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ACCLIMATION EFFECTS IN MILITARY OPERATIONAL PHYSICAL PERFORMANCE

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ABSTRACT

When exposed to extremely hot environment, humans are at considerable risk of experiencing changes in a variety of physiological parameters, such as increase in the heart rate, body temperature, blood pressure and sweat production, and heat related disorders, such as heat stroke, heat cramps and heat exhaustion. In addition to reducing the environmental heat load, people exposed to extremely hot environments should receive heat acclimation training under scientific instruction to guarantee their health and safety. Heat acclimation, i.e., the protective physiological responses of the human body under a repeated thermal stimulus, is beneficial for adapting to hot environments and can improve the body's heat tolerance capability. This article presents 6 case-studies of young military man in which, the effects of 14 days acclimation to dry heat (±40 ºC and ±30%rh) were studied, in order to access the influence and ability to withstand the stress, i.e., exercise in the heat. The measurements included: Core temperature, Heart rate (HR), Maximum oxygen consumption VO_2, Body mass loss, and Lactate concentration. Borg's scale of perceived exertion (RPE) was also used. Test protocols occurred at three types of exertion: marching without additional load (MNL), marching with additional load (MWL) and running, at two different environmental conditions: Thermoneutral (±22 ºC and ±40%rh) and Thermal Stress (±40 ºC and ±30%rh).

An improvement in the individual's performance in terms of Core temperature, HR, VO2, as also for the perceived exertion were observed, mainly for the MNL and MWL protocols performed in thermoneutral condition after acclimation and in some cases, in the Running protocol at the thermoneutral and thermal stress condition.

Despite the improvement observed in the performance based on the parameters studied, future studies are needed in order to obtain strong evidences about the efficiency of the acclimation process applied in this experiment.

Keywords: Acclimation, Thermoneutral, Thermal stress, Heat Stress, Thermoregulation, Physiology, Core temperature, Heart Rate, VO_2max, Lactate, Dehydration, Perceived exertion.

TABLE OF CONTENTS

LIST OF GRAPHICS

LIST OF TABLES

NOMENCLATURE

Abbreviation	Definition
AA	After Acclimation
BA	Before Acclimation
HE	Heat Exhaustion
MNL	Marching without additional load
MWL	Marching with additional load
NC	Thermoneutral Condition
SC	Thermal Stress Condition

1 INTRODUCTION

1.1 Scope

The aim of human temperature regulation is to protect body processes, by establishing a relative constancy of deep body temperature, in spite of external and internal influences on it (Werner, 2010).

Body heat may be transferred by 4 mechanisms: Conduction, Convection, Radiation, and Evaporation. When the body is at rest or exercising moderately in cooler temperatures, the majority of heat loss occurs through conduction, convection, and radiation. As environmental heat stress and exercise intensity increase, evaporation of sweat at the skin surface becomes the predominant mechanism for body heat dissipation. The hypothalamus triggers sweating and increased cutaneous blood flow upon detection of an elevation in core body temperature. (Pryor, Bennett, O'Connor, Young, & Asplund, 2015)

Problems due to heat stress may occur whenever the rate of heat production or heat gain from the environment is sufficiently large in relation to the body's ability to dissipate heat. (Sonna, 2012) As a result, anyone subject to such condition may experience what is called "Heat exhaustion" (further ahead mentioned as HE),that is characterized by hypotension and cardiovascular insufficiency in persons who become dehydrated while exercising in conditions of high environmental heat stress. Symptoms include nausea and vomiting, tachycardia, dizziness, muscle cramps, energy depletion, central fatigue, and syncope. Core body temperature may be elevated but to no higher than 40°C. HE is often difficult to differentiate clinically from the early stages of exertion heat stroke. (Nichols, 2014)

Extremely hot environments, i.e., temperatures above 35 ºC for living or above 32 ºC for working, are prevalent in various workplaces, such as steel mills, laundry facilities, glass and ceramic workplaces, deep mines, metallurgy manufacturing facilities, rubber foundries, and, as well in military facilities/operations that will be the focus of the entire article.(Shen & Zhu, 2015)

Most of the earth's hot regions are inhabited, and human physiology allows people to live and work successfully in very hot climates because they are acclimatized (physiologically adjusted to an environment, in nature) to heat.

However, military operations in a hot climate must confront problems of heat stress that differ substantially from those ordinarily faced by the local inhabitants. Military operations may involve troops who were not acclimatized to heat before their deployment, and local supplies of fresh water may be insufficient for the requirements of a large military force. Moreover, because of the demands of combat or other mission requirements, troops may have to perform physical exercise during the heat of the day, or at levels that exceed established guidelines for prevention of heat casualties. This can be aggravated by a need to perform some exercises when they do not have free access to drinking water. (Sonna, 2012)

Also, military uniform and equipment are necessary components for the survivability and success of troops, but induce additional stress to the soldier working in warm climates. (Lee et al., 2012) During physical tasks, protective clothing causes a downward shift in the temperature at which heat strain occurs, resulting in an increased body core temperature, heart rate and sweat rate.

Thus, sustained high-intensity physical exercise; excessive thermal insulation due to body armor or protective clothing; or thermoregulatory impairment due to fever, drugs, or dehydration may create the conditions for heat-impaired performance or heat illness, even during cool weather on the health and performance of troops; thus, the overall impact on military operations is probably much greater than generally appreciated.(Sonna, 2012)

1.2 Effects of Acclimatization protocols in performance

When humans are repeatedly exposed to conditions that are sufficiently stressful to elicit profuse sweating and elevate skin and core temperature, adaptations develop that reduce the deleterious effects of heat stress: heat acclimation or acclimatization. Heat acclimation refers to repeated periods of heat exposure undertaken in artificial or laboratory settings, whereas heat acclimatization results from exposure to natural environments. Although both natural and artificial hot environments elicit similar physiological adaptations (Armstrong and Pandolf, 1988; Wenger, 1988), heat acclimatization provides more specific responses due to exposure to the exact conditions that will be encountered during exposure (i.e. exercise task, solar radiation and terrain/geography) (Périard et al., 2015a).

The major physiologic adjustments that occur during heat and humidity acclimation include:

1. Plasma volume expansion;
2. Improved cutaneous blood flow;
3. Lower threshold for initiation of sweating;
4. Increased sweat output;
5. Lower salt concentration in sweat;
6. Lower skin and core temperatures for a standard exercise;

These adaptations allow for better dissipation of heat during exercise and increases temperature limits in the body, compared with subjects who have not been acclimated. (Pryor et al., 2015)

1.3 Study objectives

Many studies have measured the incidence of heat casualties among military personnel in a training environment. The reported incidence of heat injury at basic military training facilities is typically about 5 to 8 cases per 10.000 troops per week. New recruits and reservists typically have the highest rates of heat injury; reservists appear to be at particularly high risk. (Sonna, 2012) By contrast, less is known about the incidence of heat illness during actual military operations. For this reason, it is necessary to reduce the risk that they are exposed to. Whether it is in training or in a real context. And for that, acclimation may be the answer.

Accordingly to Brake, Bates, Brake, & Bates (2016) it is difficult to have a simple, practical measure of (heat) acclimation. A robust protocol needs to be provided for this.

In order to better understand how the body reacts to different thermal conditions after being acclimated, this study presents a laboratory 6 case studies experiment in which military young males were physiological monitorized inside a climatic chamber during the performance of several physical tests, where environmental settings, activities and performed tasks during military training were recreated.

The main objective of this experimental study is to evaluate the influence of acclimation in the performance of military personnel exposed to different environmental conditions (Thermoneutral and Thermal stress), based on the collected physiological data. The duration of the state of acclimation and a possible state of non-acclimation was also noted.

2 MATERIAL AND METHODS

2.1 Subject/Sample

The tested subjects are Caucasian males, working for the Portuguese Army in the north region. In order to protect individual's identity, each of them will be referred in this study as M0X, where the "X" refers to his trial number.

From an initial sample of 9 subjects, 3 of them were excluded from the study due to different reasons: M03 did not endure the intensity of the exercise, complaining of physical pain although no medical reason was discovered, M04 contract with the military was terminated and M08 was excluded due to medical reasons.

Their ages are between 21-24 years old. They did not present cardiac, vascular, pulmonary, or any allergic medically diagnosed disease, being considered mentally healthy, without any kind of psychological disturbances by the military center of psychology. Regular medication use was not declared.

Accordingly to Helsinki Declaration, all participants gave informed consent prior to their inclusion in the study.

2.2 Test protocols

The protocols applied to the following case studies were defined together with Portuguese Army and tries to recreate the real environmental settings, activities and performed tasks during military training. It was performed inside a Climatic Chamber (Fitoclima 25000) and can be divided into three sub-protocols, occurring at two different environmental conditions:

1. A Thermo Neutral Condition test, in which air temperature was regulated to 22.0º ± 0.5ºC and relative humidity to 40 ± 2%, selected for this protocol based on the work of (Costa &Baptista, 2013).
2. A Thermal Stress Condition test, in which air temperature was regulated to 40.0 ± 0.5ºC and relative humidity to 30 ± 2% (defined to recreate the Afghanistan real environmental conditions).

For each of the conditions mentioned above, three tests (sub-protocols) were performed in a Treadmill Ergometer (General Electric T2100):

1. Marching without additional load;
2. Marching with additional load;
3. Running.

All the protocols and its subdivisions were recreated in two distinct acclimation scenarios. Initially, tests were performed in an acclimated condition of the subject to a thermal stress condition, the second when the subject was thought not to be acclimated. The acclimation process will be described further ahead.

To assure physical integrity of the subjects, some parameters were controlled before every experiment: water intake (shouldn't be less than 1.5 l), medication (any kind of analgesics, antipyretics or sleep deprivation that took less than 6 hours before), excess of alcohol or caffeine in the 12 hours prior the tests and spice food (Pryor et al., 2015). For example, medication and drug use can put users at increased risk of developing heat illness. Alcohol and some commonly used medications (diuretics, laxatives) can contribute to dehydration, increasing body temperature during exercise.

Other drugs may affect the subjects by either increasing heat production or compromising thermoregulation. (Dube, Imbeau, Dubeau, Lebel, & Kolus, 2016) (Wenger, 1997)

For a better understanding of the relationship between the variables involved, is presented a summary table (Table 1) with the sub-protocols conducted for this case study.

Table 1 - Summary of the sub-protocol conducted for this case study

State of Acclimation	**Sub-protocol**	**Thermal Condition**
After Acclimation	Marching Without Additional Load	22ºC 40% Hr
	Marching Without Additional Load	40ºC 30% Hr
	Marching With Additional Load	22ºC 40% Hr
	Marching With Additional Load	40ºC 30% Hr
	Running	22ºC 40% Hr
	Running	40ºC 30% Hr
Before Acclimation	Marching Without Additional Load	22ºC 40% Hr
	Marching Without Additional Load	40ºC 30% Hr
	Marching With Additional Load	22ºC 40% Hr
	Marching With Additional Load	40ºC 30% Hr
	Running	22ºC 40% Hr
	Running	40ºC 30% Hr

The tests took place in the months of May and June 2015.

2.2.1 Marching Without additional load Protocol

This sub-protocol, further ahead mentioned as “MNL”, consists of a sub-maximal intensity test, in which is intended to reach body overload by time exposure trough marching, without changing the effort intensity during the test.

In order to do so, the subjects, were only equipped with their uniform (consisting of a t-shirt, trousers and military boots) and would need to complete 3 stages. The first one consists of 20 minutes acclimatization to create a baseline point for the beginning of the test. After these 20 minutes, subject would perform an initial 3 minutes warm-up in the treadmill, set up for 4km.h^{-1}, only then, the subjects would perform the actual experiment with a maximum duration of 20 minutes at 6 km.h^{-1}.

To simulate real ground conditions, treadmill was adjusted to have 1% of inclination.

The perceived effort was estimated every 5 minutes using Borg's Scale.

2.2.2 *Marching With Additional Load Protocol*

The "Marching With Load" protocol, further ahead mentioned as "MWL", is in all similar to the previous sub protocol (MNL), but in this case, subjects would be equipped just like they would be on a field day or in a combat day. Besides the normal uniform they would be carrying a backpack (with the following items: tent, sleeping bag, alternative uniforms, meals, etc.) as well as belt with canteen, chargers and his weapon, creating a total load of about 29.20kg.

2.2.3 *Running Protocol*

This is an incremental protocol that intends to access the maximum oxygen uptake ($VO_{2\ max}$), which, as described in the literature, is an indicator of aerobic power and physical condition of a given person.

Based on the studies of (Boulay, Simoneau, Lortie, & Bouchard, 1997), subjects would perform 3 different stages. First, a 5 minute warm-up at 8 $km.h^{-1}$, then, after a recovery period of 5 minutes walking at 4 $km.h^{-1}$ subjects would start the progressive continuous test on the treadmill until exhaustion. Starting from an initial 10 $km.h^{-1}$, with increments of 1 $km.h^{-1}$ every 2 minutes during the whole period of the test.

In this test protocol, treadmill was programmed to have 0% of inclination.

Contrarily to the previous protocols, this assay does not have a maximum length defined, and as mentioned above, subjects would perform the exercise until exhaustion, providing the indication to stop the test.

The perceived effort was estimated for each stage using Borg's Scale.

2.3 Acclimation Process

Heat acclimation refers to the gradual advancement of physiological adaptations to exercise in conditions of high environmental heat stress. The process occurs optimally over10–14 days of heat stress exposure exercise sessions that last at least 60–90 minutes per day (Nichols, 2014).

The acclimation process of the subjects for this protocol took place for 14 consecutive days. During this period, subjects remained in the climatic chamber at the

Thermal Stress Condition (40.0 ± 0.5ºC) and relative humidity (30 ± 2%) designed for this study for 3 hours per day without performing any physical effort.

Throughout the article, the acclimation condition of the subjects will be referred to as “After Acclimation”, and its opposite as “Before acclimation”, both mentioned further ahead as “AA” and “BA” respectively.

2.4 Physiological monitoring

During all experimental protocols subjects were monitored in real time through the parameters that are set out in the following points:

2.4.1 Core temperature

One of the best performance/fatigue identifiers is the core temperature, in particular, when the individuals are exposed to high temperatures. So, the monitorization of this parameter is one of the best methods to minimize the risk of heat damage (Goodman et al., 2009, Byrne & Lim 2007). This kind of monitorization has been applied in different studies either in the laboratory or in the real world, especially among athletes, students and military forces.

Core Temperature (Mentioned Further ahead as “CT”) was monitored with resource to core temperature-sensing pills (8.7 mm diameter by 23 mm length.) (EQ-01, Respironics Inc., Murrysville, PA, USA). It travels along the digestive track harmlessly and leaves the body naturally within 24 to 72 hours.

Each pill is individually calibrated during manufacture and can be set, in the field, to transmit within 15-second intervals, one minute after being activated externally by a specific device(EQ-01 Core Pill Activator, Hidalgo, Cambridgeshire, UK). Data are sent by telemetry, with a precision of 0.01ºC for the recording system through the Equivital EQ02 Life monitor—Sensor Electronics Module (SEM), (Equivital^{TM} Life monitor, EQ02-SEM, Hidalgo, Cambridgeshire, UK) in real time, via Bluetooth.

These pills had to be swallowed 10 hours before the beginning of the experiment, and are not recovered.

After the activation of the pill, it begins to transmit a signal in which an ID code is generated. All ID of the administered pills were recorded for further identification and connection with protocols made by the subjects.

Gastrointestinal temperature is considered to be more closely related to rectal temperature than to esophageal temperature and, therefore, is likely to be about 0.5ºC below the temperature of blood leaving the heart and defusing through the body core.(Low et al., 2007) The rectum is well insulated from the environment, so rectal temperature is independent of environmental temperature and is the most reliable clinical index of body temperature, and has also the advantage of being directly comparable with numerous historical studies, which invariably measured core temperatures rectally.(Wenger, 1997)

2.4.2 Heart rate

Heart rate (Mentioned Further ahead as "HR") is a very cost effective non-invasive measure that can be easily and safely obtained over long working periods, and can be used as a replacement of VO_2 to estimate metabolic rate. (Dube et al., 2016) HR also provides an index of the degree of circulatory strain during exercise. (Golbabaei et al., 2014)

In this protocol, HR was obtained through the cardio pulmonary equipment K4-b2 (Cosmed, Rome Italy).

2.4.3 Pulmonary gas exchange

The maximal rate of oxygen consumption (VO_{2max}), also maximal oxygen consumption, maximal oxygen uptake, peak oxygen uptake, or maximal aerobic capacity, is one of the most commonly measured parameters in the basic and applied physiological sciences. The measure has a history dating back to 1923. VO_{2max} is the maximum capacity of an individual's body to transport through circulatory system and use oxygen in motor muscles. Nowadays, scientists believe that the ability to perform physical exercise should be determined using the aerobic capacity.(Habibi, Dehghan, Moghiseh, & Hasanzadeh, 2014), (BYUNG-KON YOON, LEN KRAVITZ, 1983)

In this protocol, pulmonary Gas Exchange was measurement with a breath-by-breath analysis (VO_2, VCO_2) obtained using the cardio pulmonary equipment from K4-b2 (Cosmed, Rome Italy).

2.4.4 Lactate concentration

The concentration of Lactate in capillary blood was measured by collecting a sample (approximately 0.3µl) from subject's right earlobe right after the ceasing of exercise, at 3rd, 5th and 7th minutes. At the 10th minute, another sample would be collected if the values had not decrease by then. To accomplish that, Lactate Pro (Lactate Pro, Arkray, Kyoto, Japan) was used.

The lactate as a physiological marker has been used as an important tool to control the intensity of aerobic exercise. It is not that the lactate molecule by itself that causes fatigue, but its accumulation in the blood reflects an increase in the anaerobic metabolism and/or a decrease in the mechanisms responsible for lactate removal, causing the loss of an equilibrium state in the body.(Caputo, Fernandes, Oliveira, & Greco, 2009)

2.4.5 Dehydration

When exposed to heat stress, the maintenance of an individual's hydration status is essential to preserve exercise capacity and reduce the risk of heat illness, because fluid loss is associated with a core body temperature increase, and therefore a less efficient thermoregulation.(Nichols, 2014)

Dehydration due to water mass loss was calculated through the weight difference before and after each test, using a 50g precision scale from SECA (Hamburg, Deutschland).

2.4.6 Borg Rate of Perceived Exertion

In order to measure the level of subjective physical workload, the RPE scale proposed by Borg is very useful, which is a rating scale, and rating scales are important supplemental measures of psycho - physical performance and work capacity. (Habibi et al., 2014)

2.4.7 Climatic Chamber

As previously stated, the tests were performed inside a Climatic Chamber, (FITOCLIMA 25000EC20), built according EC standards and directives relating to health and safety requirements. This chamber allows simulating the exposure to thermal environments of very different workplaces.

The temperature inside the chamber can be controlled between –20 °C to +50 °C and the humidity from 30% to 98%. The chamber is also equipped with O_2 and CO_2 sensors, and has been validated for human trials (Guedes et al., 2012).

2.5 Stopping criteria

In order to ensure the physical integrity of the subjects, stopping criteria were created for all protocols, and, during real-time monitoring, if only one of these were achieved, the test would be stopped immediately.

These were:

1. Core temperature above 38.5ºC (Costa et al., 2012) (Richmond, Davey, Griggs, & Havenith, 2015), the need for a heat stress index led to the development of the thermal work limit (TWL). Defined as the limiting (or maximum) sustainable metabolic rate that euhydrated, acclimatized individuals can maintain in a specific hermal environment within safe limits of body core temperature.(Brake et al., 2016)
2. Heart rate beyond a value, given by a formula (HR_{max} = 220 – age of them subject) commonly used in sports experimental protocols, which in this case, was 196 bpm (HR_{max} = 220 – 24). (Bruijns, Guly, Bouamra, Lecky, & Lee, 2013)
3. Respiratory coefficient higher than 1.10. (Teixeira, Grossl, Lucas, Guilherme, & Guglielmo, 1980)

3 RESULTS

The subject M06 was considered separately from the others because of a huge mass loss that he put himself through from one year of experiment to another. Bearing this in mind, all of his tests were performed again, during May-June, 2015. However, due to calendar limitations, he went through the acclimation process and less than one month later he performed the “before acclimation” tests, this fact will be taken into account later in the discussion of the results.

Due to the repetition of all the data related to subject M06, all this investigation will focus on the data obtained for this military. For all the others, only the main results obtained will be presented and discussed.

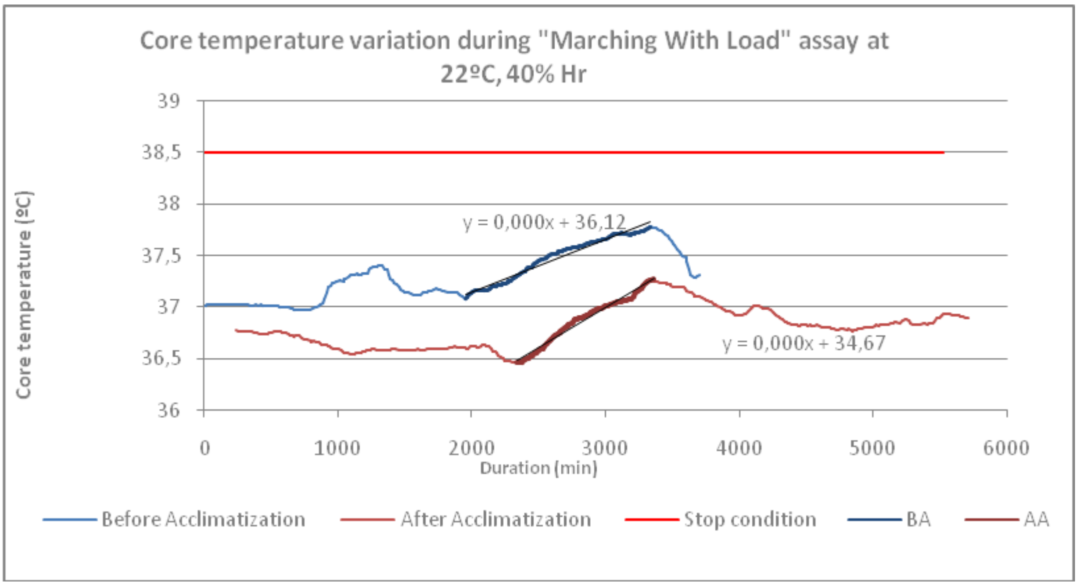
3.1 Subject M06

3.1.1 Core temperature

In order to draw conclusions from the obtained data by monitoring the internal temperature, all available data recorded from the core pills were exported and treated. The results (as it can be seen in the example below – Graphic 1) were drawn in the graphic form, in which, for each protocol, the results of Before and After Acclimation were put together for a better comparison of his evolution.

As mentioned before, all the protocols applied in this case study presented several steps that had to be supplemented in order to perform the desired exercise. Once the equipment registered all activity performed during these steps, it became necessary to identify the actual exercise period. To do this, the curves were synchronized after the identification of the basal state of the subject (experiment beginning) and the highest temperature reached during the test, knowing that this was not indicative of the end of the test, but the moment immediately after the end of it. For each one of the curves, those selected data were identified with a distinct color.

In the Graphic 1 is presented the behavior of the core temperature variation during the Marching With additional Load (MWL) protocol on a Thermoneutral Condition, Before and After the Acclimation.



Graphic 1 - Core temperature variation during "Marching with additional Load" assay at 22ºC, 40% Hr – Study Case M06

It is possible to observe that there is a distinct evolution of the subject core temperature during the protocols performed before and after acclimation. Before the acclimation (BA), temperatures were always higher than the temperatures obtained on the AA condition, for the same test period. In the same graphic it is also possible to observe the indicator line for the stopping criteria of this type of monitoring (38.5ºC).

On Table 2, a summary of each test performed is presented. Due to equipment failure, initial temperature data could not be retrieved from the “Running” Protocol in the Thermoneutral Condition, After Acclimation.

Table 2 - Core Temperature Summary – Case Study M06

		Thermoneutral Condition		**Thermal Stress Condition**	
		Initial Core Temperature **(ºC)**	Maximum Core Temperature **(ºC)**	Initial Core Temperature **(ºC)**	Maximum Core Temperature **(ºC)**
Marching Without Additional Load	BA	36,98	37,54	36,58	37,66
	AA	36,76	37,39	37,24	37,89
Marching With Additional Load	BA	37,08	37,78	36,72	38,16
	AA	36,46	37,27	36,88	38,04
Running	BA	36,85	38,02	37,16	38,42
	AA	---	38,06	37,32	39,01
BA - Before Acclimation; AA - After Acclimation					

By analyzing the mentioned table, from a general point of view of the obtained data, it is possible to state that temperatures reached higher values for Thermal Stress Condition tests, than they did in Thermoneutral Condition ones.

Maximum temperatures for Marching protocols were never below 37°C and in the Running protocols, never below 38ºC, showing only minor differences between Before and After the Acclimation.

In general, throughout the tests, it is possible to observe a decrease of the maximum temperature achieved, when compared the same sub protocols, performed Before or After Acclimation, observing lower maximum temperatures in the tests performed in the AA state, with the exception of the running protocol on both temperature conditions, wherein the maximum temperature reached was higher AA. Thus there has been an improvement in performance after adaptation, once the subject was able to perform the same test with lower internal temperature.

The protocol that had showed higher maximum temperatures was the running protocol for both temperature conditions. It also presented a greater variation between the initial and maximum temperature for stress condition, having reached a maximum temperature of 39.01ºC. This value was not obtained during the course of the test, but after its ceasing. As mentioned earlier, one of the safety criteria for the protocols was that the internal temperature would not exceed 38.5ºC. In this particular case, the test was aborted when this value has been reached, and the maximum value shown was obtained at rest as a body response to the exercise performed.

However, in all the observed cases, the differences in the temperatures are very low.

In order to understand how the subject´s organism would react if exposed to the same conditions for longer periods of time, from each test, obtained curves were adjusted to linear models, as it can be seen on Table 3.

From these mathematical expressions, gradients were calculated and converted from degrees per second to degrees per hour. (Table 4)

Table 3 - Mathematical expressions from the obtained curves – Study Case M06

		Thermoneutral Condition	**Thermal Stress Condition**
Marching Without Additional Load	BA	y = 0.0005x + 35.931	y = 0.0008x + 34.977
	AA	y = 0.0006x + 34.163	y = 0.0005x + 35.251
Marching With Additional Load	BA	y = 0.0005x + 35.945	y = 0.0011x + 34.061
	AA	y = 0.0008x + 34.561	y = 0.0008x + 35.093
Running	BA	y = 0.001 x + 34.667	y = 0.001x + 35.066
	AA	y = 0.0009x + 35.48	y = 0.0009x + 34.595
BA - Before Acclimation; AA - After Acclimation			

Table 4 - Obtained Gradients in Degrees per hour – Study Case M06

		Gradient (ºC / hour)	
		Thermoneutral Condition	**Thermal Stress Condition**
Marching Without Additional Load	BA	1,8	2,88
	AA	2,16	1,8
Marching With Additional Load	BA	1,8	3,96
	AA	2,88	2,88
Running	BA	3,6	3,6
	AA	3,24	3,24
BA - Before Acclimation; AA - After Acclimation			

Running protocols presented higher values, as well as the protocols performed in the Thermal Stress Conditions, where the highest gradient was observed (MWL - BA).

Through the data, mathematical simulations were performed for one and two hours of exposure to the same conditions. The results are shown in the table 5.

Table 5 - Mathematical simulations for the core temperature, considering the calculated gradients and initial temperatures – Study Case M06

		Thermoneutral Condition			**Thermal Stress Condition**		
		Initial Core Temperature **(ºC)**	1st Hour	2nd Hour	Initial Core Temperature **(ºC)**	1st Hour	2nd Hour
Marching Without Additional Load	BA	36,98	38,78	40,58	36,58	39,46	42,34
	AA	36,76	38,92	41,08	37,24	39,04	40,84
Marching With Additional Load	BA	37,08	38,88	40,68	36,72	40,68	44,64
	AA	36,46	39,34	42,22	36,88	39,76	42,64
Running	BA	36,85	40,45	44,05	37,16	40,76	44,36
	AA	---	---	---	37,32	40,56	43,8
BA - Before Acclimation; AA - After Acclimation							

Once again, Thermal Stress Condition showed the highest core temperature values, as well as the running protocol at this thermal condition.

However, the projections shown that in the Thermal Stress Condition temperatures reached After the Acclimation were below those achieved Before the Acclimation.

Although these calculations are merely assumptions, at no given moment a body should be subjected to such conditions, once human body could not even handle many of the temperatures achieved at the end of the first hour of exposure.

3.1.2 Heart rate

The table 6 presents a summary for the heart rate data obtained in the different tests performed. Displayed values are the result of the average of every minute of exercise performed. The gradient value is a mean value, a result of the difference between the heart rhythm that occurred at the beginning of the test and the average of the last minute of exercise.

Table 6 - Summary of the main results of the Heart Rate parameter – Study Case M06

		Thermoneutral Condition			**Thermal Stress Condition**		
		Initial Heart Rate **(bpm)**	Final Heart Rate **(bpm)**	Heart Rate Increase **(bpm)**	Initial Heart Rate **(bpm)**	Final Heart Rate **(bpm)**	Heart Rate Increase **(bpm)**
Marching Without Additional Load	BA	71	105	34	69	113	44
	AA	---	---	---	76	135	59
Marching With Additional Load	BA	67	127	60	72	151	79
	AA	70	125	55	84	152	68
Running	BA	71	171	100	73	175	102
	AA	79	181	102	---	---	---
BA - Before Acclimation; AA - After Acclimation							

Due to equipment malfunctioning no data were obtained from the MNL AA test performed at the Thermoneutral condition, as well as the Running AA test performed at the Thermal Stress condition.

Through a table analysis, it is noted that the heart rate react differently between different temperature conditions, with higher values for the tests performed at the Thermal Stress Condition.

In terms of acclimation there was a reduction of the gradient for the MWL protocol in the tests carried out AA, however, the analysis performed to the remaining available data, shown that the same was not verified, particularly for “Running” protocol at the Thermoneutral condition, and MNL at Thermal stress Condition, in which, there was an increase in the gradient to the AA condition

In order to evaluate a possible relationship between the variation of temperature with the variation in the cardiac rhythm, the data related to these were placed side by side with the data obtained for the core temperature.

The treatment given to the mentioned data was transversal to all tests.

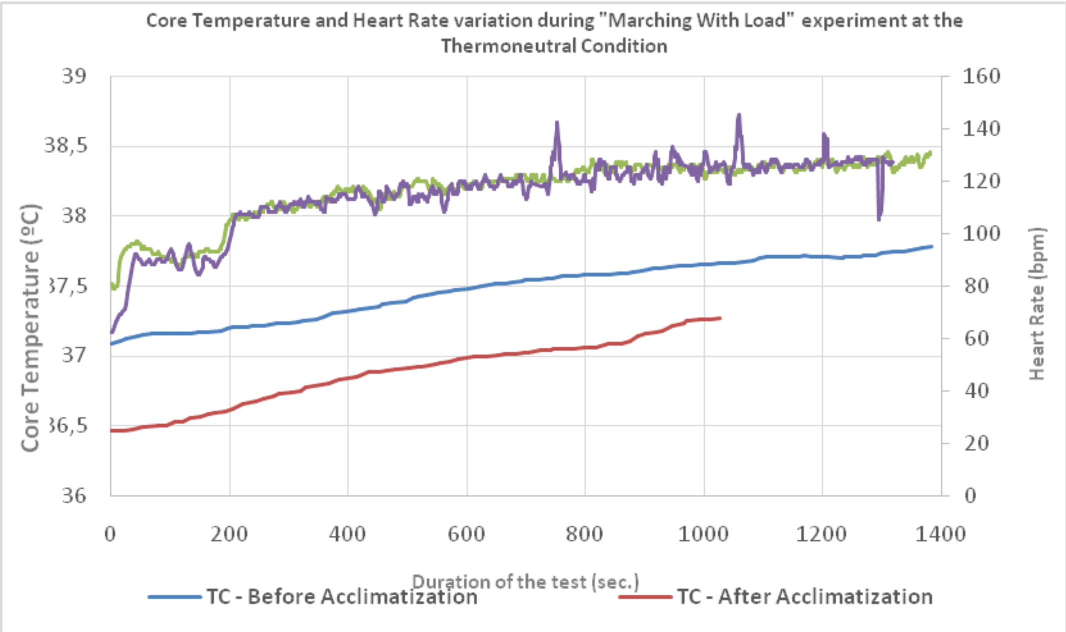
An example can be seen in Graphic 2.

The graphic 2 is relative to the MWL protocol for Thermoneutral condition (the same as presented in this article for the CT data).

In this, it is possible to observe that the variation of heart rate followed the variation of the temperature. Tests performed BA began with higher values of TC and HR when compared to the initial values of the AA condition, having increased throughout the performance of the exercise.

However, only there is a very slight difference in heart rhythm reached in the tests.

It is also possible to observe that for the AA condition, the test started at a lower HR value and despite being less constant throughout the test time, accompanied by some variations (possible higher effort), in general, the rate heart was lower than that observed for BA condition.



Graphic 2 - Heart rate and core temperature variation during MWL protocol at the Thermoneutral condition - Study Case M06

3.1.3 Maximum Oxygen Uptake

The following graphic (Graphic 3) is related with Oxygen Consumption, measured during the course of the experimental sub-protocol “Running”, at the Thermo neutral Condition.

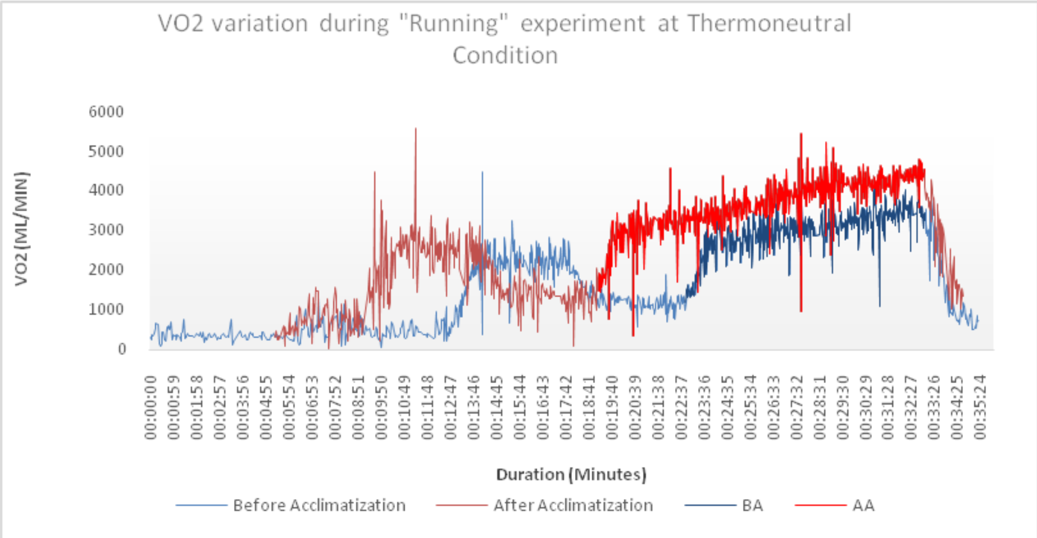
In the mentioned graphic it is apparent that oxygen consumption was greater in the test carried out AA. However it is noteworthy that despite being conducted at the same temperature, the duration of the test was not the same. In this example, there was a performance improvement, explained by the decrease in O_2 consumption. On top of that, there was also an improvement concerning test duration, once for the same conditions, the subject withstood the exercise for a longer period of time. It is noted that for the “Running” protocol did not exist a predefined duration of the exercise. The subject would stop the test whenever he felt exhausted.

This graphic was chosen as an example amongst others, since it is possible to observe with some clarity the body's response to the different steps of the "Running" protocol designed for this project. As mentioned above, 5 minutes heating were considered at 8 km h^{-1}, followed by a recovery period of about 5 minutes. For a better visualization in the graph, are indicated in the Table 8 the minutes in which each step was performed.

Just like for the parameters discussed in the preceding paragraphs, the data of all protocols performed regarding the oxygen consumption were synthesized in the table 7.

Table 7 - Summary of the average and maximal VO_2 consumption for each protocol – Study Case M06

		Thermoneutral Condition	**Thermal Stress Condition**
		Average VO2 **(ml/min/Kg)**	Average VO2 **(ml/min/Kg)**
Marching Without Additional Load	BA	19,445	19,496
	AA	19,113	22,408
Marching With Additional Load	BA	24,990	27,485
	AA	20,734	30,728
		VO2 Max. **(ml/min/kg)**	VO2 Max. **(ml/min/Kg)**
Running	BA	41,937	44,331
	AA	52,995	50,902
BA - Before Acclimation; AA - After Acclimation			



Graphic 3 - Oxygen consumption for Running protocol at the Themoneutral condition - Study Case M06

Table 8 - Identification of warm-up and recovery periods visualized in Graphic 3 - Study Case M06

	Warm-up (minutes)	Recovery (minutes)
BA	12:57-17:53	17:53-22:00
AA	09:04-14:44	14:44-19:16

For the running protocols, the data related with the initial value of oxygen consumption have been identified, as well as the average of all the O_2 consumption values obtained during the test period. For the "Running" protocol the initial value of VO_2 has been identified and the VO_{2max} was calculated. To do this, and according to Edwards (2013), the data collected for this trial period were divided into intervals of 1 minute, for which the respective averages were calculate, extracting the higher value among these.

For the “Marching” protocols at the Thermoneutral Condition is observed a decrease in the average O_2 consumption in the test performed AA. The same is not observable in the Thermal stress Condition in which the mean values increased for AA.

Overall it is evident the difference between the initial values and average consumption of O_2 for the “Marching” protocols when the Themoneutral condition is compared with the Thermal stress Condition, showing this last one higher values.

For the VO_{2max}, when viewed separately for each temperature condition, it is observed for AA condition values higher than BA, meaning therefore that the VO_2 consumption was higher.

However, when comparing the “Running” protocol between different temperature conditions, it is observed that the value of VO_{2max} at the Thermal Stress condition is higher for the BA condition, and lower relatively to the AA condition.

3.1.4 Lactate

In the Table 9 are presented in a summary form the lactate values obtained in accordance with the procedure mentioned earlier. The peak value for each test was also identified, as well as the time it was obtained.

Table 9 - Summary of the Lactate concentration for each experiment – Study Case M06

			Lactate concentration (mml/L)				**Max. lactate concentration (mml/L)**
			0'	**3'**	**5'**	**7'**	
BA	**Marching Without Additional Load**	NC	1,7	1,1	0,9	0,9	1,7
		SC	1,1	1,1	1	1	1,1
	Marching With Additional Load	NC	1,7	0,8	---	0,8	1,7
		SC	1,3	1,2	1,1	1,1	1,3
	Running	NC	2,5	2	2	1,6	2,5
		SC	1,1	3,1	3	2,8	3,1
AA	**Marching Without Additional Load**	NC	1,2	---	0,7	0,6	1,2
		SC	1,2	1,3	1,4	1,4	1,4
	Marching With Additional Load	NC	1	1	0,7	0,6	1
		SC	1,3	1,3	1,2	1,2	1,3
	Running	NC	1,2	5,9	6,1	4,6	6,1
		SC	1,3	3,8	3,5	3,2	3,8
NC - Thermoneutral Condition; SC - Thermal Stress Condition							

By analyzing the results, it is possible to observe lower lactate values in AA Marching protocols in relation to BA Marching protocols for the Thermo neutral Condition. With the exception of the “Running” protocol, in which the values were higher for the AA condition regarding the BA condition.

For the Thermal Stress Condition the opposite is observed, since that the lactate values obtained were always higher in the AA tests performed, both in the “Marching" protocols as in the “Running” protocol.

By comparison of the temperature condition it is possible to observe a general increase of the lactate concentration in the “Marching” protocols for the Thermal Stress Condition.

The highest blood lactate values were always measured in running protocols, being the AA values greater than BA.

In general, the peak values were obtained in the first 3 minutes after the end of the exercise, not being necessary to perform a lactate measurement within the 10th min. after the end of exercise at any of the performed tests.

For the 3rd minute of sampling, of the MNL at the Thermo neutral condition performed AA no value is available

3.1.5 **Body mass loss**

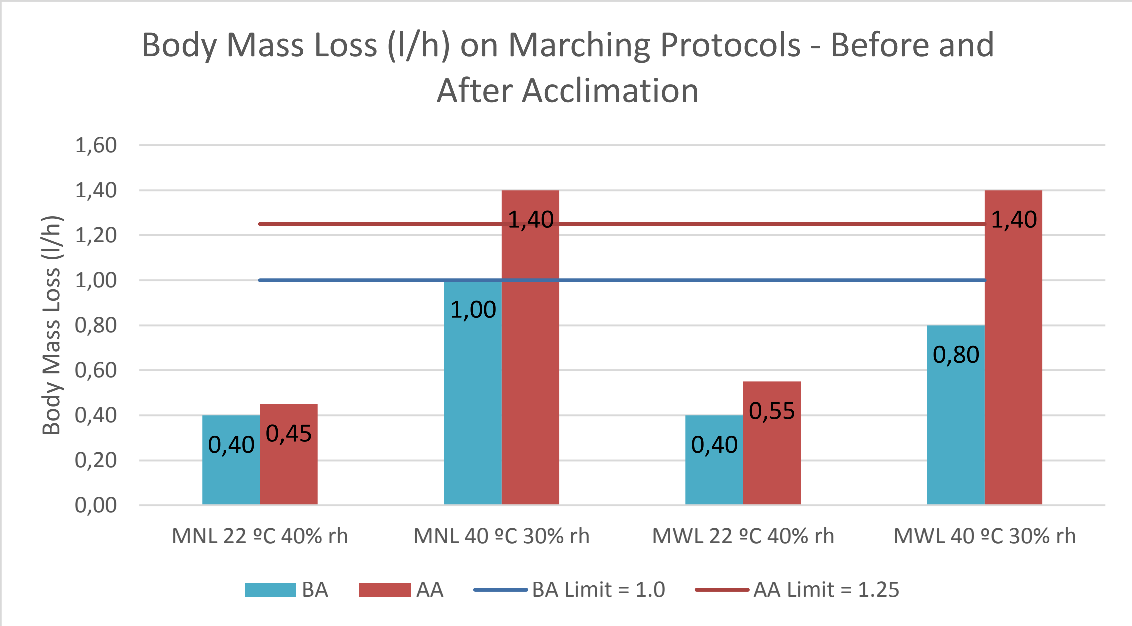
As mentioned before, a weighing of individuals was performed at the beginning and end of the test. With this data, body mass loss was calculated by 2 different methods (liters / hour and percentage of body mass loss), in order to obtain comparable data with the guidance provided by ISO 9886-2004.

In the referred normative reference there are recommended values of body mass loss for a normal operation of 8 hours per day / 40 hours per week. The sweat rate should be limited to 1.0 l/h for non-acclimatized subjects and to 1.25 l/h for acclimatized subjects. Taking this into consideration, the obtained results are showed in the charts (Graphic 4 and 5).

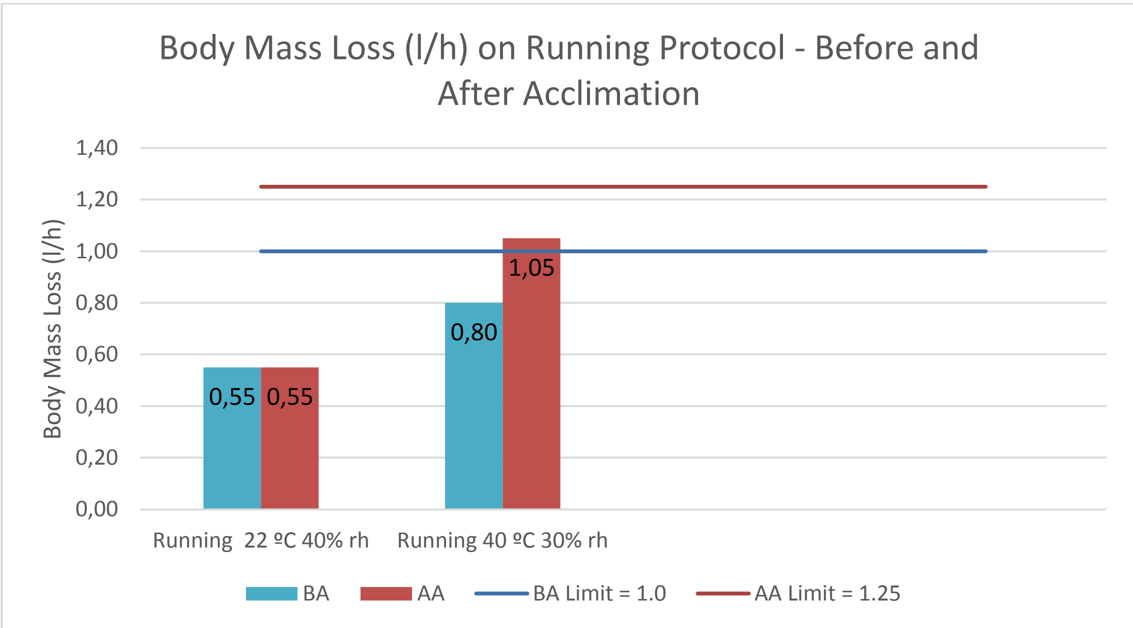
Graphic 4 shows body weight loss obtained in “Marching” protocols. It is evident a greater loss of mass in the protocols performed in the Thermal Stress Condition. However, the greater body weight loss was observed in tests of the MNL in both environmental condition, when an increased loss in the MWL protocol for this same temperature condition would be expected.

In terms of acclimatization, the weight loss was higher in all tests performed AA.

In relation to recommended values, only for the MNL protocol at the thermal stress condition performed AA the recommended value was exceeded (AA limit = 1.25).



Graphic 4 - Body Mass Loss in liters per hour on marching protocols - Study Case M06



Graphic 5 - Body Mass Loss in liters per hour on running protocols - Study Case M06

For "Running" protocols it no changes were observed in body mass loss in AA tests at the Thermoneutral condition regarding the BA condition. For the Thermal Stress Condition the mass lost AA exceeded the BA value.

For this protocol the recommended values were not exceeded.

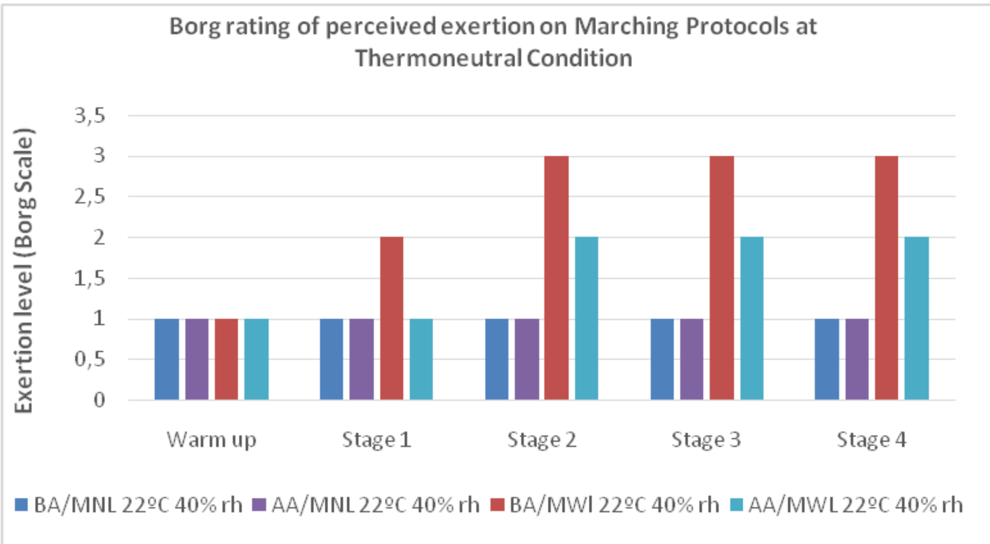
Table 10 shows a summary of body mass loss in all performed sub-protocols.

Table 10 - Summary Body Mass Loss calculated through percentage and liters per hour – Case Study M06

Acclimation State	Protocol	Initial Weigh (Kg)	Final Weight (Kg)	Difference (l)	Test duration (min)	Body mass Loss (l/hour)	% of Body mass Loss (%)
BA	MNL 22ºC 40% rh	83,100	82,700	0,4	24,150	0.36	0.25
	MWL 22ºC 40% rh	82,150	81,750	0,4	23,033	0.51	0.35
	Running 22ºC 40% rh	82,250	81,700	0,55	10,200	0.74	0.50
	MNL 40ºC 30% rh	83,100	82,100	1	24,933	1.32	0.90
	MWL 40ºC 30% rh	81,450	80,650	0,8	23,983	1.91	1.30
	Running 40ºC 30% rh	82,800	82,000	0,8	9,933	1061	1.10
AA	MNL 40ºC 30% rh	83,300	81,900	1,4	23,150	0.65	0.45
	Running 40ºC 30% rh	83,300	82,250	1,05	10,950	0.85	0.60
	MWL 40ºC 30% rh	85,800	84,400	1,4	24,333	0.72	0.50
	MNL 22ºC 40% rh	83,750	83,300	0,45	24,400	1.58	1.10
	MWL 22ºC 40% rh	84,100	83,550	0,55	17,067	1.40	0.97
	Running 22ºC 40% rh	82,950	82,400	0,55	13,883	1.99	1.40
BA - Before Acclimation; AA - After Acclimation							

3.1.6 *Borg Rating of Perceived Exertion*

As shown in the following chart (Graphic 6), for the "Marching With no Load" protocol at the Termoneutral condition, subject haven't reported any increase in perception of effort throughout the stages at different conditions of acclimation.

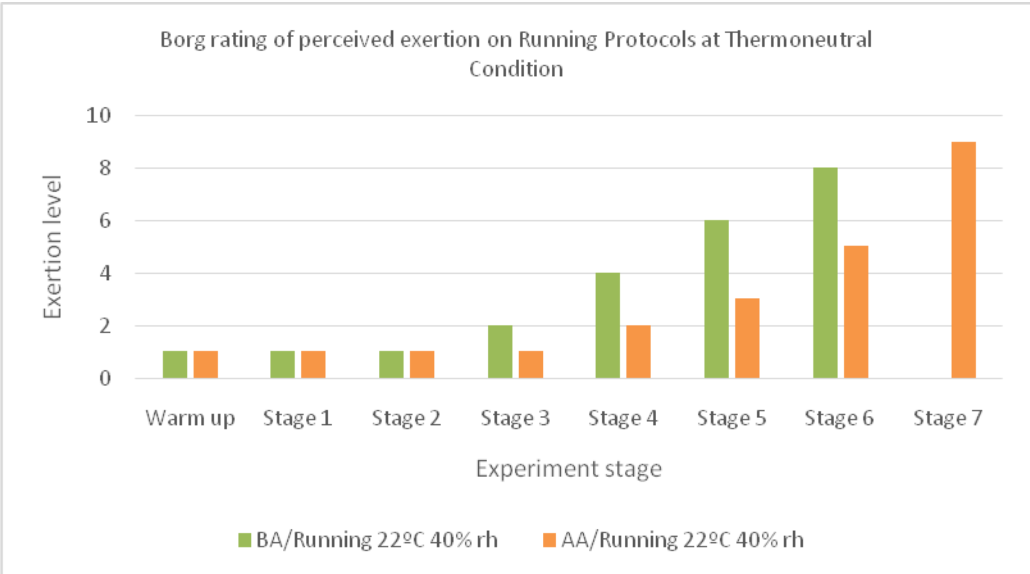


Graphic 6 - RPE of Marching protocols at Thermoneutral Condition - Study Case M06

He only reported differences in effort perception for the sub protocol "Marching with Load", and, according to the Borg's scale, the individual felt more effort at the BA test. However, it only occurred an increase from Stage 1 till Stage 2, having remained constant in the following steps for both conditions of acclimation.

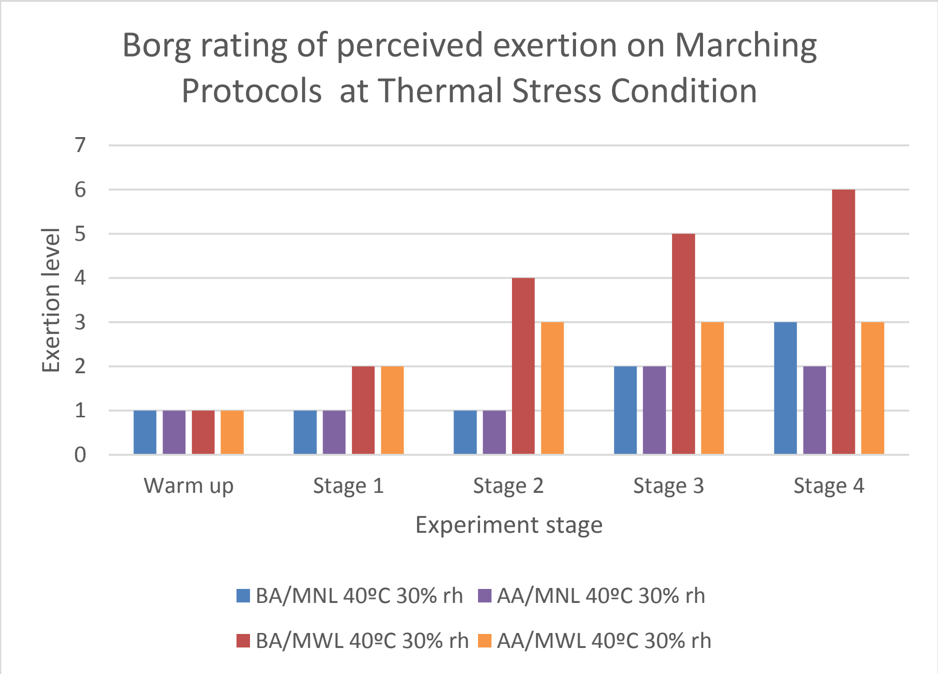
In the "Running" protocol, the perception of effort for tests carried out before and after acclimation was similar (level 1) till Stage 2. From there on, the perception of effort increased in a progressive manner. Also in this case there was a greater perception of effort for the test performed BA.

It was also noted that in the "Running Protocol" at the Termoneutral Condition after the Acclimation (AA), subject had performed more steps (has achieved an longer duration of the test) when compared with all conducted sub-protocols (Graphic 7).

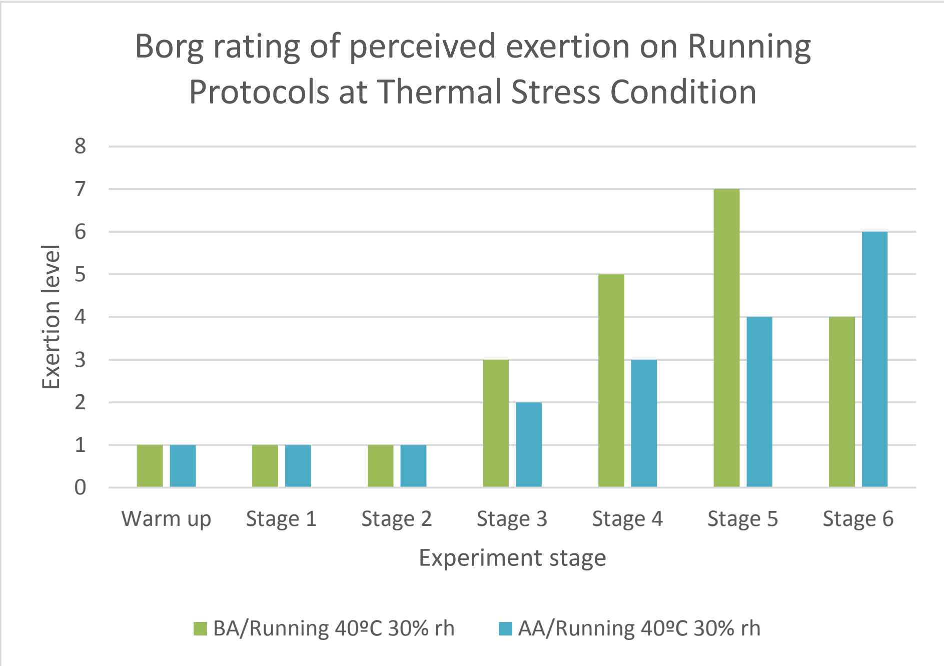


Graphic 7 – RPE of Running protocols at the Thermoneutral Condition - Study Case M06

The following graphics (Graphics 8 and 9) are related to the heat stress condition. For the Thermal Stress condition of "Marching with no load" protocols, the perception was the same (Borg = 1) for tests carried out before and after acclimatization until step 2. From there, the perception increased for the test conducted before acclimatization



Graphic 6 - RPE of Marching protocols at Thermal Stress Condition - Study Case M06



Graphic 7 - RPE of Running protocols at Thermal Stress Condition - Study Case M06

In the last step performed, there was a decrease in the perception of effort in the test performed AA, comparatively to the test performed BA.

For the “Marching With Load” protocol performed BA, the perception of effort have increased from the first stage, increasing gradually and steadily from Stage 2. For MWL AA test, despite having increased perception in Stage 2, it remained constant until the end of the test and always below the perception obtained for the same test condition on the BA test.

At the “Running” protocol, the perception of effort was in all similar to the Thermoneutral condition, verifying a higher perception of effort for the test performed BA.

Table 11 shows a summary of Borg´s perceived effort results for all the performed sub-protocols.

Table 11 - Summary o the RPE scale for every performed test – Study Case M06

Aclimation State	**Protocol**	**Borg Scale Perception**							
		Warm up	**Stage 1**	**Stage 2**	**Stage 3**	**Stage 4**	**Stage 5**	**Stage 6**	**Stage 7**
BA	MNL 22ºC 40% rh	1	1	1	1	1	---	---	---
	MWL 22ºC 40% rh	1	2	3	3	3	---	---	---
	Running 22ºC 40% rh	1	1	1	2	4	6	8	---
	MNL 40ºC 30% rh	1	1	1	2	3	---	---	---
	MWL 40ºC 30% rh	1	2	4	5	6	---	---	---
	Running 40ºC 30% rh	1	1	1	3	5	7	4	---
AA	MNL 40ºC 30% rh	1	1	1	2	2	---	---	---
	Running 40ºC 30% rh	1	1	1	2	3	4	6	---
	MWL 40ºC 30% rh	1	2	3	3	3	---	---	---
	MNL 22ºC 40% rh	1	1	1	1	1	---	---	---
	MWL 22ºC 40% rh	1	1	2	2	2	---	---	---
	Running 22ºC 40% rh	1	1	1	1	2	3	5	9

3.2 Subject M01

3.2.1 *Core temperature*

Accordingly to the procedures that were applied in the data treatment for M06, core temperature graphics were elaborated, using all available data. Then, for each test, a range of temperatures was identified, from basal state (experiment beginning) to maximum temperature (a little after test conclusion), in order to draw conclusions.

Table 12 summaries the main results for this parameter.

It is not possible to draw conclusions regarding the MWL protocols performed in both Thermal conditions, as well as for the MWL at the Thermoneutral condition.

In all other protocols, the maximum temperature reached was higher in the tests performed before acclimatization.

A peak of 39.03ºC at the Running protocol performed after the acclimation at the thermal stress condition was observed, which lead to the interruption of the test.

Table 12 - Core Temperature Summary – Case Study M01

		Thermoneutral Condition		**Thermal Stress Condition**	
		Initial Core Temperature (ºC)	Maximum Core Temperature (ºC)	Initial Core Temperature (ºC)	Maximum Core Temperature (ºC)
Marching Without Additional Load	BA	---	---	---	---
	AA	---	---	37,44	38,03
Marching With Additional Load	BA	37,39	38,12	36,96	38,17
	AA	---	---	37,14	38,17
Running	BA	36,73	37,70	37,42	38,52
	AA	---	---	37,22	39,03
BA - Before Acclimation; AA - After Acclimation					

3.2.2 *Heart Rate*

Table 13 presents a summary of the heart rate behavior of this military.

It is not possible to draw conclusions regarding the MNL protocol performed at the Thermoneutral condition, as well as for the MWL protocol performed at the thermal stress condition.

In terms of performance, subject showed an improvement in the heart rate increase at the MWL an running protocols performed at the thermoneutral condition, as in the MNL protocol performed ate the thermal stress condition. In witch, for these cases, the heart rate increase was lower at the tests performed after the acclimation process.

In the MWL protocol performed after the acclimation process at the thermal stress condition, the heart rate of the subject hit a 210 bpm peak, which was high above the considered maximum. In addition to the core temperature maximum, the test was stopped.

Table 13 - Summary of the main results of the Heart Rate parameter – Study Case M01

		Thermoneutral Condition			Thermal Stress Condition		
		Initial Heart Rate **(bpm)**	Final Heart Rate **(bpm)**	Heart rate increase during experiment **(bpm)**	Initial Heart Rate **(bpm)**	Final Heart Rate **(bpm)**	Heart rate increase during experiment **(bpm)**
Marching Without Additional Load	BA	69	119	50	---	---	---
	AA	---	---	---	96	152	56
Marching With Additional Load	BA	88	163	75	76	191	115
	AA	70	139	69	106	188	82
Running	BA	117	199	82	81	198	117
	AA	65	199	134	84	210	126
BA - Before Acclimation; AA - After Acclimation							

3.2.3 Maximum Oxygen Uptake

As well as for the M06, in order to analyze the maximum oxygen consumption of the subject, marching and running protocols had to be examined separately, as they have different calculation methodologies. Table 14 summarizes the main results for each experiment.

Table 14 - Summary of the average and maximal VO_2 consumption for each protocol – Study Case M01

		Average VO2 (**ml/min/Kg**)	
		Thermoneutral Condition	**Thermal Stress Condition**
Marching Without Additional Load	BA	24,033	22,287
	AA	22,564	25,649
Marching With Additional Load	BA	34,953	22,675
	AA	22,675	34,904
BA - Before Acclimation; AA - After Acclimation			

		VO2 Max. (**ml/min/Kg**)	
		Thermoneutral Condition	**Thermal Stress Condition**
Running	BA	43,16	42,693
	AA	51,868	59,011
BA - Before Acclimation; AA - After Acclimation			

An improvement in performance was only observed in the MNL protocol in the the thermal stress condition and at the MWL protocol performed in the thermoneutral condition.

3.2.4 Lactate

Lactate concentration values obtained for each experiment were put together in Table 15.

The peak lactate value increased for all protocols performed AA in the exception of the MWL protocol in the condition of thermal stress.

Table 15 - Summary of the Lactate concentration for each experiment – Study Case M01

			Lactate concentration (mml/L)				Max. lactate concentration (mml/L)
			0'	3'	5'	7'	
Thermoneutral Condition	Marching Without Additional Load	BA	1,1	---	---	---	1,1
		AA	1,3	0,7	0,6	0,6	1,3
	Marching With Additional Load	BA	1,3	---	1,3	1,4	1,4
		AA	0,9	1,5	1,4	1,2	1,5
	Running	BA	0,9	6,78	6,7	6,6	6,78
		AA	0,9	6,3	7,6	6,9	7,6
Thermal Stress Condition	Marching Without Additional Load	BA	0,9	1,6	1,3	---	1,6
		AA	3,1	1,6	2,5	1,4	3,1
	Marching With Additional Load	BA	0,8	2,4	2,2	2,1	2,4
		AA	1,3	1,7	1,9	1,6	1,9
	Running	BA	1,1	6,2	6	5,7	6,2
		AA	1,1	11,6	7,9	6,1	11,6
BA - Before Acclimation; AA - After Acclimation							

3.2.5 *Body Mass Loss*

The main results for each experiment, concerning the different calculations: body mass loss through percentage and liters per hour are sown at Table 16.

With the exceptions of the MWL protocol in the thermoneutral condition, and Running protocol athe Thermoneutral condition in all the ther protocols, BML (l/hour) was superior in the AA condition.

Table 16 - Summary Body Mass Loss calculated through percentage and liters per hour – Case Study M01

		Thermoneutral Condition	Thermal Stress Condition
		Body mass Loss (l/hour)	Body mass Loss (l/hour)
Marching Without Additional Load	BA	0,25	0,90
	AA	0,45	1,10
Marching With Additional Load	BA	0,35	1,30
	AA	0,60	0,97
Running	BA	0,50	1,10
	AA	0,50	1,40
BA - Before Acclimation; AA - After Acclimation			

3.2.6 Borg Rating of Perceived exertion

Table 17 - Summary o the RPE scale for every performed test – Study Case M01

<table>
<tr><th colspan="3"></th><th colspan="6">Borg's Scale of perceived exertion</th></tr>
<tr><th colspan="3"></th><th>Warm up</th><th>Stage 3</th><th>Stage 4</th><th>Stage 5</th><th>Stage 6</th><th>Stage 7</th></tr>
<tr><td rowspan="6">Thermoneutral Condition</td><td rowspan="2">Marching Without Additional Load</td><td>BA</td><td>1</td><td>3</td><td>3</td><td>---</td><td>---</td><td>---</td></tr>
<tr><td>AA</td><td>1</td><td>2</td><td>2</td><td>---</td><td>---</td><td>---</td></tr>
<tr><td rowspan="2">Marching With Additional Load</td><td>BA</td><td>1</td><td>---</td><td>---</td><td>---</td><td>---</td><td>---</td></tr>
<tr><td>AA</td><td>1</td><td>3</td><td>3</td><td>---</td><td>---</td><td>---</td></tr>
<tr><td rowspan="2">Running</td><td>BA</td><td>2</td><td>3</td><td>5</td><td>7</td><td>---</td><td>---</td></tr>
<tr><td>AA</td><td>1</td><td>2</td><td>3</td><td>5</td><td>7</td><td>---</td></tr>
<tr><td rowspan="6">Thermal Stress Condition</td><td rowspan="2">Marching Without Additional Load</td><td>BA</td><td>1</td><td>2</td><td>2</td><td>---</td><td>---</td><td>---</td></tr>
<tr><td>AA</td><td>4</td><td>3</td><td>3</td><td>---</td><td>---</td><td>---</td></tr>
<tr><td rowspan="2">Marching With Additional Load</td><td>BA</td><td>2</td><td>5</td><td>5</td><td>---</td><td>---</td><td>---</td></tr>
<tr><td>AA</td><td>3</td><td>7</td><td>7</td><td>---</td><td>---</td><td>---</td></tr>
<tr><td rowspan="2">Running</td><td>BA</td><td>1</td><td>3</td><td>5</td><td>7</td><td>---</td><td>---</td></tr>
<tr><td>AA</td><td>1</td><td>4</td><td>5</td><td>6</td><td>8</td><td>---</td></tr>
<tr><td colspan="9">BA - Before Acclimation; AA - After Acclimation</td></tr>
</table>

In all the performed protocols in the thermoneutral condition, the perception of effort was lower in the AA condition, and an extra step was reached for the running protocol in condition AA.

For the thermal stress condition in the Marching protocols, the perception was equal before and after acclimation and constant (= 1) during all steps. For the MWL protocol the effort perception was higher in the AA condition.

For running in the Thermal stress condition the perception of effort was lower in condition AA, having reached an extra step for the protocol of race in condition AA

3.3 Subject M02

3.3.1 Core temperature

Table 18 summarizes the main core temperature results obtained for the M02 subject.

Table 18 - Core Temperature Summary – Case Study M02

		Thermoneutral Condition		Thermal Stress Condition	
		Initial Core Temperature (**ºC**)	Maximum Core Temperature (**ºC**)	Initial Core Temperature (**ºC**)	Maximum Core Temperature (**ºC**)
Marching Without Additional Load	BA	---	---	---	---
	AA	---	---	---	---
Marching With Additional Load	BA	---	---	---	---
	AA	36,88	37,92	36,97	38,84
Running	BA	---	---	---	---
	AA	37,22	38,71	37,42	39,13
BA - Before Acclimation; AA - After Acclimation					

Due to lack of data, it is not possible to draw conclusions for any of the protocols performed. Because the subject met the stopping criterion at the MWL and running protocols performed AA, those tests were aborted.

3.3.2 Heart Rate

For the MNL and Running protocols at both environmental conditions, the HR increase was lower at the AA condition. For all the others, the increase was higher at the AA condition.

Table 19 - Summary of the main results of the Heart Rate parameter – Study Case M02

		Thermoneutral Condition			Thermal Stress Condition		
		Initial Heart Rate (**bpm**)	Final Heart Rate (**bpm**)	Heart rate increase during experiment (**bpm**)	Initial Heart Rate (**bpm**)	Final Heart Rate (**bpm**)	Heart rate increase during experiment (**bpm**)
Marching Without Additional Load	BA	79	125	46	85	132	47
	AA	73	105	32	85	128	43
Marching With Additional Load	BA	95	156	61	82	172	90
	AA	60	145	85	82	181	99
Running	BA	61	193	132	83	199	116
	AA	67	191	124	95	187	92

BA - Before Acclimation; AA - After Acclimation

3.3.3 Maximum Oxygen Uptake

In all protocols performed AA at the thermoneutral condition, the VO2 was lower. For the thermal stress condition was higher in all protocols performed AA

Table 20 - Summary of the average and maximal VO_2 consumption for each protocol – Study Case M02

		Average VO2 (**ml/min/Kg**)	
		Thermoneutral Condition	**Thermal Stress Condition**
Marching Without Additional Load	BA	28,854	24,230
	AA	23,238	25,786
Marching With Additional Load	BA	39,112	30,073
	AA	31,503	32,995
BA - Before Acclimation; AA - After Acclimation			

		VO2 Max. (**ml/min/Kg**)	
		Thermoneutral Condition	**Thermal Stress Condition**
Running	BA	66,897	64,421
	AA	62,321	67,878
BA - Before Acclimation; AA - After Acclimation			

3.3.4 Lactate

Running protocols in the thermoneutral condition had lower peak values in the AA condition. In the running protocol the peak value was higher in AA.

For the thermal stress condition, the MNL and Running protocol presented a decrease of the peak value in the AA condition. MWL showed an increase for this condition

All the obtained data are summarized on the table 21.

Table 21 - Summary of the Lactate concentration for each experiment – Study Case M02

			Lactate concentration (mml/L)				Max. lactate concentration (mml/L)
			0'	3'	5'	7'	
Thermoneutral Condition	Marching Without Additional Load	BA	1,4	---	---	---	1,4
		AA	1,3	1	1	1,1	1,3
	Marching With Additional Load	BA	1,8	---	---	---	1,8
		AA	1,6	1	1	0,9	1,6
	Running	BA	1,4	---	---	---	1,4
		AA	1,6	9	8,5	8,2	9
Thermal Stress Condition	Marching Without Additional Load	BA	1	1,5	1,8	1,3	1,8
		AA	1,5	1,7	1,6	1,6	1,7
	Marching With Additional Load	BA	1	1,9	1,7	1,6	1,9
		AA	1,7	2,2	2	1,9	2,2
	Running	BA	1,3	7,2	6,9	6,7	7,2
		AA	1,1	5,5	5,2	4,7	5,5
BA - Before Acclimation; AA - After Acclimation							

3.3.5 Body Mass Loss

Table 22 summarizes the Body Mass Loss calculated at all tests performed by subject M02.

Only in the protocols of Marching with and without additional load performed in the thermoneutral condition there was a decrease AA. In all other protocols, BML increased in the AA.

Table 22 - Summary Body Mass Loss calculated through percentage and liters per hour – Case Study M02

		Thermoneutral Condition		Thermal Stress Condition	
		% of Body mass Loss (%)	Body mass Loss (l/hour)	% of Body mass Loss (%)	Body mass Loss (l/hour)
Marching Without Additional Load	BA	0,99	0,75	0,13	---
	AA	0,50	0,40	1,14	0,90
Marching With Additional Load	BA	0,80	0,60	1,60	1,20
	AA	0,72	0,58	2,07	1,65
Running	BA	0,66	0,50	1,56	1,20
	AA	0,93	0,75	1,80	1,45
BA - Before Acclimation; AA - After Acclimation					

3.3.6 Borg Rating of Perceived exertion

Table 23 summarizes the effort perception data for all experiments.

Table 23 - Summary o the RPE scale for every performed test – Study Case M02

			Borg's Scale of perceived exertion							
			Warm up	**Stage 1**	**Stage 2**	**Stage 3**	**Stage 4**	**Stage 5**	**Stage 6**	**Stage 7**
Thermoneutral Condition	**Marching Without Additional Load**	BA	2	2	2	2	2	---	---	---
		AA	1	1	1	1	1	---	---	---
	Marching With Additional Load	BA	3	3	3	3	3	---	---	---
		AA	1	1	2	2	2	---	---	---
	Running	BA	1	1	2	3	3	4	7	---
		AA	1	1	1	2	2	3	3	4
Thermal Stress Condition	**Marching Without Additional Load**	BA	1	1	1	1	1	---	---	---
		AA	1	1	1	1	1	---	---	---
	Marching With Additional Load	BA	2	2	2	2	2	---	---	---
		AA	2	3	4	5	5	---	---	---
	Running	BA	1	1	1	2	3	4	---	---
		AA	1	1	1	1	2	4	7	---
BA - Before Acclimation; AA - After Acclimation										

In all protocols performed in the thermoneutral condition, the perception of effort was lower AA, and an extra step was reached for the running protocol performed AA.

For the thermal stress condition in the MNL protocol, the perception was equal before and after acclimation and constant (= 1) during all steps. For the MWL protocol the effort perception was higher in the AA condition.

For running protocol in the condition of thermal stresse it is not possible to draw conclusions since during the first 3 steps the perception was equal in both states of acclimation, being that in the following 2 stages the perception was smaller AA, returning to equalize in the Step 5. For the AA condition an extra step occurred with respect to the BA condition, so it is not possible to compare results.

3.4 Subject M05

3.4.1 Core temperature

The procedures for this parameter's data treatment were the same as the applied before. Table 24 summarizes the main results.

Table 24 - Core Temperature Summary – Case Study M05

		Thermoneutral Condition		**Thermal Stress Condition**	
		Initial Core Temperature (ºC)	Maximum Core Temperature (ºC)	Initial Core Temperature (ºC)	Maximum Core Temperature (ºC)
Marching Without Additional Load	BA	---	---	---	---
	AA	---	---	---	---
Marching With Additional Load	BA	---	---	---	---
	AA	---	---	37,48	39,27
Running	BA	---	---	37,86	39,22
	AA	---	---	---	---
BA - Before Acclimation; AA - After Acclimation					

Due to lack of data, it is not possible to draw conclusions for any of the protocols performed. Because the subject met the stopping criterion at the MWL performed AA and at the running protocol performed BA, those tests were aborted.

3.4.2 Heart Rate

With the exception of the MWL protocol at the thermoneutral condition, and running protocol at Thermal stress, in all the other protocols the HR increase was higher in condition AA

Table 25 - Summary of the main results of the Heart Rate parameter – Study Case M05

		Thermoneutral Condition			Thermal Stress Condition		
		Initial Heart Rate (**bpm**)	Final Heart Rate (**bpm**)	Heart rate increase during experiment (**bpm**)	Initial Heart Rate (**bpm**)	Final Heart Rate (**bpm**)	Heart rate increase during experiment (**bpm**)
Marching Without Additional Load	BA	81	128	47	105	149	44
	AA	---	---	---	89	154	65
Marching With Additional Load	BA	91	173	82	103	178	75
	AA	103	157	54	87	176	89
Running	BA	93	192	99	82	195	113
	AA	65	189	124	120	174	54
BA - Before Acclimation; AA - After Acclimation							

3.4.3 Maximum Oxygen Uptake

As well as for the M06, in order to analyze the maximum oxygen consumption of the subject, marching and running protocols had to be examined separately, as they have different calculation methodologies..

Table 26 summarize the main results for each experiment

Table 26 - Summary of the average and maximal VO_2 consumption for each protocol – Study Case M05

		Average VO_2 **(ml/min/Kg)**	
		Thermoneutral Condition	**Thermal Stress Condition**
Marching Without Additional Load	BA	25,933	21,603
	AA	16,960	22,665
Marching With Additional Load	BA	43,66	35,951
	AA	32,621	30,098
BA - Before Acclimation; AA - After Acclimation			

Only in the thermal stress MNL protocol the mean VO_2 was higher in AA. In all the others, there was a decrease in condition AA

		VO_2 Max. (**ml/min/Kg**)	
		Thermoneutral Condition	**Thermal Stress Condition**
Running	BA	56,084	46,205
	AA	52,728	52,757
BA - Before Acclimation; AA - After Acclimation			

The Maximum value of VO_2 decreased AA in the thermoneutral condition and increased in the stress condition.

3.4.4 *Lactate*

As lactate values were directly measured they were put together in Table 27 concerning each and every test.

Table 27 - Summary of the Lactate concentration for each experiment – Study Case M05

			Lactate concentration (mml/L)					**Max. lactate concentration (mml/L)**
			0'	**3'**	**5'**	**7'**	**10'**	
Thermoneutral Condition	**Marching Without Additional Load**	BA	1,1	---	---	---	---	1,1
		AA	1,9	1	1	0,8	---	1,9
	Marching With Additional Load	BA	1,8	4,8	2,4	2,7	3,8	4,8
		AA	1,2	2,8	2,3	2,2	---	2,8
	Running	BA	1,7	12	10,4	10,2	---	12
		AA	2,1	10,5	11,8	12,8	9,8	12,8
Thermal Stress Condition	**Marching Without Additional Load**	BA	1,9	---	---	---	---	1,9
		AA	1,3	1,4	1,2	1,5	1,3	1,5
	Marching With Additional Load	BA	1,4	5,1	4,3	4,4	---	5,1
		AA	0,9	4,4	5,1	4,9	---	5,1
	Running	BA	1,2	9	9,9	9,4	---	9,9
		AA	1,9	7,2	7,7	6,7	---	7,7
BA - Before Acclimation; AA - After Acclimation								

The peak lactate value in the thermoneutral condition only decreased in the testes performed AA for the MWL protocol. In the MNL and Running protocols, the peak lactate value increased.

For the stress condition, there was a decrease in the tests performed AA at the MNL and Running protocols. At MWl the peak lactate value increased.

3.4.5 *Body Mass Loss*

After collecting all the values, a table was organized with the main results for each experiment, concerning the different calculations: body mass loss through percentage and liters per hour, Table 29.

Table 28 - Summary Body Mass Loss calculated through percentage and liters per hour – Case Study M05

		Thermoneutral Condition		Thermal Stress Condition	
		% of Body mass Loss (%)	Body mass Loss (l/hour)	% of Body mass Loss (%)	Body mass Loss (l/hour)
Marching Without Additional Load	BA	0,00	0,35	2,26	1,60
	AA	0,22	0,15	1,26	0,85
Marching With Additional Load	BA	1,35	0,95	1,25	0,88
	AA	0,52	0,35	1,98	1,30
Running	BA	0,79	0,55	1,82	1,20
	AA	0,90	0,60	1,61	1,10
BA - Before Acclimation; AA - After Acclimation					

The MNL protocol presented a decrease of BML in the tests performed AA in both thermal conditions. Concerning MWL, this was only observed in the thermoneutral condition and at running in the stress condition.

3.4.6 Borg Rating of Perceived exertion

Table 29 summarizes the effort perception data for all experiments.

There was a lower perception of effort in the tests performed AA for the MNL and running protocols at the thermal stress condition, in which for running protocol an extra stage was obtained in the AA condition.

MWL presented an equal perception throughout all stages for both acclimatization conditions at the termoneutral environment.

MNL at thermal stress presented a higher effort perception in AA in the first 2 stages, being equal to BA in the following stages. The effort perception in MWL was lower in AA, and it presented 2 extra steps.

The perceived effort in running at thermal stress condition was lower AA with 2 extra steps relative to BA.

Table 29 - Summary o the RPE scale for every performed test – Study Case M05

			Borg's Scale of perceived exertion							
			Warm up	**Stage 1**	**Stage 2**	**Stage 3**	**Stage 4**	**Stage 5**	**Stage 6**	**Stage 7**
Thermoneutral Condition	**Marching Without Additional Load**	BA	1	2	2	2	2	---	---	---
		AA	1	1	1	1	1	---	---	---
	Marching With Additional Load	BA	2	3	4	4	4	---	---	---
		AA	1	2	2	3	3	---	---	---
	Running	BA	---	3	3	4	5	7	---	---
		AA	1	1	1	1	2	3	4	5
Thermal Stress Condition	**Marching Without Additional Load**	BA	2	2	2	2	2	---	---	---
		AA	1	1	2	2	2	---	---	---
	Marching With Additional Load	BA	2	4	---	---	---	---	---	---
		AA	4	7	10	---	---	---	---	---
	Running	BA	2	2	4	5	6	7	---	---
		AA	2	2	2	3	4	---	---	---
BA - Before Acclimation; AA - After Acclimation										

3.5 Subject M07

3.5.1 Core temperature

Table 30 summarizes the main core temperature results obtained by the M07 subject.

Table 30 - Core Temperature Summary – Case Study M07

		Thermoneutral Condition		Thermal Stress Condition	
		Initial Core Temperature (ºC)	Maximum Core Temperature (ºC)	Initial Core Temperature (ºC)	Maximum Core Temperature (ºC)
Marching Without Additional Load	BA	---	---	---	---
	AA	---	---	---	---
Marching With Additional Load	BA	37,64	38,31	37,12	38,05
	AA	36,89	37,81	37,01	38,22
Running	BA	36,93	37,96	37,1	38,06
	AA	37,08	38,42	37,15	38,46
BA - Before Acclimation; AA - After Acclimation					

Due to lack of data it is not possible to draw conclusions regarding the thermoneutral and thermal stress condition for MNL protocols.

With the exception of MWL protocol in the Thermoneutral condition, all protocols showed a maximum temperature in the tests performed AA.

3.5.2 Heart Rate

Table 31 summarizes the main results of HR obtained thought the tests performed by the M07 subject.

Table 31 - Summary of the main results of the Heart Rate parameter – Study Case M07

		Thermoneutral Condition			Thermal Stress Condition		
		Initial Heart Rate (**bpm**)	Final Heart Rate (**bpm**)	Heart rate increase during experiment (**bpm**)	Initial Heart Rate (**bpm**)	Final Heart Rate (**bpm**)	Heart rate increase during experiment (**bpm**)
Marching Without Additional Load	BA	87	135	48	106	143	37
	AA	79	103	24	66	133	67
Marching With Additional Load	BA	102	115	13	113	182	69
	AA	82	150	68	---	---	---
Running	BA	86	187	101	95	188	93
	AA	78	188	110	82	189	107
BA - Before Acclimation; AA - After Acclimation							

For the MWL protocol in the stress condition it is not possible to draw conclusions.

With the exception of the MWL protocol at the Thermoneutral condition, in all other protocols the increase of HR was higher in the tests performed AA.

3.5.3 Maximum Oxygen Uptake

Concerning this parameter, marching and running protocols must be examined separately, as they have different calculation methodologies. Table 23 summarizes the main results for each experiment.

Table 32 - Summary of the average and maximal VO_2 consumption for each protocol – Study Case M07

		Initial VO2 **(ml/min/Kg)**	
		Thermoneutral Condition	**Thermal Stress Condition**
Marching Without Additional Load	BA	22,944	---
	AA	21,559	---
Marching With Additional Load	BA	34,197	35,431
	AA	27,483	35,551
BA - Before Acclimation; AA - After Acclimation			

The MNL and MWL protocols performed in the thermoneutral condition showed decreases of the average VO2 in the tests performed AA.

For MNL in stress condition it is not possible to draw conclusions

The average VO_2 consumption increased in the MWL protocol at thermal stress condition in tests performed AA.

		VO2 Max. **(ml/min/Kg)**	
		Thermoneutral Condition	**Thermal Stress Condition**
Running	BA	46,136	42,078
	AA	56,557	59,462
BA - Before Acclimation; AA - After Acclimation			

The VO_2 Max. was higher in the tests performed AA for both environmental conditions.

3.5.4 Lactate

As lactate values were directly measured they were put together in Table 33 concerning each and every test.

Table 33 - Summary of the Lactate concentration for each experiment – Study Case M07

			Lactate concentration (mml/L)					Max. lactate concentration (mml/L)
			0'	3'	5'	7'	10'	
Thermoneutral Condition	Marching Without Additional Load	BA	1	0,8	0,9	0,9	---	1
		AA	1,1	0,7	0,7	0,6	---	1,1
	Marching With Additional Load	BA	1,1	1,6	1,3	1,5	---	1,6
		AA	1,4	0,9	0,9	0,9	---	1,4
	Running	BA	1	2	3,5	3,5	---	3,5
		AA	1,3	5,9	6,1	4,5	---	6,1
Thermal Stress Condition	Marching Without Additional Load	BA	1,2	1,7	1,8	1,9	1,5	1,9
		AA	1,5	1,6	1,3	1,3	---	1,6
	Marching With Additional Load	BA	1,6	2,6	2,5	2,5	---	2,6
		AA	1,8	2,4	5,8	2,6	---	5,8
	Running	BA	1,6	3,8	3,3	3,4	3,1	3,8
		AA	1,2	3,9	4,8	4,6	---	4,8
BA - Before Acclimation; AA - After Acclimation								

With the exception of the MWL at thermoneutral condition and MNL protocol at stress condition in all other tests, the peak lactate value was higher in the tests performed AA.

3.5.5 *Body Mass Loss*

The main results for each experiment, concerning the different calculations: body mass loss through percentage and liters per hour are sown at Table 34.

Table 34 - Summary Body Mass Loss calculated through percentage and liters per hour – Case Study M07

		Thermoneutral Condition		Thermal Stress Condition	
		% of Body mass Loss (%)	Body mass Loss (l/hour)	% of Body mass Loss (%)	Body mass Loss (l/hour)
Marching Without Additional Load	BA	0,32	0,20	1,65	1,03
	AA	0,16	0,10	1,57	1,00
Marching With Additional Load	BA	0,88	0,55	1,88	1,18
	AA	0,32	0,20	1,42	0,90
Running	BA	0,81	0,50	1,67	1,06
	AA	0,64	0,40	2,04	1,30
BA - Before Acclimation; AA - After Acclimation					

With the exception of the Running protocol at the thermal stress condition, in all the protocols performed BMl was lower in the tests performed AA

3.5.6 Borg Rating of Perceived exertion

Table 29 summarizes the effort perception data for all experiments performed by subject M07.

The perception of effort in the MNL protocol at Thermoneutral condition AA was lower in the last stage, having remained similar to the test performed BA in the previous ones. MWL at the termoneutral condition was lower AA in the first 2 stages, having remained equal to BA in the remaining stages.

Running protocol at Thermoneutral condition presented a lower perceived effort, with an additional stage in relation to the test performed BA.

The marching protocols in the stress condition showed similar effort perceptions in the tests performed BA and AA. The perception was lower for MWL AA with 2 extra stages compared to BA.

The running protocol in the stress condition presented a lower effort perception AA with an additional stage relative to BA

Table 35 - Summary of the RPE scale for every performed test – Study Case M07

			Borg's Scale of perceived exertion							
			Warm up	**Stage 1**	**Stage 2**	**Stage 3**	**Stage 4**	**Stage 5**	**Stage 6**	**Stage 7**
Thermoneutral Condition	**Marching Without Additional Load**	BA	2	2	3	3	3	---	---	---
		AA	1	1	1	1	1	---	---	---
	Marching With Additional Load	BA	3	4	5	5	7	---	---	---
		AA	1	3	4	5	5	---	---	---
	Running	BA	2	2	3	4	5	10	---	---
		AA	1	1	1	2	2	4	6	8
Thermal Stress Condition	**Marching With No Load**	BA	2	3	3	3	3	---	---	---
		AA	1	2	2	3	3	---	---	---
	Marching With Load	BA	3	5	10	---	---	---	---	---
		AA	3	5	6	7	7	---	---	---
	Running	BA	2	3	4	6	10	---	---	---
		AA	1	1	2	3	5	9	9	---
BA - Before Acclimation; AA - After Acclimation										

3.6 Subject M09

3.6.1 Core temperature

The procedures for this parameter's data treatment were the same as the applied before. Table 36 summarizes the main results

Table 36 - Core Temperature Summary – Case Study M09

		Thermoneutral Condition		**Thermal Stress Condition**	
		Initial Core Temperature **(ºC)**	Maximum Core Temperature **(ºC)**	Initial Core Temperature **(ºC)**	Maximum Core Temperature **(ºC)**
Marching Without Additional Load	BA	---	---	---	---
	AA	---	---	37,74	38,26
Marching With Additional Load	BA	---	---	---	---
	AA	37,11	37,85	37,42	38,76
Running	BA	36,73	38,42	37,17	38,91
	AA	36,43	37,93	37,71	38,86
BA - Before Acclimation; AA - After Acclimation					

It is not possible to draw conclusions regarding the MNL and MWL protocols for both temperature conditions.

In the running protocol for both temperature conditions, a better performance was observed at the maximum temperature reached. Since it was lower in the tests performed AA.

3.6.2 Heart Rate

Table 37 summarizes the HR results obtained by subject M09 for the performed test protocols.

Table 37 - Summary of the main results of the Heart Rate parameter – Study Case M09

		Thermoneutral Condition			**Thermal Stress Condition**		
		Initial Heart Rate **(bpm)**	Final Heart Rate **(bpm)**	Heart rate increase during experiment **(bpm)**	Initial Heart Rate **(bpm)**	Final Heart Rate **(bpm)**	Heart rate increase during experiment **(bpm)**
Marching Without Additional Load	BA	---	---	---	84	136	52
	AA	---	---	---	97	136	39
Marching With Additional Load	BA	81	174	93	---	---	---
	AA	94	158	64	111	201	90

Running	BA	74	196	122	95	174	79
	AA	71	202	131	105	199	94
BA - Before Acclimation; AA - After Acclimation							

It was not possible to draw conclusions from the data concerning the MNL protocol in the thermoneutral condition, as well as in the MWL protocol in the stress condition.

It was observed an improvement of the performance in the protocols of MWL and running in the thermoneutral condition, as well as in the MNL protocol in the stress condition.

In three of the tests (MWL and Running at Thermal stress condition, Running at Thermoneutral Condition) the maximum possible heart rate was hit so the tests were interrupted.

3.6.3 Maximum Oxygen Uptake

Concerning this parameter, marching and running protocols must be examined separately, as they have different calculation methodologies. Table 38 summarize the main results for each experiment

Table 38 - Summary of the average and maximal VO_2 consumption for each protocol – Study Case M09

		Average VO2 **(ml/min/Kg)**	
		Thermoneutral Condition	**Thermal Stress Condition**
Marching Without Additional Load	BA	16,934	20,822
	AA	20,823	17,815
Marching With Additional Load	BA	30,866	32,330
	AA	29,587	37,100
BA - Before Acclimation; AA - After Acclimation			

There was an improvement in performance at the level of a decrease of the average VO_2 consumption in the tests carried out AA of the protocols MNL in the condition of stress and MWL in the neutral condition.

		VO2 Max. (**ml/min/Kg**)	
		Thermoneutral Condition	**Thermal Stress Condition**
Running	BA	46,15	37,965
	AA	50,775	54,088
BA - Before Acclimation; AA - After Acclimation			

For both temperature conditions, the VO_2 max. was higher in the AA tests, and there was no improvement in the performance of the subject.

3.6.4 *Lactate*

Once lactate values were directly measured they were put together in Table 39 concerning each and every test.

Table 39 - Summary of the Lactate concentration for each experiment – Study Case M09

			Lactate concentration (mml/L)					Max. lactate concentration (mml/L)
			0'	**3'**	**5'**	**7'**	**10'**	
Thermoneutral Condition	**Marching Without Additional Load**	BA	1,5	1,1	0,9	0,9	---	1,5
		AA	0,8	1,1	0,8	0,7	---	1,1
	Marching With Additional Load	BA	1,2	2	1,7	1,6	---	2
		AA	0,7	1	1	1	---	1
	Running	BA	1,1	1,15	6,1	8,8	6,7	8,8
		AA	1,8	9	10,1	8,4	---	10,1
Thermal Stress Condition	**Marching Without Additional Load**	BA	1,3	1,3	1,5	1,5	---	1,5
		AA	2	1,5	1,4	1,6	1,5	2
	Marching With Additional Load	BA	1,7	3,5	3,3	---		3,5
		AA	1,5	1,9	1,9	---	---	1,9
	Running	BA	1,6	6,8	5,9	6,3	4,7	6,8
		AA	1,1	10,3	7,9	8,4	4,6	10,3
BA - Before Acclimation; AA - After Acclimation								

In running tests the lactate concentrations were higher than in the marching experiments.

Peak lactate values were lower in the tests performed AA in both marching protocols at the Thermoneutral condition.

Running protocols showed higher lactate peak values in the tests performed AA on both temperature conditions.

3.6.5 *Body Mass Loss*

Table 40 organizes the main results for each experiment, concerning the different calculations: body mass loss through percentage and liters per hour.

Table 40 - Summary Body Mass Loss calculated through percentage and liters per hour – Case Study M09

		Thermoneutral Condition		Thermal Stress Condition	
		% of Body mass Loss (%)	**Body mass Loss (l/hour)**	**% of Body mass Loss (%)**	**Body mass Loss (l/hour)**
Marching Without Additional Load	BA	0,28	0,20	---	---
	AA	0,35	0,25	1,13	0,80
Marching With Additional Load	BA	0,64	0,45	1,48	1,02
	AA	0,45	0,33	1,47	1,05
Running	BA	0,46	0,33	1,11	0,77
	AA	0,49	0,35	1,56	1,10
BA - Before Acclimation; AA - After Acclimation					

A decrease in BLM in the tests performed AA only was observed for the MWL protocol in the thermoneutral condition. In all other protocols BML was higher in the tests performed AA.

3.6.6 Borg Rating of Perceived exertion

Table 41 summarizes the perceived exertion data for all experiments performed by the subject M09.

Table 41 - Summary o the RPE scale for every performed test – Study Case M09

			Borg's Scale of perceived exertion							
			Warm up	**Stage 1**	**Stage 2**	**Stage 3**	**Stage 4**	**Stage 5**	**Stage 6**	**Stage 7**
Thermoneutral Condition	**Marching Without Additional Load**	BA	2	1	1	1	2	---	---	---
		AA	1	1	1	1	1	---	---	---
	Marching With Additional Load	BA	2	5	6	7	7	---	---	---
		AA	3	4	6	7	7	---	---	---
	Running	BA	3	3	4	5	6	8	---	---
		AA	2	2	3	4	5	7	10	---
Thermal Stress Condition	**Marching Without Additional Load**	BA	1	1	2	2	2	---	---	---
		AA	1	2	2	2	2	---	---	---
	Marching With Additional Load	BA	3	5	6	---	---	---	---	---
		AA	2	4	4	5	7	---	---	---
	Running	BA	2	4	6	6	---	---	---	---
		AA	2	3	4	5	7	---	---	---
BA - Before Acclimation; AA - After Acclimation										

MNL protocol in the thermoneutral condition presented a lower perception of effort AA only in the last step, having remained constant and equal throughout the test relative to the test performed BA .

MWL protocol presented a similar effort perception in the tests performed BA and AA.

The running protocol in both temperature conditions showed a lower perceived effort throughout all the stages in the tests carried out AA, presenting an extra step in each of these in relation to the tests performed BA.

The MNL protocol in the stress condition showed similar and constant effort perceptions (RPE = 2) along the different stages.

MWL protocol in the stress condition presented less perceived effort in the test performed AA, presenting two extra steps in this test when compared to the BA test, indicating an improvement in performance.

4 DISCUSSION

Heat acclimation is documented to induce numerous physiological adaptations that theoretically could improve aerobic exercise performance in hot environmental conditions (Ma & Maughan, 1993), (Lee et al., 2012)(Shen & Zhu, 2015)(Nielsen, Hales, Strange, & Juel, 1993)

These physiological adaptations from heat acclimation include: (Wenger, 1997)(Nielsen et al., 1993)

- Lower core temperature;
- Lower heart rate;
- Earlier onset of sweating response during exercise in the heat;
- Higher perceived exertion.

Also, some but not all investigators reported a lower VO_2 at a given workload after acclimation. (Ma & Maughan, 1993) These adaptations reduce physiological strain, improve the individual's ability to exercise in a warm environment and reduce the incidence of heat illness.(Lee et al., 2012) Expressed in a (Nielsen et al., 1993),(Nichols, 2014)

- A gradual increase in practice duration
- A gradual increase in practice intensity
- A gradual increase in environmental heat exposure

According to the data obtained for subject M06, regarding the internal temperature was observed a decrease in maximum temperatures resulting acclimation for MWL and MNL protocols at the Thermoneutral and Thermal stress conditions. However, the same was not verified for the "Running" protocol for both temperature conditions. In this, the maximum temperatures were higher for AA tests, as well as the variation between initial and final temperature, in which were higher. The MNL protocol at the thermal stress condition also showed no improvement in performance.

However, and noting only the data concerning the temperature gradient, projections shown that in the Thermal Stress Condition temperatures reached AA were below those achieved BA, which means that, generally acclimation has taken effect.

Is known that severe heat stress ensues when the core body temperature reaches a critically elevated threshold temperature of 41.6°C – 42°C for a prolonged duration of time, As it has been said before, although these calculations are merely assumptions, at no given moment a body should be subjected to such conditions, once extreme temperatures injure tissue directly, leading to cellular protein denaturation, also damaging, and interrupting the normal mechanisms of cells (Nichols, 2014). Temperatures higher than about 45ºC, is the temperature at which heating the skin causes pain (Wenger, 1997). The degree of injury depends on both temperature and duration of the heating, and as can be seen in the projections, such temperature was practically reached in the first hour of simulation.

When the body is working at high temperatures, the heart rate significantly accelerates, the cardiac output and blood flow to the muscle and myocardium increase, and the skin blood flow also accelerates to dissipate excess heat. When the intensity of labour and ambient temperature are within the limits of human endurance, the cardiovascular system gradually enters another steady state, which attenuates increases in the heart rate. The increase in the heart rate slightly declined after the training, which reflects the effect of the heat acclimatization training on the heart rate.(Shen & Zhu, 2015)

For the data from HR of the subject M06, in terms of acclimation there was a reduction of the gradient for the MWL protocol in the tests carried out AA, however, the analysis performed to the remaining available data, shown that the same was not verified, particularly for “Running” protocol at the Thermoneutral condition, and MNL at Thermal stress Condition, in which, there was an increase in the gradient to the AA condition. Again, a trend towards a decrease in values for an acclimatized condition was observed. Concerning the other subjects, performance improvements were observed, essentially at the level of Marching protocols. Subject M01 showed improvement at MNL NC, and MNL SC. Subject M02 at MNL NS and SC as well as for the Running at NC and SC. Subject M05 at MWL NC and Running SC. Subject M07 at MWL SC. And subject M09 at MWL NS, MNL SC and Running at SC.

With respect to VO_2, there was only a performance improvement for subject M06 in the MNL and MWL tests performed AA on a Termoneutral condition. Higher oxygen consumption has been observed during exercise in hot environments. This indicates that thermal stress *per se* increases the energy requirements during exercise. This finding agrees with Consolazio et al. (1963) and Kaufmann et al. (1963). This increase may be due to various factors, such as increased demand on circulation for thermoregulation, increased activity of sweat glands, and increased body temperature which in turn increases the rate of biochemical reaction in the body (Brooks et al. 1971; Claremont et al. 1975). Concerning the other subjects, performance improvements were only observed for Marching protocols, mainly at thermoneutral condition.

The maximum oxygen consumption (VO_{2max}) is the physiological index that best represents the maximum aerobic power. It is clear that a good performance require a high value of VO_{2max} but according to Caputo, Fernandes, Oliveira, & Greco (2009), not always those with the highest values of this index, are those who have a better aerobical performance. Observing this single variable, it is difficult to explain the large variation of income that can occur in performances with high value of VO_{2max}. Improvement in this parameter was only found for running protocols at thermoneutral condition

Sweat production is an indication of the magnitude of heat stress, and this sweat may evaporate or drip off the body. Heat acclimation training reduced the body's sweating threshold, which increases the body's ability to produce sweat. The sensitivity of the sweat glands to thermal and hormonal stimuli after acclimation may increase through an increase in the receptor density for neural and humoral stimuli or an increase in the size or number of active sweat glands. (Shen & Zhu, 2015)

One of the consequences of the dehydration is the increasing of core body temperature during physical activity, in moderate temperature at 23–25 °C, or in hot environments 26–28 °C. Studies suggest that during intense exercise in the heat, for every 1% of body mass lost from dehydration, there is aconcomitant increase in core body temperature of 0.21ºC. Once dehydrated, the transpiration rate decreases, and the body heat loss by evaporation is significantly reduced (Ely et al., 2009, Kenefick& Sawka 2007), (Pryor et al., 2015), (Costa & Baptista, 2013)

Maximum sweat rates vary by age, level of conditioning, and the strenuousness of physical activity. Maximal sweat rates range from 300–700 ml/hour in 9–12 year old children, 2.5 liters/hour in elite adolescent tennis players, and as much as 3 liters/hours in a trained 70 kg adult athletes. (Nichols, 2014)

In the data is a clear difference of the M06 subject's body in response to acclimatized condition, wherein in each test performed AA except for the running test at the thermoneutral condition, body weight loss through transpiration is greater. Concerning the other subjects, performance improvements were observed mainly for Marching protocols at the thermoneutral condition, And in some specific cases in the running protocol at the thermal stress condition. Concerning the ISO values exceeded, according to (Brake et al., 2016), the corresponding ISO 7933 sweat rate limit is 1.04 liters per hour, although ISO 9886(28) comments that the 1.04 liter per hour limit in ISO 7933 “must be considered not as a maximum value but as a minimal value that can be exceeded by most subjects in good physical condition.”

One of the parameter settings discussed in which the response of the organism to acclimation was assumed as consistent with the literature was the BORG perception scale, wherein in all tests performed AA, the subjects perceived a lower effort. This perception was accentuated primarily as the intensity of the tests were increasing (duration), as found in the case of MNL / MWL tests. The same was found in the incremental testing (running) in which the perception of effort gradually increased.

Thus, and from a general point of view we observed an improvement in the individual's performance mainly for the MNL / MWL protocols performed in thermoneutral condition AA, and in some cases, in the Running protocol at the thermoneutral and thermal stress condition. In all other cases this did not happen. However should be pointed out the relatively small differences between the values obtained BA and AA.

What could possibly be on the back of this analysis and that may have affected the results it is the duration of the state of unacclimation. This was one of the aspects that would be subject to analysis in this study. The acclimation and AA tests were performed first, and the BA tests were performed next. The time interval between AA and BA tests lasted approximately 4 weeks.

According to the literature, the physiological adaptations associated with heat acclimation are transient and gradually disappear if consistent heat exposure is not maintained. The adaptations that develop most rapidly (e.g. improvements in heart rate) during acclimation are also those that are lost most quickly (Williams et al., 1967; Pandolf et al., 1977). Currently, there is no agreement concerning the rate of decay for heat acclimation. A number of studies has show loss of heat acclimation in periods of less than 7 daysafter the cessation of heat acclimation sessions. Wyndham and Jacobs, found that adaptation at work in the heat, as in a workshift in a mine, was significantly reduced after 6 days in cool conditions. (Adam et al, 1960). reported that the better heat tolerance of heat acclimated subjects was mostly lost after 6 day without heat exposure, but not totally lost even after 34 days. Williams et al (1967) found that after 1 week in a cool environment the effect of acclimatization trough heart rate and sweat rate was largely lost. However, other investigators have found the effects of acclimation are retained over 8 days after the cessation of acclimation sessions. Stein et al (1949) found that, with the exception of decreased sweat rate, little loss of acclimation occurred after 14 days in a cool environment with 5 h of cold exposure per day. Lind and Bass (1963) found no loss of acclimation, as measured by rectal temperature, and only a small increase in heart rate during re-exposure to heat/exercise, either 3, 5 or 8 days after heat acclimation. Pandolf et al (1988) found no significant loss in heat acclimation, as assessed by changes in heart rate and rectal temperature, 3, 6, 12 or 18 days after subjects completed 9 days of heat acclimation.

However, for the parameters and conditions to which the present study was subject, this may be the reason for the existence of such low differences between protocols. What could mean that the gap of time between the tests may not have been enough to get the individual unnaclimated. Future studies are needed in order to obtain strong evidences about the time that takes an individual to lose the state of acclimation.

5 CONCLUSIONS

Starting from the initial assumptions, it was possible to observe some improvement in the performance of the subjects for the acclimated condition. A decrease in maximum temperatures was observed, as well as a lower heart rate variation. Oxygen uptake was also lower. One of the parameter settings discussed in which the response of the organism to acclimation was assumed as consistent with the literature was the BORG perception scale, wherein in all tests performed AA, the subject perceived a lower effort. Regarding the main objective, despite the observed trends, it is not possible to state with certainty the effectiveness of acclimation for the tested conditions.

The differences observed between the two states of acclimation were not very significant for the studied parameters, so possibly the individuals would not be fully “unaclimated”. More studies are needed to solidify these findings. However, this was a pioneering study on the amount of parameters and variables involved, showing a good comparability between themselves and suitability for similar studies.

6 LIMITATIONS AND FUTURE WORK

As previously stated, it was not always possible to schedule the tests in the same period that the previous were performed, so some data may contain errors related to biological processes intrinsic to the human body. In the future this aspect should be subject to tighter control.

In this study protocol, the acclimation of the subjects was performed without any physical activity involved, and, accordingly to Wenger, (1997), the acclimation response could be greater if heat exposure and exercise are combined, causing a greater rise of internal temperature and more profuse sweating. Thus as a proposal for future work, a new protocol could contemplate acclimation associated with physical exercise.

For the same subject of this case study, other aspects were monitored. Physiological stress indicators, such as CK enzyme, among other parameters were obtained true the collection of blood samples in the first two minutes after the exercise. As well as mean skin temperature, following the recommendations of ISO 8996:2004.

The parameters mentioned above should be the subject of study and comparison with the data discussed in this article

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