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Hot and dry environment influence on physiological parameters of Malian military in Sahara casern in Northern Mali

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Abstract

Mali is a Sahelo-Saharan country covered at 60% by the Sahara desert. Despite high heat and cold periods in Tessalit and Gao, two cities, military live in barracks or for operations in accordance with their regal mission. The aim of this study was to assess the influence of hot season on the physiological parameters of soldiers living in Gao and Tessalit. An experimental study was carried out in May 2022 under Gao and Tessalit climatic conditions on military. The body temperature (RBT), resting heart rate (RHR) and blood pressure (BP) were recorded between 6 and 8 a.m., 11 a.m. and 1 p.m. and 3 to 6 p.m. respectively. No significant difference was observed in resting body temperature (RBT) at the mid-day period ($p = 0.05507$). However, in Tessalit, from 3 p.m., RBT increased significantly ($p = 0.0235$). In both study regions, a significant increase was observed in heart rate with $p = 0.0001$. These results show that environmental stress could be deleterious or enhance exercise during thermal stress in the Sahara of northern Mali, and influence the operational effectiveness of military.

Keywords: Thermal stress; physiological parameters; operational efficiency; Mali.

Introduction

Environmental analysis is a key step in the strategic development of military operations plans. It is the first factor of armies success on fighting ground. It enables decisions for efficient deployment of logistics in the operational field. This analysis contributes to elaborate modalities of employment and actions of the forces and to evaluate their operational efficiency on the ground. In northern Mali Sahara region, soldiers are exposed to constant heat stress (39 to 44°C). In order to minimize this stress, access to the military corps is conditional to a physical aptitude above or equal to the genetic average. This aptitude is well worked to be well developed and improved by military specific and operational physical training (Lapouge, 2012). Muscular exercise was shown to be a wealthy and instructive model in physiology, as it has the particularity of bringing into play an integrated response from the organism, involving cardiovascular, respiratory, metabolic and hormonal responses in an adapted manner (Gonzalez-Alonso and al., 2008).

In addition to physical ability and training level, the environment has a decisive effect on athlete performance (El Helou and al., 2019). The ability to perform exercises in hot environment is reduced compared to neutral environment (Maughan and Shirreffs, 2010; Maxwell and al., 2009; Kayilou and al., 2020). Heat stress influence on organism need to be considered to increase physiological and psychological capacities efficiency and to transcend all trials and constraints linked to different environments (Lapouge, 2012).

Gao is in east-central Mali, on the zero meridian, 250 m above sea level. The average temperature during the hottest month (May) is 43.3°C. Tessalit, on the other hand, is in the northeast, with an average temperature of 39.9°C. During the hottest months in Tessalit, ambient temperature is 43 ± 4°C, with a very low humidity of 6 to 12% and a low wind speed of 12 to 27 km/h. However, it has been shown that raising the ambient temperature above 44°C results in a rise in internal temperature close to 40°C. This would lead to premature fatigue of the cardiovascular system, as revealed by electroencephalography (Nielsen and Nybo, 2003). An increase in ambient temperature from 46°C to 48°C causes a significant rise in heart rate (HR) from 52 ± 2 to 93 ± 4 bpm (Crandall and al., 2008). An alteration in peripheral blood flow and a spectacular increase in cutaneous blood flow from 200 ml. min-1 to 8000 ml.min-1 during passive heat exposure have been observed (Gonzalez-Alonso and al., 2008; Rowell and al., 1969). Similarly, a 1-2% loss in body mass can exacerbate thermal and cardiovascular strains, impairing sports performance (Kayilou and al., 2020; Sawka and al., 2007; Hoffman and al., 2005).

The intense practice of high-level, high-intensity physical and sporting activities induces very high energy lost. So military activities in training or on operations also generate high physical, psychological and health-related requirements and constraints, depending on the environment (Lapouge, 2012).

During periods in Sahara of high heat, sweat in shade is roughly equal to that of athletes competing in thermal neutrality, requiring input of large quantities of water to compensate (Godek and al., 2008).

According to these aspects, a study of the influence of such an environment on the physical conditions of military, and output their performance, is essential. This study was initiated to determine effect of saharaheat in north Mali on the physiological abilities of soldiers in Tessalit and Gao.

1. Materials and methods

1.1. Population and sampling

65 soldiers from two combat sections, 35 in Gao and 30 in Tessalit, with an average seniority of 12 years { 3.8 were recruited using the non-probabilistic method. To take part in the study, people had to be a soldier in one of the both

combat sections, either in barracks or engaged in operations in the Saharan zone of Mali.

Soldier who not respect this condition was excluded from the study.

1.2 Experimental protocol

1.2.1 Measurement of anthropometric parameters

Anthropometric parameters were measured during three (03) periods: 6 to 8 a.m., 11 to 1 p.m. and 3 to 6 p.m. respectively.

1.2.2 Physiological parameters

Skin temperature, heart rate and blood pressure were determined in subjects at rest during the same periods as anthropometric measurements.

Body temperature (T°C) was taken on the forehead and under the armpit of subjects in the seated position. Resting heart rate (HRR) and resting blood pressure (BP) were measured in the supine position using the SPENGLER Autotensio SPG340 electronic wrist blood pressure monitor (France). Humidex (temperature and relative humidity comfort scale) as used to assess subjects' degree of thermal comfort.

The subjects' water loss (WL) was assessed during 6 a.m. to 6 p.m. using the following formula:

$$WL\ (\%) = \frac{\text{Weight before} - \text{Weight after}}{\text{Weight before}} \times 100$$

(Kayilou and al., 2020).

Weight before = weight recorded between 6 a.m.to 8 a.m.;
Weight after = weight recorded between 3 p.m. to 6 p.m.

1.3 Statistical analysis

Graph-pad prism version 8.4.3 (686) was used to analyze data expressed as mean ± standard deviation. A repeated-measures ANOVA between the means of the variable values for the three periods was used. T-tests for independent and dependent samples were used to check for significance between cities and within periods. The significance level of the results was set at $P < 0.05$.

2. Results

2.1 Meteorological data at the time of the study

Table I shows meteorological data

Table I: Meteorological data

Parameters	Gao	Tessalit	Gao	Tessalit	Gao	Tessalit
	6 a.m.-8a.m.		11 a.m.-1 p.m.		3 p.m.- 6 p.m.	
Temperature (°C) (P = 0,5587)	38 { 1.9	39 { 0.8	43 { 2.6	44 { 2.8	40 { 2.1	39 { 0.8
Humidity (%) (P = 0,0001)	7-12	7-13	7-12	7-13	7-12	7-13
Wind speed (Km/H) (P = 0,4664)	11-27	13-32	11-27	13-32	11-27	13-32

TA= Ambient temperature; °C = Degree Celsius; % = Percentage; Km/h = Kilometres per hour

2.2 Anthropometric data

Subjects' anthropometric data were determined. These included body mass, height, body mass index and water loss. Subjects in Gao recorded higher water loss than those in Tessalit, with no significant difference (p = 0.145).

Table II: Anthropometric data

Parameters	Region		p
	Tessalit (n = 30)	Gao (n = 35)	
Age (years)	31 ± 9	31 ± 9	0.9528
Height (cm)	175 ± 15	175 ± 15	0.9941
Body mass (kg)	75.93 ± 12.41	75.77 ± 9.22	0.9522
BMI (kg/m^2)	24.84 ± 04	24.78 ± 04	0.4857
Water loss(%)	0.57 ± 0.36	0.67± 0.24	0.145

Cm = centimeter; kg = kilogram; kg/m2 = kilogram per square meter; n = number of employees

2.3 Resting body temperature in the experimental group (EG)

A significant increase in body temperature was observed in Tessalit between 6 a.m. to 1 p.m. (p = 0.0063), between 6 a.m. to 6 p.m. (p = 0.0001) and between 11 a.m. to 6 p.m. (p = 0.0071). On the other hand, it remained constant among subjects in Gao, with p = 0.1416 (between 6 a.m. and 1 p.m.), p = 0.8994 (between 6 a.m. and 6 p.m.) and p = 0.1404 (between 11 a.m. and 6 p.m.) respectively. No difference was observed between the body temperature of subjects in Gao and that of subjects in Tessalit at 6 a.m.-8 a.m with p = 0.5032 and at 11 a.m. to 1 p.m. with p = 0.0550. However, a significant increase in body temperature was observed in Tessalit compared to Gao at 3 p.m. to 6 p.m. (p = 0.0235).

Table III: Subjects' body temperature

Parameters	Period	Region		p
		Tessalit (n = 30)	Gao (n = 35)	
Body temperature(^{O}C)	**6 a.m.-8 a.m.**	36.47 ± 0.70	36.65 ± 1.30	0.5032
	11 a.m.-1 p.m.	36.80 ± 0.43	36.35 ± 1.20	0.0550
	3 p.m.- 6 p.m.	37.12 ± 0.50	36.68 ± 0.92	0.0235

°C= degree Celsius

2.4 Resting heart rate

Resting heart rate increased significantly in Gao over the three measurement periods (Figure 1), with p = 0.0038 at 8 am, p = 0.0001 at 1 pm and p = 0.0001 at 6 pm respectively.

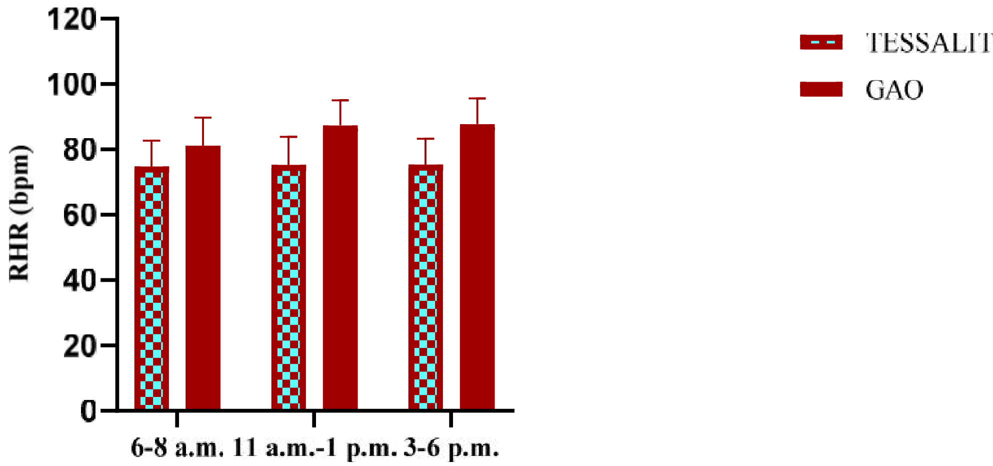

Figure 1: Variation in subjects' resting heart rate

2.5 Blood pressure

Blood pressure was high in Gao subjects during all three periods, with a significant difference respectively p = 0.0025 at 6 a.m.-8 a.m., p = 0.0001 at 11 a.m.-1 p.m. and p = 0.0001 at 3 p.m.-6 p.m. (Table IV). Although tensions are high in Gao, they are within norms if not falling.

Table IV: Blood pressure in the experimental group

Parameters	Period	Region		p
		Tessalit (n = 30)	Gao (n = 35)	
Blood pressure (mm Hg)	**6 a.m.-8 a.m.**	12.73 ± 1.44	13.78± 1.23	0.0025
	11 a.m.-1 p.m.	12.19 ± 1.31	13.90± 1.13	0.0001
	3 p.m.- 6 p.m.	11.96 ± 1.29	14.26± 1.38	0.0001

mmHg: millimeters of mercury

2.6 Thermal comfort

Subjects felt the heat a lot in both cities (Table V). No difference was observed (p = 0.0746; p = 0.9447 and p = 0.2244).

Table V: Subjects' assessment of thermal comfort

Parameter	Sensation	Region		p
		Tessalit (n = 30)	Gao (n = 35)	
Thermal Comfort	Slightly hot	10 %	14.28 %	0.0746
	Hot	10 %	22.86 %	0.9447
	Very hot	80 %	62.86 %	0.2244

Discussion

As the body is an "open system" immersed in its environment, all modification has repercussions on the internal environment, and the organism reacts in order to recoverits previous properties. The present study was implemented to determine the influence of high heat on physiological parameters of military engaged in Tessalit and Gaoin Mali, in order to evaluate their effectiveness in the field. The study was carried out during May 2022, at a maximum ambient temperature of 43°C day and 27°C night, a wind speed of 11-32 km/h and a humidity level of 7-13%. To achieve this objective, anthropometric and physiological parameters such as body mass, height, resting heart rate, blood pressure, water loss, thermal comfort and body temperature were measured over three periods.

The average external temperature is 40°C, which is higher than the human body temperature. However, if external changes become too great, either in duration or intensity, the body's capacity to adapt (thermoregulation system) may be exceeded. The balance is then upset, and dysfunctions leading to pathologies may be revealed. These pathologies can be potentiated if the modifications are less significant. It has been shown on numerous occasions and for many pathologies that our meteorological environment can play a major role in triggering them (Lamandin, 2014).

Body temperature is the result of a balance between metabolic heat production and heat loss (Hausfater and al., 2010). As ambient temperature rises, body temperature tends to increase. The body reacts to keep its internal temperature constant by increasing cutaneous blood flow and activating sweat glands. In this way, the body increases the rate at which it loses heat in order to reduce its thermal burden. In a very hot environment, heat gain exceeds heat loss and body temperature rises, posing potentially serious health risks. This is the reason for the rise in body temperature observed among military personnel living in Gao. These results corroborate those of Crandall and al. (2008), who demonstrated that exposure to a temperature of 46°C significantly increases skin temperature (from 34.3 ± 0.3°C to 38.3 ± 0.2°C) and intestinal temperature (from 36.9 ± 0.08°C to 38.22 ± 0.08°C). Moreover, water loss has a negative effect not only on physical performance but also on thermoregulation (Edwards et Noakes, 2009).

The significant increase in resting heart rate observed in the Gao subjects is due to an excess load on their bodies. Indeed, in a moderately warm environment, the body "goes to work" to evacuate excess heat in order to maintain its normal body temperature. Vascular structures are widely innervated by sympathetic adrenergic fibers responsible for vasoconstriction at rest. Heat inhibition of the vasoconstrictive effect of these fibers, resulting in peripheral vasodilation (Martinet and Meyer, 1999). The heart rate increases in order to accelerate blood flow to the external parts of the body and the skin to evacuate excess heat into the environment through perspiration. Increased blood flow and excessive sweating reduce the subject's ability to perform mental and physical tasks (CCOHS, 2022). The results of this study are in line with those of a study which found that a passive increase in air temperature (heat) induced a significant increase in resting heart rate (RHR) from 52 ± 2 to 93± 4 bpm, in humans, and a drop in blood pressure (Crandall and al., 2008). This result is identical to those of Gonzalez-Alonso and al, (2008), who demonstrated and highlighted the spectacular rise in cutaneous blood flow from 200 ml.min-1 to 8000 ml.min-1 during passive exposure to heat, with increasing ambient temperature.

The thermal discomfort felt by most subjects (62 and 80%) and the water loss ranging from 0.57 to 0.67 (around 1%) in both cities would be due to the increase in ambient temperature. This result is similar to that of Sunderland and al. (2008), who demonstrated that, at a temperature level added to a high wind speed and humidity percentage, thermal discomfort is perceptible through convection and radiation. In hot climatic environments (dry air temperature above 30-

35°C), at rest, sweat flow can be1 to 1.5 liters per hour (l/h), depending on relative air humidity (Savourey and al., 2003). Dehydration of 1% of body weight is perfectly tolerated. At 2%, thirst becomes significant and physical capacity begins to deteriorate. At 4%, physical and intellectual capacities deteriorate. At 6%, the subject is exhausted. At 8%, mental confusion sets in, and at 15%, death can occur. Thirst is a poor indicator of real water requirements, as it is delayed and only partially compensates for water loss (Melin, 2001).

Conclusion

Hot thermal environments can induce specific, general and/or local pathologies. Analysis of the data developed in this study highlights the major influence of ambient temperature on physiological parameters. In military applications, taking these results into account would be an advantage that could strengthen strategic environmental analysis, which was only concerned with climates and relief.

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