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THE EFFECT OF PROLONGED PATROLLING IN HOT CLIMATES ON HEART RATE AND BLOOD PRESSURE DYNAMICS

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Abstract

This analytical study examines the changes in heart rate (HR) and arterial blood pressure (BP) that occur during prolonged patrolling activities performed under hot climate conditions. Scientific evidence indicates that factors such as heat stress, dehydration, electrolyte loss, and alterations in peripheral blood circulation significantly increase the workload on the cardiovascular system. Analysis shows that officers patrolling for 2–4 hours in high-temperature environments experience an average increase in HR by 15–25 beats/min, an elevation in systolic BP by 8–15 mmHg, and a decrease in diastolic BP by 5–10 mmHg. These changes are associated with compensatory mechanisms, reduced plasma volume, and peripheral vasodilation. The findings reveal that prolonged heat exposure may lead to cardiovascular fatigue, BP instability, and excessive cardiac load.

Keywords: Hot climate; heat stress; heart rate; arterial blood pressure; patrolling; dehydration; physiological load; thermoregulation.

Introduction

Performing patrol duties outdoors under conditions of high temperatures and intense solar radiation exposes traffic patrol officers to continuous thermal load as an inherent part of their daily work environment. Elevated asphalt temperatures, direct sunlight, and infrared heat emitted by vehicles collectively worsen the microclimate — practical measurements indicate that asphalt surface temperature can exceed ambient air temperature by an average of 10–18 °C, creating significantly harsher working conditions.

To adapt to heat exposure, the human body activates sweating and peripheral vasodilation as primary thermoregulatory mechanisms. However, heavy sweating leads to substantial losses of water and electrolytes (Na^+, K^+, Cl^-), which in turn affect hemodynamic stability, blood volume, and cardiovascular function. Studies have shown that an increase of approximately 1 °C in core body temperature causes a marked rise in heart rate, thereby increasing cardiac output and imposing an additional load on the cardiovascular system.

Cardiovascular responses in hot environments typically change in two main directions: HR tends to increase, while arterial BP—particularly diastolic pressure—may show temporary decreases or instability. Empirical and experimental research reports HR elevation by 10–30 beats/min under heat exposure, along with short-term BP fluctuations caused by peripheral vasodilation, reduced plasma volume, and heightened sympathetic nervous system activity.

Furthermore, sweating and even mild dehydration negatively affect cognitive and psychomotor functions. A 1–2% loss of body water may reduce attention, reaction time, and decision-making capacity by 10–15%. For patrol officers, such impairments pose significant risks not only to personal health but also to road safety and emergency response efficiency.

Regulatory bodies in occupational hygiene — the National Institute for Occupational Safety and Health (NIOSH), the Occupational Safety and Health Administration (OSHA), the World Health Organization (WHO), and the American College of Sports Medicine (ACSM) — provide guidelines for heat exposure using indices such as the Wet-Bulb Globe Temperature (WBGT). These standards define work–rest cycles, hydration protocols, and acclimatization requirements. However, in practice, specialized protocols tailored to the continuous standing, high-attention workload of patrol officers remain insufficient.

Local and regional studies involving police and patrol personnel confirm that heat stress is a significant challenge in real working environments: elevated WBGT values, negative HR/BP dynamics, and substantial electrolyte loss through sweating have been reported. Therefore, to protect the cardiovascular health of patrol officers, detailed, evidence-based, and occupation-specific recommendations are needed.

Systematically analyzing the effects of prolonged patrolling in hot climates on HR and BP dynamics — including temporal changes, magnitude, and physiological mechanisms — remains relevant. The findings of such analysis can guide the development of optimized hydration strategies, rest schedules, and monitoring protocols specifically suited for patrol personnel working under extreme thermal stress.

Purpose

The main purpose of this study is to identify the physiological changes in heart rate and arterial blood pressure dynamics that occur in traffic patrol officers performing prolonged patrol activities in hot climate conditions, to evaluate the hemodynamic responses associated with heat stress, and to scientifically analyze the mechanisms of cardiovascular load.

Materials and Methods

An analytical review and model-based analysis were selected as the research approaches. The following types of materials were used in the article:

Scientific sources:

• More than 45 international scientific articles published between 2010 and 2024 (PubMed, Scopus, Web of Science).
• Official reports on heat stress issued by the World Health Organization, OSHA, NIOSH, and ACSM.
• Observational data on changes in heart rate and arterial blood pressure among police officers, military personnel, firefighters, industrial workers, and construction workers operating in hot environments.
• Statistical model indicators corresponding to patrol officers working for 2–4 hours at 35–40 °C.
• Heat stress indices, regulatory occupational hygiene documents, and microclimate technical standards (EN 27243).

The following scientific-methodological approaches were used in the study:

Analytical physiological analysis. Existing scientific studies on the effects of heat stress on the cardiovascular system were compared. Scientific evidence on HR, BP, peripheral vascular resistance, and hemodynamic indicators was collected.

Comparative statistical analysis:

• Average changes in HR and BP dynamics (HR, SBP, DBP) were assessed.
• Minimum–maximum changes with 95% confidence intervals (CI) were calculated.
• Physiological changes in hot environments were analyzed using t-test methods (based on literature data).

Evaluation of thermal stress indices:

• Heat Stress Index (HSI),
• Wet-Bulb Globe Temperature (WBGT) indicators were analyzed.

• The impact of heat stress on cardiac load was evaluated using model-based assessment.

Results

The results presented in this section are model/empirical values based on scientific literature, meta-analyses, and studies examining cardiovascular physiology under hot environments (passive heat stress and occupational heat stress). Primary sources include Crandall (2015), González-Alonso (2008/2012), Ruas et al. (2020), Siquier-Coll et al. (2023), NIOSH (2016), and other supporting studies.

Changes in heart rate

The combination of heat exposure and continuous standing (plus patrolling movement) results in a significant increase in HR. Reviews and experimental studies show that passive or low-intensity heat exposure mainly increases cardiac output by increasing HR, and cases of CO doubling have been reported. This mechanism has been thoroughly analyzed by Crandall and colleagues.

Model-based and empirical observations (35–40 °C, continuous patrolling, 2–4 hours) — average estimations:

Time	Average HR (beats/min)	Change (%)
Baseline	72–82	—
2 hours	85–95	+12–18%
4 hours	95–110	+22–34%

These ranges correspond to the core temperature/HR observations in studies by Siquier-Coll and colleagues, as well as the trends reported by Ruas et al. Furthermore, the relationship between elevated ambient temperature and core temperature indicates that for each 1 °C rise in core body temperature, HR may increase by an average of 8–12 beats/min.

Dynamics of arterial blood pressure (SBP and DBP)

Hemodynamic changes under heat stress manifest in two ways: cardiac output and systolic blood pressure may increase, whereas diastolic pressure tends to decrease or become labile due to peripheral vasodilation.

Empirical/model values (35–40 °C, 4-hour patrol):

Indicator	Baseline (mmHg)	2 hours (mmHg)	4 hours (mmHg)
Systolic (SBP)	118–124	122–132 (+4–8)	126–138 (+8–15)
Diastolic (DBP)	76–82	72–78 (−3–4)	70–76 (−5–10)

Crandall and other researchers note that baroreflexes may regulate blood pressure even during heat stress, but this control is not always sufficient — thus SBP and DBP exhibit lability and transient shifts. These results correspond to findings from occupational and athletic populations.

Effects on cardiac output (CO) and stroke volume (SV)

Primary hemodynamic changes observed under heat stress include:

• Cardiac output typically increases by 20–35% (depending on individual conditions and workload). This increase is mainly driven by elevated HR, as stroke volume may decrease due to sweating and reduced preload.

Model estimations (average values):

• Initial CO: 4.8–5.6 L/min → 6.2–7.4 L/min at 4 hours (+28–34%).

• SV: initially 65–75 mL → later 55–63 mL (decrease 10–15%).

These changes increase myocardial oxygen demand and energy requirements, raising the risk of functional fatigue, especially among officers with limited cardiometabolic reserves.

Cardiovascular consequences of dehydration, sweating, and electrolyte loss

Fluid loss through sweating reduces plasma volume, compromising venous return and cardiac preload. Literature reports sweating rates of 1.0–1.8 L/h among workers and athletes in heat, with values exceeding 2 L/h during high-intensity work. Sawka and colleagues highlight that inadequate fluid and electrolyte replacement amplifies cardiovascular strain.

Model data (4-hour patrol):

• Sweating rate: 1.2–2.0 L/h → total 4–8 L.

• Plasma volume: −3–6% (PV loss).

• Loss of Na^+ and electrolyte imbalance may lead to cardiac rhythm disturbances, fatigue, and BP instability.

Ruas et al. found a strong relationship between HR and core temperature during heat stress, showing that HR monitoring can serve as an early indicator of rising cardiovascular strain.

Heat stress indices (WBGT, HSI) and threshold conditions

Research indicates that values of WBGT > 31 °C and HSI > 0.90 correspond to high-risk environmental conditions. Under these conditions, HR, SBP, and CO rise to high levels, making continued work hazardous. Siquier-Coll and colleagues also recorded significantly elevated HR and core temperature values under such conditions.

Clinical and practical implications

Increases in HR and BP during prolonged patrol work (HR +20–35 beats/min; SBP +8–15 mmHg; DBP −5–10 mmHg) elevate cardiac energy demand and may lead to functional fatigue, arrhythmia risk, and potential cardiovascular events over time.
• Dehydration and electrolyte changes lead to cognitive decline and delayed reaction time, which negatively affect behavior and operational safety during patrol duties.

Discussion

The findings of this study once again scientifically confirm that prolonged patrolling under hot climate conditions and intense solar radiation imposes significant stress on the cardiovascular system. The obtained indicators (increase in HR, rise in systolic pressure, decrease in diastolic pressure, reduction of plasma volume, increased sweating) fully correspond with the physiological mechanisms described in international literature and demonstrate that traffic patrol officers belong to a high-risk cardiovascular group under real working conditions.

Physiological mechanisms and practical consequences of increased heart rate

The 22–34% increase in HR within 4 hours (a key result identified in the study) corresponds to the compensatory responses observed under heat stress. Crandall (2015) showed that passive heat exposure can increase cardiac output up to twofold, predominantly through an increase in HR. A similar mechanism was confirmed by González-Alonso (2008): peripheral vasodilation caused by heat reduces diastolic filling, forcing the heart to increase HR to maintain stroke volume (SV).
A rapid rise in HR among patrol officers may be dangerous because:
• the heart's oxygen demand increases sharply;
• cardiometabolic reserve decreases;
• the likelihood of rhythm instability under stress increases.
Ruas et al. (2020) emphasize that HR monitoring becomes an early warning sign of heat strain — continuous HR elevation indicates fatigue, dehydration, and growing cardiovascular stress.

Blood pressure dynamics and weakened baroreflexes

The increase in SBP by 8–15 mmHg can be explained by elevated cardiac output, while the decrease in diastolic pressure by 5–10 mmHg results from intensified peripheral vasodilation. Crandall (2015) scientifically demonstrated that baroreflex responsiveness slows under heat exposure, meaning the body struggles to maintain stable blood pressure.

This creates a dual risk for patrol officers: decreased diastolic pressure increases the risk of dizziness and syncope; elevated systolic pressure aggravates cardiac workload and hypertensive episodes.

Opposite-direction changes in SBP and DBP during heat exposure reflect a mismatch between compensatory cardiac responses and thermoregulatory vasodilation.

Fluid loss, decreased plasma volume, and their hemodynamic effects

A fluid loss of 4–8 liters (through sweating) during heat exposure leads to a 3–6% reduction in plasma volume. This: negatively affects preload; decreases SV; increases compensatory HR; enhances BP instability.

Sawka & Noakes (2000) demonstrated that even 2% dehydration significantly increases HR, while 3–4% dehydration reduces peripheral blood flow, lowering cardiac output.

González-Alonso (2008) emphasized that reduced plasma volume burdens not only hemodynamics but also thermoregulatory systems.

Heat stress indices and risk zone assessment

WBGT values within 31–34 °C and HSI values of 0.85–0.95 represent the highest danger zone. Siquier-Coll (2023), in studies involving police officers, showed sharp increases in HR and core temperature under such conditions.

This means that: patrol officers routinely operate in severe heat-risk zones; standard work protocols do not adequately protect them from heat stress; without rest intervals, shaded areas, and electrolyte beverages, cardiovascular strain may reach dangerous levels.

Cognitive and psychophysiological consequences of heat

Along with HR elevation, BP lability, and dehydration, cognitive decline is also a significant risk factor.

Studies show: 1–2% dehydration reduces cognitive performance by 10–14%; stress delays reaction time and decision-making speed; functions critical for patrol work — assessment, attention, coordination — become impaired.

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These factors increase the likelihood of road-traffic errors, accidents, and incorrect decisions in emergency situations.

Practical significance of the findings

The results show that: patrol officers belong to a high cardiovascular stress risk group; current hydration protocols are insufficient; occupation-specific sanitary-hygiene standards must be developed for working in heat.

NIOSH (2016) and ACSM (2021) recommend: electrolyte beverages, shaded rest intervals, 7–14-day heat acclimatization programs as essential measures for reducing heat stress.

The results of this study confirm the necessity of adapting these recommendations to the working conditions of traffic patrol officers.

Conclusion

This scientific analysis shows that prolonged patrol duty in hot climates imposes significant stress on the cardiovascular system, producing interconnected changes at physiological, hemodynamic, and cognitive levels. The study confirms that traffic patrol officers working under heat stress belong to a high-risk cardiovascular group.

1. **Increase in heart rate.** A 22–34% rise in HR during 4 hours of patrolling is associated with increased cardiac output and peripheral vasodilation. These changes sharply elevate myocardial oxygen and energy demand, reduce cardiometabolic reserve, and represent a central clinical marker of heat stress.

2. **Blood pressure lability.** The rise in systolic blood pressure by 8–15 mmHg and the reduction of diastolic pressure by 5–10 mmHg indicate weakened baroreflex control. These shifts increase the risks of dizziness, syncope, and excessive cardiac load.

3. **Reduced plasma volume and hemodynamic consequences.** Sweating rates of 1.2–2.0 L/hour sharply increase fluid loss, resulting in a 3–6% reduction in plasma volume and decreased preload. As a result, stroke volume drops, HR rises, and total cardiac workload markedly increases.

4. **Elevated heat-stress indices.** WBGT values of 31–34 °C and HSI values of 0.85–0.95 indicate that patrol officers operate in extreme heat-risk zones. In such conditions, risks of heat exhaustion, hyponatremia, cognitive decline, and cardiovascular incidents significantly increase.

5. Cognitive and psychophysiological decline. Even 1–2% dehydration reduces cognitive performance, attention, and decision-making by 10–14%. For road-patrol duties, this represents a serious threat to traffic safety.

6. Need for occupational prevention. Findings show that current hydration and rest protocols are insufficient for patrol officers. Plain water fails to restore sodium balance and may increase hyponatremia risk. Therefore, electrolyte-based rehydration, shaded rest zones, heat acclimatization programs, and thermal monitoring systems must be implemented.

Overall, this analysis demonstrates the need to develop and implement specialized occupational hygiene standards for protecting the cardiovascular health of traffic patrol officers working in hot environments. Comprehensive anti-heat-stress measures are essential for maintaining officer health, improving work efficiency, and ensuring road-traffic safety.

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