable of interest in the analysis of covariance. In addition, a regression model relating the slope of the CAR pattern to the continuous forms of the stress indices was fitted to assess a linear trend in slope across increasing values of stress indices. In the second approach, repeated measures analyses were used to examine differences in awakening cortisol pattern over time across the three categories (tertiles) of stress indices. A model relating the cortisol values (in log-scale) to time of collection (defined as time since awakening in minutes), tertiles of stress indices, and the interaction between time and tertiles of stress indices was fit. The statistical significance of the interaction term was used to determine whether the CAR pattern depended on stress categories (tertiles). The MIXED procedure in SAS was used to model the repeated measures by applying the autoregressive covariance structure as a model for correlations among repeated measurements made on the same subject. In all analyses, adjustment for potential confounding factors including age, gender, marital status, alcohol consumption, and police rank were made. Prior to statistical adjustment, all covariates were tested for potential effect modification by including an interaction term between the exposure and the covariate. The statistical analyses were performed using the SAS software version 9.3 (SAS Institute, Inc., Cary, NC) and significance level was set at 5%.

3. Results

3.1. Participant demographic and lifestyle characteristics

The demographic and lifestyle characteristics of the study participants (n = 338) are presented in Table 1. The study population consists of 78% males and the majority was white (79%), married (77%), and had a rank of patrol officer (65%). The mean age was 42.9 years (range: 27–74 years). The distribution of demographic and lifestyle characteristics of the participants did not vary significantly across tertiles of the major stress index except for police rank, age, and years of service (Table 2). Officers in the lowest stress index category had a greater proportion of higher ranking officers (53%) and a smaller proportion of patrol officers (47%) compared to those in the middle and highest tertiles of major stress index. In addition, those in the lowest stress index category were significantly older (46.2 ± 9.0 years) and had longer years of service (20.2 ± 8.4) compared to officers in the middle or highest stress index tertiles. Comparisons across tertiles of the minor stress index yielded similar findings (data not shown).

Table 1
Demographic and lifestyle characteristics of study participants, BCOPS Study, 2004–2009.

Characteristics	N	% (or mean ± SD)
Gender		
Male	262	77.5
Female	76	22.5
Race		
White	265	79.3
Black/Hispanic	69	20.7
Education		
≤High school/GED	44	13.1
College <4years	176	52.2
College 4+ years	117	34.7
Marital status		
Single	36	10.7
Married	259	76.8
Divorced	42	12.5
Smoking status		
Current	52	15.5
Former	90	26.9
Never	193	57.6
Rank		
Patrol officer	218	64.5
Other[a]	120	35.5
Age (in years)	338	42.9 ± 7.9
Years of service	338	16.2 ± 8.0
Body mass index (kg/m^2)	338	29.5 ± 4.6
No. of alcohol drinks/week	338	5.9 ± 10.0

Results for continuous variables are means ± SD.
[a] Other includes Sergeant, Lieutenant, Captain, and Detective.

3.2. Police work events rated as most and least stressful

Based on rating of stressfulness on a scale of 0 to 100, the top five most stressful events (major stressors) were: exposure to battered or dead children (mean rating = 64.6), killing someone in the line of duty (62.9), fellow officer killed in the line of duty (62.4), situations requiring the use of force (56.8), and physical attack on one's person (56.1) (Table 3). All five belong to the *Physical/Psychological* danger sub-scale of the instrument. The mean frequency of occurrence in the past month for the major stressors ranged from 0.01 (killing someone in the line of duty; range: 0–2) to 1.5 (situations requiring the use of force; range: 0–10). The combined mean frequency of occurrence for the major stressors was 2.4 times per month (range: 0–19), indicating an officer on average experienced the major stressors 2.4 times during the past month. The stress indices (a measure that combines the frequency of occurrence of the event with its rating of stressfulness) varied from 0.06 (killing someone in the line of duty) to 89.7 (situations requiring the use of force).

The bottom five least stressful events (minor stressors) were: strained relations with non-police friends (mean rating = 25.5), lack of participation on policy-making decisions (24.9), periods of inactivity and boredom (19.3), promotion or commendation (16.8),

Table 2
Demographic and lifestyle characteristics of study participants by tertiles of total stress index for the top five most stressful events, BCOPS Study, 2004–2009.

	Tertiles of stress index (rating × frequency) for the top five stressful events (range)						
	Low (0) n = 115		Medium (5–140) n = 110		High (142–1360) n = 113		
Characteristics	n	%	n	%	n	%	p-value*
Gender							
Women	29	25.2	21	19.1	26	23.0	0.5386
Men	86	74.8	89	80.9	87	77.0	
Race							
White	85	74.6	86	80.4	94	83.2	0.2622
Black/Hispanic	29	25.4	21	19.6	19	16.8	
Education							
≤High school/GED	15	13.0	15	13.8	14	12.4	0.8687
College <4 yrs.	64	55.7	56	51.4	56	49.6	
College 4+ yrs.	36	31.3	38	34.9	43	38.0	
Marital status							
Single	13	11.3	12	11.0	11	9.7	0.7867
Married	90	78.3	80	73.4	89	78.8	
Divorced	12	10.4	17	15.6	13	11.5	
Smoking status							
Current	15	13.3	15	13.6	22	19.6	0.0801
Former	40	35.4	28	25.5	22	19.6	
Never	58	51.3	67	60.9	68	60.7	
Rank							
Patrol officer	54	47.0	78	70.9	86	76.1	<0.0001
Other[a]	61	53.0	32	29.1	27	23.9	
Age (in years)	115	46.2 ± 9.0	110	41.3 ± 6.6	113	41.0 ± 6.7	<0.0001
Years of service	115	20.2 ± 8.4	110	14.9 ± 7.0	113	13.4 ± 7.0	<0.0001
Body mass index (kg/m^2)	115	29.6 ± 4.8	110	29.1 ± 4.1	113	29.7 ± 5.0	0.5665
No. of alcohol drinks/week	112	6.5 ± 12.1	110	5.8 ± 10.2	111	5.6 ± 7.0	0.7698

* P-values are from χ^2 tests of independence or Fisher's exact test for categorical variables and from ANOVA testing differences in means across tertiles of stress index. Results for the continuous variables are means ± SD.
[a] Other includes Sergeant, Lieutenant, Captain, and Detective.

Table 3
Summary of stress ratings, frequency of occurrence in the past month, and stress indices for the top five most and least stressful events (n = 338).

	Stress ratings			Frequency of occurrence (past month)			Stress indices (ratings × frequency of occurrence)		
Events	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD
Top five most stressful									
Exposure to battered or dead children	0–100	64.6	36.3	0–10	0.6	1.3	0–700	38.5	94.9
Killing someone in the line of duty	0–100	62.9	44.4	0–2	0.01	0.1	0–20	0.06	1.1
Fellow officer killed in the line of duty	0–100	62.4	41.3	0–1	0.04	0.2	0–100	2.5	13.9
Situations requiring the use of force	0–100	56.8	32.1	0–10	1.5	2.0	0–850	89.7	138.9
Physical attack on one's person	0–100	56.1	37.3	0–4	0.3	0.8	0–396	20.7	55.0
Total summary score	0–500	301.2	167.2	0–19	2.4	3.1	0–1360	151.1	225.8
Bottom five least stressful									
Strained relations with non-police friends	0–100	25.5	27.8	0–10	0.5	1.4	0–675	27.3	90.3
Lack of participation on policy-making decisions	0–100	24.9	27.4	0–10	0.6	1.6	0–850	27.6	96.2
Periods of inactivity and boredom	0–100	19.3	21.4	0–10	2.7	3.1	0–1000	72.0	150.0
Promotion or commendation	0–100	16.8	24.5	0–10	0.1	0.7	0–900	5.1	51.1
Performing non-police tasks	0–80	16.4	19.1	0–10	1.3	2.5	0–700	29.9	80.6
Total summary score	0–410	102.6	86.1	0–32	5.2	5.3	0–1600	161.2	250.2

and performing non-police tasks (16.4). Periods of inactivity and boredom was the most frequently occurring event (mean occurrence = 2.7) and had the highest stress index while promotion or commendation was the least prevalent (0.1 times in the past month) and also had the lowest stress index.

3.3. Most stressful events and the awakening cortisol pattern

Comparisons of the mean slope of the regression line fitted to the log-transformed CAR pattern across tertiles of the major stress index are shown in Table 4 (top panel). The results from the unadjusted model indicate that the mean slopes of the awakening pattern differed significantly across the stress index categories (low stress: 0.0174 ± 0.034, moderate stress: 0.0067 ± 0.031, high stress: 0.0060 ± 0.025, p-value for difference = 0.0070). Further pairwise multiple comparison tests showed that the mean slopes for the moderate and high stress index categories were significantly smaller compared to the mean slope of officers in the lowest stress index tertile. Note that the first tertile contains officers with zero stress index (meaning the stress score or the frequency of occurrence or both were reported as zero). Trend analysis where the mean slope was regressed against the continuous form of the stress index also indicates a significant linear association between major stress index and slope of the wakening cortisol regression line (trend p-value = 0.0244). These results show that as the major stress index increases, the slope of the wakening cortisol

Table 4
Mean slope[a] of the regression line fitted to the awakening cortisol pattern by tertiles of the total stress index for the top five most stressful and bottom five least stressful events.

Stressor category	Tertiles of stress index[b] (range)	N	Unadjusted (mean ± SD)	Age-adjusted (mean ± SE)	Multivariable adjusted[c] (mean ± SE)
Top five most stressful	Low (0–0)	115	0.0174 ± 0.034	0.0171 ± 0.003	0.0173 ± 0.003
	Medium (5–140)	110	0.0067 ± 0.031	0.0069 ± 0.003	0.0072 ± 0.003
	High (142–1360)	113	0.0060 ± 0.025	0.0062 ± 0.003	0.0068 ± 0.003
	P-value (ANOVA)*		0.0070	0.0163	0.0188
	P-value (trend)**		0.0244	0.0386	0.0430
Bottom five least stressful	Low (0–0)	114	0.0081 ± 0.031	0.0076 ± 0.003	0.0089 ± 0.003
	Medium (5–155)	111	0.0120 ± 0.031	0.0124 ± 0.003	0.0132 ± 0.003
	High (160–1600)	113	0.0103 ± 0.030	0.0105 ± 0.003	0.0092 ± 0.003
	P-value (ANOVA)*		0.6403	0.5118	0.5171
	P-value (trend)**		0.8610	0.8299	0.7595

* P-value from analysis of variance or covariance comparing any differences in mean slope across stress index tertiles. Pairwise multiple comparison shows significant differences in mean slope between those in the lowest tertile and those in medium or high stress index categories for the top five most stressful events.
** P-value from linear regression testing linear trend in mean slope across increasing stress index.
[a] Slope was estimated by fitting a simple linear regression model where cortisol in log scale was regressed on time (in minutes) since baseline sample.
[b] The sum of stress index (product of rating and frequency of occurrence in the past month) for the top five most stressful or bottom five least stressful events.
[c] Adjusted for age, gender, marital status, alcohol consumption, and rank.

line tends to decrease approaching zero (indicative of dampened or flatter CAR profile). Further adjustment for age, gender, marital status, alcohol consumption and rank only slightly attenuated the association. Results were consistent when we also controlled for medication use, smoking status, and phase of menstrual cycle (low stress: 0.00173 ± 0.003, moderate stress: 0.0070 ± 0.003, high stress: 0.0069 ± 0.003, p-value = 0.0210). Further adjustment for time of awakening and sleep quality only slightly attenuated the association of interest.

A repeated measures analysis was conducted to test if the pattern of awakening cortisol over time differed by levels (tertiles) of major stress index (Fig. 1). The figure shows that although the total hormonal output did not differ among the three groups (p = 0.7985), there was a significant difference in the pattern of cortisol over time (interaction p-value for time by stress category: 0.0078 for the unadjusted model and 0.0039 for the multivariate adjusted model). Those with zero major stress index showed a steep and steady increase in cortisol from baseline while officers with moderate and high major stress index showed a dampened response over time (relative to those with zero stress index). The result from repeated measures analysis is consistent with the mean slope comparison approach presented in Table 4 where the four repeated measurements were reduced to a single estimate.

3.4. Least stressful events and the awakening cortisol pattern

The mean slope of the awakening cortisol pattern did not differ significantly across tertiles of the minor stress index (Table 4 bottom panel). The results from the unadjusted model indicate that the mean slopes were similar across the three minor stress index categories (low stress: 0.0081 ± 0.031, moderate stress: 0.0120 ± 0.031, high stress: 0.0103 ± 0.030, p-value for difference = 0.6403). The result from the trend analysis (trend p-value = 0.8610) also indicates absence of a significant linear association between minor stress index and slope of the wakening cortisol pattern. In addition, the results from the repeated measures analysis indicate that the pattern of awakening cortisol over time did not differ significantly across tertiles of minor stress index (Fig. 2). The Figure shows that the awakening cortisol pattern is similar regardless of the level of minor stress index (interaction p-value for time by stress category: 0.7892 for the unadjusted model and 0.8972 for the multivariate adjusted model). The pattern for each of the three groups is consistent where awakening cortisol levels rise peaking around 30 min after awakening and followed by a gradual decline.

Finally, in order to assess the relative impact of the major vs. the minor stressors on the slope of the awakening cortisol pattern, we fit a multiple regression model relating the slope to both types of stressors in the same model adjusting for covariates. The result

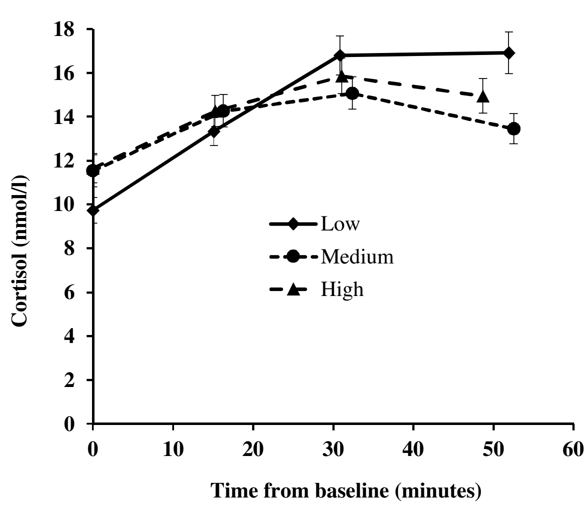

Fig. 1. Awakening cortisol pattern by tertiles of major stress index (stress index tertiles: Low (0–0), Medium (5–140), and High (142–1360)).

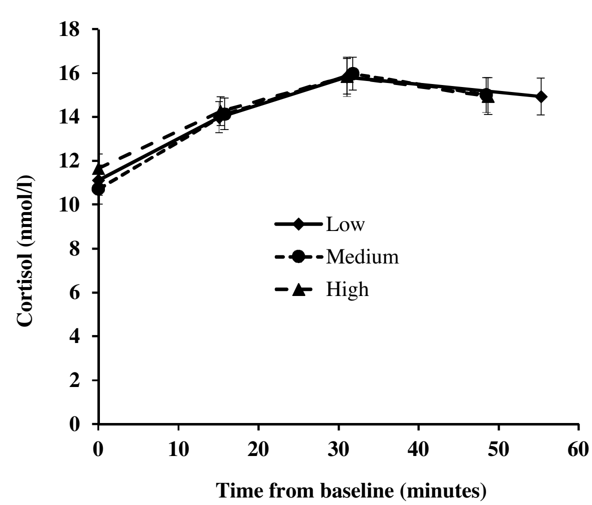

Fig. 2. Awakening cortisol pattern by tertiles of minor tress index (stress index tertiles: Low (0–0), Medium (5–155), and High (160–1600)).

showed a significant negative association between the slope and major stress index (standardized regression coefficient = −0.118, p-value = 0.0427) while the association with the minor stress index was not statistically significant (standardized regression coefficient = 0.020, p-value = 0.7317).

4. Discussion

The present study examined the possible association of the major and minor stressors from the Spielberger Police Stress Survey with the CAR pattern. Results indicated a significant negative association between the stress index of the top five most stressful events and slope of the CAR pattern. As the highly rated stress index increased, the pattern tended to flatten over time. Officers with zero stress index showed a steep and steady increase in cortisol from baseline while officers with moderate and high stress index showed a dampened or flatter response over time (relative to those with zero stress index). Conversely, the stress index of the five least stressful events was not significantly associated with changes in the awakening cortisol pattern. Direct comparison of the two groups of stressors indicated that the most stressful events had significantly larger impact on the waking cortisol pattern relative to the least stressful events.

The results suggest that officers who perceive certain events associated with police work as highly stressful may have a blunting of the awakening cortisol pattern and this blunting may represent an alteration in the functioning of the HPA axis relative to officers who do not perceive these events as stressful. To some degree, the blunted CAR pattern observed here may be related to the traumatic or violent nature of the highly rated stressors perceived by officers. Four of the five top rated stressors involved acts of violence which represented a direct threat to the officer's safety. A fifth stressor, witnessing battered or dead children, represented feelings of the lack of control over such violent events. Dickerson and Kemeny (2004) comment that cortisol secretion is highly affected under conditions of physical self-preservation and safety. Previous work has demonstrated that such highly stressful incidents may initiate a lower or blunted cortisol response. Wessa et al. (2006) found a blunting of awakening cortisol in PTSD compared to controls. Yehuda (2002) found that the biologic alterations observed in trauma stress do not uniformly resemble those associated with other types of stress. Cortisol levels were found to be lower than normal in studies of patients with traumatic stress, even decades after a traumatic event.

Several studies have looked at the association between stress and cortisol in police officers. Groer et al. (2010) examined simulated critical incident police scenarios and the association with cortisol secretion. They observed a higher cortisol elevation in officers during a higher stress scenario. Walvekar et al. (2015) found an association between perceived stress and increased secretion of cortisol among police officers. Violanti et al. (2009) found increased cortisol secretion after awakening was independently associated with impaired brachial artery flow mediated dilation in female but not male police officers indicating a possible link between HPA axis cortisol response and subclinical cardiovascular disease in female officers. Wirth et al. (2014) examined the effect of shift work on cortisol levels among police officers and found that awakening cortisol AUC (Area Under the Curve) values were lower among officers working short-term night or afternoon shifts than day shifts, with maximal differences occurring after five days of shiftwork. Cortisol values were attenuated among officers with more shift changes. Austin-Ketch et al. (2012) found noticeable differences in levels of measurable cortisol present across the varying levels of traumatic stress symptoms in police officers.

Debate exists about the relationship between the various types of circumstances and events that result in HPA axis activation and cortisol release (Dickerson and Kemeny, 2004). According to these authors, different types of stressful situations may not affect cortisol secretions in a similar manner. Several authors comment that unpredictable, uncontrollable, threatening or novel situations may likely elicit a stronger activation of the HPA axis and the subsequent cortisol response. Police officers quite often experience these types of stressors. (Sapolsky et al., 2000; Blascovich and Mendes, 2000). It is therefore likely that the response to police stressors and their effect on cortisol can, to some degree, be attributed to the type and perceived intensity of the stressor by the individual officer (Skoluda et al., 2015; Bosch et al., 2009). This is what Skoluda et al. (2015) termed "stimulus response specificity".

The five high stressors in this study have been observed in police work. In 2015, 123 officers were killed in the line of duty (Federal Bureau of Investigation, 2014a,b http://www.nleomf.org/facts/officer-fatalities-data/year.html). Another highly rated but not prevalent (0.27%) stressor was killing someone in the line of duty (Violanti et al., 2007). Similar to experiencing the death of a fellow officer, being involved in a shooting and killing someone can be a very stressful for officers (Bond et al., 2014). The aftermath of a shooting can lead to scrutiny by both the department and the judicial system concerning the legality of the shooting and the proper use of justifiable deadly physical force by the officer. Additionally, PTSD may result from involvement in shooting incidents (Paton et al., 2006).

Situations requiring use of force (58.5%) was a prevalent and highly rated stressor (Violanti et al., 2007). On average, over the last decade (2004–2013), there have been 57,346 assaults against law enforcement each year, resulting in 15,375 injuries (http://www.nleomf.org/facts/officer-fatalities-data/daifacts.html). In 2014, there were 48,315 officers assaulted at a rate of 9.0 per 100 officers (FBI Uniform Crime Reports, 2014, https://www.fbi.gov/aboutus/cjis/ucr/leoka/2014/tables/table_71_leos_asltd_region_and_geographic_division_2014.xls). Of these assaults, 1950 were by firearm, 951 by knife, 6803 by other dangerous weapons, and 38,611 by personal weapons (e.g. hands, fists or feet). Over one-quarter (28.3%) of these assaults resulted in injury to the officer (FBI Uniform Crime Reports, https://www.fbi.gov/aboutus/cjis/ucr/leoka/2014/tables/table_76_leos_asltd_type_of_weapon_and_percent_injured_2005-2014.xls).

Exposure to battered or dead children was a highly ranked stressor (Table 3). Involvement with child crimes is a difficult task for police officers and it requires a special ability and social support in order to avoid traumatization. Prior research regarding police investigations of children related crimes such as neglect, homicide, or sexual abuse suggest that officers are often at greater risk for developing secondary traumatic stress (Krause, 2013; Chouliara et al., 2009; Powell and Tomyn, 2011). Officers working these cases may also be at risk for depression and anxiety (Powell and Guadagno, 2013; Russ et al., 2009).

Strengths of the present study include the collection of data using standardized protocols and equipment and performed at the same time at a clinic site by trained staff. The Spielberger Police Stress Survey is a well validated frequently used instrument to study specific police stressors. All samples were subject to quality control. In addition, we were able to adjust the association of interest for a wide variety of potential confounder including age, gender, marital status, alcohol consumption, rank, medication use, smoking status, contraceptive use, phase of menstrual cycle, time of awakening, and sleep quality.

Limitations of this study include a cross-sectional study design, which precludes causal inferences and concern for generalizability to other police departments. Future longitudinal designs would be beneficial to better understand changes in perceptions of stressors over time and the factors associated with such changes. While our sample size is adequate, the procurement of larger samples, especially women officers, would be beneficial in helping to disentangle gender differences. The waking saliva samples were collected for only one-day which limits reliability. We were not able to adjust for sexual activity, menstrual cycle phase, and menstrual cycle regularity. As with any self-report survey instrument, recall bias may be a factor.

The present study examines only how HPA axis responds to the awakening condition and the association between the CAR and how an officer perceives events experienced in police work. Although we see an association between a high stress index and a blunting of the CAR, it is not certain that this is due to the experiences of the officers in policing. Officers may have responded differently in the field to these events and we do not know the status of their HPA axis when they entered the police force. More information would obtained if police officers were followed from the time they were recruits across their careers. It is really the only way to determine if police work alters the status and operation of the HPA axis assessed by the CAR or other conditions/challenges across the length of their careers.

There is more work to be done in this occupation that is replete with exposure to a variety of events and conditions that can be considered stressors. However, the effects of stressors on cortisol are highly variable (Gaab et al., 2005) and it is commonly accepted that stressors can be perceived differently by different people (Lazarus, 1999). Additionally there may be forces in police work specific to the occupation which determines the perception of what is stressful. Police officers share a cohesive cultural bond which may influence perceptions of stress on the job (Paton et al., 2009). Semmer et al. (2005) comment that shared meaning is one element by which cultures are defined and this influences the appraisal of stress, and that the probability that a given situation is appraised as stressful will be different in different cultures. Under influence of the cohesive police culture, the probability of collective stress reactions is increased and may develop into specific occupational stress factors (Levi, 2005). Webster (2014) proposed that it is necessary to assess the importance of cognitive appraisal, coping, and person-environment fit as well as stressors in police work. Automatically labelling work demands as stressful in policing is to assume that an officer appraises it as such. Gaab et al. (2005) comment that HPA activation is more strongly associated with *what will happen* due to a stressor as opposed to *what did happen*. We hope to address this question in our future work with prospective analysis of cortisol secretion based on changes over an extended period of time.

In conclusion, the present study provides some clues as to which stressors in police work are associated with the CAR. Further work utilizing additional cortisol challenges may yield important additional information. These may be useful in determining which particular stressors should be the focus of intervention. Psychological support and timely interventions are important to help officers deal with stress and possible biological consequences in the occupation of policing.

Conflict of interest

The authors declare that there are no conflict of interest.

Contributors

All authors contributed substantially to the conception and design of the study. J.M.V. oversaw data acquisition and cleaning data. D.F., M.E.A., T.A.H., L.E.C., D.B.M., and C.M.B. analyzed and interpreted the data. J.M.V. wrote the first draft of the manuscript and all authors contributed to its review and critical revision. All authors have approved the final version of the article.

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Disclaimer

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