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Shiftwork and Diurnal Salivary Cortisol Patterns Among Police Officers

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Abstract

Objective—To investigate associations between shiftwork and diurnal salivary cortisol among 319 police officers (77.7% men)

Methods—Information on shiftwork was obtained from the City of Buffalo, NY electronic payroll records. Saliva was collected using Salivettes at seven time points and analyzed for free cortisol concentrations (nmol/L) using a chemiluminescence immunoassay. Mean slopes and areas under the curve were compared across shift schedule using analysis of variance (ANOVA)/analysis of covariance (ANCOVA).

Results—Officers working primarily on the night shift had a significantly shallower slope. Mean slope (nmol/L/minutes) of the cortisol curve varied significantly across shifts (day: −0.00332 ± 0.00017, afternoon: −0.00313 ± 0.00018, night: −0.00257 ± 0.0002); adjusted $P = 0.023$.

Conclusions—Our results suggest that night shiftwork is a work-place factor that may alter the response of the hypothalamic–pituitary–adrenal (HPA) axis to the circadian cues responsible for the pattern of the diurnal cortisol curve.

The need or demand for services 24 hours a day has resulted in shiftwork becoming an integral part of several industries and occupations (U.S. Congress OTA, 1991). While providing many advantages,[1] shiftwork can also be disadvantageous in that it has been linked to adverse health outcomes. Shiftwork has been associated with a higher prevalence of cancer, cardiovascular disease (CVD), and metabolic-related conditions.[2–5] Some shift workers, such as police officers, are exposed to additional occupational stressors.[6–11] Exposure to stressful events activates the hypothalamic–pituitary–adrenal (HPA) axis. Such

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repeated activation has been associated with HPA axis dysregulation and adverse health consequences.[12–16]

Cortisol is produced primarily by the adrenal glands and is often used as a biomarker of HPA axis function.[17] In most individuals, upon awakening, cortisol levels increase immediately then peak about 20 to 30 minutes later, after a steady decrease throughout the day. Flattening of the diurnal salivary cortisol profile is thought to be a reflection of dysregulation in basal HPA axis function.[18,19] Research has shown that disturbances of this typical time curve may be associated with a variety of negative health outcomes. For example, studies indicate that flattened diurnal cortisol curves are associated with posttraumatic stress disorder, depression, continuous exposure to stress, chronic fatigue syndrome, as well as decreased cancer survival.[13,20,21] In addition, flattened diurnal cortisol patterns are significantly associated with subclinical CVD and CVD mortality.[22–25]

Although law enforcement is an occupation with repeated exposure to many different types of stressors, this occupational cohort remains under-studied. To date, a small number of studies have examined the relationship between shiftwork and cortisol patterns among police officers with emphasis on the cortisol awakening response (CAR). In a recent investigation conducted on the Buffalo Cardio-metabolic Occupational Police Stress (BCOPS) study cohort, Fekedulegn et al[26] found that concentrations of the CAR were significantly lower in night-shift workers compared with those working on the afternoon and day shifts; the pattern during the first hour after awakening, however, was similar across all three shifts. In addition, the peak morning cortisol concentration, although not significantly different among the shift groups, was smaller for night-shift officers compared with officers on the afternoon and day shifts. Wirth et al[27] reported that area under the curve for the CAR among the BCOPS police officers was lower in officers working short-term, but not long-term, night or afternoon shifts compared with day shift. In this study, we compared diurnal cortisol profiles in BCOPS police officers working on day, afternoon, and night as their primary shifts. We hypothesized that officers working the night shift would display a different diurnal cortisol profile with a shallower slope when compared with officers on the other shifts. Men and women in this cohort are differentially scheduled on shifts and may vary in physiological response, so the association between shiftwork and the diurnal profile may be different between them. Therefore, a secondary objective is to assess whether gender significantly modifies this association in the BCOPS cohort.

MATERIALS AND METHODS

Study Design and Participants

The BCOPS study began in 2004 as a cross-sectional comprehensive examination of the health consequences of stress associated with work-related factors/situations in law enforcement officers. Between June 2004 and October 2009, approximately 710 police officers employed at the Buffalo, New York Police Department were invited to participate in this study. After pregnant women were excluded, 464 (65.4%) officers consented to participate. Institutional Review Boards at The State University of New York at Buffalo and the National Institute for Occupational Safety and Health approved the study. Informed consent was obtained from all participants. Data were collected at The Center for Health

Research, School of Public Health and Health Professions, University at Buffalo, State University of New York.[28] For this cross-sectional study, we excluded retired officers and any officer who had missing information on shiftwork and diurnal cortisol. The final sample size for analyses of shiftwork and diurnal salivary cortisol was 319 officers, 71 women and 248 men.

Assessment of Shiftwork

Electronic work history data from the City of Buffalo, NY payroll records were available from May 1994 to the date of each officer's examination (2004 to 2009). The database contained information regarding the activities for each officer and included the start and end time of work, the type of activity (ie, regular work, overtime work, court appearances), the type of leave (ie, weekend, vacation, work-related injury, other types of sick leave), and the number of hours worked on each activity. The time officers started their shift for regular work was used to classify each record into one of the following three shifts: day shift if the start time was between 4 AM and 11 AM; afternoon if the start time was between 12 noon and 7 pm; and night shift is the start time was between 8 pm and 3 am. A numeric variable that quantified the percent of total hours worked on the night shift was also derived.

The Buffalo NY police department instituted fixed or permanent shifts for their officers in 1994, however officers occasionally worked other shifts for other officers on leave. All officers worked weekdays and weekends and were scheduled four days on and three days off. The total number of hours worked by each officer was obtained by summing over all records from 1994 to the date of examination. Then, hours worked on the day, afternoon, and night shifts were calculated. An officer's dominant shift was defined as the shift on which he/she worked the largest percentage of hours. For example, the primary or dominant shift for an officer who worked 10% on the day shift, 5% on the afternoon shift, and 85% on the night shift would be night shift.

Assessment of Cortisol

Full details of the cortisol assessment procedures are provided elsewhere.[26,28] Briefly, 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 by micro-injuries of the oral cavity.[26] Participants collected saliva by means of Salivettes at seven time points (ie, seven saliva samples assayed for cortisol): on awakening, 15, 30 and 45 minutes after waking, at lunch, dinner, and bedtime. At the designated collection time, the officers removed the dental roll from the centrifuge tube and placed it in their mouth for approximately 2 minutes, allowing for saturation of the roll. When saturated, the roll is returned to the tube for storage. The tube is centrifuged in the laboratory to provide a non-viscous saliva sample for assay. The saliva samples were frozen at −80 8C until analyzed for free cortisol concentrations (nmol/L) using a chemiluminescence immunoassay (IBL, Hamburg, Germany) at the Technical University of Dresden. Four diurnal cortisol variables were derived: (1) total area under the curve (AUCG), (2) area under the curve with respect to increase against the baseline (ie, the first sample cortisol value after awakening) (AUCI), (3) slope of fitted regression line to the seven diurnal cortisol values, and (4) slope of fitted regression line to the cortisol values in the four diurnal samples (exclude the 15-minute, 30-minute, and 45-minute samples from the seven above). The AUCG and AUCI are expressed as nmol/L × minutes and the slopes as nmol/L/minute. Use of AUCG and AUCI reduces the diurnal cortisol measurements and time of collection into a single numerical value for each officer.

Assessment of Covariates

Demographic characteristics, lifestyle behaviors, and medical history and medication use were obtained from all officers through self- and interviewer-administered questionnaires. Officers reported the total number of alcoholic drinks they consumed per week and their smoking status as current, former, or never. Body mass index was calculated as weight (in kilograms) divided by height (in meters) squared. Waist circumference was obtained from the average of three measurements that were within 0.5 cm of each other. Physical activity during the previous seven days was obtained with the Seven-Day Physical Activity Recall questionnaire used in the Stanford Five-City Project.[29] Sleep duration for the previous month was assessed using the Pittsburgh Sleep Quality Index (PSQI) questionnaire.[30]

Statistical Analyses

Descriptive statistics were determined for all variables. The chi-square test of independence, analysis of variance (ANOVA), and Pearson's correlations were used to assess associations for selected variables with both shiftwork and diurnal salivary cortisol parameters. The seven samples for the diurnal cortisol variable were collected on awakening, 15, 30 and 45 minutes after waking, at lunch, dinner, and at bedtime. When we refer to the four-sample diurnal cortisol variable, we use all samples excluding the 2nd, 3rd, and 4th waking samples. To compare similarity in diurnal cortisol patterns across shifts, repeated measures analysis was performed to test the significance of the interaction between shiftwork and time of collection. The spatial power covariance model was used to account for interdependence among measurements within a subject and the unevenly spaced time intervals. A slope reflecting the diurnal pattern of salivary cortisol secretion was estimated by fitting a simple linear regression model for each participant, where cortisol values (in log-scale) were regressed on time of collection. In addition, the total area under the curve was calculated using the trapezoid formula.[31]

Diurnal salivary cortisol parameters were log-transformed prior to analyses to account for the skewed distributions. Gender was examined for effect modification by including interaction terms in the model. Mean slopes and area under the curve were compared across shift schedule using ANOVA and analysis of covariance (ANCOVA) while adjusting for demographic characteristics (age, race/ethnicity, education, marital status, and police rank), lifestyle behaviors, and waist circumference. Post hoc power analyses showed that observed differences in slope across shiftwork were detectable with a power of 80%. All analyses were conducted in SAS v. 9.3 (SAS, Cary, NC).

RESULTS

The officers ($n = 319$) ranged in age from 27 to 67 years (mean ± standard deviation [SD] = 42.8 ± 7.7 years) (Table 1). The majority of officers were white (79.1%) and men (77.7%).

Forty two percent of officers worked on the day shift, 33.2% on the afternoon shift, and 24.8% on the night shift. Gender was significantly associated with shiftwork, with a smaller percentage of women (14.1%) compared with men (27.8%) working the night shift. There was no association between any of the cortisol parameters and gender.

Associations between selected variables and shiftwork are presented in Table 2. Age and sleep duration were significantly associated with shiftwork, $P < 0.001$ and 0.038, respectively. Officers who worked the night shift were on average younger (39.9 ± 7.2 years) and had the shortest sleep duration ± 1.1 hours). After adjustment for age and gender, however, sleep duration was no longer associated with shiftwork (data not shown).

Age-adjusted associations between selected variables and the four cortisol parameters are shown in Table 3. Sleep duration and alcohol intake were significantly and inversely associated with the diurnal slope; $r = -0.128$, $P = 0.027$ and $r = -0.133$, $P = 0.021$, respectively. Global sleep quality score (assessed using PSQI) was not significantly correlated with any of the cortisol parameters (results not shown). Waist circumference was inversely correlated with total area under the curve (AUCG); $r = -0.137$, $P = 0.018$.

The two-way repeated measures ANOVA revealed that there was a significant time by shift interaction effect ($P = 0.006$), suggesting different profiles of cortisol concentrations over time among day, afternoon, and night shifts (data not shown). Effect modification by gender in the association between shiftwork and cortisol profile was not significant at the 10% level.

Our results show that shiftwork was not significantly associated with area under the curve (Table 4). Shiftwork was significantly associated with the slope of diurnal cortisol, however, before and after risk factor adjustment. After adjustment for demographic and other factors, mean slope (nmol/L/minute) of the curve representing seven cortisol samples varied significantly across shift (day: −0.00332 ± 0.00017, afternoon: −0.00313 ± 0.00018, night: −0.00257 ± 0.0002, $P = 0.023$). Officers working on the night shift had a significantly shallower slope (Fig. 1). After adjusting for the same factors, mean slope (nmol/L/minute) of the diurnal cortisol curve (representing the four samples) also varied significantly across shift (day: −0.00288 ± 0.00018, afternoon: −0.00237 ± 0.00019, night: −0.00194 ± 0.0002, $P = 0.008$) with those working on the night shift also showing a significantly shallower slope.

Gender-stratified results of the association between shiftwork and the cortisol parameters are shown in Table 5. In the unadjusted models, both diurnal slopes differed significantly across shiftwork among men, but not among women. After risk factor adjustment, only the mean slope (nmol/L/minute) of the diurnal cortisol curve (four cortisol samples) showed significant overall variation across shift, $P = 0.028$. The risk-factor adjusted results for multiple comparisons showed that men officers on the night shift, compared with those on the day shift, had shallower mean slopes of the diurnal curves representing seven ($P = 0.031$) and four ($P = 0.008$) cortisol samples.

Percent of hours worked on the night shift was significantly and positively correlated with both slopes of diurnal cortisol curves among all officers; seven-sample curve ($r = 0.166$, $P = 0.005$) and four-sample curve ($r = 0.120$, $P = 0.041$) (Table 6). Note that this positive correlation also means that there is an inverse association between percent of hours worked on the night shift and the steepness of the decline in the diurnal cortisol pattern. After risk-factor adjustment, significant positive correlations among both women and men were only observed with the diurnal slope representing seven samples.

DISCUSSION

In the BCOPS cohort of police officers, we compared diurnal salivary cortisol profiles across shift schedules. Our results showed that officers who worked the night shift had significantly flatter diurnal cortisol curves compared with those on the day shift. Although all three shift schedules showed a decline in diurnal cortisol concentrations following awakening, the rate of decrease over time was significantly attenuated for those working on the night shift (ie, flatter slope). The inverse association between percent of hours worked on the night shift and the magnitude of the diurnal cortisol decline suggests a flattening of the diurnal cortisol pattern with increasing hours of work on the night shift.

Although we have evidence of significant associations between night shiftwork and a flatter cortisol awakening profile,[26,27,32,33] we did not find many studies that investigated associations between shiftwork and the diurnal cortisol profile.

Shiftwork is associated with circadian disruption and with increased stress levels as determined by serum cortisol levels.[34–38] Cortisol, one of the primary stress hormones in man, has a well-documented circadian pattern which is established in infancy.[39–41] Light is a powerful synchronizer of the circadian rhythms and the external light–dark cycle synchronizes the central oscillator in the hypothalamus.[35,42,43] Light also induces corticosterone, the major HPA axis hormone in rodents, to be released via sympathetic regulation mediated by suprachiasmatic nucleus-sympathetic nervous system in mice.[42] It is plausible that the constant circadian disruption caused by shiftwork influences cortisol production resulting in a flatter pattern over time. Fujiwara et al[34] examined the temporal changes in circadian rhythms of serum cortisol and other variables due to experimental short-term shifts. Their results showed that the diurnal variations of serum cortisol were greatly modified, indicating that the normal circadian phase relations of cortisol and the other variables were disrupted more by the night shift.

A major limitation of this study is that the cross-sectional design prevents the inference of causality between shiftwork and a flatter diurnal cortisol slope. Recently published guidelines recommend more than one day of collection of saliva samples when determining the CAR (a component of our diurnal cortisol data) to reduce the intra-individual variability and measurement error that can be influenced by situational variables.[44] Our study was planned and executed, however, before these guidelines were available and we collected saliva samples on one day to reduce subject burden as saliva samples were collected after a number of challenges (eg, high protein meal, etc). Also, prior to the dissemination of these guidelines, collection of samples on one day was considered sufficient in cross-sectional research provided two or more samples on one day were collected to determine the CAR. Also, the results of this study have limited generalizability; it may only be generalizable to police officers working in similar departments and having other similar characteristics. A fourth limitation is that the analysis among women is underpowered. On average 50 women officers in each shift category are needed to detect the observed differences with a power of at least 80%. Among men, about 80 officers in each shift are required to attain a power of 80%. A fifth limitation is related to chronotype, which may be associated with cortisol secretory patterns.[45] Unfortunately, we were unable to assess for interaction by chronotype because this information was not collected. Night shift-work is considered a stressor because it forces the body to be awake at an unnatural time, causing desynchronization between the circadian day and the officer's occupational day. Although some persons adapt more easily to night shifts than others, we were unable to determine the officers' adaptability to night shifts. Therefore, another limitation of our study is our inability to compare workers on the three shifts with precision. Another issue pertains to whether officers who are more likely to tolerate night shift elected to work or chose to work for longer durations on night shift. If this were the case, we would expect the officers on night shift to show a more normal diurnal cortisol profile, that is, a steeper (not flatter) profile. Our results showed that night shift officers had a flatter diurnal cortisol profile. More importantly is the fact that officers are assigned their shift schedule by management; they do not have a choice regarding work schedules. Men and much younger officers are more likely to be assigned to work the night shift. So we do not believe that officers' greater tolerance for night shiftwork biased our associations.

Nevertheless, this study makes a contribution to the literature, being the first to compare diurnal cortisol levels across shifts in a cohort of law enforcement officers. This study has other strengths. An important strength is the use of objective shiftwork data obtained from payroll records. Other studies that have used shiftwork have frequently collected self-reported data.

In conclusion, we found that officers on the night shift had a flatter diurnal cortisol profile. Our results suggest that night shift-work is a stressful exposure. A flatter diurnal curve has implications for several adverse health outcomes including cancer, increased mortality risk, and psychosocial disorders.[12,13,20,46] Strategies to reduce the effects of night shiftwork on officers should be considered. Use of longitudinal study designs would shed light on the question of whether shiftwork is a risk factor for development of a more adverse diurnal cortisol profile.

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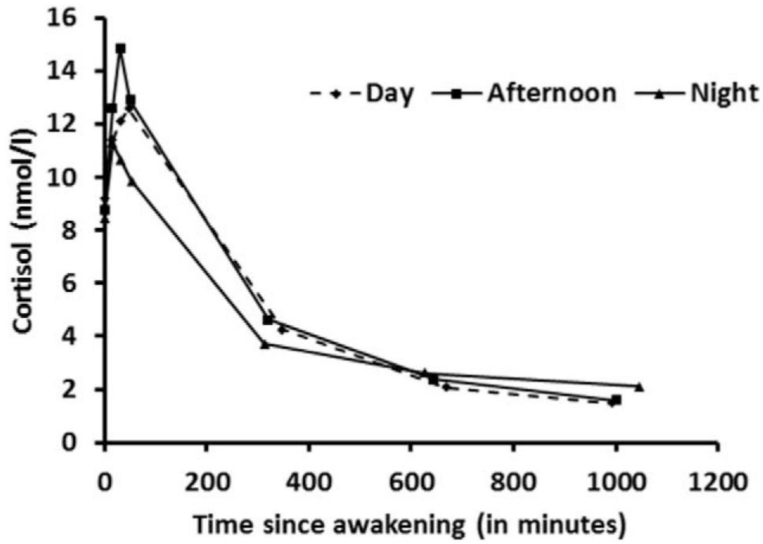

FIGURE 1.
Multivariate-adjusted diurnal cortisol pattern by shiftwork.

TABLE 1

Demographic and Other Characteristics of the Police Officers by Gender; BCOPS 2004 to 2009

	All (*n*=319)	Women (*n*=71)	Men (*n*=248)	
Characteristics	**Mean±SD**	**Mean±SD**	**Mean±SD**	***P***
Age (yrs) (27–67 yrs)	42.8±7.7	41.7±5.5	43.1±8.2	0.109
Waist circumference (cm)	95.5±14.0	80.3±12.0	99.9±11.2	<0.001
Physical activity (hr/week)	22.4±18.4	23.3±18.3	22.2±18.5	0.639
Hours of sleep/per 24-hr	6.1±1.2	6.1±1.2	6.1±1.2	0.899
Alcohol (drinks/week)	5.8±9.7	3.7±5.2	6.3±10.6	0.005
AUC_G †	6109.0±3049.4	6036.1±2444.6	6129.9±3205.7	0.792
AUC_I ‡	−4893.1±7144.0	−4231.8±6425.2	−5082.3±7338.0	0.377
$Slope_7$ (nmol/L/min)§	−0.0031±0.0018	−0.0031±0.0016	−0.0030±0.0018	0.718
$Slope_4$ (nmol/L/min)‖	−0.00244±0.0019	−0.0026±0.0017	−0.0024±0.0019	0.348
	N (%)	*N* (%)	*N* (%)	
Race/ethnicity				0.003
White	250 (79.1)	51 (71.8)	199 (81.2)	
Black	60 (19.0)	20 (28.2)	40 (16.3)	
Hispanic	6 (1.9)	0 (0.0)	6 (2.5)	
Educational level				0.181
≤HS/GED	43 (13.5)	5 (7.0)	38 (15.3)	
<4 yrs college	169 (53.0)	39 (54.9)	130 (52.4)	
≥4 yrs college	107 (33.5)	27 (38.0)	80 (32.3)	
Marital status				<0.001
Single	36 (11.3)	16 (22.5)	20 (8.1)	
Married	41 (75.8)	4 (59.2)	199 (80.6)	
Divorced	41 (12.9)	13 (18.3)	28 (11.3)	
Body mass index (kg/m^2)				<0.001
<25	54 (16.9)	34 (47.9)	20 (8.1)	
25–30	132 (41.4)	25 (35.2)	107 (43.2)	
>30	133 (41.7)	12 (16.9)	121 (48.8)	
Police rank				0.055
Patrol officer	206 (64.6)	52 (73.2)	154 (62.1)	
Sergeant/lieutenant	44 (13.8)	11 (15.5)	33 (13.3)	
Captain/detective/other	69 (21.6)	8 (11.3)	61 (24.6)	
Smoking status				0.001
Current	50 (15.8)	19 (27.9)	31 (12.5)	
Former	83 (26.3)	22 (32.4)	61 (24.6)	
Never	183 (57.9)	27 (39.7)	156 (62.9)	
Shiftwork				<0.001

Characteristics	All (n=319) Mean±SD	Women (n=71) Mean±SD	Men (n=248) Mean±SD	P
Day	134 (42.0)	48 (67.6)	86 (34.7)	
Afternoon	106 (33.2)	13 (18.3)	93 (37.5)	
Night	79 (24.8)	10 (14.1)	69 (27.8)	

GED indicates General Education Development; HS, high school; SD, standard deviation.

P values are for differences between women and men.

For continuous variables, the *P* values were obtained from *t* tests.

For categorical variables, the *P* values were obtained from chi-square or Fisher exact tests. Shiftwork refers to the dominant shift in the past 1 year.

*AUCG: Total area under the curve (expressed as nmol/L × minute).

†AUCI: Area under the curve with respect to increase (expressed as nmol/L × minute).

‡Slope7: Slope of the diurnal cortisol curve of seven samples (at awakening, 15, 30, and 45 minutes after waking, lunch, dinner, and bedtime).

§Slope4: Slope of the diurnal cortisol curve of four samples (at awakening, lunch, dinner, and bedtime).

TABLE 2

Associations of Selected Characteristics of Police Officers With Shiftwork

	Shiftwork			
	Day	Afternoon	Night	
	Mean±SD	Mean±SD	Mean±SD	*P*
Age (yrs)	46.4±7.4	40.3±6.5	39.9±7.2	<0.001
Waist circumference (cm)	93.8±15.3	97.1±13.2	96.5±12.7	0.156
Physical activity (hr/week)	16.1±12.9	17.6±16.4	14.1±11.4	0.240
Hours of sleep/per 24-hr	6.4±1.1	6.2±1.3	5.9±1.1	0.038
Alcohol (drinks/week)	6.2±10.5	6.1±10.9	4.5±5.9	0.405
	N (%)	*N* (%)	*N* (%)	
Gender				<0.001
Men	86 (64.2)	93 (87.7)	69 (87.3)	
Women	48 (35.8)	13 (12.3)	10 (12.7)	
Race/ethnicity				0.052
White	95 (71.4)	88 (84.6)	67 (84.8)	
Black	34 (25.6)	14 (13.5)	12 (15.2)	
Hispanic	4 (3.0)	2 (1.9)	0 (0.0)	
Educational level				0.411
≤HS/GED	21 (15.7)	12 (11.3)	10 (12.7)	
<4 yrs college	75 (56.0)	57 (53.8)	37 (46.8)	
≥4 yrs college	38 (28.4)	37 (34.9)	32 (40.5)	
Marital status				0.948
Single	16 (11.9)	10 (9.5)	10 (12.7)	
Married	102 (76.1)	81 (77.1)	58 (73.4)	
Divorced	16 (11.9)	14 (13.3)	11 (13.9)	
Police rank				<0.001
Patrol officer	67 (50.0)	76 (71.7)	63 (79.8)	
Sergeant/lieutenant	22 (16.4)	10 (9.4)	12 (15.2)	
Captain/detective/other	45 (33.6)	20 (18.9)	4 (5.1)	
Smoking status				0.053
Current	18 (13.7)	17 (16.0)	15 (19.0)	
Former	46 (35.1)	22 (20.8)	15 (19.0)	
Never	67 (51.2)	67 (63.2)	49 (62.0)	

GED indicates General Education Development; HS, high school; SD, standard deviation.

Results are means±SD for the continuous variables, and *n* (%) for categorical variables.

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 dominant shift for continuous variables.

TABLE 3

Age-Adjusted Associations of Selected Characteristics of Police Officers With Diurnal Cortisol Measures

	AUCG[*]	**AUCI**[†]	**Slope$_7$**[‡]	**Slope$_4$**[§]
Waist circumference (cm)	**−0.137, 0.018**	−0.060, 0.303	−0.079, 0.175	−0.085, 0.144
Physical activity (h/week)	0.080, 0.169	−0.024, 0.679	−0.042, 0.472	−0.034, 0.560
Hours of sleep/per 24-hr	−0.085, 0.141	−0.003, 0.958	**−0.128, 0.027**	−0.101, 0.079
Alcohol (drinks/week)	−0.022, 0.709	−0.025, 0.665	**−0.133, 0.021**	−0.093, 0.107
	Mean ± SE	**Mean ± SE**	**Mean ± SE**	**Mean ± SE**
Gender				
Women	6047.4±363.6	−4253.0±851.0	−0.0031±0.0002	−0.0026±0.0002
Men	6126.6±194.3	−5076.3±454.7	−0.0030±0.0001	−0.0024±0.0001
P value	0.848	0.395	0.713	0.370
Race/ethnicity				
White	6107.3±193.8	−5485.9±448.2	−0.0032±0.0001	−0.0026±0.0001
Black	6252.3±396.4	−2930.2916.9	−0.0025±0.0002	−0.0020±0.0002
Hispanic	4230.0±1251.3	−4178.1±2894.1	−0.0033±0.0007	−0.0026±0.0008
P value	0.306	**0.043**	**0.039**	0.118
Marital status				
Single	6609.8±518.0	−3378.0±193.7	−0.0024±0.0003	−0.0018±0.0003
Married	6008.5±197.5	−5392.6±455.1	−0.0032±0.0001	−0.0026±0.0001
Divorced	6270.1±478.3	−2874.5±1102.3	−0.0025±0.0003	−0.0019±0.0003
P value	0.522	**0.047**	**0.004**	**0.012**
Rank				
Patrol officer	−0.0022±0.0001	−0.0022±0.0001	−0.0028±0.0001	−0.0022±0.0001
Sergeant/lieutenant	−0.0026±0.0003	−0.0026±0.0003	−0.0032±0.0003	−0.0026±0.0003
Captain/detective/other	−0.0031±0.0003	−0.0031±0.0003	−0.0037±0.0002	−0.0031±0.0003
P value	**0.020**	**0.020**	**0.009**	**0.020**
Smoking status				
Current	6330.8±437.6	−4320.5±1018.4	−0.0028±0.0003	−0.0025±0.0003
Former	5845.2±357.1	−4042.3±830.9	−0.0030±0.0002	−0.0024±0.0002
Never	6181.7±230.1	−5378.9±535.5	−0.0031±0.0001	−0.0025±0.0001
P value	0.657	0.342	0.576	0.938

Continuous variables: partial Pearson's correlation coefficients and *P* values.

Bold values indicate statistically significant results.

All P values were obtained from ANCOVA.

SE indicates standard error.

[*] AUC: Total area under the curve (expressed as nmol/L × minute).

[†] AUCI: Area under the curve with respect to increase (expressed as nmol/L × minute).

[‡] Slope7: Slope of the diurnal cortisol curve of seven samples (at awakening, 15, 30, and 45 minutes after waking, lunch, dinner, and bedtime).

[§] $Slope_4$: Slope of the diurnal cortisol curve of four samples (at awakening, lunch, dinner, and bedtime).

TABLE 4

Mean Values of Diurnal Cortisol Parameters by Shiftwork for all Officers: BCOPS Study 2004 to 2009

	Shiftwork				*P* value† for multiple comparisons		
Model I	**Day (*n*=134)**	**Afternoon (*n*=106)**	**Night (*n*=79)**	***P****	**D vs. N**	**A vs. N**	**D vs. A**
AUC_G †	5914.80±2739.6	6302.26±3036.0	6179.1±3547.6	0.605	0.542	0.786	0.330
AUC_I §	−5316.20±7205.2	−4911.18±7414.4	−4150.97±6684.6	0.518	0.252	0.475	0.663
$Slope_7$ //	−0.00328±0.0017	−0.00321±0.0017	−0.00242±0.0019	**0.001**	**0.001**	**0.003**	0.744
$Slope_4$ ¶	−0.00278±0.0018	−0.00245±0.0019	−0.00185±0.0019	**0.002**	**<0.001**	**0.029**	0.159
Model II	**(*n*=127)**	**(*n*=100)**	**(*n*=76)**				
AUCG‡	5859.70±308.6	6278.8±322.8	6194.60±376.9	0.666	0.522	0.860	0.378
AUCI§	−5511.37±705.8	−4593.18±738.2	−4347.80±861.9	0.581	0.331	0.823	0.399
$Slope_7$ //	−0.00332±0.00017	−0.00313±0.00018	−0.00257±0.0002	**0.023**	**0.009**	**0.033**	0.456
Slope4¶	−0.00288±0.00018	−0.00237±0.00019	−0.00194±0.0002	**0.008**	**0.002**	0.122	0.061

Model I: unadjusted means (±SD) of diurnal cortisol parameters across shiftwork.

Model II: adjusted means (±SE) of diurnal cortisol parameters across shiftwork. Adjustmentwas made for demographic characteristics (age, gender, race/ethnicity, education, marital status, and rank) and life style behaviors (smoking status, alcohol consumption, physical activity), and waist circumference.

Bold values indicate statistically significant results.

*Overall P value comparing differences across the three shift categories.

†*P* value for pairwise differences.

‡AUCG: Total area under the curve (expressed as nmol/L × minute).

§AUCI: Area under the curve with respect to increase (expressed as nmol/L × minute).

//Slope7: Slope of fitted regression line to the diurnal samples (*n*=7), nmol/L/minute.

¶Slope4: Slope of fitted regression line to the diurnal samples (*n*=4), nmol/L/minute.

TABLE 5

Mean Values of Diurnal Cortisol Parameters by Shiftwork, Stratified by Gender: BCOPS Study 2004 to 2009

Women	**Shiftwork**				***P*[†] for multiple comparisons**		
Model I	**Day (*n*=48)**	**Afternoon (*n*=13)**	**Night (*n*=10)**	***P*[*]**	**D vs. N**	**A vs. N**	**D vs. A**
AUC_G[†]	5741.09±2236.76	6079.60±2400.5	7395.27±3185.9	0.150	0.053	0.199	0.655
AUC_I[§]	−4793.34±7064.9	−2890.88±3833.7	−3279.81±5963.2	0.569	0.503	0.887	0.350
$Slope_7$[//]	−0.00334±0.0015	−0.00289±0.0014	−0.00234±0.0020	0.166	0.071	0.406	0.364
$Slope_4$[¶]	−0.00290±0.0016	−0.00238±0.0016	−0.00165±0.0021	0.098	0.038	0.312	0.331
Model II	**(*n*=43)**	**(*n*=12)**	**(*n*=10)**				
AUC_G[†]	5729.51±395.9	6464.45±763.0	7612.01±822.7	0.155	0.055	0.284	0.423
AUC_I[§]	−4117.78±1072.5	−3143.77±2067.3	−3160.45±2228.9	0.898	0.714	0.995	0.694
$Slope_7$[//]	−0.00333±0.00027	−0.00297±0.00052	−0.00229±0.00056	0.291	0.118	0.352	0.564
$Slope_4$[¶]	−0.00283±0.00029	−0.00262±0.00057	−0.00170±0.00062	0.289	0.122	0.254	0.754
Men							
Model I	**Day (*n*=86)**	**Afternoon (*n*=93)**	**Night (*n*=69)**		**D vs. N**	**A vs. N**	**D vs. A**
AUC_G[†]	6011.74±2991.8	6333.39±3124.1	6002.82±3583.8	0.742	0.986	0.518	0.504
AUC_I[§]	−5608.03±7307.0	−5193.59±7756.7	−4277.22±6813.3	0.526	0.264	0.433	0.707
$Slope_7$[//]	−0.00325±0.0018	−0.00325±0.0017	−0.00244±0.0019	**0.006**	**0.005**	**0.004**	0.998
$Slope_4$[¶]	−0.00272±0.0018	−0.00246±0.0019	−0.00188±0.0019	**0.021**	**0.006**	0.054	0.348
Model II	**(*n*=84)**	**(*n*=88)**	**(*n*=66)**				
AUC_G[‡]	5863.94±394.6	6329.51±353.02	5957.87±417.1	0.648	0.879	0.487	0.406
AUC_I[§]	−5878.85±902.5	−4977.73±807.4	−4718.73±954.0	0.686	0.410	0.832	0.482
$Slope_7$[//]	−0.00333±0.00021	−0.00312±0.00019	−0.00262±0.00022	0.073	0.031	0.075	0.494
$Slope_4$[¶]	−0.00291±0.00022	−0.00232±0.00020	−0.00199±0.00023	0.028	0.008	0.273	0.060

Model I: unadjusted means (±SD) of diurnal cortisol parameters across shiftwork.

Model II: adjusted means (±SE) of diurnal cortisol parameters across shiftwork. Adjustment was made for demographic characteristics (age, race/ethnicity, education, marital status, and rank), lifestyle behaviors (smoking status, alcohol consumption, physical activity), and waist circumference.

Bold values indicate statistically significant results.

[*]Overall P value comparing differences across the three shift categories.

[†]*P* value for pairwise differences.

[‡]AUCG: Total area under the curve (expressed as nmol/L × minute).

§ AUCI: Area under the curve with respect to increase (expressed as nmol/L × minute).

// Slope7: Slope of fitted regression line to the diurnal samples (n=7), nmol/L/minute.

¶ Slope4: Slope of fitted regression line to the diurnal samples (*n*=4), nmol/L/minute.

TABLE 6

Pearson Correlations (*r*) Between Percent of Hours Worked on Night Shift and the Diurnal Cortisol Parameters for all Participants: BCOPS Study 2004 to 2009

	Simple Correlations (*n*=319)		Partial Correlations (*n*=303)	
Derived Cortisol Parameters	***r***	***P****	**r**	***P*†**
All Officers				
AUC_G †	0.023	0.683	0.023	0.698
AUC_I §	0.056	0.319	0.017	0.778
$Slope_7$ //	0.216	**<0.001**	0.166	**0.005**
$Slope_4$ ¶	0.165	**0.003**	0.120	**0.041**
Women				
AUC_G ‡	0.115	0.341	0.134	0.344
AUC_I §	0.061	0.613	0.006	0.967
$Slope_7$ //	0.229	0.055	0.290	**0.037**
$Slope_4$ ¶	0.225	0.059	0.247	0.077
Men				
AUC_G ‡	0.005	0.936	0.013	0.543
AUC_I §	0.064	0.316	0.014	0.831
$Slope_7$ //	0.213	**0.001**	0.148	**0.027**
$Slope_4$ ¶	0.146	**0.022**	0.093	0.164

Gender was removed from the gender-stratified model.

Bold values indicate statistically significant results.

[*] Unadjusted *P* value.

[†] *P* value adjusted for demographic characteristics (age, gender, race/ethnicity, education, marital status, and rank), lifestyle behaviors (smoking status, alcohol consumption, physical activity), and waist circumference.

[‡] AUCG: Total area under the curve (expressed as nmol/L × minute).

[§] AUCI: Area under the curve with respect to increase (expressed as nmol/ L × minute).

[//] Slope7: Slope of fitted regression line to the diurnal samples (*n*=7), nmol/L/ minute.

[¶] Slope4: Slope of fitted regression line to the diurnal samples (*n*=4), nmol/L/ minute.