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Enhancing Tactical Readiness in Law Enforcement: Analysis of psychophysiological response in close quarter engagements

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Abstract

This study aims to elucidate the autonomic and psychophysiological responses of professional soldiers subjected to high-stress, close-quarter combat simulations facilitated by the Redman system. The research enlisted a cohort of 67 male professional soldiers with extensive experience in international conflict zones including Lebanon, Afghanistan, Bosnia, Kosovo, and Iraq. Through a detailed examination, this study tracked the participants' heart rate (HR) and heart rate variability (HRV) before, during, and after engaging in a series of controlled combat scenarios that alternated between periods of rest and active confrontation with both male and female adversaries. This methodical approach enabled a nuanced analysis of the autonomic nervous system's reactions under varied stress levels. Results showed pronounced alterations in physiological markers post-simulation, notably a substantial increase in heart rate and a significant decrease in heart rate variability parameters such as the Average of the RR intervals, the RMSSD, and the PNN50. These changes underscore the heightened autonomic arousal and reduced heart rate variability associated with the stress of close-quarter engagements, reflecting the body's acute stress response. Thus, present research contributes to the understanding of the complex interplay between physiological stress responses and tactical readiness. By providing empirical evidence on how simulated combat impacts the autonomic nervous system, the study underscores the importance of integrating psychophysiological insights into training protocols to enhance the tactical efficacy and resilience of military personnel in high-stress environments.

KEY WORDS: *Heart Rate Variability; Autonomic Modulation; Stress; Tactical Readiness; Psychophysiological response; Police; Military.*

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1. Introduction

The realm of research within military and police domains encompasses a diverse spectrum of critical inquiries, contributing significantly to the advancement of these crucial sectors. Studies in these areas have far-reaching implications for the safety, preparedness, and effectiveness of military personnel and law enforcement officers. This body of research delves into multifaceted aspects, ranging from the psychophysiological responses of soldiers and police officers during high-stress operations [1,2], to the fine motor skills and cognitive readiness of elite forces in urban combat simulations [1]. It extends to explore the impact of experience, equipment, and tactical actions on psychophysiological responses and memory of personnel [3]. Furthermore, research has examined the effects of acute stress on the psychophysiology and physical performance of personnel serving in armed tactical occupations, shedding light on the intricate relationship between stress and performance [4]. Additionally, studies have explored the psychophysiological response of soldiers in combat situations, providing insights into the challenges faced by personnel in high-stress combat environments [5,6]. These investigations collectively contribute to the development of evidence-based practices and policies aimed at optimizing the capabilities and well-being of military and law enforcement professionals.

Understanding the psychophysiological response of individuals in combat situations holds paramount significance in the realms of both police and military operations [7]. The dynamic and high-stress nature of these environments necessitates a comprehensive examination of how the human body and mind react under duress. Research has shown that acute stress, such as that experienced in combat situations, can have profound effects on the psychophysiology of individuals. There were discussed the implications of acute stress on the psychophysiology and physical performance of personnel serving in armed forces, highlighting the need to understand how stress influences physiological responses in such contexts [4,8]. In this line, it was emphasized the importance of gaining knowledge about psychophysiological changes in high-stress situations to optimize training for combat scenarios, underscoring the relevance of studying the psychophysiological response in combat and simulation situations [9]. In addition to combat, psychophysiological responses have also been studied in other high-stress contexts, such as parachute jumps and ultra-endurance situations [10,11]. Understanding these responses can provide valuable insights into human performance and resilience under extreme stress, benefiting both military and police operations.

In this line, accidents and injuries in real police and military events and training are critical concerns within the domains of law enforcement and military operations [12]. The inherent risks associated with these professions necessitate a comprehensive understanding of the factors contributing to accidents and injuries, as well as the development of effective prevention strategies. Research has shown that police officers and military personnel often face high-stress situations and physical hazards, increasing the likelihood of accidents and injuries [13]. These incidents not only impact the well-being of individuals but also have broader implications for mission success and public safety. Recent works have shed light on the challenges faced by first responders, highlighting the need for research in this area [14–16]. Among the interventions that both police and military have to carry out, interventions in closed areas and hand-to-hand are the most stressful and those that can potentially harm personnel the most. The training for these events is complicated and entails risks to the physical integrity of the participants, both those who use systems like the "Redman" and those who have to face it [17–19].

Therefore, this manuscript aims to delve into the multifaceted aspects of accidents and injuries in real-world police and military contexts. By examining the causes, consequences, and preventive measures related to accidents and injuries, this research contributes to the enhancement of safety protocols, training methods, and overall operational effectiveness in these crucial domains. The comprehensive examination of psychophysiological responses, cognitive functions, and performance in high-stress scenarios continues to advance our understanding of how individuals in these critical roles navigate challenges, make decisions, and execute tasks under pressure. This knowledge plays a pivotal role in enhancing training protocols, operational strategies, and support systems for military and police personnel, ultimately contributing to the effectiveness and resilience of these essential sectors.

Specifically in Portugal, the General Directorate of Justice Policy (DGPJ) has released data indicating a significant rise in crime rates, reaching a ten-year peak in 2023. A total of 371,995 incidents were documented by the Portuguese police and criminal police bodies (OPC), underscoring a concerning uptrend in criminal activities [20]. The report further highlights a 5.5% increase in violent crimes in 2023 compared to the previous year, with the OPC registering 14,022 incidents of violent crime. The OPC plays a pivotal role in ensuring public safety and security, making the surge in violent crimes against them even more alarming. The Minister of Internal Administration, in an October 2023 interview with "Diário de Notícias", revealed that over 1,300 Portuguese police officers faced assaults in just the first six months of 2023 [21]. This escalation in crime and violence poses significant challenges to law enforcement and underscores the urgent need for enhanced strategies and measures to protect both the public and the officers tasked with their safety.

Then, the primary aims of this study are to comprehensively investigate the autonomic response of participants engaged in training simulations facilitated by the Redman systems. This research seeks to delve into the intricacies of how participants' autonomic nervous systems react during these training sessions, shedding light on the physiological aspects of their responses. Furthermore, the study aims to analyze and understand the contextual factors that may exert influence on these autonomic responses within the training environment. By addressing these three key objectives, this research aspires to provide a comprehensive understanding of the autonomic dynamics of individuals immersed in Redman system-based training simulations, ultimately contributing valuable insights to the field of training and simulation science.

2. Methods

2.1. Participants

We analyzed one Redman (male, 34 years, 179 cm, 86 kg, 26.8 kg/m2) and a total sample of 67 professional soldiers that faced Redman actions (male; 33.3±5.7 years; 174.7±7.2 cm; 73.5±2.2kg). Experience in actual theaters of operations as Lebanon, Afghanistan, Bosnia, Kosovo or Iraq. An informed consent was obtained from all participants for being included in the study according to the Declaration of Helsinki guidelines. The study protocol was approved by the GNR Command with Reference S026629/2024/CDF/GAB and Process Number 080.30.04 authorized on 15/03/2024.

2.2. Redman intervention:

In the study's procedures section, it was noted that Redman encountered ten distinct situations, with the odd-numbered situations designated as 'Rest' periods lasting one minute each, during which there were no stimuli. The even-numbered situations involved active confrontations with an adversary, alternating between male and female opponents. Specifically, encounters 2, 6, 10, 12, 14, 16, and 18 featured male opponents, while encounters 4, 8 and 20 presented female adversaries. This alternating pattern provided a balanced approach to assessing Redman's physiological and psychological reactions across various controlled scenarios, juxtaposing passive recovery with active engagement.

2.3. Design and procedure.

Given the relatively small sample size, a cross-sectional pre-post design was employed to minimize individual differences and better account for changes in the autonomic nervous system response. The independent variable (IV) in this study was the Redman intervention.

The following dependent variables (DV) were used to explore the changes due to the combat simulation:

Hearth rate (HR) was measured during the entire manoeuvre by a Polar V800 with RR function to analyze heart rate variability (HRV). We analyzed 20 minutes of HR and HRV before the Redman intervention with participants lie in a strecher as HRV and HR baseline values [22]. HRV and HR were recorded during the entire Redman intervention. We used the Kubios HRV software (University of Kuopio. Kuopio, Finland) in line with previous studies [23,24] to analyze the HRV time-domain parameters of average of the time between RR intervals (Average RR, ms) Average RR: Average of the RR intervals, which represent the time between successive heartbeats, measured in milliseconds (ms), RMSSD: Root Mean Square of Successive Differences. It is a measure of the variability of the RR intervals and is used to estimate the activity of the autonomic nervous system, measured in milliseconds (ms), and PNN50: Percentage of successive differences between adjacent RR intervals that are greater than 50 ms.

2.4. Data analysis

The data were analyzed using the SPSS statistical software (version 19.0; SPSS, Inc., Chicago, IL). We checked for assumptions of normality and homoscedasticity using the Kolmogorov-Smirnov test. Differences between the pre- and post-samples were determined using a dependent t-test for all variables, as they exhibited a parametric distribution. The effect size was measured using Cohen's d. A significance level of p≤0.05 was set for all comparisons.

3. Results

Post-intervention, we observed a substantial increase in heart rate (HR) and significant reductions in the Average RR interval, RMSSD, and PNN50 values (Figure 1). All changes were statistically significant with p-values below 0.001. The effect sizes for these changes varied, with HR and Average RR showing particularly large effect sizes (Table 1).

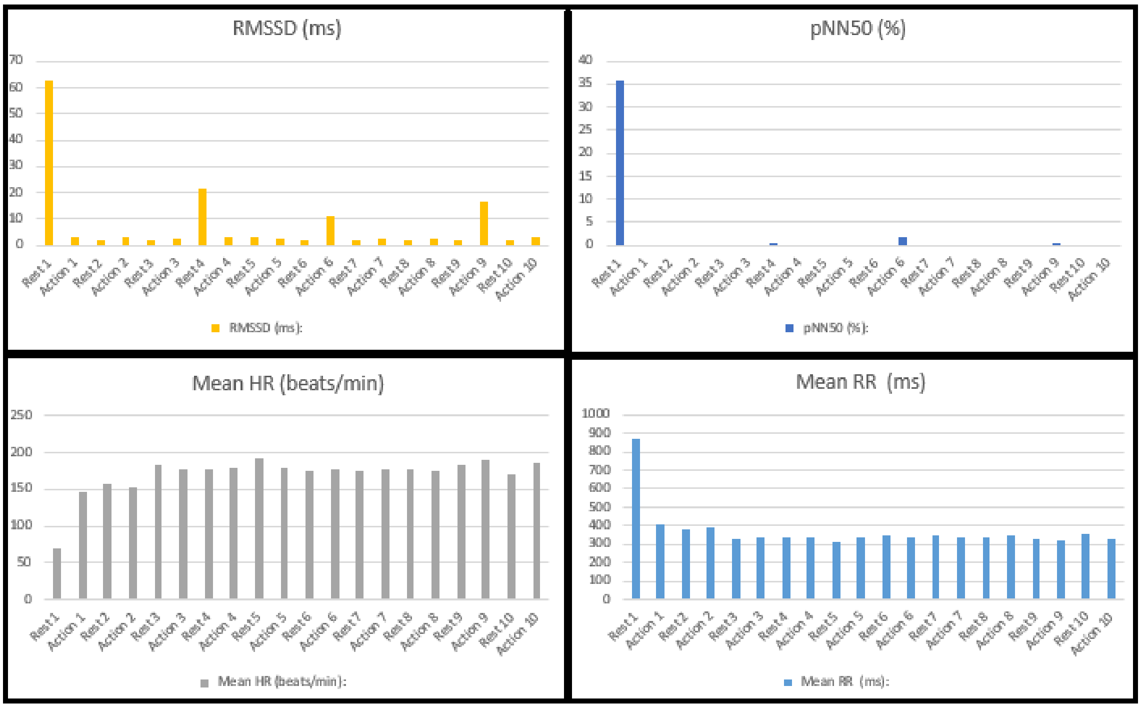

Figure 1. Heart rate variability changes in al actions and rest Redman intervention. Mean HR: Average Heart Rate (beats/min), Mean RR: Average of the RR intervals (ms); RMSSD: Root Mean Square of Successive Differences (ms); PNN50: Percentage of successive differences between adjacent RR intervals that are greater than 50 ms (%).

Table 1.
Heart rate variability changes after Redman intervention.

Variable	Unit	PRE	POST	% Change	t	p	Effect Size Cohen's D
HR	bpm	62.9±12.3	138.2±12.4	119.6	-33.85	.000	6.02
Average RR	ms	956.4±135.3	387.4±54.1	-59.5	-31.94	.000	5.52
RMSSD	ms	42.4±9.9	8.5±4.4	40.1	6.97	.000	0.91
PNN50	%	23.5±11.3	5.3±3.8	77.5	27.67	.000	2.16

Heart Rate (HR), Average RR: Average of the RR intervals; RMSSD: Root Mean Square of Successive Differences; PNN50: Percentage of successive differences between adjacent RR intervals that are greater than 50 ms.

4. Discussion

This research presents acute autonomic and psychophysiological responses of professional soldiers in high-stress situations, simulated close-quarter combat scenarios using the Redman system, The findings were characterized by a significant increase in HR and substantial reductions in HRV metrics, which indicates a pronounced autonomic arousal response. These physiological shift, indicative of a predominance towards sympathetic nervous system activation.

Similar to previous research [9,24,25] these findings showcase the intricate responses of the autonomic nervous system to stress. Emerging as a critical factor for performance in military personnel. Throughout military operations, as showcased by our findings and previous research [26], there is a decrease in parasympathetic activity translating shifting autonomic modulation towards a "fight or flight" response represented by an increased HR together with decreased HRV. Characteristic of military contexts. Further on, the concept of autonomic flexibility is gaining momentum amongst experts as it permits military personnel to seamlessly shift between autonomic modulation stations states depending on conditions [27]. Given the nature of military operations, which frequently require quick transitions between periods of high exertion and recovery, such autonomic adaptability could become a critical determinant of both the immediate effectiveness and sustained well-being of military personnel. Moreover, for military personnel to reach enhanced autonomic flexibility an integrative approach is essential combining physical training, psychological support, and the implementation of technology-based interventions aimed at fortifying the body's stress response mechanisms. Notably, biofeedback and HRV training programs have demonstrated efficacy in enabling individuals to consciously modulate their autonomic state [28], thereby bolstering their resilience to stress and enhancing overall emotional regulation. Further on, this technologically advanced approach could aid in the identification of personnel who may exhibit a heightened risk of negative stress reactions or who could benefit from supplementary support to augment their resilience.

Further on, the collective body of evidence underscores HRV as a measure of an individual's capacity for stress adaptation [29]. Assuming critical significance within the ambit of military operations where there are plenty of high-stakes situations demanding rapid decision making. Additionally, HRV serves as a pivotal monitoring instrument for training interventions designed to augment stress resilience allowing the customization of training regimens [28]. Individualized training regimens, allows soldiers to be systematically exposed to escalating stress levels, thereby refining their stress response mechanisms therefore enhancing autonomic modulation. Furthermore, the integration of HRV monitoring into routine training protocols enables the provision of real-time feedback, facilitating the fine-tuning of training intensity and concentration to optimize autonomic balance [28]. Permitting the identification of personnel potentially susceptible to adverse stress reactions allowing for timely and targeted interventions. Thus, mitigating the onset of stress-related health complications. Moreover, research has shown association between greater HRV and improved decision-making capabilities under stress [30] showcasing the importance of greater HRV within operational deployment, justifying the importance of autonomous modulation training which can directly influence on operational efficacy on both simulated and real combat scenarios. This correlation shows a shift form classic training methodologies to methodologies based on last research findings [8,31] which advocate for the elevation of physiological benchmarks such as HRV to a status commensurate with that of physical and tactical competencies. This approach necessitates of the use of technological and methodological innovations for the effective execution of HRV-centric training. Therefor, the use of wearable technology capable of accurately capturing HRV metrics in real-time and through non-invasive means is indispensable for this endeavour. Additionally, the formulation of algorithms capable of deciphering HRV data within the specific context of military tasks and stressors could yield critical insights, enabling strategic refinement of training and operational procedures to maximize soldier resilience and operational performance.

Furthermore, PTSD and the modulation of autonomic responses via virtual reality (VR)-based simulations, manifests profound connotations for the domains of military training and health management [32]. On this line, a correlation between diminished HRV and the precursory symptoms of PTSD [33,34] accentuates a pivotal concern within military health, positioning HRV as a potential indicator of susceptibility to stress-induced pathologies. The implementation of VR-based combat simulations for the fortification of stress resilience emerges as a methodology aimed at acclimating soldiers to the physiological and psychological exigencies of combat [35]. These interventions promote a controlled environment which soldiers can navigate stressors that meticulously replicate real-world adversities, thereby facilitating the development of adaptive coping strategies within a safe and controlled setting. This training modality emerges as a great tool in the enhancement of autonomic regulation granting soldiers with the tools to enhance their stress response modulation techniques in the face of simulated provocations, potentially culminating in the amplification of HRV and, by extrapolation, an augmented resilience to stress [36]. Moreover, the symbiosis between VR simulations and HRV monitoring engenders a tailored training experience where can detect the specific areas where soldiers may necessitate support. The prioritization of early detection and intervention for stress-induced vulnerabilities enables military organizations to adopt a proactive posture in forestalling the onset of PTSD and other stress-related afflictions. This preventive strategy not only holds the potential to elevate the quality of life for soldiers but also to mitigate the long-term implications associated with the management of chronic mental health conditions. Thus, underscoring the exigency for persistent research and innovation within military psychophysiology. Furthermore, the cultivation of synergies among researchers, military training specialists, and healthcare providers facilitates the establishment of a comprehensive support ecosystem, adept at addressing both the immediate and protracted consequences of combat stress.

The synthesis of empirical data from the referenced studies [18,28,37] lays an essential groundwork for the evolution of military training procedures. This holistic perspective on stress response and autonomic regulation illuminates the complex array of challenges confronting military personnel, underscoring the necessity for a comprehensive, multidisciplinary strategy towards training and intervention initiatives [38]. Such programs are imperative not only for boosting immediate operational efficiency but also for safeguarding long-term health and fostering resilience among soldiers, thereby comprehensively addressing the spectrum of acute and chronic stress effects resultant from combat engagements. To expand upon this integrated approach, military training regimes could combine aspects from physical conditioning, cognitive-behavioural methodologies, and VR simulations. Tailoring physical conditioning programs, with an emphasis on cardiovascular health enhancement, could significantly influence HRV, thus promoting autonomic regulation. Moreover, cognitive-behavioural strategies, including the practice of mindfulness and stress inoculation training, are poised to equip soldiers with vital psychological competencies for efficacious stress response management [39]. Concurrently, the implementation of technology-enhanced simulations, possess authentic and controlled settings for soldiers to hone and refine their stress management techniques, facilitating a comprehensive understanding of individual stress catalysts and effective coping strategies [35]. Furthermore, the integration of biofeedback systems within training protocols presents a direct mechanism to augmenting autonomic regulation. Enabling individuals to identify their unique stress signatures and master control over them through techniques such as regulated breathing, meditation, and other strategies [40]. This engagement with physiological stress markers proves a profound comprehension of stress response on a personal level, paving the way for tailored autonomic regulation strategies. In addition, by normalizing discourse pertaining to stress, resilience, and mental health within military contexts, organizations can produce a supportive environment within the military which motivates personnel to seek assistance as needed, and exchange stress management tactics freely.

4.1. Limitation of the study

This study, focusing on training simulations facilitated by the Redman systems, provides valuable insights but has several inherent limitations. Firstly, the results may not be fully generalizable to all real-world combat or police situations due to the controlled nature of training environments. Individual physical and psychological differences that can influence reactions under stress were not controlled for, leading to potential variability in the results. Participants who are already familiar with the Redman training systems might have reactions different from those new to the system. While the study offers an understanding of autonomic responses, it might not capture the full spectrum of physiological and psychological measures that can provide a comprehensive view of participants' states during simulations. The awareness of participants that they are in a simulated environment might also lead to the "Hawthorne Effect", influencing their behavior and responses. The findings are specific to the Redman system, and variations in results might arise if other training systems or methods are used. Additionally, factors such as the duration and intensity of training, participants' prior sleep quality, nutritional status, personal stressors, and other external factors can influence results but were not comprehensively accounted for in this research. Thus, while the study offers significant insights, these limitations should be kept in mind when interpreting and generalizing the findings.

4.2. Practical applications

The study's findings on the psychophysiological reactions during Redman training simulations can lead to the refinement of training regimens for law enforcement and military personnel. Tailoring training scenarios based on the autonomic responses can ensure that personnel are not only physically but also psychologically prepared for real-world confrontations. Insights into the nuances of the autonomic nervous system's reaction during high-intensity training can guide the development of recovery and stress-relief protocols. Understanding the triggers and physiological markers can allow trainers to implement cooldown or debrief sessions more effectively. The observed physiological responses can be used to set benchmarks or indicators for training progression. As individuals become more adept and experienced, their psychophysiological responses might stabilize or change, indicating readiness or the need for further training. By understanding the specifics of how individuals react under stress during simulations, more personalized training approaches can be developed. For example, individuals who show extreme stress responses can undergo additional resilience and stress-management training.

The data can also guide the technological development of more advanced simulation systems. By pairing this psychophysiological data with virtual or augmented reality simulations, developers can design systems that adapt in real-time to the user's stress levels, creating a more dynamic and responsive training environment. Using the insights from this study, training sessions can be scheduled optimally. If certain times of day or conditions amplify stress responses, trainers can adjust schedules to ensure that training is both challenging and effective without being overwhelmingly stressful. This research can also help in the development of post-training interventions. For those showing heightened or prolonged stress responses post-training, additional support, counseling, or interventions can be provided to ensure their mental well-being. Finally, understanding the detailed psychophysiological responses can be crucial for medical teams associated with law enforcement or military units. In case of injuries or incidents during real-world operations, having baseline data on how individuals react under stress can guide medical interventions, ensuring rapid and effective responses. Overall, the practical applications of this research are vast, influencing not just training methodologies but also well-being protocols, technological developments, and medical support systems for law enforcement and military personnel.

Conclusions

This study significantly advances our understanding of the psychophysiological responses of professional soldiers to high-stress, close-quarter combat scenarios, employing the Redman system for simulated engagements. The documented changes—increases in heart rate (HR) and decreases in heart rate variability metrics like the Average RR, RMSSD, and PNN50—underline a heightened autonomic arousal and a diminished heart rate variability, signalling the body's acute stress response to such simulated combat conditions. These findings are crucial for informing and enhancing tactical readiness and resilience training programs within military frameworks. By demonstrating the profound impact of simulated combat on autonomic responses, this research emphasizes the importance of incorporating comprehensive psychophysiological insights into military training protocols. The goal is to not only prepare soldiers for the physical aspects of combat but also to equip them with the psychological fortitude necessary to manage and adapt to stress. Ultimately, this study contributes valuable empirical evidence to the field, underscoring the intricate relationship between physiological stress responses and tactical performance, thereby offering a foundation for developing more effective training strategies that address both the physical and psychological demands faced by military personnel.

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