Diurnal Cortisol Variation According to High-Risk Occupational Specialty Within Police

Comparisons Between Frontline, Tactical Officers, and the General Population

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Objective: The aim of this study was to compare diurnal salivary cortisol among high-risk occupational police specialties and the general population (n = 18,698). Methods: Tactical and frontline officers provided salivary cortisol samples for 2 days (four times: wake, 30 minutes, 11 hours, and 17 hours post-awakening) and were compared with a general population sample of group field studies utilizing similar methodology. Samples were analyzed for free cortisol concentrations (nmol/L) using chemiluminescence immunoassay. Results: Repeated-measures mixed-model analysis of variance (ANOVA) revealed significantly greater salivary diurnal cortisol among tactical than frontline officers. Furthermore, both tactical and frontline officers had higher cortisol levels on average at all time points than the general population sample. Conclusion: Results suggest that diurnal cortisol response may be associated with level of risk exposure in hazardous occupational subspecialties within policing compared with the general population.

Keywords: diurnal cortisol, HPA, law enforcement, occupational risk, police, stress

INTRODUCTION

Policing is generally considered a high-risk occupation. Yet within policing, some subspecialties are exposed to higher risk encounters more frequently. In this paper, we consider the occupational subspecialties within policing of frontline and tactical team officers. A frontline police officer is a term used by police services to indicate a patrol officer. A frontline officer’s daily duties focus on, but are not limited to, direct interaction with members of the public due to witnessing unlawful acts while on patrol or civilian-reported events via radio dispatch. Frontline officers usually respond to calls for service either by themselves or with a partner. These officers are often the first to arrive on the scene during an incident and they are responsible for assessing the situation and determining if a specialty police unit, such as a tactical team or an investigative unit, is required to resolve the situation.

Tactical team units are comprised of officers within a police service that have the skills, equipment, and training to respond to the highest-risk incidents; such encounters may include barricaded suspects, active shooter events, or hostage situations. These incidents often require skills and capabilities beyond the average frontline officer and require a coordinated, team approach to resolve problems safely. Tactical officers typically require approximately 5 years as an active-duty frontline officer, a variety of specialty skills training courses, and the physical and mental capability to pass a barrage of testing. Tactical officers face the same pressures that frontline officers report, such as organizational management and community pressures, shiftwork, particularly stressful and traumatic exposures, as well as the additional hazards for which they have been specially trained and equipped for.1–5 Although research among frontline police is becoming more common, research with tactical officers is rare due to the confidential nature of their occupational requirements.6–8 Thus, less is known about the biological correlates of stress associated with level of occupational risk among these groups.

Research reveals that first responders exposed to repeated stress and life-threatening (eg, violent) encounters may experience maladaptive physiological stress responses and negative health consequences.9–11 Previous studies have shown that repeated exposure to high stress situations increase the risk of depression, anxiety, diabetes, obesity, cardiovascular disease, and risky changes in neuroendocrine and cardiovascular functioning among police officers and the general population.12–14 An explanatory mechanism that has been proposed to explain increased risk of disease among police officers is hypothalamic-pituitary-adrenal (HPA) axis dysregulation, as measured by cortisol diurnal regulation.12

The current study comparing diurnal cortisol between the general population, frontline, and tactical officers bridges a gap in the literature by investigating the association between increasing levels of risk in occupational specialty and cortisol regulation, with long-term implications for health and functioning.

Stress Response Physiology

When an individual perceives environmental threat, the body engages in a series of automatic physiological processes to prepare the body to respond. This response is colloquially known as the “fight or flight” response.15 The response occurs due to the dual activation of the sympathetic nervous system (SNS) and HPA axis, along with the suppression or withdrawal of the parasympathetic nervous system (PNS). The level of SNS activation is further determined by the intensity of the perceived threat, either from an individual’s cognitive perception or implicit behavioral survival responses.16,17 The “fight or flight” response can further be
stimulated, diminished, or even maintained by various psychological factors (eg, perceived control of the situation) and processes (eg, anxiety or implicit associations). The HPA axis releases a cascade of hormones to prepare the body for the “fight-or-flight” response by altering various physiological functions, including suppression of the immune system, changing metabolic actions, and increasing the function of organs related to physical exertion.16,18 A key regulating hormone in the HPA cascade is cortisol. Cortisol is excreted in a dose–response manner, equivalent to the perceived level of threat, providing a negative feedback loop to the HPA axis to sustain or cease a stress response.19 Cortisol also serves additional functions providing a negative feedback loop to the HPA axis to sustain or dose–response manner, equivalent to the perceived level of threat, within civilian samples indicates that there are health outcomes associated with dysregulated diurnal cortisol levels.27–29 However, trajectories and normative diurnal cortisol patterns remain unclear within occupational risk, or multiday comparisons to alterna-
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Among healthy individuals, cortisol follows a diurnal pattern in which levels are higher upon waking, increase significantly (~30 minutes), and steadily decrease from the peak throughout the rest of the day, reaching the nadir in the middle of the night.24 Much of the work examining diurnal patterns of cortisol among police has centered on examining the effects of shiftwork, post-traumatic stress disorder, sleep quality, cardiovascular disease, and occupational stress.7,12,22–24 There is a current research gap in that there are no established norms for officers’ diurnal cortisol patterns by occupational risk, or multiday comparisons to alternative populations. Researchers have been able to demonstrate that at the end of night shiftwork, there is an increased risk of dysregulated cortisol levels following waking period among operational police officers.24,25 Maladaptive cortisol levels induced by stress have been noted as a risk factor for peri-traumatic dissociation and acute stress reactivity when experiencing trauma.26 Occupational stressors have also been found to cause CAR dysregulation, which can predict changes in brachial artery flow-mediated dilation and cardiovascu-
lar disease in police officers.27

The goal of the present study is to investigate possible differences in diurnal cortisol patterns between high-risk occupational subspecialties of police and the general population. Research within civilian samples indicates that there are health outcomes associated with dysregulated diurnal cortisol levels.27–29 However, trajectories and normative diurnal cortisol patterns remain unclear among varying levels of law enforcement.

On the basis of a prior pilot study examining CAR patterns between tactical teams and elite athletes, it is hypothesized that tactical unit members will have higher diurnal cortisol at all time points relative to frontline officers, and that frontline officers will have higher diurnal cortisol levels at all time points than the general population.30

METHODS

The participants comprise three groups (frontline officers, tactical officers, general population) and originate from five different studies. Each study was slightly different in content and purpose, but cortisol sampling and analyses were completed using similar methods.

Participants

Frontline Officers
A sample of n = 57 (eight female, Mean age = 32.80 years, SD = 6.29) police constables from a Canadian metropolitan police force. All officers had comparable years of service (Mean = 7.09, SD = 5.63) (see Table 1). Of the original participants, n = 52 provided complete cortisol samples for testing purposes and are included in the present analyses.

Tactical Unit Officers
The sample of tactical officers examined in this study is comprised of three different active duty Finnish Special Response Teams (SRTs) (n = 44, all males). Two regional-level tactical teams (n = 32, Mean age = 32.14 years, SD = 4.26) and one federal tactical team (n = 12, Mean age = 31.50 years, SD = 2.02)13 were tested within 6 months of one another (see Table 1). The methods were consistent between studies, described below, and are detailed in the study by Andersen et al.13,31 Pairwise comparisons confirmed that tactical samples were not different from one another on cortisol values at each time point (P > 0.1), or self-reported perceived stress (P > 0.1); therefore, all tactical team members are grouped into one sample in all subsequent analyses.

General Population
The population analyzed is from the meta-database by Miller et al.27 a convenience sample comprised of both published and unpublished group field studies (n = 15) across North America and Europe. The dataset totaled n = 18,698 participants, with the majority of the sample (~74%) being within the age range of the police studies. All studies used to create this database were selected by the criteria of appropriate protocol adherence and saliva collection using industry standard saliva collection vials.27 To generate the average diurnal cortisol from the general population, data points were extrapolated (see Statistical Analyses section for description of extrapolation method) from the 10th, 25th, 50th, 75th, and 90th percentiles at each of the four time points of interest in the current study (ie, wake, 30 minutes, 11 hours, and 17 hours post-wake). Therefore, a complete sample of n = 5 data points with four observations each are included in the statistical analyses representing the entire general population, a total sample of n = 18,698.

Materials and Measures
All police study participants completed a consent form that was approved by the University of Toronto Research Ethics Board. The three studies within Finland (tactical officers) received additional approval from the Ethics Review Board at the Police University College of Finland. The materials for the collection of saliva were the same across all police samples.

Cortisol Collection
The method of saliva collection for the police samples followed Salimetrics passive drool protocol (State College, Pennsylvania). Each participant was issued a diurnal salivary kit for each
Cortisol samples from tactical officers were collected in Finland and were stored in a −20°C freezer 12 to 15 hours post sample to preserve freshness in a freezer located in the facilities of the Police University College of Finland. Within 5 days of completion of the study, saliva samples were packed in dry ice and shipped to an independent laboratory for cortisol analysis (Clemens Kirschbaum, Technische Universität Dresden, DE). After thawing, samples were centrifuged at 3000 rpm for 5 minutes, which resulted in a clear supernatant of low viscosity. Salivary cortisol concentrations were measured using commercially available chemiluminescence-immuno- assay with high sensitivity (IBL assay; IBL International, Hamburg, Germany). The intra and inter-assay coefficients of variation for cortisol were below 8%.

For the general population meta dataset, Miller et al27 report that “the schedule of collection across the day varied across studies from a maximum of 4 samples during the first hour after awakening to studies that sampled every two hours and then after stressful events.” Miller et al27 report that salivary cortisol levels were restricted to studies using the Delfia-assay (Dressendorfer et al, 1992, University of Trier) or the IBL chemiluminescence-assay depending on the field study (see Miller et al for specific protocols). For the general population data were extrapolated from Fig. 1 by Miller et al27. Meta dataset of diurnal salivary cortisol, using a browser-based software called WebPlotDigitizer (Ankit Rohatgi, Austin, Texas). The software analyzes the study’s relevant figure(s), placing points at each axes’ start and end values. Users are able to manually select points on a graph and manipulate the value on one axis to determine the corresponding value on the other axis. From the study by Miller et al27 Fig. 1, we extrapolated the average diurnal cortisol value for each of the 10th, 25th, 50th, 75th, and 90th percentiles of the general population at the zero (ie, wake) hour, 30 minutes post-wake, 11 hours post-wake, and 17 hours post-wake time points. As such, our statistical analyses included diurnal cortisol values from a sample of n = 5 data points that together represent all cortisol values of the general population sample (n = 18,698) from Miller et al27.

One tactical participant’s measurements were dropped from the analysis due to extreme cortisol values (> 3 SD above the mean at each time point). These extreme values were used as a case example within an alternate publication.28 Final analysis for the present study was conducted on a sample of n = 52 frontline officers, n = 44 tactical officers, and n = 5 (representing the total sample of n = 18,698) from the general population extrapolation. Due to differences in sample size between groups, a repeated-measures mixed-model analysis of variance (ANOVA) was performed, with Bonferroni corrections to assess pairwise differences in cortisol values between groups at each time point across the diurnal cycle.33 The independent variables included group (frontline, tactical, or general population) and time (four cortisol samples across the day). Simple descriptive measures were calculated at each time point per group for the continuous outcome variable (cortisol in nmol/L), including means and standard deviations (SDs). All effects are reported as significant a P value less than 0.05.
Self-reported stress was analyzed using independent samples t test, comparing the total PSQ-Op score between tactical officers and frontline officers. All analyses were carried out using SPSS Statistic 25 (IBM, Armonk, New York).

**RESULTS**

**Cortisol**

ANOVA results revealed a significant main effect for cortisol levels across time, $F(3, 27) = 108.45, P < 0.001$, confirming that all participants displayed a typical CAR as shown in previous studies.21,30 A significant main effect of group, $F(2, 18) = 64.04, P < 0.001$, determined that the general population group had significantly lower cortisol levels than both the frontline officers ($P < 0.001$) and the tactical officers ($P < 0.001$). Further, post hoc comparisons revealed that tactical officers had significantly higher cortisol levels on average than frontline officers ($P = 0.003$) (Table 2). A significant interaction between time and group variables was also found, $F(6, 16) = 13.32, P < 0.001$ (Fig. 1).

Post hoc pairwise comparisons were completed to determine between-group differences in diurnal cortisol levels at each time point. The summary of these pairwise comparisons, together with mean and standard deviations for diurnal cortisol for each group at each time point, can be found in Table 3. At the initial wake time point, results revealed that both tactical officers ($P < 0.001$) and frontline officers ($P = 0.004$) have greater cortisol levels than the general population, and that tactical officers also have greater cortisol levels than frontline officers ($P = 0.045$). The results for 30 minutes post awakening indicate the same pattern as the wake timepoint, with tactical ($P = 0.001$) and frontline officers ($P = 0.010$) showing greater cortisol levels than the general population, and higher cortisol levels among tactical versus frontline officers ($P = 0.003$). The results for 11 hours post-awakening indicate that tactical officers do not differ from frontline officers ($P = 0.199$), but both groups of officers have significantly greater levels of cortisol than the general population ($P < 0.001$). The

**TABLE 2.** Post Hoc Analysis for Significant Main Effect of Group From Repeated-Measures Mixed-Model ANOVA

|                         | Frontline | General Population |
|-------------------------|-----------|--------------------|
| Tactical unit           | $P = 0.003$, CI [0.73–4.63] | $P = 0.000$, CI [8.72–14.22] |
| Frontline               | $P = 0.000$, CI [6.09–11.49] |                  |

CI, confidence interval.

**FIGURE 1.** Mean diurnal salivary cortisol (nmol/L) levels. A significant main effect of time revealed that all groups showed a typical pattern of diurnal cortisol ($P < 0.001$), peaking 30 minutes after waking and decreasing significantly over the course of the day. A main effect of group showed that on average, tactical and frontline officers had significantly higher cortisol levels than the general population ($P < 0.001$), and a significant time by group interaction revealed that tactical officers had significantly higher cortisol levels than frontline officers at wake and 30 minutes post-wake time points, and frontline officers showing marginally higher cortisol at the final time point obtained before bedtime.

**TABLE 3.** Post Hoc Pairwise Comparisons for Significant Time by Group Interaction

|                         | Diurnal Cortisol Means, nmol/L |
|-------------------------|---------------------------------|
|                         | Frontline | Tactical Unit | General Population |
| Waking                  | 15.03 (6.67) | 18.55 (7.03) | 5.79 (3.57) |
| Frontline               | —         | $P = 0.045$   | $P = 0.004$   |
| Tactical                | —         | —             | $P = 0.000$   |
| 30 minutes post-waking  | 24.45 (10.23) | 31.23 (9.30) | 9.65 (6.37) |
| Frontline               | —         | $P = 0.003$   | $P = 0.010$   |
| Tactical                | —         | —             | $P = 0.001$   |
| 11 hours post-waking    | 7.49 (5.90) | 10.80 (10.30) | 1.42 (1.10) |
| Frontline               | —         | $P = 0.199$   | $P = 0.000$   |
| Tactical                | —         | —             | $P = 0.000$   |
| 17 hours post-waking    | 5.85 (7.69) | 2.96 (2.30)  | 0.82 (0.72)  |

Mean (SD) diurnal cortisol levels are reported for each group and time point.
results for 17 hours post-awakening indicate a different pattern than previous, with tactical officers having lower levels of cortisol than frontline officers ($P = 0.046$). However, both groups of officers still have significantly greater levels of cortisol than the general population at day's end (tactical: $P = 0.002$, frontline: $P < 0.001$).

**Self-Reported Stress**

An independent-samples $t$ test revealed a significant difference on PSQ-Op scores between tactical (mean = 46.6) and frontline (mean = 57.9) officers, $t(90.6) = -3.01$, $P < 0.01$.

**DISCUSSION**

The present study provides novel evidence for normative diurnal cortisol levels among subspecialties of police officers with varying degrees of occupational risk, and compared with the general population. In line with previous research, cortisol did change as a function of time, following the typical diurnal cycle. As hypothesized, tactical officers had the highest cortisol levels at all time points on average and becoming approximately equal to frontline officers' cortisol levels at 11 hours post-awakening. When examining the morning CAR levels (wake and 30 minutes post-waking), the tactical teams showed significantly elevated cortisol compared with frontline officers, and greater than triple the level of the general population. Frontline officers displayed more than double the CAR levels of the general population. These results suggest that both police officer samples experience higher diurnal cortisol than population averages, and that increasing occupational risk within police samples demonstrate further increases in CAR.

There is currently limited existing evidence in the literature as to why the tactical officers' cortisol levels within CAR would be significantly higher, but most explanations are psychological rather than physiological. One probable explanation as to this increase in CAR cortisol levels could be explained by a person's psychological expectations of the upcoming day. According to a literature review on the CAR, anything that causes an increased burden of the day (eg, competitions, workload, night shifts, social stress, or work overload) can create an increased CAR response. Both tactical unit and frontline officers wake up with the expectation that their workday may be contain risk and novelty, not knowing what environments and situations they will be exposed to. Tactical officers may have even higher expectation of risk given that their occupational specialty and training means they will be called to the most dangerous situations.

The potential for “life threat” is inherent in the occupational specialty of policing, and particularly so for tactical teams. As such, the potential for life threat could provide an additional psychological explanation as to why the tactical unit and frontline officers experience higher CAR levels than the general population, and greater CAR among tactical officers than frontline. In humans, explicit or implicit associations of threat stimulate a set of automatic and continuous activation of the autonomic nervous system to engage this “flight or fight” response may create a dysregulation in the HPA axis in response to daily stress, resulting in diurnal cortisol and CAR over time relative to the general population as shown in the present results.

Lovelock reviews evidence that life threat is often accompanied by emotional reactions such as fear and anger. Over time, these negative emotions may become risk factors for dysregulated physiological adaptations to future stress. Whether or not these affective psychological factors are related to a permanent upward shift in officer CAR is unknown. The data presented are not a causal analysis, so it may be the case that individuals with higher CAR values are attracted to the occupation of policing or high-risk encounters, rather than higher cortisol levels being occupationally induced.

Shiftwork is also a proposed mechanism by which CAR responses may be dysregulated in police officers, as most are required to work in rotating shifts. Researchers have linked shift-work to dysregulated diurnal cortisol patterns using longitudinal analysis. In an attempt to control for the factor of fatigue induced by shift work in the current study, all police officers were tested (ie, saliva samples were collected) on a week when the officers were on day shift and had not been on night shift for a minimum of at least the previous 2 days. However, it is possible that routine shift work results in dysregulated HPA and diurnal cortisol function that an individual is not able to recover from within 2 days.

Results revealed that tactical officers reported significantly lower perceived stress than frontline officers, according to the PSQ-Op scale. Despite the significant difference in mean score between groups, it is important to note that both groups reported a score of below 60, which falls within the low/moderate range of perceived stress (ie, a score of 20 is “no stress at all” and a score of 80 is a “moderate amount of stress”). The finding that tactical officers report even less perceived stress than the frontline officers may seem counterintuitive, particularly given that tactical diurnal cortisol levels are higher than frontline officers. There may be several reasons for this finding (which are speculative given the limitations of this study). The profession of policing is one where showing weakness is looked down upon, particularly as the occupational risk level increases (eg, tactical officers are to be the “toughest” and show the least weakness of all officers). Self-reporting stress may be seen as a sign of weakness or may elicit fear of potential reprisals from superiors if they were to be found out. Another possibility is that tactical officers always work as part of a cohesive team that trains and respond to calls as a unit. Whereas frontline officers may work independently or are assigned to respond to a call with any available officer on their shift. These differences in occupational and social structure may influence the perception of stress.

**Limitations and Future Research**

A limitation in this study is the extrapolation of the general population data. The study by Miller et al did not specify cortisol values at wake and 30 minutes post-awakening, but we were able to graph this data due to the large number of studies in the meta-analysis. As such, data points were extrapolated at each quartile as well as at the 10th and 90th percentiles to approximate diurnal analysis. As such, data points were extrapolated at each quartile as well as at the 10th and 90th percentiles to approximate diurnal analysis. As such, data points were extrapolated at each quartile as well as at the 10th and 90th percentiles to approximate diurnal analysis. As such, data points were extrapolated at each quartile as well as at the 10th and 90th percentiles to approximate diurnal analysis. In addition, cortisol collection methods and approaches, as well as participant selection criteria (eg, age) could not be accounted for in the selected population studies, or from the studies included in the meta-analysis by Miller et al. Nonetheless, salivary cortisol sampling methods and times were highly controlled for in the police samples, supporting the validity of the current findings.

Another limitation of the current study, and of applied police research in general, includes the sample sizes of each policing group. It is difficult to gather a large sample of tactical unit officers due to fewer occupational positions in comparison to frontline officers. In addition, tactical unit officers do not typically allow the public or researchers to view or investigate their training approaches due to its highly classified and sensitive nature (ie, response protocols for violent encounters or life-or-death decisions). Given these constraints, we believe that this preliminary comparison study includes a relatively large police sample that includes two occupational specialties with varying degrees of risk exposure. The significant findings between tactical and frontline officers are supported by sound statistical analyses and provide a unique insight to the diurnal cycle of these groups that can stimulate further research in this limited area.
Future longitudinal research is encouraged to determine whether diurnal cortisol is different between retired and active duty officers. This comparison could provide evidence as to whether stressful police work, among either tactical units or frontline officers, causes a permanent shift within the diurnal cycle, or if it is acutely occupationally induced and reversed later in life. Future studies could also include other specialized forces of police officers, such as bomb defusal squads, K9 units, and special victims’ units, to determine whether exposure to different types and sources of extreme occupationally relevant stressors may be related to dysregulation in HPA or CAR responses.

CONCLUSION

The current investigation reveals a graded increase in diurnal cortisol levels among law enforcement officials exposed to increasingly demanding roles relative to the general population. Dysregulation within the diurnal cortisol cycle is associated with increased risk of mental and physical health problems and may be related to occupational performance.13,14 Identifying risk factors inherent in occupations that expose individuals to high stress and potential life threat can inform effective interventions and occupational training to prevent or reduce long-term health implications. In North America, the occupation of policing is well-established, and there will always be a need to employ individuals in numerous areas of law enforcement. Thus, it is important to continue to conduct research in this area in order to support the health and well-being of those who serve the public.

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