Chapter

Physiological Stress Responses Associated with High-Risk Occupational Duties

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Abstract

Occupational stress is a pervasive problem that is relevant across the world. Stress, in combination with occupational hazards, may pose additive risks for health and wellbeing. This chapter discusses the influence of physical and psychosocial stressors on basal cortisol regulation as associated with higher-risk occupational duties among two subspecialties of police officers (frontline and special tactical unit officers). Results reveal significant differences in dysregulated cortisol awakening response associated with the higher risk duties among special tactical unit officers. In contrast, frontline officers with a lower objective occupational risk profiles report higher subjective stress levels. Dysregulated or maladaptive cortisol levels are associated with increased health risk. Thus, individuals working in high stress occupations with elevated cortisol profiles may be at increased risk of chronic health conditions. Results suggest that considering both objective physiological markers and subjective reports of stress are dually important aspects in designing interventions for police officers of differing subspecialties.

Keywords: stress, diurnal cortisol, occupational risk, HPA, fight-or-flight, police

1. Introduction

Most of the world's population spends approximately a third of their adult life at work [1]. Interestingly, work also consistently remains a top cited source of adult stress (64% of 3602 surveyed United States adults) [2]. In the context of occupational health, the World Health Organization (WHO) defines occupational stress as the response when presented with work demands that do not match knowledge and abilities, thus, challenging the individual's ability to cope; research suggests the most stressful types of work are those that provide excessive demands and pressures, low perception of control, and provides little support from others [3]. Occupational stress can manifest in physical symptoms, especially cardiovascular ailments; stress is linked to seven of the top ten causes of death in the world, with heart disease being the leading cause for men and women, and chronic occupational stress increasing coronary heart disease risk by 40–50% [4–6].

With occupational stress cited as such a pervasive part of our lives, there is great interest to better understand the impact that stress, in combination with objective occupational hazards, may have on physical and mental health. Thus it is critical to better understand how different workplace factors contribute to or exacerbate stress. As occupational duties and stress exposure varies across occupations, occupational stress sources (i.e., stressors) can be further separated into operational stressors (i.e., job content-inherent aspects of the occupation) and organizational stressors (i.e., job context-characteristics and behaviors of the organization and people of them) [7]. One route to understand how different levels of occupational stress can affect the body is by looking to varying levels of occupational risk exposure within a single occupation via its operational stressors.

Researchers have specialized in examining the effects of occupational responsibilities [7–9], comparing risk subtypes within a high-risk occupation [10]. In a previous study [10], the authors focused on identifying the objective physiological stress associated with risk-subtype among police officers in comparison to the general public. This prior literature revealed that police had significantly higher physiological stress responses (i.e., basal cortisol regulation) in comparison to the general population, with the effect even more pronounced as objective occupational hazards increased (i.e., frontline vs. tactical police).

The goal of this chapter is to discuss stress of varying occupational risk profiles and objective hazards' impact on physiological stress response, while considering participants' subjective reports of stress. Specifically, the authors present analyses to assess subjective measures of stress to further stratify and identify specific factors that may drive objective physiological stress (i.e., basal cortisol regulation) trends observed in a police sample. We hypothesized a positive association between increased risk associated with objective occupational hazards and self-reported stressors. Specifically, that dysregulation in HPA function would be higher among tactical unit officers and this would align with both increased occupational hazards (objective) and self-reported occupational stressors (subjective).

2. The "fight-or-flight" response

Evolutionarily speaking, stress and our ability to respond to it is adaptive and essential for our survival. When presented with a potential threat, the body automatically engages in a series of adaptive physiological processes to maximize survival [11]. Colloquially this process is known as the "fight-or-flight" response. During fight-or-flight, the autonomic nervous system's (ANS) two sub-systems are engaged: the sympathetic nervous system (SNS) is activated, and the parasympathetic nervous system (PNS—responsible for calming and stabilizing the body) is suppressed. The Hypothalamic–Pituitary–Adrenal (HPA) axis is a critical system, producing a cascade of hormones that both maintain and dampen the fight-or-flight response when a threat is presented or removed, respectively.

While fight-or-flight is strictly a physiological response, it can be maintained and stimulated by psychological processes. The degree of activation among the SNS, PNS, and HPA axis is determined by an individual's perception of how threatening the stimulus is, and can be influenced by psychological factors (e.g., threat perception, anxiety, anticipation, perceived control over the situation, etc.) [12]. When a stimulus is perceived as stressful, the hypothalamus releases corticotropin-releasing hormone (CRH), which subsequently triggers the pituitary gland to release of adrenocorticotropic hormone (ACTH). ACTH travels in the bloodstream to the adrenal glands, located above the kidneys, triggering the release of stress hormones glucocorticoids (i.e., cortisol) and catecholamines (e.g., epinephrine, and norepinephrine) [13].

Stress hormones act upon the SNS and PNS, and higher priority survival functions such as heart rate, respiration, energy reserves, and short-term immunity are increased, while lower priority functions for threat response such as reproduction, gastrointestinal activity, and long-term immunity are suppressed [14]. As a result, prolonged dysregulation of HPA activity can have systemic negative effects on regulatory processes in the body, thus increasing the risk of health conditions.

2.1 Cortisol

Cortisol (i.e., glucocorticoids) is a key regulating stress hormone in the human HPA axis cascade. Cortisol potentiates the effects of catecholamines on beta receptors (necessary for impacting peripheral receptors), suppresses immune function, and terminates the fight-or-flight response (via negative feedback loop) [15]. Cortisol is excreted in a dose–response manner to the level of perceived threat by the individual, meaning the greater the perceived threat, the more cortisol that is excreted [16].

Cortisol also has important regulatory functions outside times of stress; cortisol is additionally excreted in a systemic diurnal pattern over every 24-hour period cycle. Among healthy individuals, the diurnal pattern consists of higher levels upon waking, a significant peak around 30 minutes post-waking (i.e., the cortisol awakening response—CAR), steady decline throughout the day, and reaches its lowest point in the middle of the night before again elevating again in the early hours of the next day [17].

2.2 Health risks of maladaptive stress responses

A normal diurnal cortisol pattern indicates individual ability to maintain and return to homeostasis after experiencing stress [16, 18, 19]. However, chronic or repeated stress and subsequent over-activation of the fight-or-flight response can exhaust the HPA axis, resulting in excessive cortisol secretion and eventually, dysregulated diurnal cortisol cycles. Systemically, cortisol influences a wide range of organs and functions including blood pressure regulation and metabolic activity [13, 20]. Thus, long-term, dysregulated cortisol levels significantly increase potential physical and mental illness risks [21]. Physical issues include but are not limited to, compromised immunity, diabetes, hypertension, and cardiovascular disease. Mental health associations include development of depression, anxiety, and psychophysiological PTSD symptoms, such as hyperarousal, and elevated heart rate [22, 23]. Measuring diurnal cortisol patterns, and distinguishing maladaptive patterns and their associated triggers, are critical for identifying potential health risks in populations.

3. High-risk occupations

High-risk occupations present a useful framework for studying the effect of chronic stress on health. By definition, high-risk occupations include work that may be disproportionately exposed to hazardous work environments (e.g., construction, materials handling, emergency response, military) [24]. High-risk occupations imply greater exposure to situations considered potentially dangerous, harmful, or threatening, and potentially, chronically elevated stress responses and excessive cortisol release. Studying the effects of stress in high-risk occupations is also important when taking into consideration performance and duties that are expected to be executed when under stress. Occupational stress that influences performance can result in errors, lower productivity, burnout, or workplace injury, affecting not only the individual but straining the infrastructure of their workplace and health resources [25]. While there are many different types of high-risk occupations, this chapter will focus on the occupation of policing and two subspecialties as an example, given the authors' existing expertise in first responder stress, both from a physiological and psychological standpoint.

3.1 Police stress

Police are often the first to arrive to emergencies where they are regularly exposed to dangerous or threatening situations which pose possible harm to their physical and mental health. Previous literature has established that police exhibit stress responses during active duty and in training [26, 27]. Police occupational stress is significantly linked to poorer health, including lower physical and mental health, and higher physician-diagnosed morbidity, cardiovascular disease, and metabolic syndrome [28]. Heightened anticipatory threat anxiety in these high pressure environments can also result in reduced attentional control that influences active performance [29] and decision making tasks [30] (e.g., motor execution, inhibitory control, use-of-force decisions). Because police health significantly impacts their performance and communities, researchers have focused on understanding how models of physiological stress may apply to their operational stress conditions.

While previous research on police diurnal cortisol focused on the effects of factors such as shift-work, posttraumatic stress disorder (PTSD), sleep quality, and cardiovascular disease, there was limited research providing baseline norms for diurnal cortisol patterns as a function of occupational risk. Our research group has addressed an existing gap in the literature by examining diurnal cortisol patterns of police officers from different risk subspecialties, specifically, frontline and tactical police [10]. Frontline police officers' duties include direct interaction with members of the community in response to unlawful acts witnessed while on patrol, or civilian-reported events. As frontline officers are frequently first to arrive to the scene, they also determine if further specialty units are needed to resolve an incident. Specialty units within a police service, such as tactical teams, are equipped with skills, tools, and training to respond to the highest risk incidents that are beyond the capabilities of an average frontline officer (e.g., active shooter events, barricaded suspects, hostage situations); in many police organizations, tactical units are required to first serve as a frontline officer before enrolling in specialized training to obtain and maintain advanced skills for such incidents [31, 32].

The authors' prior work revealed objective evidence that police had higher diurnal cortisol patterns in comparison to the general population, especially within 30 minutes of waking (CAR). Cortisol levels also differed in respect to police subspecialties. Specifically, tactical officers (the highest risk subspecialty) displayed significantly higher CAR in comparison to frontline officers.

3.2 Present study

The goal of the present chapter is to take a deeper dive and stratify physiological differences between risk-subspecialties, by focusing on officers' subjective reported stress. Because tactical officers have higher objective physiological stress and risk exposure, we expect that tactical police will report higher levels of subjective stress in comparison to frontline police.

3.2.1 Participants

Frontline Officers (n = 57, 14% female) consisted of police constable level volunteers from a Canadian municipal police force (M_{Age} = 32.80, SD = 6.29;

M_{Exp} = 7.09 years, SD = 5.63). Of the 57 participants, 52 provided complete cortisol samples, and 55 provided complete survey data. Inclusion criteria required frontline officers who completed the entirety of their training, and deemed healthy and fit for active duty (as per standards defined and measured by their police service). Exclusion criteria included non-frontline law enforcement or civilian workers, and officers on leave or deemed unfit for duty.

Tactical Officers (n = 44, all male; M_{Age} = 32.31, SD = 3.79; M_{Exp} = 4.66 years, SD = 3.98) were comprised of three active duty Finnish Special Response Teams: two regional-level (n = 32, M_{Age} = 32.14, SD = 4.26) and one federal-level (n = 12, M_{Age} = 31.50, SD = 2.02) the tactical teams were tested within 6 months of one another. All tactical officers provided complete cortisol and survey data. Inclusion criteria allowed for any tactical team members deemed fit or healthy by their police agency. Exclusion criteria included non-tactical officers or civilian workers, and officers deemed unfit for duty.

3.2.2 Cortisol collection and measurement

For full details of cortisol collection and measurement, refer to Planche et al. [10]. Police participants were instructed to use the passive drool method to collect saliva samples into a collection tube at four time points: immediately upon waking, 30 minutes following wake, before dinner (11 hours post waking), and before bed (~17 hours post waking). Participants were instructed they should not eat, drink, or brush their teeth within the hour before the sample collection. After collection, samples were frozen for preservation until analyses.

Frontline officers' cortisol levels were determined with enzyme-linked immunosorbent assay (ELISA) kits (No. 80957; Crystal Chem, Elk Grove Village, Illinois), using a plate reader (Biotek, Winooski, Vermont) and commercial software (Gen 5) to quantify cortisol concentration.

Tactical officers' cortisol samples were collected in Finland and were shipped to an independent laboratory for analyses (Clemens Kirschbaum, Technische Universitat Dresden, DE). Salivary cortisol concentrations were measured using commercially available chemiluminescence-immuno-assay with high sensitivity (IBL assay; IBL International, Hamburg, Germany).

To compare frontline and tactical police cortisol levels to the general population, data were extrapolated from **Figure 1** of Miller et al., 2016's North American and European meta-dataset of diurnal salivary cortisol [33]. Salivary cortisol levels were restricted to studies using the Delfia-assay (Dressendörfer et al., 1992, University of Trier) or the IBL chemiluminescence-assay depending on the field study. Average diurnal cortisol value for each of the 10th, 25th, 50th, and 75th, and 90th percentiles general population (15 studies, n = 18,698) for the same time points collected in the frontline and tactical police samples (wake, 30 minutes post-wake, 11 hours post-wake, and 17 hours post-wake).

3.2.3 Subjective stress

Subjective stress was measured via the Police Stress Questionnaire (PSQ). The PSQ is a 40-item self-report questionnaire that measures police stress across two subscales (organizational stressors—20 questions, operational stressors—20 questions). Participants are asked to rate stress for each item on a 7-point Likert scale ("No stress" (1) – "Moderate stress" (4) – "A lot of stress" (7)) experienced over the prior 6 months. The PSQ displays high internal consistency on both subscales (Cronbach's α = 0.93Op, 0.92Org); it also has good construct, discriminant, and convergent validity, with low shared variance between the subscales, low shared variance to other general stress measures, and positively correlates with other measures of job satisfaction [34]. For this study, the 20 items of the operational stress subscale of the PSQ (PSQ-Op) was used for measuring self-reported subjective operational job-context related stress in frontline and tactical police officers.

3.2.4 Data analysis

Pairwise comparisons confirmed that tactical regional and federal-level subsamples did not significantly differ from each other across all time points for cortisol and self-reported stress data, and sufficient to combine regional and federal subsamples into a single tactical sample group.

For subjective stress comparisons, self-reported stress responses on the PSQ had a non-normal distribution violating the assumptions of a t-test. Therefore, a Wilcoxon rank sum test was used to compare overall reported stress between frontline and tactical officers.

Average diurnal cortisol levels were calculated for each police participant at each time point. Factorial ANOVA was performed to compare specific diurnal time point cortisol levels across each group. Repeated-measures mixed-model analysis of variance (ANOVA) with Bonferroni corrections was used to compare multiple pairwise differences in cortisol levels between groups across time points.

3.2.5 Objective physiological police stress results

As previously cited in Planche et al. [10], ANOVA comparisons for between-group diurnal cortisol differences revealed that police officers had significantly higher levels of cortisol at all collected time points in comparison to the general population ($p < 0.05$). In comparison to frontline officers, tactical officers displayed significantly higher levels of cortisol at awakening and 30 minutes post-awakening in comparison to the frontline officers ($p < 0.05$), non-significantly different levels 11-hours post ($p > 0.05$), and significantly lower levels of cortisol at 17 h post ($p < 0.05$) (See **Figure 1**).

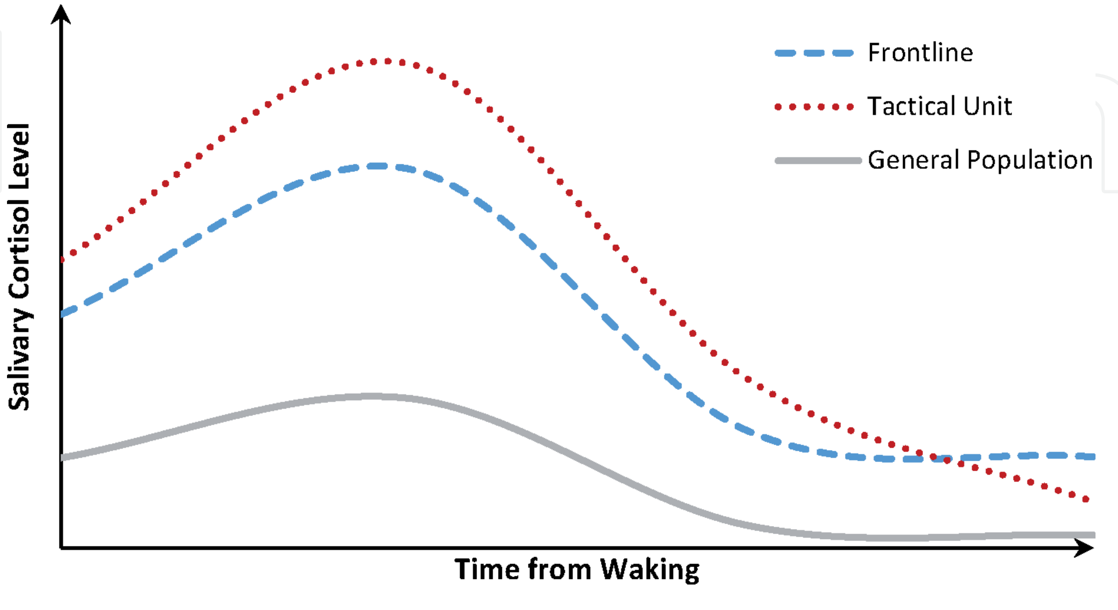

Figure 1.
Overview of diurnal salivary cortisol relationships across 17 h from waking in frontline police (n = 52), tactical police (n = 44), and the general population (n = 18,698). Adapted from Planche et al., 2019.

3.2.6 Subjective police stress results

Using Wilcoxon rank sum testing, frontline officers self-reported significantly higher total levels of operational stress in comparison to tactical officers ($Median_{Frontline}$ = 56, IQR = 33; $Median_{Tactical}$ = 44, IQR = 16; $p < 0.05$) with small effect (r = 0.26) (See **Figure 2**).

When comparing the means across PSQ-Op items (See **Table 1**), the two groups had the largest magnitude differences (ΔMean), with frontline reporting greater stress, on: negative comments from the public, upholding a "higher image" in public, over-time demands, and lack of understanding from family and friends about work. Furthermore, these four items fell within the six lowest reported sources of operational stress for tactical officers. In comparison, tactical officers reported more objective risk items such as being injured on the job, traumatic events, and working alone at night as higher levels of stress in comparison to frontline. For both groups, fatigue, paperwork, and not enough time available to spend with family were ranked among the highest sources of stress.

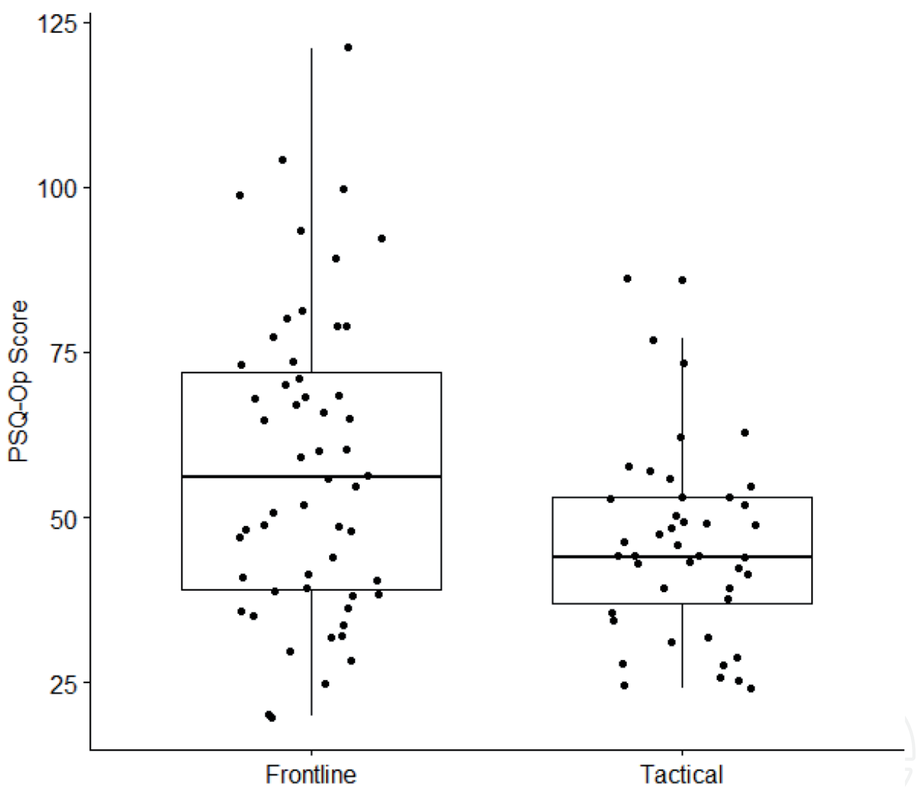

Figure 2.
Boxplot distribution of police (frontline and tactical) total scores on the PSQ-Op. Frontline officers self-reported significantly higher total levels of operational stress in comparison to tactical officers (p < 0.05).

3.3 Discussion

The aim of the current study was to discern potential differences of tactical and frontline police officers' subjective self-reported stress, and the relationship to objective occupational hazard profiles. It was expected that, similar to previous findings of police objective stress (i.e., diurnal salivary cortisol), officers from tactical teams would report significantly higher levels of subjective stress on the PSQ-Op in comparison to frontline officers. However, in contrast to our hypotheses, Wilcoxon rank sum testing revealed that 1) frontline officers reported significantly

PSQ-Op Item	Frontline mean(SD)	Tactical mean(SD)	ΔMean
Total Police Operational Stress Score	**57.95(23.08)**	**45.60(13.90)**	**12.35**
Shift work	3.20(1.64)	3.16(1.27)	0.04
Working alone at night	2.28(1.32)	2.15(1.20)	0.13
Over-time demands	2.91(1.69)	1.69(0.84)	1.22
Risk of being injured on the job	2.53(1.68)	2.47(1.08)	0.06
Work related activities on days off (e.g. court, community events)	3.00(1.59)	2.65(1.62)	0.35
Traumatic events (e.g. MVA, domestics, death, injury)	2.56(1.49)	2.26(1.24)	0.30
Managing your social life outside of work	2.89(1.65)	2.47(1.24)	0.42
Not enough time available to spend with friends and family	3.25(1.67)	2.88(1.53)	0.37
Paperwork	3.51(2.03)	2.84(1.33)	0.67
Eating healthy at work	3.11(1.69)	2.30(1.01)	0.81
Finding time to stay in good physical condition	3.40(1.62)	2.65(1.31)	0.75
Fatigue (e.g. shift work, over-time)	3.65(1.79)	3.28(1.50)	0.37
Occupation-related health issues (e.g. back pain)	3.02(1.69)	2.26(1.20)	0.76
Lack of understanding from family and friends about your work	2.70(1.69)	1.67(0.64)	1.03
Making friends outside the job	2.24(1.53)	1.84(1.00)	0.40
Upholding a "higher image" in public	3.00(1.72)	1.58(0.66)	1.42
Negative comments from the public	3.40(1.98)	1.86(1.01)	1.54
Limitations to your social life (e.g. who your friends are, where you socialize)	2.72(1.52)	1.74(0.98)	0.98
Feeling like you are always on the job	2.73(1.72)	2.14(1.28)	0.59
Friends / family feel the effects of the stigma associated with your job	2.31(1.40)	2.02(1.18)	0.29

Table 1.
Frontline (n = 55) and tactical police (n = 44) mean and standard deviation (SD) scores for total PSQ-Op sum, as well as individual items, and magnitude difference scores between frontline and tactical (ΔMean). Average stress level of each item compared to recommended PSQ-Op cut-off scores: Low stress (≤2.0), moderate stress (2.1–3.4), high stress (≥3.5) [34].

higher levels of overall subjective stress in comparison to tactical officers, and 2) frontline and tactical police reported qualitatively different stressors, with tactical police reporting more work-related objective stressors, and frontline police reporting more public-image related stressors.

Results are discussed within the limitations of the study. First, due to the difficulty of recruiting police samples, this study consisted of smaller sample sizes, which limits its generalization capabilities. Second, this is data is strictly correlational, thus causal relationships cannot be stated. However, we can review the data results within the lens of modern policing in regards to the following perspectives:

1. The current media spotlight focused on frontline officers, including psychological expectations and demands

2. Physical fitness requirements of tactical versus frontline police

3.3.1 Stress and psychological demands

While the subjective stress findings countered our hypothesis, they may be explained by current issues and pressures in modern policing. Rising issues and media coverage of police incidents such as excessive use of force, systemic racism, and criminal charges, continue to erode the public's trust, as well as damage the police-community relationship [35, 36]. This inference is further bolstered by the findings of this study that frontline officers considered PSQ-Op items related to public image greater of sources of stress than tactical officers did. In comparison, tactical officers are only called to the most high-risk and violent situations (e.g., hostage, school shootings, etc.) and in comparison to frontline police are less in the spotlight, thus aligning with the current study results that subjective stress reported by tactical officers reflected primarily objective operational stressors (i.e., risk to life).

Due to the duties of a tactical officer, they are much more likely to encounter life-threatening situations. CAR can also represent psychological anticipation of the day, with higher demands predicting a more pronounced CAR [37]. Given officers' pre-existing awareness of the increased risk associated with joining a tactical unit, individuals with certain personality characteristics or physiological profiles (e.g., cortisol) may be self-selecting towards higher-risk occupational roles. However, this theory is difficult to test without longitudinal data about individuals prior to entering a high-risk occupation of any kind.

3.3.2 Stress and physical demands

Another possible explanation as to why the results reveal a higher objective stress profile but lower subjective stress profile among tactical officers compared to frontline may be due to the physical condition of tactical officers in comparison to frontline officers. By demand of their duties, tactical teams are required to remain in good health and take part in many hours of specialized training, including physical fitness [38–40]. Higher levels of exercise have been found to affect diurnal cortisol patterns, particularly CAR, in lower-risk occupations, the general population, and athletes. Increased regular exercise has been shown to increase CAR; seniors who completed a 6-month aerobic exercise intervention displayed significant increased CAR, but not associated with changes in diurnal cortisol as measured by area under the curve (AUC) [41]. Similarly, high-performance athletes also exhibit higher diurnal cortisol patterns including an elevated CAR response [42]. These findings parallel the results of the present study, in which tactical teams display elevated CAR, but maintain similar cortisol levels to frontline officers later in the day.

By the same token, evidence suggests that frontline officers do not meet the same level of physical fitness requirements as tactical officers. Frontline officers in this study were not required to maintain physical fitness, rather it remained the responsibility of the individual officer [43, 44]. With further support from findings of the present study, frontline officers reported finding time to stay in good physical condition as a higher source of stress on the PSQ-Op than tactical officers did, suggesting frontline officers have greater difficulty maintaining exercise as part of daily routine. Due to the original design of the study, it is difficult to determine whether the physiological and subjective stress differences between tactical and frontline are exercise related. However, future research could control for exercise by targeting frontline and tactical samples with the same exercise regiments and practices and compare their cortisol levels to rule out this possibility.

3.3.3 Implications

Within the limitations of the current study, results suggest that both frontline and tactical officers display dysregulated cortisol patterns that are associated with their higher-risk occupational duties in comparison to the general population (see also [10]). This places officers at higher risk of negative health outcomes (e.g., greater rates of mental illness and cardiovascular disease) [21, 45]. Furthermore, the subjective stress reported by officers differs by subspecialty and may inform intervention strategies aimed at mitigating officer stress and assisting with the regulation physiological stress, specifically CAR profiles.

Of note, the top rated operational stressors for both frontline and tactical groups were fatigue, paperwork, and not enough time available to spend with family. These subjective factors may significantly drive the elevated diurnal cortisol patterns across the entire day observed in comparison to the general population. If this relationship is true, these same stressors are often found or can be applied to a vast number of occupations, and it can be inferred that the presence of these stressors would potentially have the similar impact and associated health risks for other occupational groups.

4. Conclusion

While the stress response is beneficial from an evolutionary standpoint, chronic activation associated with occupational duties results in an excessive CAR profile, placing the worker at higher risk for negative health outcomes. High-risk occupations provide a framework for analyzing the effect of different stress exposure on physiology. While previous research has found that different risk- subspecialties of policing display increased cortisol patterns in line with increasing risk, follow-up analyses of subjective stress measures of the same groups found an opposite relationship, with lower-risk subtypes reporting higher levels of operational stress despite lower CAR profiles. Differentiating relationships provided an opportunity to explore the nuances of occupational stress profiles, and explanations of several other factors that also have impact (e.g., exercise and public image concerns). Results may inform tailored interventions to reduce both objective, physiological stress profiles (i.e., CAR response) and subjective self-reported stress profiles among high-risk occupational subspecialties.

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Conflict of interest

The authors declare no conflict of interest.

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