



Cardiovascular recovery in elite firefighters and police officers: insights from high-intensity occupational challenges

Recuperación cardiovascular en bomberos y policías de élite: perspectivas desde desafíos ocupacionales de alta intensidad

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Abstract

Background: Firefighters and police officers face high-stress situations requiring intense physical exertion, posing cardiovascular challenges. This study evaluated cardiovascular recovery in these professionals under simulated emergency and maximal exertion conditions.

Methods: Thirty-five firefighters and sixteen police officers completed a simulated high-intensity task and a cardiopulmonary exercise test. Heart rate variables (resting, maximal, and 1-minute recovery) were measured and analyzed using repeated measures ANOVA.

Results: Maximal HR was significantly higher during CPET than SHITC ($p < 0.01$). Firefighters showed more efficient HR recovery than police officers ($p = 0.01$), suggesting better cardiovascular conditioning. The interaction effect between exercise conditions and the professional group for HR recovery was significant.

Conclusions: Specialized cardiovascular training enhances recovery and prepares elite responders for the physical demands of their role. This study highlights the need for tailored programs to reduce cardiovascular risks and optimize readiness.

Keywords

Cardiovascular recovery; firefighters; police officers; high-intensity interval training; autonomic function.

Resumen

Introducción: Los bomberos y los agentes de policía se enfrentan a situaciones de alto estrés que requieren un esfuerzo físico intenso, lo que supone desafíos cardiovasculares. Este estudio evaluó la recuperación cardiovascular en estos profesionales en condiciones simuladas de emergencia y de esfuerzo máximo.

Métodos: Treinta y cinco bomberos y dieciséis agentes de policía completaron una tarea simulada de alta intensidad y una prueba de esfuerzo cardiopulmonar. Se midieron y analizaron variables de la frecuencia cardíaca (en reposo, máxima y recuperación al minuto) mediante ANOVA de medidas repetidas.

Resultados: La frecuencia cardíaca máxima fue significativamente mayor durante la prueba de esfuerzo cardiopulmonar que durante la tarea simulada de alta intensidad ($p < 0,01$). Los bomberos mostraron una recuperación de la frecuencia cardíaca más eficiente que los agentes de policía ($p = 0,01$), lo que sugiere un mejor acondicionamiento cardiovascular. El efecto de interacción entre las condiciones de ejercicio y el grupo profesional para la recuperación de la frecuencia cardíaca fue significativo.

Conclusiones: El entrenamiento cardiovascular especializado mejora la recuperación y prepara a los respondedores de élite para las demandas físicas. Este estudio destaca la necesidad de programas adaptados para reducir los riesgos cardiovasculares y optimizar la preparación.

Palabras clave

Recuperación cardiovascular; bomberos; agentes de policía; entrenamiento interválico de alta intensidad; función autonómica.

Introduction

The cardiovascular health of elite responders, such as firefighters and police officers, is paramount due to the physically demanding and often unpredictable nature of their work (Hendricks et al., 2023; Yousof Mohamed et al., 2025). These professionals frequently face high-stress situations that require intense physical exertion, which can significantly strain the cardiovascular system (Antoine-Santoni et al., 2024; Violanti et al., 2017). This strain is exacerbated by the adrenergic surges associated with emergency responses, increasing the risk of acute cardiovascular events such as coronary heart disease (CHD) and myocardial infarctions (Jeung et al., 2022; Kales et al., 2009). Studies have shown that a significant proportion of on-duty deaths among firefighters (45%) and police officers (22%) are related to cardiovascular events, highlighting the critical need for effective cardiovascular health management within these populations (Kales et al., 2009; Soteriades et al., 2011).

Heart rate recovery (HRR), the rate at which the heart returns to baseline after exercise, is a crucial indicator of cardiovascular fitness and autonomic function (Dewar et al., 2023). Rapid HRR is linked to lower cardiovascular risk and better prognosis, and in tactical contexts, it reflects the ability to recover quickly between repeated bouts of exertion, critical for operational readiness (Dewar et al., 2023; Saari, 2019; Stephenson et al., 2021).

Efficient HRR is particularly crucial for elite responders, as it indicates resilience of the cardiovascular system to handle acute stressors, helping to maintain readiness and reduce the risk of incidents during and after high-intensity tasks (Feito et al., 2018; Monteiro et al., 2024; Qiu et al., 2017). Studies have demonstrated that individuals with a faster HRR have a lower risk of cardiovascular disease and overall mortality, making it a vital measure in assessing the health and fitness of these professionals (Cole et al., 1999; Jouven et al., 2005; Qiu et al., 2017).

Implementing specific training regimens, such as High-Intensity Interval Training (HIIT), has significantly improved HRR and cardiovascular health (Atakan et al., 2021; Ito, 2019). HIIT is characterized by short bursts of intense exercise followed by periods of rest or low-intensity exercise, and it has been effective in enhancing $\dot{V}O_2$ max, reducing body fat, and improving metabolic health markers (Atakan et al., 2021; Potisaen et al., 2025). HIIT mimics the unpredictable and intense nature of the work that first responders often encounter, making it particularly relevant for these professionals (Sempf & Thienes, 2022). The demands of their duties frequently require sudden, intense physical exertion followed by periods of lower intensity or rest, like the HIIT structure. This makes HIIT not just a training method but a practical preparation for real-world scenarios encountered by firefighters and police officers, enhancing their readiness and resilience on the job (Dulsky et al., 2022; Monteiro et al., 2024).

This research is critically important as it examines cardiovascular recovery in elite responders, such as firefighters and police officers, under both simulated high-intensity occupational tasks and controlled maximal exertion tests. Understanding how these professionals recover from physical stress is essential to determine whether their cardiovascular systems can adequately sustain the demands of their duties without undue risk. Insights from this work can guide the development of targeted training programs that improve cardiovascular health, resilience, and readiness, ultimately reducing the likelihood of adverse events and enhancing operational performance and safety. Despite the growing body of research on tactical populations, few studies have directly compared firefighters and police officers under both simulated and laboratory conditions. By addressing this gap, the present study provides new evidence on cardiovascular responses, particularly HRR, in these two groups when exposed to different types of physical stress.

Method

Participants

The study involved 35 male professional firefighters and 16 Special Operations Group Officers of the Portuguese Public Security Police (PSP), aged between 24 and 46 years. These participants were selected based on achieving a positive classification (excellent, very good, good, or reasonable) on the

shuttle run test, a criterion set to ensure a baseline fitness level. All participants were free of any cardiovascular diseases or conditions that could affect exercise performance, and all were fully informed of the study's purpose and provided written informed consent before participation.

This investigation was approved by the University Ethics Committee (P02-S09-27.04.22). Informed consent was obtained before beginning the experiment. All procedures followed the ethical standards of the Declaration of Helsinki for the Study of Humans (2014).

It is important to acknowledge that the sample was relatively small, uneven across groups ($n=35$ vs. $n=16$), and composed exclusively of male participants. These factors may limit the generalizability of the findings, but they reflect the available elite responder populations for this study.

Study Design

The study employs a comparative design to evaluate cardiovascular recovery under two conditions: (i) simulated high-intensity job-related tasks and a controlled condition, and (ii) maximal exertion cardiorespiratory endurance test. Participants were randomly assigned to complete both conditions on separate days with a minimum of 48 hours between sessions to prevent fatigue effects. The research received approval from the Higher Institute of Police Sciences (Approval code number 12/SECDE/2024, January 25th, 2024), and the study protocol follows the Declaration of Helsinki (2014) guidelines.

Procedures

Simulated High-Intensity Task Condition (SHITC): Participants engaged in simulated tasks designed to mimic real-world emergency scenarios, including hose dragging, ladder climbing, victim rescue simulations, shooting drills, and pursuit exercises. Each professional group —firefighters and Special Operations Group police officers— performed a circuit tailored to their specific job-related tasks. These circuits were developed based on a preliminary questionnaire to ensure the tasks were appropriate and relevant to the respective professions. Both circuits were balanced regarding execution time and required physical capabilities, comparing performance metrics fairly. This design aimed to simulate the physical and physiological demands encountered in real emergencies, including the high-stress conditions of pursuit and arm use for the Special Operations Group Officers (police officers).

Maximal Cardiopulmonary Exercise Test (CPET): Maximal exercise testing was performed on a treadmill with an individualized incremental protocol based on the maximal velocity reached on the 20-m shuttle run test. The protocol started with a 5-minute warm-up at maximal velocity reached on the shuttle run test. The velocity was increased by 26.8 m/min every two minutes for four minutes, after which the treadmill grade increased by 2.5% every minute until volitional exhaustion. The protocol ended with a 1-minute active recovery at 66.6 m/min plus 2 minutes of passive recovery in a seated position. Rating of perceived exertion (RPE) was assessed each minute using a 6-20 category-ratio scale. The test was completed when participants reached volitional exhaustion, or at least three of the following criteria were achieved: (i) a peak HR greater than 90% of the maximal HR predicted ($220 - \text{age}$) (Karvonen & Kentala, 1957); (ii) a plateau in oxygen consumption ($\dot{V}O_2$; i.e., <150 ml/min or <2.1 ml/kg/min increase in $\dot{V}O_2$ with a concurrent increase in work rate); (iii) a respiratory exchange ratio of >1.1 ; (iv) an RPE between 18-20 (Howley et al., 1995). Inspired and expired gases were continuously analyzed in a breath-by-breath metabolic cart (QUARK RMR, version 9.1, Cosmed, Rome, Italy) on a treadmill (Pulsar 3p, HP Cosmos, Munich, Germany). The turbine flowmeter was calibrated. Peak oxygen uptake ($\dot{V}O_{2\text{peak}}$) was the highest 20-s value attained during the CPET.

Measurements

Heart Rate Monitoring: A chest strap monitor will continuously monitor heart rate. Key heart rate metrics will include resting heart rate, peak heart rate during activity, and heart rate recovery (HRR) one-minute post-exercise.

Perceived Exertion: Participants will rate their perceived exertion using the Borg Rating of Perceived Exertion (RPE) scale during and at the end of the simulated and maximal tasks.

Cardiovascular Recovery: HRR will be assessed by measuring the decrease in heart rate from peak to one-minute post-exercise. This will provide an indicator of autonomic function and cardiovascular fitness.



Data analysis

Descriptive statistics (mean $\pm$ standard deviation) were used to summarize the central tendency and dispersion of the data. The normality of the variable distributions was tested using the Shapiro-Wilk test. Cardiovascular and hemodynamic variables, such as heart rate recovery (HRR), maximal, and rest, were compared between the CPET and the SHITC conditions using independent and paired t-tests to account for the repeated measures design. A two-way repeated measures ANOVA was employed to assess the differences in these variables across the two conditions (CPET vs. SHITC) and over time (rest vs. post-intervention). The significance level was set at $p < 0.05$. All statistical analyses were performed using SPSS version 28.0 for Windows (SPSS Inc., Chicago, IL, USA).

While VO_2peak was measured, it was not included as a covariate in this analysis. Future studies may benefit from incorporating VO_2max values, years of service, or other occupational characteristics as covariates to better account for differences in fitness levels and professional experience.

Results

The study included 16 male police officers with an average age of 37.06 ± 7.19 years, a mean weight of 80.30 ± 7.92 kg, and an average height of 1.77 ± 0.06 m. In contrast, the 35 male firefighters had an average age of 31.12 ± 5.36 years, a mean weight of 72.44 ± 5.96 kg, and an average height of 1.74 ± 0.05 m.

Table 1 presents the demographic variables of the participants, categorized by group, including age, weight, height, body mass index, fat mass percentage, and index of appendicular fat-free mass. The participant's body mass index (BMI), fat mass, and lean mass were evaluated against age-specific reference values (Kelly et al., 2009). The BMI of police officers (25.56 ± 1.74 kg/m²) and firefighters (23.90 ± 1.94 kg/m²) suggests that both groups fall within the "normal" to "overweight" categories according to standard BMI classifications. This measurement, whatever, does not differ between muscle and fat mass, which is critical given that muscle building is often necessary in these professions. The typical fat mass percentage ranges for males aged 20-40 are approximately 23.4% to 28.2%. In this study, both groups demonstrated lower average relative fat mass than the general reference values, with police officers averaging 14.37% and firefighters at 15.60%, indicating a relatively lean body composition suitable for their physically demanding roles.

Regarding lean mass, the index of appendicular fat-free mass for police officers was 10.01 ± 0.67 kg/m², and for firefighters, it was 9.15 ± 0.95 kg/m². These values are higher than typical age-specific references, ranging from 8.87 to 9.11 kg/m² for males aged 20-45 (lean mass). This superior lean mass index reflects the physical training and muscular development inherent in your occupational activities, as well as supporting the fitness of your physical condition for your professional responsibilities.

The data highlights that police officers and firefighters maintain a physical fitness level consistent with, or superior to, general population norms for body composition, reinforcing the importance of physical readiness in these roles.

Table 1. Mean and standard deviation (M $\pm$ SD) for the Participant Characteristics divided by group.

Variables	Police Officers (n=16)	Firefighters (n=35)
	M $\pm$ SD	M $\pm$ SD
Age (years)	37.06 $\pm$ 7.19	31.12 $\pm$ 5.36
Body mass (kg)	80.30 $\pm$ 7.92	72.44 $\pm$ 5.96
Height (m)	1.77 $\pm$ 0.06	1.74 $\pm$ 0.05
Body Mass Index (kg/m ²)	25.56 $\pm$ 1.74	23.90 $\pm$ 1.94
Fat mass (% of total mass)	14.37 $\pm$ 3.95	15.60 $\pm$ 3.63
Index Appendicular fat-free mass (kg/m ²)	10.01 $\pm$ 0.67	9.15 $\pm$ 0.95

In Table 2, heart rate data show that police officers and firefighters had similar resting heart rates during the CPET condition. However, significant differences were observed in maximal heart rates and heart



rates during the 1-minute recovery period, with firefighters displaying higher maximal heart rates and faster recovery rates.

Table 2. Mean and standard deviation (M±SD) of the Heart Rate Variables in 2 conditions (CPET and SHITC), divided by groups (Police officers and Firefighters).

Conditions	Variables	Police Officers	Firefighters
		M±SD	M±SD
CPET	Rest Heart Rate (bpm)	75.81 ± 12.33	73.40 ± 12.56
	Maximal Heart Rate (bpm)	184.56 ± 13.55	187.24 ± 7.25
	1-minute Heart Rate recovery (bpm)	147.50 ± 16.55	150.20 ± 16.58
SHITC	Rest Heart Rate (bpm)	94.88 ± 16.04	75.00 ± 9.17
	Maximal Heart Rate (bpm)	159.69 ± 17.42	169.56 ± 12.39
	1-minute Heart Rate recovery (bpm)	127.31 ± 22.87	112.40 ± 14.76

Note: maximal cardiopulmonary exercise test (CPET); simulated high-intensity task condition (SHITC).

Table 3 expands on these findings by comparing heart rate variables between the two groups across both CPET and SHITC conditions. During the CPET, no significant differences were found in resting heart rate ($p = 0.54$), maximal heart rate ($p = 0.41$), or 1-minute post-exercise heart rate ($p = 0.61$), indicating similar cardiovascular responses under these controlled conditions. In contrast, the SHITC condition revealed significant differences: firefighters had a lower resting heart rate ($p < 0.01$, $t = 5.06$), higher maximal heart rate ($p = 0.04$, $t = -2.12$), and faster recovery rate ($p = 0.02$, $t = 2.54$) compared to police officers. These findings suggest that the occupational demands of firefighting, which often include intense physical exertion and the need for rapid recovery, may contribute to their more efficient cardiovascular responses.

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Table 3. Results of Heart Rate Variables Comparing Professions on two different conditions (CPET and SHITC). * $p < 0.05$

Conditions	Police Officers vs. Firefighters	p-value	t
CPET	Rest Heart Rate	0.54	0.60
	Maximal Heart Rate	0.41	-0.82
	1-minute Heart Rate recovery	0.61	-0.51
SHITC	Rest Heart Rate	<0.01*	5.06
	Maximal Heart Rate	0.04*	-2.12
	1-minute Heart Rate recovery	0.02*	2.54

Note: maximal cardiopulmonary exercise test (CPET); simulated high-intensity task condition (SHITC).

Table 4 provides further detail by comparing heart rate responses within each group between the CPET and SHITC conditions. For police officers, all heart rate measures differed significantly between conditions, indicating a greater cardiovascular challenge in the SHITC condition. Conversely, firefighters showed significant differences in maximal heart rate and 1-minute recovery but not in resting heart rate, suggesting a more consistent cardiovascular response to high-intensity tasks. This differential response may reflect the firefighters' greater cardiovascular adaptability, potentially due to specific training and the physical demands of their job.

Table 4. Results of Heart Rate Variables Comparing CPET and SHITC Conditions for Police Officers and Firefighters. * $p < 0.05$

Groups	CPET vs. SHITC	p-value	t
Police Officers	Rest Heart Rate	<0.01*	5.42
	Maximal Heart Rate	<0.01*	-7.62
	1-minute Heart Rate recovery	<0.01*	-4.93
Firefighters	Rest Heart Rate	0.62	0.51
	Maximal Heart Rate	<0.01*	-7.53
	1-minute Heart Rate recovery	<0.01*	-8.29



Note: maximal cardiopulmonary exercise test (CPET); simulated high-intensity task condition (SHITC).

The results of the repeated measures ANOVA, as presented in Table 5, indicate significant differences in heart rate variables across different exercise conditions and between professional groups. Specifically, there was a significant main effect of exercise condition on maximal heart rate ($F(1,39) = 117.519$, $p < 0.01$, η^2 partial = 0.75), indicating that maximal heart rate differed significantly between the CPET and SHITC conditions across all participants. The corresponding effect size (Cohen's d) for this difference was 1.63, indicating a very large effect.

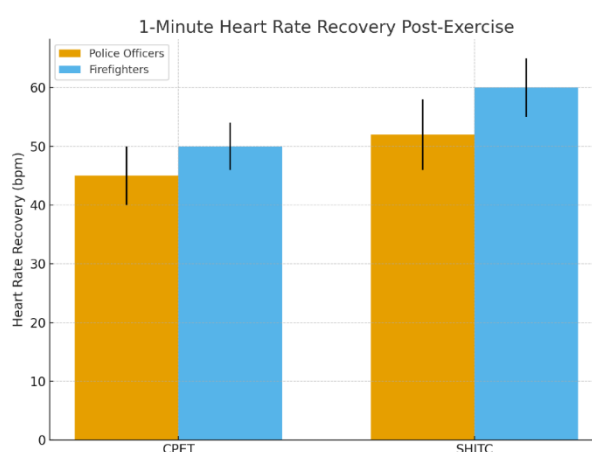
The interaction between exercise condition and professional group for maximal heart rate approached significance ($F(1,39) = 3.359$, $p = 0.07$, η^2 partial = 0.08), suggesting a potential trend towards different maximal heart rate responses between the groups under different conditions, although this was not statistically significant. In the SHITC condition, firefighters exhibited a moderately higher maximal HR than police officers (Cohen's $d = 0.63$).

Regarding heart rate recovery (1-minute post-exercise), the main effect of exercise condition was also significant ($F(1,39) = 77.576$, $p < 0.01$, η^2 partial = 0.67), indicating that heart rate recovery differed significantly between the CPET and SHITC conditions. Firefighters showed a very large effect size (Cohen's $d = 2.40$) between conditions, while police officers showed a large effect (Cohen's $d = 0.99$). Additionally, there was a significant interaction between exercise condition and professional group for heart rate recovery ($F(1,39) = 7.156$, $p = 0.01$, η^2 partial = 0.16). This suggests that the impact of the exercise conditions on heart rate recovery varied between groups. In the SHITC condition, firefighters had significantly faster recovery than police officers (Cohen's $d = 0.75$). As illustrated in Figure 1, firefighters exhibited a greater decrease in heart rate one minute after exercise in both CPET and SHITC conditions, supporting the statistical interaction found between group and condition.

Table 5. Two-way repeated measures for both conditions. * $p < 0.05$

	Variables	F	p-value	η^2
Conditions	Maximal Heart Rate	117.519	<0.01*	0.75
	1 min Heart Rate recovery	77.576	<0.01*	0.67
Conditions vs. Professions	Maximal Heart Rate	3.359	0.074	0.08
	1 min Heart Rate recovery	7.156	0.01*	0.16

Figure 1. Mean heart rate recovery (1-minute post-exercise) in CPET and SHITC conditions, comparing firefighters and police officers.



Moreover, a very large difference in resting heart rate between groups was observed in the SHITC condition (Cohen's $d = 1.42$), reinforcing group differences in cardiovascular regulation at rest during high-intensity tasks.

Discussion

The present study investigated cardiovascular recovery in elite responders, specifically firefighters and police officers, under conditions that closely mimic their work-related stress. These findings underscore the relevance of exercise context in shaping cardiovascular responses among elite responders, beyond what is typically observed in standard laboratory tests. The findings revealed significant differences in heart rate variables across different exercise conditions (CPET and SHITC) and between professional groups, providing valuable insights into these professionals' cardiovascular fitness and recovery capacity.

A significant main effect of exercise condition on maximal heart rate indicated that maximal heart rate was higher in the CPET condition than SHITC. This supports the idea that CPET, as a controlled maximal exertion test, drives participants closer to their physiological limits, whereas SHITC, although demanding, involves variable intensities more reflective of operational realities. Although the interaction between exercise condition and the professional group for maximal heart rate approached significance, it was not statistically significant, indicating similar maximal heart rate responses between police officers and firefighters under these conditions. Regarding heart rate recovery, the significant main effect of the exercise demonstrated notable differences between CPET and SHITC conditions.

Furthermore, a significant interaction effect suggested that firefighters exhibited more efficient cardiovascular recovery than police officers. This differential response likely reflects the specific physical conditioning and occupational demands of firefighting, which may enhance cardiovascular recovery due to regular exposure to high-intensity activities and training focused on endurance and rapid recovery. Additionally, task structure may also have influenced outcomes: CPET followed a progressive and standardized protocol, whereas SHITC tasks varied in type and order, potentially affecting physiological responses differently. It is also essential to consider the influence of age on these findings. The police officers in this study were, on average, older (37.06 ± 7.19 years) compared to the firefighters (31.12 ± 5.36 years). Age is a known factor that can affect cardiovascular recovery, with older individuals generally exhibiting slower heart rate recovery after exertion due to the natural decline in autonomic function with age (Ribeiro et al., 2023). This age disparity may have contributed to the observed differences in recovery rates between the two groups, with younger firefighters potentially benefiting from a more robust autonomic response and faster recovery times. Future studies should statistically control for age, using it as a covariate or stratifying participants, to better isolate the effects of training and professional demands.

Moreover, the specific nature of the tasks performed by each group could also play a role in influencing heart rate responses. Firefighters and police officers face different occupational challenges that could impact the intensity and type of physical exertion required. The SHITC designed for firefighters may have been more physically demanding or sustained, while police officers' tasks emphasized intermittent, skill-based efforts, which could partly explain the different cardiovascular responses. These results align with previous research indicating that elite responders generally possess superior cardiovascular fitness and recovery profiles compared to the general population (Jeung et al., 2022; Kales et al., 2009; Soteriades et al., 2011; Violanti et al., 2017). Such fitness is critical, as it supports their ability to manage the acute stressors of their work, which often involve intense physical exertion followed by periods of rest (Dulsky et al., 2022; Monteiro et al., 2024; Stephenson et al., 2021). This pattern of exertion and recovery is akin to high-intensity interval training, known to improve $\dot{V}O_2$ max, reduce body fat, and enhance cardiovascular recovery—benefits essential for maintaining operational readiness and reducing the risk of cardiovascular incidents (Atakan et al., 2021; Feito et al., 2018; Ito, 2019; Qiu et al., 2017).

Hemodynamically, the observed differences in heart rate recovery between the groups are significant for understanding the cardiovascular health of these professionals. Efficient heart rate recovery, indicative of good autonomic function and cardiovascular fitness, is crucial for elite responders who frequently transition between high exertion and rest (Dewar et al., 2023; Qiu et al., 2017; Stephenson et al., 2021). This underscores the importance of specialized cardiovascular training programs to enhance recovery capacities, potentially improving overall health outcomes and job performance (Monteiro et al., 2024; Ribeiro et al., 2023).

Therefore, implementing specialized cardiovascular training programs that focus on enhancing recovery capacities is vital. Such programs improve overall health outcomes and ensure that responders are



physically prepared to handle the demanding and unpredictable nature of their work (Monteiro et al., 2024; Sempf & Thienes, 2022). Ongoing assessment and monitoring of cardiovascular fitness in these populations are essential to tailor training programs and mitigate potential health risks associated with their high-stress occupations.

This study has several limitations that should be considered when interpreting the results. Firstly, the inability to standardize the sequence of tasks in the SHITC condition across all participants may have introduced variability in the intensity and nature of the physical stress experienced. This could affect heart rate responses, making directly comparing results across different professional groups challenging. Secondly, the relatively small sample size limits the generalizability of the findings, as it may only partially represent the broader population of elite responders. Additionally, variations in individual fitness levels, training backgrounds, and job-specific demands were not controlled for, which could influence the cardiovascular responses observed. Another limitation is that only male responders were included; future studies should expand to include women to better capture sex-specific differences in recovery.

Future research should therefore include larger, more diverse, and multinational samples, with standardized exercise protocols and longitudinal monitoring to assess training adaptations over time. Intervention studies are also needed to test whether targeted cardiovascular training can improve recovery efficiency and reduce health risks among first responders.

Conclusions

This study underscores the significant differences in cardiovascular recovery between elite responders, specifically firefighters and police officers, under various exercise conditions. The findings reveal that while both groups exhibited high cardiovascular fitness levels, firefighters demonstrated more efficient heart rate recovery, likely due to their specific occupational demands and training regimens. The CPET condition involved controlled maximal exertion, resulting in higher maximal heart rates than the SHITC, highlighting the distinct physiological responses elicited by different physical stressors. The efficient cardiovascular recovery observed in firefighters suggests that targeted training programs focused on enhancing endurance and recovery capacities can be particularly beneficial. These insights emphasize the critical need for ongoing cardiovascular assessment and the implementation of specialized training protocols to support elite responders' health and operational readiness, ultimately contributing to improved job performance and reduced risk of cardiovascular incidents in these high-stress professions.

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