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Field Monitoring the Effects of Overnight Shift Work on Specialist Tactical Police Training with Heart Rate Variability Analysis

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Abstract: Police work exposes officers to high levels of stress. Special emergency response team (SERT) service exposes personnel to additional demands. Specifically, the circadian cycles of SERT operators are subject to disruption, resulting in decreased capacity to compensate in response to changing demands. Adaptive regulation loss can be measured through heart rate variability (HRV) analysis. While HRV Trends with health and performance indicators, few studies have assessed the effect of overnight shift work on HRV in specialist police. Therefore, this study aimed to determine the effects overnight shift work on HRV in specialist police. HRV was analysed in 11 SERT officers and a significant ($p = 0.037$) difference was found in pRR50 levels across the training day (percentage of R-R intervals varying by >50 ms) between those who were off-duty and those who were on duty the night prior. HRV may be a valuable metric for quantifying load holistically and can be incorporated into health and fitness monitoring and personnel allocation decision making.

Keywords: fatigue; psychosocial stress; risk management; shift work; sleep; workload

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1. Introduction

Police work is known to expose officers to high levels of physical, mental, and emotional stress. These stressors can come in the form of challenging physical tasks, ranging from pursuing offenders on foot or performing first response to a natural disaster [1], to challenging cognitive and emotional tasks such as those encountered when performing life saving measures for a casualty. Not only are these demanding events often encountered with little warning, opportunities for recovery between response calls may be scarce. The daily duties of a police officer are often compounded by the need to perform with external load carriage, environmental stressors such as extreme heat or cold, and social stressors associated with critical incident response [2].

In addition to these external demands imposed by response to emergencies, personnel are also subject to internal organizational demands, such as irregular work hours, prolonged shifts, and collateral duties [3,4]. In the United States, the special emergency response team (SERT) is a highly demanding collateral duty. Selection is usually physically and technically challenging, requiring highly refined marksmanship skills, excellent physical fitness and an exceptional ability to perform and make decisions under extreme pressure [4,5]. Furthermore, even once accepted onto a team, personnel must devote additional time to training, accept additional on-duty hours, and respond to the most high-risk scenarios within the region served by the organization [4,6]. For example, specialist police responding to the Lindt café siege in Sydney were on-duty from 0830 to 0213 the next day, essentially proceeding from one shift directly into another [7]. As such, the circadian cycle of SERT operators is subject to frequent disruption [4,6].

Circadian cycle disruption is known to contribute to the risk of illness and injury in tactical personnel, and the neurophysiological effects of working an overnight shift can manifest for as long as three days after the shift, even when no further work is required [8,9]. Shift work may also contribute to allostatic load, the decompensation of adequate response following prolonged exposure beyond tolerable levels of stress [10,11].

The allostasis model, first proposed by Bruce McEwen et. al., describes increased susceptibility to deterioration and dysregulation as an individual is exposed to increasing stress levels beyond their tolerance [11,12]. Essentially, allostatic load occurs when an individual's efforts to compensate for and regulate in response to uncertainty fail. As neuroendocrine, cardiovascular, and emotional responses become persistently overactive in attempts to compensate for the imposed stressors, blood flow turbulences in crucial regions of the body, namely the heart and brain, develop along with hypertension, cognitive dysfunction and depressed mood. Any one of these processes can be debilitating, but all can occur in combination and accelerate disease acquisition and progression. Allostatic load can result in permanently altered brain architecture and systemic pathophysiology [13] while also minimizing an individual's ability to further cope with and reduce additional uncertainty.

While the relationship between allostasis and shift work in tactical populations is still emerging, shift work appears to be a significant contributing factor to cardioregulatory changes that may contribute to allostasis in tactical personnel [14], and the nature of tactical work appears to have effects on healthy dynamic regulatory responses that other professions working overnight shifts do not experience to the same extent [15]. It is possible that overnight shift work and the nature of stress in tactical environments act synergistically to impart extraordinary levels of physiological and psychosocial demand [15]. These stressors, if manifesting as allostatic load, may explain the known elevated incidence of heart disease among first responders [16,17].

Assessing the loss of dynamic and adaptive regulatory responses that signal the onset of allostatic load is therefore of crucial importance, especially in tactical personnel who are not only at a potentially increased risk of allostatic load, but who also carry out tasks vital for the safety of the communities they serve. Heart rate variability (HRV), the fluctuation and oscillation across time of individual heart beats, results from a dynamic relationship between intrinsic cardioregulatory factors and extrinsic factors, namely the sympathetic (SNS) and parasympathetic (PNS) nervous systems [18,19] and is therefore utilized as a measure for quantifying stress in tactical populations [20–22]. In the absence of other measurement tools with which autonomic regulation or stress response may be quantified (due to impracticality of application in tactical contexts outside of a laboratory), HRV shows promise as a viable field measurement for determining maladaptive stress responses [23,24]. Other high-intensity settings, largely in elite athletics, have demonstrated the utility of HRV in calibrating training loads [25,26] with measures potentially used to augment injury risk predictions [27,28]. Additionally, correlations between HRV and cardiorespiratory fitness [29] and psychological stress [22,30] have been described. However, no known studies have been conducted assessing the specific effect of overnight shift work on the HRV of specialist police, despite most police forces in U.S. cities with a population of 50,000 or more employing specialist police units and many smaller municipalities following suit. This equates to roughly 1200 specialist police teams in the United States alone [31]. Further, at least 94 countries in addition to the U.S. utilize similar specialist police unit models. Therefore, the purpose of this study was to determine the effects of an overnight shift on the HRV of specialist police during firearms qualification and training events, and to investigate if the utilization of HRV monitoring may be viable in the field with tactical police organizations. It was hypothesized that officers who recently completed a work shift would display lower baseline pRR50 levels overall than previously off-duty officers, and that officers proceeding into training directly following a shift would result in a greater fluctuation in pRR50 levels.

2. Materials and Methods

This study was a prospective investigation of 11 male specialist police officers with an average of 5.2 ± 4.4 years of experience as SERT members. All team members present for a regularly scheduled training exercise were eligible for inclusion. Operators prescribed cardioactive medications, medications for a renal, respiratory or neurological condition, or who disclosed a current injury or illness were excluded. No operators with a history of cardiac, chronic respiratory or renal diseases were eligible for inclusion in either group. Personnel assigned to limited or restricted duties were also not eligible. All participants were recruited, consented, and followed for data collection on a single day of training. All data were collected during a regularly scheduled training event at the team's training grounds. No further descriptive data were available as per a privacy agreement with the team, which occurred in other published studies investigating similar populations [32].

For the purposes of this study, off-duty operators (n = 6) were defined as those who were able to sleep *ad libitum* and had no scheduled duties for 10 hours preceding training. On-duty officers (n = 5) were those who were ending an overnight 10 hour shift immediately prior to reporting for training. All team members provided their informed written consent, and the unit commander provided permission for publication of this work. The research protocol was approved by the Messiah University Institutional Review Board (2019-022) and the Bond University Human Research Ethics Committee (34126723).

Three-lead seated electrocardiographs (ECGs) were recorded for five minutes prior to the start of training, between 8:00 and 8:30 am, and again immediately after the completion of yearly firearms qualification. While being recorded, participants were asked to sit quietly, refrain from moving so as to maintain the integrity of the trace and avoid using cell phones or talking. ECG recordings were obtained with an ADInstruments Powerlab (ADInstruments, Sydney, Australia) with leads placed on both wrists over the distal/lateral radius as close to where the radial artery is typically palpated. The final lead was placed on the left ankle, just above the medial malleolus. Leads were not placed on the chest so as to facilitate measurement without requiring participants to remove their protective gear. Labchart (v7, ADInstruments, Syndey, Australia) software was used to capture and record all ECG traces and was set at a sampling frequency of 40 kHz.

The qualification event consisted of static standing handgun engagement (Glock 22 firing 0.40 cal S&W ammunition) at 3, 5, 7, 10, 15, and 25 m. Rifle qualification (M4 rifle firing 5.56 mm ammunition) was also required and consisted of target engagements 50, 25, and 15 m with walking shots delivered down to 5 m. Operators were required to wear all standard issue gear (boots, uniform, plate carrier vest, helmet) and accurately place shots on all targets at all distances. The assessment was pass/fail, with 100% accuracy required to pass; failure resulted in elimination from the team and passing represented a significant yearly milestone for team members. All operators completed the qualification event within four hours of the initial baseline recording, reporting for their second measurement immediately after completion of the event and notification of passing or failing. See Figure 1 for additional details on the timeline of operator events and data acquisition.

ECG data were processed with a LabChart v8 student license (ADInstruments, Sydney, Australia). Visual ECG examination was performed in combination with a visual analysis of R-R plots to exclude outlier and ectopic beats. HRV was defined as the percentage of R-R intervals that varied by more than 50 ms (pRR50). Results from the on-duty officers (n = 5) were compared to those who were off-duty (n = 6) by determining if significant differences existed in the change between pre- and post-qualification pRR50 values. The pRR50 metric was chosen specifically because it is a clinically important feature when assessing for the risk of cardiovascular disease [33] and is also less volatile and more amendable to use in short-term recordings than frequency domain measures [18]. The change in pRR50 values across the training day was of particular interest in this study as the stress of attempting qualification could substantially perturb adaptive regulatory responses that would affect cardioregulation and therefore the HRV profile.

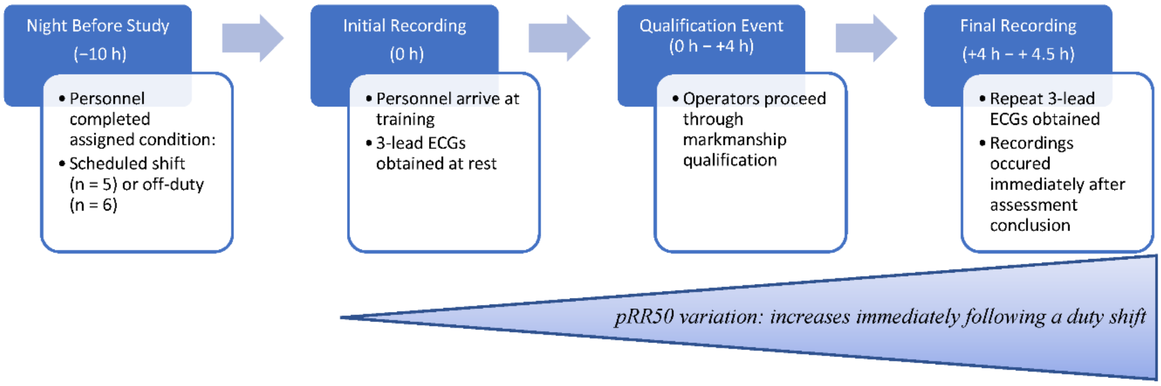

Figure 1. Sequence of participant duties and data acquisition. The triangle below the event sequence represents the hypothesis of the present study, suggesting greater variation as the training day progressed.

For statistical analysis, Shapiro-Wilk tests for normality were undertaken to determine whether parametric inferences would be suitable. Further testing via the Levene test was performed to ensure equivalence of variance between sample groups. Independent-sample *t*-tests were used to determine significant differences, with alpha levels set at 0.05. Mann-Whitney U tests were utilized for comparisons between baseline characteristics of each group. SPSS Statistics (SPSS v26, IBM, Armonk, NY, USA) were used for all analyses.

3. Results

All operators successfully passed qualification. The Shapiro-Wilk test results confirmed normality of the HRV data ($p = 0.598$ for the on-duty group, $p = 0.581$ for the off-duty group), and the Levene test showed equal variance between sample groups ($p = 0.257$), allowing for independent-sample t-tests between groups with regards to HRV. Mann-Whitney U tests revealed no differences in occupational fitness test scores ($p = 0.465$) or operational experience ($p = 0.073$) between groups. While no statistically significant differences existed when the baseline and final HRV measurements were assessed between the on-duty and off-duty groups ($p = 0.268$ and $p = 0.155$, respectively), there was a significant difference between the change in pRR50 between groups; the mean difference between groups was 3.73% (95% CI: 0.29–7.18%, $p = 0.037$). Previous research indicated that a pRR50 of 6.8% or lower may be a significant risk factor for cardiovascular disease [33]. The HRV profile of the off-duty operators remained above this level for all recordings. On-duty operators fell below the identified threshold. Detailed pRR50 values are found in Table 1.

Table 1. Heart rate variability values.

	Off-Duty Operators (n = 6)	On-Duty Operators(n = 5)
Mean pRR50 at baseline	16.71 ± 21.60	4.99 ± 4.61
Mean pRR50 post-qualification	18.00 ± 21.94	2.52 ± 2.37
Mean change in pRR50	1.27 ± 2.03 *	−2.47 ± 3.01 *

* $p < 0.05$: pRR50, percentage of R-R intervals varying by >50 ms. All values are reported as percentages (%).

4. Discussion

The purpose of this study was to determine the effects of overnight shift work on the HRV of specialist police during firearms qualification and training events. The results of this study indicated that off-duty operators, defined in this study as those with no scheduled duties during the 10 h preceding data collection and training, experienced less cardioregulatory stress response during the training day. Those who worked the previous night experienced a greater fluctuation in their regulatory capacity when exposed to the stress of the qualification event. This main finding agrees with previous research investigating the effects of shift work on stress regulation in tactical personnel, in which the authors found significant changes in HRV not only when personnel were required to work overnight, but between shifts that required different job tasks and duties [34]. The relationships between overnight shift work, specific job tasks unique to tactical professionals, and stress regulation are in need of further investigation Previous studies in healthcare workers found only limited changes in HRV during overnight shifts [35], whereas the effects in tactical personnel are more pronounced [15].

While no significant differences were observed at baseline or final measurement, this was likely due to the small sample size of this study relative to the volatility of HRV measurements; despite all operators available on the day of training volunteering to participate, the sample size still limited statistical power. Further, the standard deviation of the off-duty group was very high (greater than the mean for all recordings), and despite the substantial difference between off-duty and on-duty qualification, this variability likely precluded the differences from reaching significance.

While off-duty operators saw their mean pRR50 increase during the course of the day, as might be expected with the psychological relief of success following a substantial challenge (passing annual qualification, for which a single missed shot means elimination from the team), the mean pRR50 of the operators who worked overnight decreased even further. This result indicates that the psychophysiological strain of working overnight was exacerbated as the day continued, and even resolution of the challenging event (firearms qualification) was not sufficient to fully attenuate the stress response reaction in those officers. This finding also agrees with previous literature in tactical personnel that found the effects of working overnight can be detected with HRV analysis for as long as three days following the shift [9,14]. This residual disruption in HRV following overnight shift work may also contribute to the high variance observed in the off-duty sample but may suggest that the most substantial effects are resolved with a single night off-duty.

Additionally, while no operators reported a state of ill health or injury, previous research posited that a resting pRR50 of 6.8% or less may be linked to cardiovascular disease [33]. The operators in this study that were off-duty the night before training were, on average, well above this threshold at ~17%, whereas operators who worked overnight were below the threshold at ~2.5–5%. While this result must be interpreted with caution due to the small sample size and short-term, rather than 24 h, recordings, there is cause for further investigation considering law enforcement personnel are known to be at an elevated risk of cardiovascular disease beyond the general population [16]. It can be construed from these findings that overnight shift work contributes to lowered pRR50, which may be potentially harmful over the long term, representing a risk factor in the development of cardiovascular disease. This would agree with previous research investigating the potential harms of working overnight shifts [36].

The findings reported in this study align with previous research linking allostatic load, disrupted sleep, and chronic disease risk [10]. These relationships in tactical personnel are complex; allostatic load may be induced through both type I and type II mechanisms [11]. Type I allostatic loads relate to an energy deficit imparted by physically demanding work or training in addition to limited resource availability (i.e., poor nutritional intake). Type II mechanisms include energy abundance, social stress, and are also not uncommon in first responders; suboptimal food choices, organizational demands, and shift work can contribute to insufficient recovery, all of which may contribute to chronic diseases, including heart disease, diabetes or insulin resistance, obesity, and pathological inflammation [10,24,37]. Further research with more sensitive R-R variability cutoff values closer to 12 or 20 ms [33], additional screening for cardiovascular disease risk factors, longer HRV recordings that assess operators over multiple shifts and include larger sample sizes may clarify this relationship.

Overall, the data presented in the study agree with previous literature assessing HRV in tactical personnel [15], indicating that research in this highly specialized population may be generalizable to other tactical units such as fire departments, which are increasingly utilizing specialist teams, and general duties police, a population which this collateral duties unit still incorporates. Specifically in regards to extant literature, two previous studies with similar methodological approaches in two very different geographical locations (Finland and Portugal), both found that first responder teams assigned to rescue duties overnight, which included tasks such as motor vehicle accident response, experienced significantly different HRV changes when the same teams were assigned to more typical fire suppression duties [14,20]. Contrastingly, research in healthcare workers found much more limited differences in HRV in groups of physicians and nurses who worked rotating shifts compared to those who worked day shifts only [35]. In the present study, the effects of overnight shift work on cardioregulation in tactical police were noticeable when assessed by HRV, even in a small sample, establishing precedent for further investigation.

The need for the investigation into causal links is warranted; the specific tasks undertaken during night shifts and the psychophysiological response to those tasks may critically influence an officer's cardioregulatory profile and adaptive capacity during the period following an overnight shift. Mixed-methods studies that capture both the qualitative and quantitative elements of overnight shift work in tactical professions may begin to uncover the discrepancies between HRV profiles in first responders and professionals in other strenuous settings, such as hospitals.

5. Conclusions

The findings in this study indicate that HRV may be a valuable metric for quantifying load holistically in tactical police organizations, and that HRV can be collected and measured in instances where leadership can immediately utilize the data as a component of their decision-making matrix, rather than exclusively in laboratory environments. With further study, organizations employing collateral duty specialist police may be able to more effectively calibrate shift lengths and scheduling related to training or other operational considerations to optimize operator health. Additional further research may also consider using HRV to determine the dose-response curve for sleep and improved stability of HRV measures across a challenging training day. Further, mixed-methods approaches may be able to inductively approach the qualitative elements that may distinguish cardioregulatory responses to work in tactical professions from other strenuous overnight work environments. Finally, the incorporation of a human performance optimization expert to manage and apply these data may also benefit organizations by allowing for more regular monitoring, additional relevant data analysis, and health or fitness solutions to mitigate adverse health or fitness conditions.

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Informed Consent Statement: All participants provided informed written consent in accordance with the declaration of Helsinki.

Data Availability Statement: The dataset(s) supporting the conclusions of this article are not publicly available as data were obtained from a law enforcement agency, and as per research ethics provisions, individual participant data cannot be released without a specific request to, and approval from, the sponsoring agency. To make a request, or for further information, please contact Dr. Rob Orr, Bond University Tactical Research Unit; rorr@bond.edu.au (accessed on 14 July 2021).

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