MASTER IN OCCUPATIONAL SAFETY AND HYGIENE ENGINEERING

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THERMAL STRESS EFFECTS IN MILITARY PHYSIOLOGICAL PERFORMANCE

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ABSTRACT

Heat stress complications may affect people exposed to thermal stress environments, having utter consequences. Military are often put into confrontation with this reality, so it is crucial to have a better understanding of how the human body behaves in order to prevent illness and preserve well-being. This article presents 6 case-studies of young military man who were tested for three types of exertion: marching, marching with load and running, at two different environmental conditions: thermoneutral (±22 ºC and ±40%rh) and thermal stress (±40 ºC and ±30%rh), with two adaptation levels – unacclimated and acclimated to the thermal stress environment. Core temperature, heart rate, VO_2, body mass loss, and lactate were measured; the Borg Rating of Perceived Exertion (RPE) was also used. It was possible to verify that the body reacted worse to the thermal stress condition; however, no conclusions could be made about the adaptation situations. Future works should be done, considering other parameters in order to draw more conclusions.

Keywords: core temperature, heart rate, oxygen uptake, lactate concentration, exertion

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NOMENCLATURE

Abbreviation	Definition
A	Acclimated
HR	Heart Rate
MNL	Marching without load
MWL	Marching with load
NC	Thermoneutral Condition
SC	Stress Condition
U	Unacclimated

1 INTRODUCTION

1.1 Scope

Every animal exchange energy with the surrounding environment; human being is no exception. It is known that this exchange may occur in one of two ways: mechanical work or via heat transference (convection, conduction and radiation) (Wenger, 1997).

Heat stress complications take place when heat gain is higher than the body's ability to dissipate it. This kind of issue has negative impacts on the subjects, especially in those who are directly expose to extreme environmental conditions, such as mining workers, firefighters, foundry workers, and military, amongst others.

Concerning temperatures, the process starts with heat stress (when temperatures rise above 37 °C), then proceeds to hyperthermia (temperatures beyond 39°C) and, finally, heat stroke (higher than 40°C). Despite these tabled values, past certain temperatures (which may vary from one person to another) homeostasis cannot be sustained and death may occur (Laxminarayan, Buller, Tharion, & Reifman, 2015).

Exertion heat illness can be divided into various types (Pryor, Bennett, O'Connor, Young, & Asplund, 2015):

- ✓ Heat edema: extreme swelling caused by vasodilation
- ✓ Heat cramps: muscle spasms during/after exercise
- ✓ Heat syncope: loss of consciousness (due to blood accumulation in extremities)
- ✓ Heat exhaustion: inability to perform any exercise due to exertion heat stress
- ✓ Exertional heat stroke: hyperthermia, thermoregulatory failure

1.2 Military's heat illness history

Hot environments present themselves with great challenges, once heat stress may weaken human aptitude to complete complex tasks during military activities, and, in extreme cases, posing a threat to human life (Nunneley & Reardon, n.d.; Sonna, 2012). Heat injury occurs both because of intrinsic (i.e. genetics) and extrinsic factors (i.e. clothing and equipment). A clear example of personal characteristics which may interfere with this process, is obesity: low physical fitness is likely to reduce heat tolerance, and can also make sweating responses less sensitive (Wenger, 1997).

In order to preserve homeostasis, the human body sets off physiological responses related with the rise of the core temperature (Laxminarayan et al., 2015). The main complications usually are: decrease in exercise capacity, heat injury, sunburn, *miliaria* *rubra* (known as "heat rash", it presents itself with a pruritic eruption), rhabdomyolysis (breakdown of skeletal muscle tissue), fluid and electrolyte loss, among others. Most of the times heat illness can be prevented with suitable training, heat acclimatization processes (one of the best strategies to prevent heat illness), and fluid availability (and adequate hydration) (Nichols, 2014).

Despite this, medical personnel must always be prepared to counsel and support military forces (Nunneley & Reardon, n.d.).

However, these preventive strategies are not expected to eradicate heat stress completely; they ought to minimize its impact as much as they possibly can.

1.3 Main objectives

There are records of several cases of heat stroke during military missions and even throughout the recruiting process. Heat stress greatly hinders job performance, hence it is crucial to understand the magnitude of physiological strain human being can abide, and what factors may cause tolerance so variable.

This article presents 6 case-studies in which male militaries completed several physical tests (in laboratory, inside of a climatic chamber where real conditions were recreated), having some physiological parameters measured (such as core temperature, heart rate, oxygen consumption, lactate concentration) in order to better understand how the body reacts to heat.

The main purpose of these experiments was to evaluate the break in performance, once the individuals had to face two different environment conditions: thermoneutral and thermal stress, and then, to make a connection between the different adaptation levels (unacclimated and acclimated).

Hopefully, this study will open doors to a further investigation on this area, always with the intent of the prevention scenario in mind.

2 MATERIAL AND METHODS

2.1 Subjects

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 ceased and M08 was excluded due to medical reasons.

Their ages were 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 protocol can be divided into three sub-protocols, occurring at two different environmental settings: thermoneutral and thermal stress conditions.

In the thermoneutral condition tests, air temperature was regulated to 22.0º ± 0.5ºC and relative humidity to 40 ± 2%; these values were considered the fittest for this kind of experiment by prior studies (Costa & Baptista, 2013).

Concerning the thermal stress condition tests, these values were adjusted to 40.0º ± 0.5ºC air temperature and 30 ± 2% relative humidity. These parameters, as well as protocol developments (the three of them), were defined by consulting and working with Portuguese Army: environmental settings were in reference to Afghanistan conditions (where Portuguese Army faces several missions) and activities resulted of an assembly of performed tasks during military training, reported by the Portuguese Army itself.

For each of the settings, three tests were performed: marching with no additional load, marching with load and running.

To execute this test battery, the individuals had two different adaptation levels: unacclimated and acclimated to the thermal stress situation (this process occurred during 14 days (Nichols, 2014) were the subjects had to endure 3 hours per day inside the climatic chamber, at 40.0º ± 0.5ºC air temperature and 30 ± 2% relative humidity, in total rest). The main purpose was to evaluate the break in performance for each one of the situations individually and then, to draw a connection between the both of them.

To assure physical integrity of the subjects, some parameters were controlled before every experiment: water intake (should not be less than 1.5 l per day), medication (any kind of analgesics, antihistamines or sleep deprivation took less than 6 hours before), excess of alcohol or caffeine in the 12 hours prior the tests and spice food. Some medication such as diuretics, laxatives, etc., may contribute to dehydration, increasing body temperature during exercise; there are other kinds of medicine which may also compromise thermoregulation, by increasing the heat production (Dube, Imbeau, Dubeau, Lebel, & Kolus, 2016; Wenger, 1997)

2.2.1 Protocol 1 - Marching without load (MNL)

The main objective of this kind of experiment (marching) is to reach body overload, despite the stress intensity remains the same during the test; it is, according to literature, a sub-maximal intensity test.

To perform this experiment, each subject only had to be equipped with his uniform, consisting of a t-shirt, trousers and military boots.

The treadmill was adjusted to have 1% of inclination (in order to simulate real ground and wind friction conditions).

The test stages were: 20 minutes of adaptation until a baseline point was set (this stage is the only common point between the three protocols), then an initial warmup of 4km.h^{-1} during 3 minutes and, finally, the main experimental stage with a maximum duration of 20 minutes at 6km.h^{-1}. The subject had to go through this process each and every time, regardless acclimation level.

The perceived effort was estimated every 5 minutes using Borg's RPE. This scale supplies additional significant measures, because understanding subjective symptoms and relating them with the objective measures is also important (Habibi, Dehghan, Moghiseh, & Hasanzadeh, 2014).

2.2.2 Protocol 2 - Marching with load (MWL)

The only difference between this protocol and the former is the load transport: each subject had to carry a backpack (with the following items: tent, sleeping bag, alternative uniforms, meals) as well as belt with canteen, chargers and his weapon, creating a total load of about 29.20kg.

2.2.3 Protocol 3 - Running

This test assessed the maximum oxygen uptake ($VO_{2\ max}$), which is an indicator of aerobic power and physical condition of a given person (Boulay, Simoneau, Lortie, & Bouchard, 1997; Carter, Jones, Maxwell, & Doust, 2002).

The running protocol is the most complex of the three, having different stages regarding treadmill velocity (even though it was programmed to have 0% of inclination) and no maximal defined duration. Despite this, it was expected of each subject to last, at least, 12 minutes running, which is reported in literature as the duration which provides higher values for this parameter (Yoon, Kravitz, & Robergs, 2007; Yoshida, Chida, Ichioka, & Suda, 1986).

The first part of the test included a 5 minute warmup at $8km.h^{-1}$. Afterwards, the subjects would have a recovery period of about 5 minutes, where they kept walking at $4km.h^{-1}$. Then, the main test stage would start: the subject started running at $10km.h^{-}1$, increasing speed in 1 $km.h^{-1}$ every 2 minutes, until he reached exhaustion.

2.3 Stopping criteria

Some of the immediate stopping criteria defined for every protocol were:

- ✓ **Core temperature** above 38.5º C (Richmond, Davey, Griggs, & Havenith, 2014). The definition of this value came from the need of creating a stress index (which later led to the concept of TWL – Thermal Work Limit), in which individuals can endure a specific thermal environment, while their core body temperature remains within safe limits (Derrick John Brake & Bates, 2002)
- ✓ **Heart rate** beyond a certain value, given by the formula (HR_{max} = 220 – subject's age) (Bruijns, Guly, Bouamra, Lecky, & Lee, 2013), which, in this case, was 196 bpm (the individual was 24 years old by the time the protocol took place).

- ✓ **Respiratory coefficient** higher than 1.10 (Teixeira, Grossl, De Lucas, & Guglielmo, 2014)

2.4 Physiological monitoring

During the tests, some indicators were monitored, such as:

2.4.1 Core temperature

The body core temperature was recorded due to ingestible pills, from Vital Sense.

The temperature more closely related to rectal temperature is thought to be the gastrointestinal, which uses core pills (a non-evasive method) (Low et al., 2007). These pills had to be swallowed 3-6 hours before the beginning of the experiment. An acceptable core temperature range to apply performance tests is ±36 ºC to ±39.5 ºC, based on experimental data (Derrick J Brake & Bates, 2002).

2.4.2 Heart rate

This is a very effective and non-invasive measure for this kind of protocol (Dube et al., 2016), providing an index of the circulatory strain degree during exercise (Golbabaei et al., 2014). In some cases it can replace VO_2 in the metabolic rate estimation (Dube et al., 2016).

During these protocols, the heart rate helped evaluating stress levels on the subject, through the K4-b2 equipment.

2.4.3 Pulmonary gas exchange

The maximal rate of oxygen consumption is the maximum capacity of an individual's body to transport oxygen through the circulatory system and use it in motor muscles. VO_2 plays an important role in Man's thermoregulatory response during the practice of exercise (Greenhaff, 1989), being used as a predictor of endurance exercise, especially concerning running performance (Boulay et al., 1997).

Both VO_2 and VCO_2 were measured using the cardio pulmonary equipment from Cosmed (K4-b2), recorded breath by breath.

2.4.4 Lactate concentration

Blood lactate is used as a physiological marker and it is considered an important tool to monitor the intensity of the aerobic exercise: its accumulation on the blood usually reflects an anaerobic metabolism increase (Caputo, Fernandes, Oliveira, & Greco, 2009). Lactate threshold might be detectable when it is sampled at the end of the working periods (Boulay et al., 1997). This parameter can be used to help determining endurance capacity (Faude, Kindermann, & Meyer, 2009; Goodwin, Harris, Hernández, & Gladden, 2007).

This parameter was measured by collecting a blood sample from subject's right earlobe right after exercise, at 3rd, 5th and 7th minutes after ceasing the test. If this value had not decrease by then, another sample would be collected at the 10th. In order to do so, Lactate Pro was used.

2.4.5 Dehydration

While enduring thermal stress, the individual's hydration status may be one of the main keys to preserve homeostasis and reduce heat illness risk (Nichols, 2014). The evaluation of this parameter is important once dehydration results in diminishing body's capacity of regulating temperature, with the direct consequence of decreasing exercise performance (Barnett & Maughan, 1993).

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

2.5 Climatic Chamber

All of the prior mentioned tests took place inside of *Fitoclima* 25000, built accordingly to EC standards, which meets health and safety basic requirements. In this chamber it is possible to recreate almost any specific environment since its temperature range is -20º C to +50º C and relative humidity may vary between 30-98%. The subjects' performance was tested with the help of the T2100 model of General Electric treadmill, which allowed controlling velocity and exercising grade performed.

3 RESULTS

Despite the sample has 6 subjects, one of them (M06) had to be considered separately from the others because he had to take the unacclimated protocol twice, due to a huge mass loss that he put himself through from one year of experiment to another. However, due to calendar limitations, he went through an acclimation process and less than one month later he performed unacclimated tests.

First M06's case is going to be presented with a thorough investigation and then M01, M02, M05, M07 and M09 will be presented only with the main data results.

3.1 M06 Performance

3.1.1 Core Temperature

Core temperature graphics were elaborated, using all available data. Then, for each test, a range of temperatures was identified (in different colour), from basal state (experiment beginning) to maximum temperature (a little after test conclusion), in order to draw conclusions.

In Figure 1 are exemplified the curves behavior for the thermoneutral (blue) and stress conditions (*bourdeaux*), regarding the MWL protocol in which the subject was acclimated.

During this MWL test core temperature was higher in the entire experiment for the thermal stress condition. The curves were "synchronized" in order to have a better perception of the temperature behavior.

In Table 1, there is a summary of every test, with the exception of the initial temperature in the running protocol (acclimated subject) because of equipment misreading.

Through direct data observation, it is possible to say that temperatures reached higher values for thermal stress condition tests, than they did in thermoneutral condition, despite initial core temperature was higher in some of the cases (MWL and MNL for the unacclimated protocol, and MNL for the acclimated protocol). Comparing marching tests, in the MWL experiments, core temperature values were higher. Analyzing running experiments, maximum temperatures were never bellow 38ºC.

It is also perceptible that the body reacts slightly better when the subject has no load (lower core body temperatures).

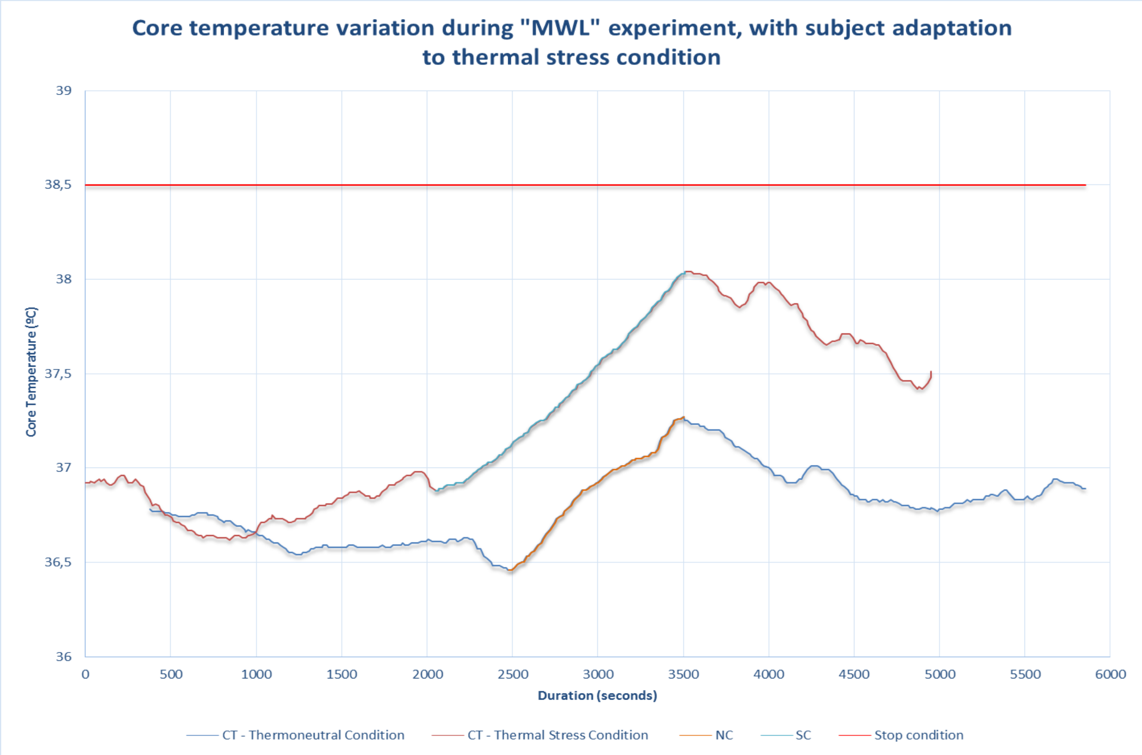

Figure 1 – Core temperature curves behavior, concerning MWL in the acclimated subject protocol (M06)

Table 1 - Core temperatures behavior summary (M06)

		Unacclimated subject		**Acclimated subject**	
		Initial Core Temperature (ºC)	Maximum Core Temperature (ºC)	Initial Core Temperature (ºC)	Maximum Core Temperature (ºC)
Marching With No Load	NC	36.98	37.54	36.76	37.39
	SC	36.58	37.66	37.24	37.89
Marching With Load	NC	37.08	37.78	36.46	37.27
	SC	36.72	38.17	36.88	38.04
Running	NC	36.85	38.02	---	38.06
	SC	37.16	38.42	37.25	39.01
NC - Thermoneutral Condition; SC - Thermal Stress Condition					

Knowing that one of the stop conditions was core temperature above 38.5ºC, the Running test for SC condition and acclimated subject protocol was interrupted. The peak of 39.01ºC did not happen during the test, but after it, while the body was recovering from the exercise.

With the purpose of investigate other core temperature aspects, from each test, curves were adjusted to linear models. Their mathematical expressions are in the table that follows.

Table 2 - Mathematical expressions of the obtained models from the experimental curves (M06)

		Unacclimated subject	Acclimated subject
Marching With No Load	NC	y = 0.0005x + 35.931	y = 0.0006x + 34.163
	SC	y = 0.0008x + 34.977	y = 0.0005x + 35.251
Marching With Load	NC	y = 0.0005x + 35.945	y = 0.0008x + 34.561
	SC	y = 0.0011x + 34.061	y = 0.0008x + 35.093
Running	NC	y = 0.001 x + 34.667	y = 0.0009x + 35.48
	SC	y = 0.001x + 35.066	y = 0.0009x + 34.595
NC - Thermoneutral Condition; SC - Thermal Stress Condition			

These gradients were then converted from degrees per second to degrees per hour, in order to calculate how the human body would react, considering, for example, a two hour exposition, Table 3.

To the initial core body temperature (Table 1) was added the temperature increase calculated through Table 2.

Table 3 - What to expect from the core body temperature, considering the calculated gradients and initial temperatures (M06)

		Unacclimated subject			Acclimated subject		
		Initial Core Temperature **(ºC)**	1st Hour **(ºC)**	2nd Hour **(ºC)**	Initial Core Temperature **(ºC)**	1st Hour **(ºC)**	2nd Hour **(ºC)**
Marching With No Load	NC	36.98	38.78	40.58	36.76	38.92	41.08
	SC	36.58	39.46	42.34	37.24	39.04	40.84
Marching With Load	NC	37.08	38.88	40.68	36.46	39.34	42.22
	SC	36.72	40.68	44.64	36.88	39.76	42.64
Running	NC	36.85	40.45	44.05	---	---	---
	SC	37.16	40.76	44.36	37.25	40.49	43.73
NC - Thermoneutral Condition; SC - Thermal Stress Condition							

For each and every case, the core body temperature would rise above acceptable levels. Once again, it has to be said that these are purely mathematical assumptions once human body could not even handle many of these temperatures (higher than 42ºC) and also these experiments would not take place during so long.

Again, the same conclusions can be drawn: running experiments have greater impact on core temperature modulation than the marching tests; what is more, between marching experiments, MWL has higher impact in core temperature variation than MNL.

3.1.2 Heart rate

Regarding this parameter, the procedure was similar: all available information was used and then, the experimental data was put into the same graphic as the core temperature. The main objective was to have an indication of what happens to body during the different tests. Figure 2 sets an example.

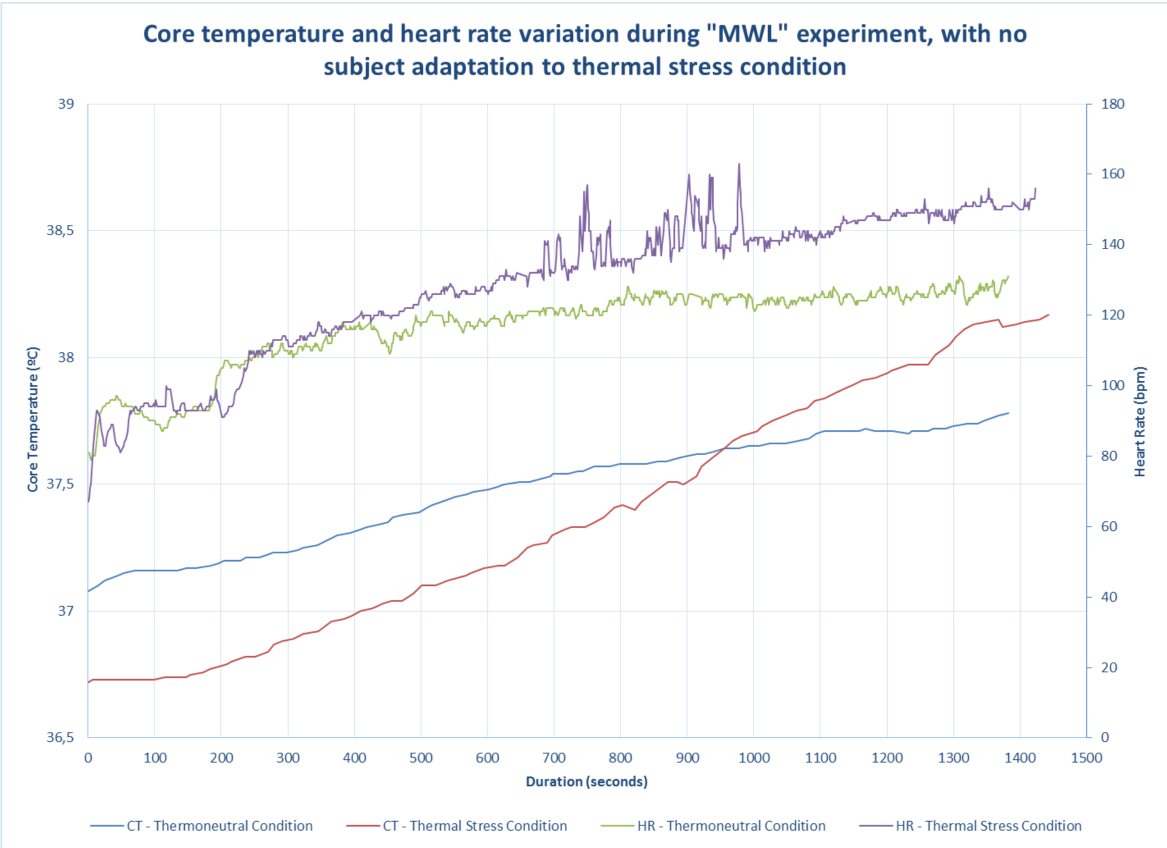

Figure 2 – Heart rate and core temperature variations during MWL experiment, for the unacclimated subject protocol (M06)

For this particular test (MWL, with no subject adaptation to SC) even though core temperature started higher for the thermoneutral protocol (blue), it did not increase as high or as quickly as for the thermal stress condition (*bordeaux*). The heart rate went with the tendency, being more unstable for the thermal stress condition, indicating a higher effort. In the remaining tests it happened exactly the same, concerning behaviors during the experiments.

It was also possible to identify and compare initial heart rate and final heart rate for every other test, smoothing the data through the average calculation, dividing it in periods of 1 minute. The results are in Table 4.

Table 4 - Summary of the main results for the heart rate component of the experiments (M06)

		Unacclimated subject			Acclimated subject		
		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 With No Load	NC	71	105	34	---	---	---
	SC	69	113	44	76	135	59
Marching With Load	NC	67	127	60	70	125	55
	SC	72	151	79	84	152	68
Running	NC	71	171	100	79	181	102
	SC	73	175	102	---	---	---
NC - Thermoneutral Condition; SC - Thermal Stress Condition							

From the available data, it is possible to sustain that the heart rate tendency accompanied the core temperature behavior.

Running experiments were the ones in which the gradient was higher, followed by MWL and MNL. There is a tendency in the response of the heart rate when comparing both environment settings: for the SC protocols, there was a higher heart response.

Concerning protocol adaptation it was not possible to draw a pattern between the different adaptation levels.

3.1.3 Maximal oxygen uptake (VO_2)

For this parameter the method was the same: all available data were used in the graphics' construction. Afterwards, both the beginning and the test ending were colored in different way as discernible in Figure 3.

Tests for both conditions were synchronized in order to have improved perception of what happened during the experiment.

Through direct data observation, it is possible to say that temperatures reached higher values for thermal stress condition tests, than they did in thermoneutral condition, despite initial core temperature was higher in some of the cases (MWL and MNL for the unacclimated protocol, and MNL for the acclimated protocol). Comparing marching tests, in the MWL experiments, core temperature values were higher. Analyzing running experiments, maximum temperatures were never bellow 38ºC.

It is also perceptible that the body reacts slightly better when the subject has no load (lower core body temperatures).

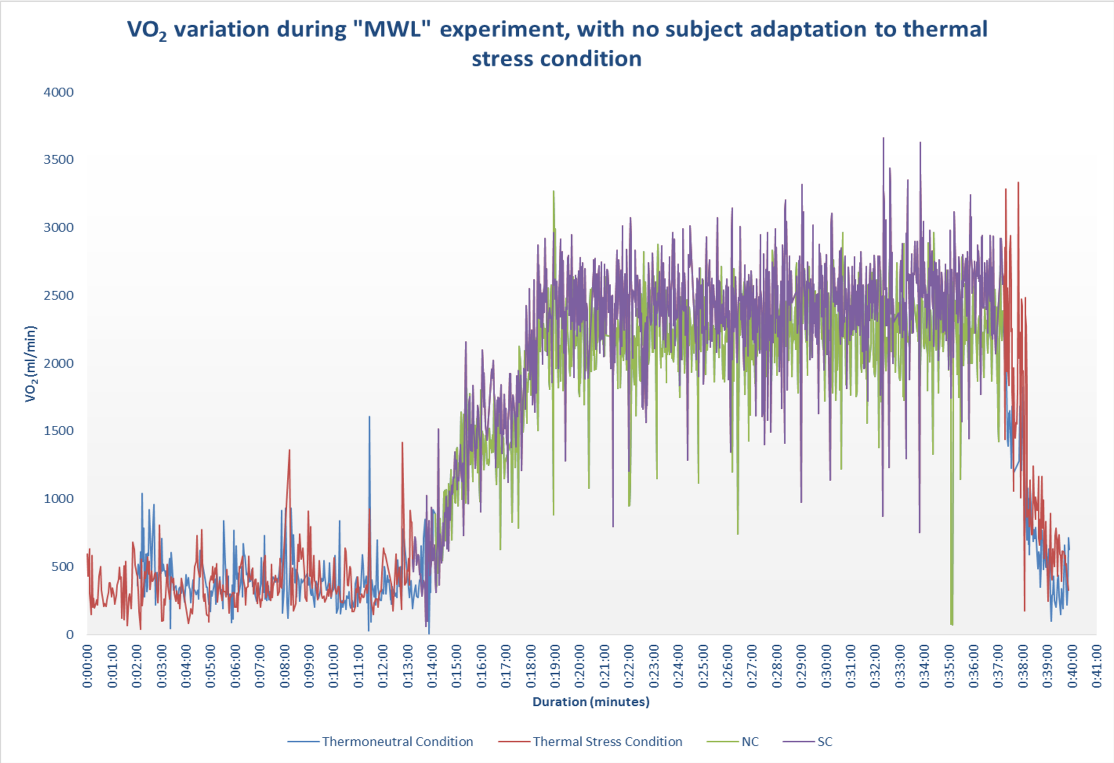

Figure 3 – Oxygen consumption for the MWL test, with reference to unacclimated subject protocol (M06)

Concerning this parameter, marching and running protocols must be examined separately, as they have different calculation methodologies.

Table 5 – Average oxygen consumptions for marching tests (M06)

		Average VO_2 (**ml/min**)	
		Unacclimated subject	**Acclimated subject**
Marching With No Load	NC	19.445	19.113
	SC	19.496	22.408
Marching With Load	NC	24.990	20.734
	SC	27.485	30.728
NC - Thermoneutral Condition; SC - Thermal Stress Condition			

Table 6 – Maximal oxygen consumption for running tests (M06)

		VO_2 max. (**ml/min**)	
		Unacclimated subject	**Acclimated subject**
Running	NC	41.937	52.994
	SC	44.331	50.902
NC - Thermoneutral Condition; SC - Thermal Stress Condition			

Regarding marching tests, even though the average volumes did not vary much, it is noticeable that oxygen consumption during SC tests was higher than in the NC, for both adaptation levels. What is more, from MNL to MWL, VO_2 consumption rose, once again regarding both adaptation levels.

During the running test, with reference to the acclimated subject protocol, oxygen uptake values were higher, when comparing NC with SC. Moreover, the duration of the Running_NC was about 13 minutes and Running_SC was 10 minutes; initial VO_2 consumption also started higher in the Running_NC test. It happened the other way round for the protocol where the subject had no adaptation to SC: VO_2 reached higher values for the SC test.

3.1.4 Lactate

The capillary blood samples were collected every time right after exercise, 3 minutes after the ending of the test, 5 minutes and 7 minutes, as stated before.

Table 7 summarizes all collected data for every performed test.

Table 7 - Summary of the lactate concentrations for each experiment (M06)

			Lactate concentration (mml/L)				**Max. lactate concentration (mml/L)**
			0'	**3'**	**5'**	**7'**	
Unacclimated subject	Marching With No Load	NC	1.7	1.1	0.9	0.9	1.7
		SC	1.1	1.1	1.0	1.0	1.1
	Marching With 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	2.0	2.0	1.6	2.5
		SC	1.1	3.1	3	2.8	3.1
Acclimated subject	Marching With No Load	NC	1.2	---	0.7	0.6	1.2
		SC	1.2	1.3	1.4	1.4	1.4
	Marching With Load	NC	1.0	1.0	0.7	0.6	1.0
		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							

Broadly speaking, lactate concentrations were higher in the running protocols when comparing with the marching tests.

When analyzing the results, in the protocol where the subject is not acclimated to SC, lactate concentrations decrease from NC to SC for both marching protocols and increases from NC to SC for the protocol which concerns subject adaptation.

3.1.5 Body mass loss

Differences in weight were measured and then body mass lost was calculated in two different ways: liters per hour and percentage. As described in ISO 9886 (2004), *"(…) the sweat rate should be limited to 1.0 l/h per hour for non-acclimatized subjects and to 1.25 l/h per hour for acclimatized subjects*" and body-water balance "*limit should be set at 5% of the body mass in order to avoid dehydration*". Bearing this in mind, the following graphics were designed Figure 4 and Figure 5.

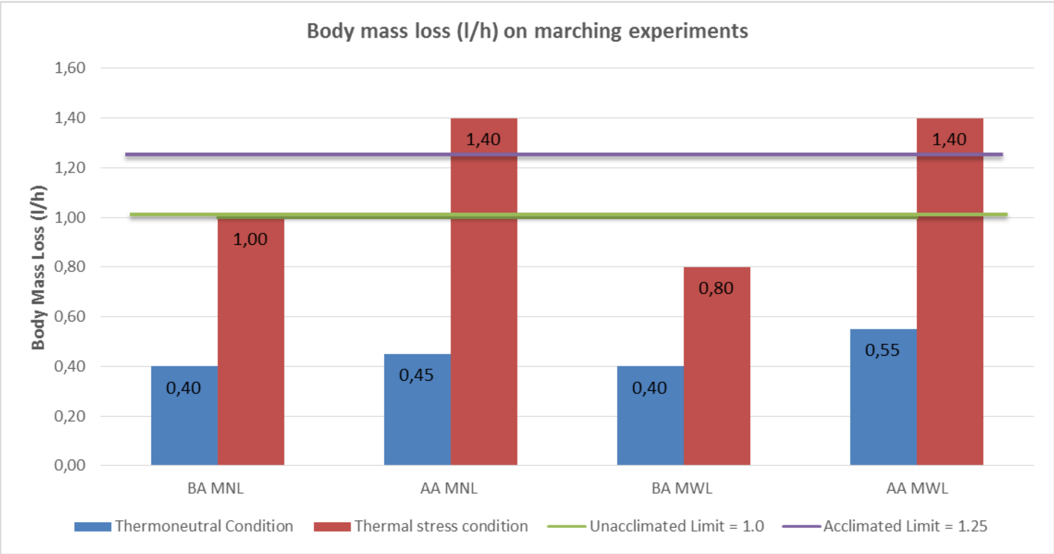

Figure 4 - Body mass loss in liters per hour, considering every marching experiment (M06)

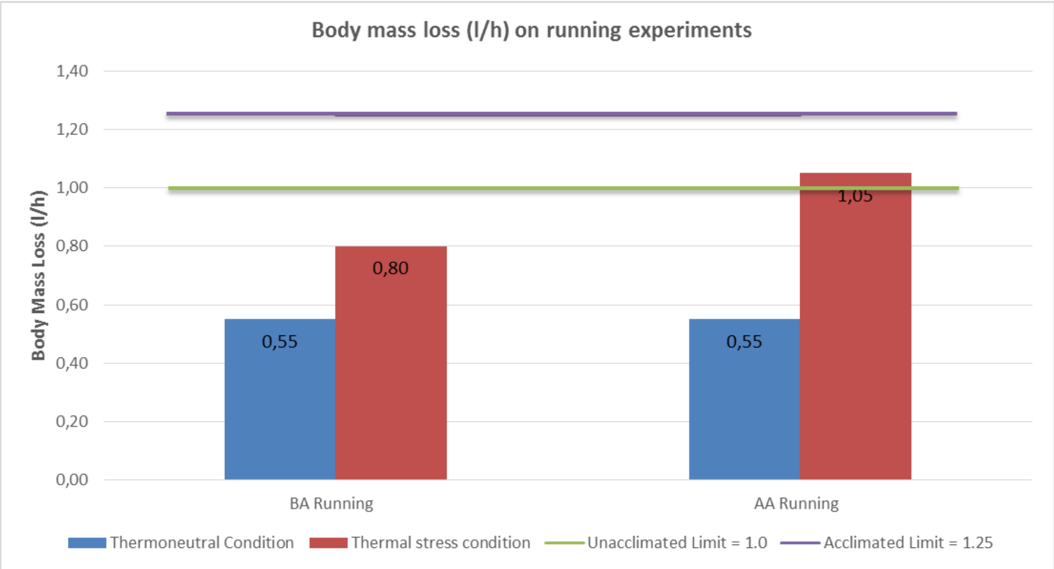

Figure 5 - Body mass loss in liters per hour, considering every running experiment (M06)

First of all, "U" stands for "unacclimated" and "A" stands for "acclimated", once every experiment was grouped in the figures.

Considering the reference values listed at the ISO 9886, with the exception of two tests (MNL and MWL for A), every other test's results remaining bellow the recommended values.

Body mass lost increased with the growing difficulty of the experiments: it was less prominent in MNL tests and hugely higher in running experiments. It is also notorious the big increase in this parameter when comparing NC with SC.

Analyzing adaptation levels, in the acclimated subject protocol, body mass loss had greater values.

While percentage of body mass loss was calculated through the subject's weight, body mass loss in liters per hour was calculated bearing in mind not the duration of the experiment but the whole time in which the individual was exposed to that thermal environment (approximately 1 hour).

Table 8 presents a complete summary of these parameters' results.

Table 8 – Body mass loss calculated through percentage and liters per hour (M06)

		Unacclimated subject		**Acclimated subject**	
		% of Body mass Loss (%)	**Body mass Loss (l/hour)**	**% of Body mass Loss (%)**	**Body mass Loss (l/hour)**
Marching With No Load	NC	0.48	0.40	0.54	0.45
	SC	1.20	1.00	1.68	1.40
Marching With Load	NC	0.49	0.40	0.65	0.55
	SC	0.98	0.80	1.63	1.40
Running	NC	0.67	0.55	0.66	0.55
	SC	0.97	0.80	1.26	1.05
NC - Thermoneutral Condition; SC - Thermal Stress Condition					

3.1.6 Borg Rating of Perceived Exertion

As stated in the protocol characterization earlier, the perception of effort was also taken into consideration for the full experiment analysis. Table 9 summarizes the data for all experiments.

Table 9 – Summary of the RPE scale for every performed test (M06)

			Borg's Scale of perceived exertion							
			Warm up	**Stage 1**	**Stage 2**	**Stage 3**	**Stage 4**	**Stage 5**	**Stage 6**	**Stage 7**
Unacclimated subject	Marching With No Load	NC	1	1	1	1	1	---	---	---
		SC	1	1	1	2	3	---	---	---
	Marching With Load	NC	1	2	3	3	3	---	---	---
		SC	1	2	4	5	6	---	---	---
	Running	NC	1	1	1	2	4	6	8	---
		SC	1	1	1	3	5	7	4	---
Acclimated subject	Marching With No Load	NC	1	1	1	1	1	---	---	---
		SC	1	1	1	2	2	---	---	---
	Marching With Load	NC	1	1	2	2	2	---	---	---
		SC	1	2	3	3	3	---	---	---
	Running	NC	1	1	1	1	2	3	5	9
		SC	1	1	1	2	3	4	6	---
NC - Thermoneutral Condition; SC - Thermal Stress Condition										

The differences observed from the table examination is that MNL tests led to lower exertion perceptions than MWL and even Running tests (from subject's point of view, running experiments were the tests in which the effort was heavier), regarding both adaptation levels (with and without acclimatization). It is also apparent that the perceived exertion rose from the NC to the SC in every experiment.

From the unacclimated to the acclimated protocol there are some differences as well: the effort perception was minor when the subject was already acclimated: he even performed an extra stage in the Running_NC.

3.2 M01 Performance

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 10 summaries the main results for this parameter.

Table 10 - Core temperatures behavior summary (M01)

		Unacclimated subject		Acclimated subject	
		Initial Core Temperature (ºC)	Maximum Core Temperature (ºC)	Initial Core Temperature (ºC)	Maximum Core Temperature (ºC)
Marching With No Load	NC	---	---	---	---
	SC	---	---	37.44	38.03
Marching With Load	NC	37.39	38.12	---	---
	SC	36.96	38.17	37.14	38.17
Running	NC	36.73	37.70	---	---
	SC	37.42	38.52	37.22	39.03
NC - Thermoneutral Condition; SC - Thermal Stress Condition					

Concerning MWL (unacclimated subject) and Running (unacclimated subject) the core body temperature rose from thermoneutral condition to thermal stress condition.

Comparing both adaptation levels, for the MWL test, maximum core temperature hit the same value for both cases and was higher in the acclimated subject protocol.

For the Running_SC (acclimated subject protocol) there is a peak of 39.03ºC, which lead to the interruption of the test.

3.2.2 Heart rate

The applied methodology for this parameter was the same as in the M06 case: all available data were used in the graphics' construction. Afterwards Table 11 was constructed in order to better understand heart rate behavior.

Table 11 - Summary of the main results for the heart rate component of the experiments (M01)

		Unacclimated subject			Acclimated subject		
		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 With No Load	NC	69	119	50	---	---	---
	SC	---	---	---	96	152	56
Marching With Load	NC	88	163	75	70	139	69
	SC	76	191	115	106	188	82
Running	NC	117	199	82	65	199	134
	SC	81	198	117	84	210	126
NC - Thermoneutral Condition; SC - Thermal Stress Condition							

Analyzing the table, heart rate rose in every test except for Running (acclimated subject) in which heart rate diminished. In the same test, heart rate hit a 210 bpm peak, which was high above the considered maximum. In addition to the core temperature maximum, the test was stopped.

Comparing both adaptation levels, heart rate diminished in the marching tests from unacclimated protocol to acclimated protocol, however it rose for the running tests.

3.2.3 Maximal oxygen uptake (VO_2)

Concerning this parameter, marching and running protocols must be examined separately, as they have different calculation methodologies. Table 12 and Table 13 summarize the main results for each experiment.

Table 12 - Average oxygen consumptions for marching tests (M01)

		Average VO_2 (**ml/min**)	
		Unacclimated subject	**Acclimated subject**
Marching With No Load	NC	24.033	22.564
	SC	22.287	25.649
Marching With Load	NC	34.953	22.675
	SC	32.731	34.904
NC - Thermoneutral Condition; SC - Thermal Stress Condition			

Table 13 - Maximal oxygen consumption for running tests (M01)

		VO_2 max. (**ml/min**)	
		Unacclimated subject	**Acclimated subject**
Running	NC	43.160	51.868
	SC	42.693	59.011
NC - Thermoneutral Condition; SC - Thermal Stress Condition			

Regarding average oxygen consumption, for the protocol in which the subject had no adaptation, the consumption decreased. However, it rose for the marching tests in which the subject was acclimated to the thermal stress condition. Comparing both adaptation levels, for the NC the consumptions rose from U to A and lowered for the SC from U to A.

The maximal oxygen consumption presented similar behavior: on the unacclimated subject protocol, the oxygen consumption was lower, despite the difference was minimal, rising in the acclimated protocol. Comparing both adaptation levels, the consumption were higher from U to A.

3.2.4 Lactate

Lactate concentration values for each experiment were put together in Table 14.

Table 14 - Summary of the lactate concentrations for each experiment (M01)

			Lactate concentration (mml/L)				**Max. lactate concentration (mml/L)**
			0'	**3'**	**5'**	**7'**	
Unacclimated subject	Marching With No Load	NC	1.1	---	---	---	1.1
		SC	0.9	1.6	1.3	---	1.6
	Marching With Load	NC	1.3	---	1.3	1.4	1.4
		SC	0.8	2.4	2.2	2.1	2.4
	Running	NC	0.9	6.8	6.7	6.6	6.8
		SC	1.1	6.2	6.0	5.7	6.2
Acclimated subject	Marching With No Load	NC	1.3	0.7	0.6	0.6	1.3
		SC	3.1	1.6	2.5	1.4	3.1
	Marching With Load	NC	0.9	1.5	1.4	1.2	1.5
		SC	1.3	1.7	1.9	1.6	1.9
	Running	NC	0.9	6.3	7.6	6.9	7.6
		SC	1.1	11.6	7.9	6.1	11.6
NC - Thermoneutral Condition; SC - Thermal Stress Condition							

These concentration rose between tests, except for Running in the unacclimated subject protocol. These concentrations were also higher for the running experiments than for the marching tests.

Comparing both adaptation levels, the concentrations were higher from U to A except for the MWL in the SC, where the lactate concentration diminished.

3.2.5 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 15.

Body mass lost increased with the growing difficulty of the experiments: it was less prominent in MNL tests and hugely higher in running experiments. It is also notorious the big increase in this parameter when comparing NC with SC.

Analyzing adaptation levels, in the acclimated subject protocol, body mass loss had greater values.

Table 15 - Body mass loss calculated through percentage and liters per hour (M01)

		Unacclimated subject		Acclimated subject	
		% of Body mass Loss (%)	**Body mass Loss (l/hour)**	**% of Body mass Loss (%)**	**Body mass Loss (l/hour)**
Marching With No Load	NC	0.36	0.25	0.65	0.45
	SC	1.32	0.90	1.58	1.10
Marching With Load	NC	0.51	0.35	0.85	0.60
	SC	1.91	1.30	1.40	0.97
Running	NC	0.74	0.50	0.72	0.50
	SC	1.61	1.10	1.99	1.40
NC - Thermoneutral Condition; SC - Thermal Stress Condition					

3.2.6 Borg Rating of Perceived Exertion

The effort perception was also taken into consideration for the full experiment analysis.

Table 16 summarizes the data for all experiments.

Table 16 - Summary of the RPE scale for every performed test (M01)

			Borg's Scale of perceived exertion							
			Warm up	**Stage 1**	**Stage 2**	**Stage 3**	**Stage 4**	**Stage 5**	**Stage 6**	**Stage 7**
Unacclimated subject	Marching With No Load	NC	1	3	3	3	3	---	---	---
		SC	1	2	2	2	2	---	---	---
	Marching With Load	NC	1	4	4	---	---	---	---	---
		SC	2	4	5	5	5	---	---	---
	Running	NC	2	2	3	3	5	7	---	---
		SC	1	1	2	3	5	7	---	---
Acclimated subject	Marching With No Load	NC	1	2	2	2	2	---	---	---
		SC	4	4	3	3	3	---	---	---
	Marching With Load	NC	1	3	3	3	3	---	---	---
		SC	3	5	6	7	7	---	---	---
	Running	NC	1	1	1	2	3	5	7	---
		SC	1	2	3	4	5	6	8	---
NC - Thermoneutral Condition; SC - Thermal Stress Condition										

Concerning MNL for the unacclimated subject protocol, the exertion perception was higher from NC to SC and for the MWL test, these difference was not significant. Taking Running (for the same adaptation protocol) into account, until stage 2 the effort perception was higher for NC than for SC; however there are no differences in the subject's perception from that stage on.

In the acclimated subject protocol, in every test the subject's exertion perception was higher in the SC condition.

3.3 M02 Performance

3.3.1 Core Temperature

The procedures for this parameter's data treatment were the same as the applied before. Table 17 summarizes the main results.

Table 17 - Core temperatures behavior summary (M02)

		Unacclimated subject		Acclimated subject	
		Initial Core Temperature (ºC)	Maximum Core Temperature (ºC)	Initial Core Temperature (ºC)	Maximum Core Temperature (ºC)
Marching With No Load	NC	---	---	---	---
	SC	---	---	---	---
Marching With Load	NC	---	---	36.88	37.92
	SC	---	---	36.97	38.84
Running	NC	---	---	37.22	38.71
	SC	---	---	37.42	39.13
NC - Thermoneutral Condition; SC - Thermal Stress Condition					

Concerning this subject, there were several problems determining the beginning of the experiment and maximum core temperature values due to core pill readings. However, from the available data, core temperature rose from NC to SC for both tests.

For Running_SC (acclimated subject) there was a temperature peak of 39.13 ºC which occurred after the subject hit the stop criteria considered for core temperature.

3.3.2 Heart rate

Once again, applying the same procedures lead to Table 18.

Heart rate rose for both adaptation levels on the marching protocols from NC to SC, however for MNL_U, this difference was minimal. In the running protocols it happened the other way round: heart rate was lower from NC to SC for both adaptation levels.

Table 18 - Summary of the main results for the heart rate component of the experiments (M02)

		Unacclimated subject			Acclimated subject		
		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 With No Load	NC	79	125	46	73	105	32
	SC	85	132	47	85	128	43
Marching With Load	NC	95	156	61	60	145	85
	SC	82	172	90	82	181	99
Running	NC	61	193	132	67	191	124
	SC	83	199	116	95	187	92
NC - Thermoneutral Condition; SC - Thermal Stress Condition							

3.3.3 Maximal oxygen uptake (VO_2)

Concerning this parameter, marching and running protocols must be examined separately, as they have different calculation methodologies. Table 19 and Table 20 summarize the main results for each experiment.

Table 19 - Average oxygen consumptions for marching tests (M02)

		Average VO_2 (**ml/min**)	
		Unacclimated subject	**Acclimated subject**
Marching With No Load	NC	28.854	23.238
	SC	24.230	25.786
Marching With Load	NC	39.112	31.503
	SC	30.073	32.995
NC - Thermoneutral Condition; SC - Thermal Stress Condition			

Table 20 - Maximal oxygen consumption for running tests (M02)

		VO_2 max. (**ml/min**)	
		Unacclimated subject	**Acclimated subject**
Running	NC	66.897	62.361
	SC	64.421	67.878
NC - Thermoneutral Condition; SC - Thermal Stress Condition			

Concerning average oxygen consumption, for the protocol in which the subject had no adaptation, the consumption diminished in every test from NC to SC. However, it happened the opposite for the protocol in which the subject was acclimated: the consumption values rose from NC to SC in every test. Comparing both adaptation levels, for NC battery of tests, the consumption of oxygen was lower and for the SC it was higher.

Regarding the maximal oxygen consumption parameter the behavior was similar: on the unacclimated subject protocol, the oxygen consumption was lower from NC to SC, rising in the acclimated protocol. Comparing both adaptation levels, the consumption were lower in the NC from U to A and higher in the SC from U to A.

3.3.4 Lactate

Again, as lactate values were directly measured they were put together in Table 21 concerning each and every test.

Table 21 - Summary of the lactate concentrations for each experiment (M02)

			Lactate concentration (mml/L)				**Max. lactate concentration (mml/L)**
			0'	**3'**	**5'**	**7'**	
Unacclimated subject	Marching With No Load	NC	1.4	---	---	---	1.4
		SC	1.0	1.5	1.8	1.3	1.8
	Marching With Load	NC	1.8	---	---	---	1.8
		SC	1.0	1.9	1.7	1.6	1.9
	Running	NC	1.4	---	---	---	1.4
		SC	1.3	7.2	6.9	6.7	7.2
Acclimated subject	Marching With No Load	NC	1.3	1.0	1.0	1.1	1.3
		SC	1.5	1.7	1.6	1.6	1.7
	Marching With Load	NC	1.6	1.0	1.0	0.9	1.6
		SC	1.7	2.2	2.0	1.9	2.2
	Running	NC	1.6	9.0	8.5	8.2	9.0
		SC	1.1	5.5	5.2	4.7	5.5
NC - Thermoneutral Condition; SC - Thermal Stress Condition							

Analyzing the table, for every experiment the lactate concentration was higher from NC to SC, except for the Running test in which the subject was acclimated (it was lower from NC to SC). Higher lactate values were hit in Running experiments for NC. Lactate concentrations were higher for the tests which required more effort.

When comparing adaptation levels, with the exception of MWL_SC, Running_NC and Running_SC lactate concentrations were lower from U to A.

3.3.5 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 22.

Table 22 - Body mass loss calculated through percentage and liters per hour (M02)

		Unacclimated subject		Acclimated subject	
		% of Body mass Loss (%)	**Body mass Loss (l/hour)**	**% of Body mass Loss (%)**	**Body mass Loss (l/hour)**
Marching With No Load	NC	0.99	0.75	0.50	0.40
	SC	0.13	---	1.14	0.90
Marching With Load	NC	0.80	0.60	0.72	0.58
	SC	1.60	1.20	2.07	1.65
Running	NC	0.66	0.50	0.93	0.75
	SC	1.56	1.20	1.80	1.45
NC - Thermoneutral Condition; SC - Thermal Stress Condition					

Body mass loss values are higher from NC to SC in every test with exception to MNL with no adaptation to SC condition. From the analysis of the table it is possible to say that this mass loss tendency accompanied the difficulty level of the experiments.

3.3.6 Borg Rating of Perceived Exertion

The effort perception was also taken into consideration for the full experiment analysis; Table 23 summarizes the data for all experiments.

Table 23 - Summary of the RPE scale for every performed test (M02)

			Borg's Scale of perceived exertion							
			Warm up	**Stage 1**	**Stage 2**	**Stage 3**	**Stage 4**	**Stage 5**	**Stage 6**	**Stage 7**
Unacclimated subject	Marching With No Load	NC	2	2	2	2	2	---	---	---
		SC	1	1	1	1	1	---	---	---
	Marching With Load	NC	3	3	3	3	3	---	---	---
		SC	2	2	2	2	2	---	---	---
	Running	NC	1	1	2	3	3	4	7	---
		SC	1	1	1	2	3	4	---	---
Acclimated subject	Marching With No Load	NC	1	1	1	1	1	---	---	---
		SC	1	1	1	1	1	---	---	---
	Marching With Load	NC	1	1	2	2	2	---	---	---
		SC	2	3	4	5	5	---	---	---
	Running	NC	1	1	1	2	2	3	3	4
		SC	1	1	1	1	2	4	7	---
NC - Thermoneutral Condition; SC - Thermal Stress Condition										

For both marching tests in the unacclimated subject protocol, exertion perception was higher for NC than SC. In the running test for the same protocol, these differences were minimal, however there is a tendency in higher effort perception for NC than SC. Despite that, the subject performed an additional stage in the NC test.

In the protocol in which the subject was adapted to the thermal stress condition, in the MNL test the effort perception is the same, hitting higher values from NC to SC for the MWL test. The running test does not show a behavior pattern, however the subject also performed an extra stage for the NC.

When comparing both adaptation levels, the differences are minimal, still, from U to A the perception of exertion was lower.

3.4 M05 Performance

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 temperatures behavior summary (M05)

		Unacclimated subject		**Acclimated subject**	
		Initial Core Temperature (ºC)	Maximum Core Temperature (ºC)	Initial Core Temperature (ºC)	Maximum Core Temperature (ºC)
Marching With No Load	NC	---	---	---	---
	SC	---	---	---	---
Marching With Load	NC	---	---	---	---
	SC	---	---	37.48	39.27
Running	NC	---	---	---	---
	SC	37.86	39.22	---	---
NC - Thermoneutral Condition; SC - Thermal Stress Condition					

Concerning this parameter, no conclusions can be drawn.

3.4.2 Heart rate

Once again, applying the same procedures lead to Table 25.

Concerning marching tests, the heart rate values diminished from NC to SC for the unacclimated subject protocol and rose for the acclimated subject protocol. In the running tests, heart rate increased from NC to SC (not acclimated subject protocol) and lowered down in the acclimated subject protocol.

Comparing both adaptation levels, no behavior pattern is detectable: in some cases heart rate rose, but in the others it lowered.

Table 25 - Summary of the main results for the heart rate component of the experiments (M05)

		Unacclimated subject			Acclimated subject		
		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 With No Load	NC	81	128	47	---	---	---
	SC	105	149	44	89	154	65
Marching With Load	NC	91	173	82	103	157	54
	SC	103	178	75	87	176	89
Running	NC	93	192	99	65	189	124
	SC	82	195	113	120	174	54
NC - Thermoneutral Condition; SC - Thermal Stress Condition							

3.4.3 Maximal oxygen uptake (VO2)

Concerning this parameter, marching and running protocols must be examined separately, as they have different calculation methodologies.

Table 26 and Table 27 summarize the main results for each experiment.

Table 26 - Average oxygen consumptions for marching tests (M05)

		Average VO_2 **(ml/min)**	
		Unacclimated subject	**Acclimated subject**
Marching With No Load	NC	25.933	19.690
	SC	21.603	22.665
Marching With Load	NC	43.660	32.621
	SC	35.951	30.098
NC - Thermoneutral Condition; SC - Thermal Stress Condition			

Table 27 - Maximal oxygen consumption for running tests (M05)

		VO_2 max. **(ml/min)**	
		Unacclimated subject	**Acclimated subject**
Running	NC	56.084	52.728
	SC	46.205	52.757
NC - Thermoneutral Condition; SC - Thermal Stress Condition			

Concerning average oxygen consumption, in the MNL and MWL with no subject adaptation and MWL with subject adaptation to thermal stress, there was a decrease in the parameter's values. However, for the MNL in which the subject had adaptation to SC, the consumption rose.

Comparing both adaptation levels, with the exception of MNL_SC, in every other test the consumption was lower.

Regarding the maximal oxygen consumption parameter in the running tests, oxygen consumption was lower from NC to SC in one protocol and residually higher in the other.

3.4.4 Lactate

As lactate values were directly measured they were put together in Table 28 concerning each and every test.

Table 28 - Summary of the lactate concentrations for each experiment (M02)

			Lactate concentration (mml/L)					**Max. lactate concentration (mml/L)**
			0'	**3'**	**5'**	**7'**	**10'**	
Unacclimated subject	Marching With No Load	NC	1.1	---	---	---	---	1.1
		SC	1.9	---	---	---	---	1.9
	Marching With Load	NC	1.8	4.8	2.4	2.7	3.8	4.8
		SC	1.4	5.1	4.3	4.4	---	5.1
	Running	NC	1.7	12	10.4	10.2	---	12
		SC	1.2	9	9.9	9.4	---	9.9
Acclimated subject	Marching With No Load	NC	1.9	1.0	1.0	0.8	---	1.9
		SC	1.3	1.4	1.2	1.5	1.3	1.5
	Marching With Load	NC	1.2	2.8	2.3	2.2	---	2.8
		SC	0.9	4.4	5.1	4.9	---	5.1
	Running	NC	2.1	10.5	11.8	12.8	9.8	12.8
		SC	1.9	7.2	7.7	6.7	---	7.7
NC - Thermoneutral Condition; SC - Thermal Stress Condition								

Concerning both marching experiments for the unacclimated protocol, lactate concentrations rose from NC to SC, despite in the running test it happened the opposite. However, in the running tests, lactate concentrations were much higher than on marching tests and even between marching experiments there are differences: MWL lactate concentrations were higher than in MNL.

In the acclimated protocol, for the MNL and Running tests theses concentrations lowered from NC to SC, however they rose from NC to SC for the MWL test.

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.

The body mass loss was higher from NC to SC in every test, with the exception of MWL with no adaptation level in the liters per hour calculation. Once again, for running tests, these values were higher.

When comparing both adaptation levels, body mass loss was lower, broadly speaking.

Table 29 - Body mass loss calculated through percentage and liters per hour (M05)

		Unacclimated subject		Acclimated subject	
		% of Body mass Loss (%)	**Body mass Loss (l/hour)**	**% of Body mass Loss (%)**	**Body mass Loss (l/hour)**
Marching With No Load	NC	0.50	0.35	0.22	0.15
	SC	2.26	1.60	1.26	0.85
Marching With Load	NC	1.35	0.95	0.52	0.35
	SC	1.25	0.88	1.98	1.30
Running	NC	0.79	0.55	0.90	0.60
	SC	1.82	1.20	1.61	1.10
NC - Thermoneutral Condition; SC - Thermal Stress Condition					

3.4.6 Borg Rating of Perceived Exertion

The effort perception was also taken into consideration for the full experiment analysis; Table 30 summarizes the data for all experiments.

Table 30 - Summary of the RPE scale for every performed test (M05)

			Borg's Scale of perceived exertion							
			Warm up	**Stage 1**	**Stage 2**	**Stage 3**	**Stage 4**	**Stage 5**	**Stage 6**	**Stage 7**
Unacclimated subject	Marching With No Load	NC	1	2	2	2	2	---	---	---
		SC	2	2	2	2	2	---	---	---
	Marching With Load	NC	2	3	4	4	4	---	---	---
		SC	2	4	---	---	---	---	---	---
	Running	NC	---	3	3	4	5	7	---	---
		SC	2	2	4	5	6	7	---	---
Acclimated subject	Marching With No Load	NC	1	1	1	1	1	---	---	---
		SC	1	1	2	2	2	---	---	---
	Marching With Load	NC	1	2	2	3	3	---	---	---
		SC	4	7	10	---	---	---	---	---
	Running	NC	1	1	1	1	2	3	4	5
		SC	2	2	2	3	4	---	---	---
NC - Thermoneutral Condition; SC - Thermal Stress Condition										

For MNL with no subject adaptation, exertion perception was similar for both thermal conditions. Concerning MWL for the same protocol, no conclusions can be drawn due to lack of data. In the running test there was a higher effort perception from NC to SC, except in the Stage 1.

For the tests in which the subject was adapted do SC, exertion perception is higher from NC to SC, presenting utterly big differences for the MWL test which was interrupted in the SC.

Comparing both adaptation levels, the perception of effort was lower in the acclimated situation.

3.5 M07 Performance

3.5.1 Core Temperature

The procedures for this parameter's data treatment were the same as the applied before. Table 31 summarizes the main results.

Table 31 - Core temperatures behavior summary (M07)

		Unacclimated subject		**Acclimated subject**	
		Initial Core Temperature (ºC)	Maximum Core Temperature (ºC)	Initial Core Temperature (ºC)	Maximum Core Temperature (ºC)
Marching With No Load	NC	---	---	---	---
	SC	---	---	---	---
Marching With Load	NC	37.64	38.31	36.89	37.81
	SC	37.12	38.05	37.01	38.22
Running	NC	36.93	37.96	37.08	38.42
	SC	37.10	38.06	37.15	38.46
NC - Thermoneutral Condition; SC - Thermal Stress Condition					

For every test core temperature values rose from NC to SC except for MWL with adaptation to SC in which the temperature lowered.

Comparing both adaptation levels, maximum core temperatures rose from U to A, with the exception of MWL_NC in which the maximum temperature was lower from U to A.

3.5.2 Heart rate

Once again, applying the same procedures lead to Table 32.

Concerning MNL and Running tests for the protocol in which the subject had no adaptation to SC, the heart rate increase was lower from NC to SC. However, in the MWL tests for the same protocol, it happened the opposite.

In the adaptation to SC protocols the behavior was variable: in the MNL test it rose from NC to SC, but in the Running tests it decreased.

Table 32 – Summary of the main results for the heart rate component of the experiments (M07)

		Unacclimated subject			**Acclimated subject**		
		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 With No Load	NC	87	135	48	79	103	24
	SC	106	143	37	66	133	67
Marching With Load	NC	102	115	13	82	150	68
	SC	113	182	69	---	---	---
Running	NC	86	187	101	78	188	110
	SC	95	188	93	82	189	107
NC - Thermoneutral Condition; SC - Thermal Stress Condition							

3.5.3 Maximal oxygen uptake (VO2)

Concerning this parameter, marching and running protocols must be examined separately, as they have different calculation methodologies. Table 33 and Table 34 summarize the main results for each experiment.

Table 33 - Average oxygen consumptions for marching tests (M07)

		Average VO_2 **(ml/min)**	
		Unacclimated subject	**Acclimated subject**
Marching With No Load	NC	22.944	21.559
	SC	---	---
Marching With Load	NC	34.197	27.483
	SC	35.431	35.551
NC - Thermoneutral Condition; SC - Thermal Stress Condition			

Table 34 - Maximal oxygen consumption for running tests (M07)

		VO_2 max. **(ml/min)**	
		Unacclimated subject	**Acclimated subject**
Running	NC	46.136	56.557
	SC	42.078	59.462
NC - Thermoneutral Condition; SC - Thermal Stress Condition			

Concerning average oxygen consumption, in the MWL for both adaptation protocols, the parameter rose from NC to SC.

Comparing both adaptation levels, with the exception of MWL_SC, in every other test the consumption was lower.

Regarding the maximal oxygen consumption parameter in the running tests, oxygen consumption was lower from NC to SC in one protocol and residually higher the other.

3.5.4 Lactate

As lactate values were directly measured they were put together in Table 35 concerning each and every test.

Table 35 - Summary of the lactate concentrations for each experiment (M07)

			Lactate concentration (mml/L)					**Max. lactate concentration (mml/L)**
			0'	**3'**	**5'**	**7'**	**10'**	
Unacclimated subject	Marching With No Load	NC	1.0	0.8	0.9	0.9	---	1.0
		SC	1.2	1.7	1.8	1.9	1.5	1.9
	Marching With Load	NC	1.1	1.6	1.3	1.5	---	1.6
		SC	1.6	2.6	2.5	2.5	---	2.6
	Running	NC	1.0	2.0	3.5	3.5	---	3.5
		SC	1.6	3.8	3.3	3.4	3.1	3.8
Acclimated subject	Marching With No Load	NC	1.1	0.7	0.7	0.6	---	1.1
		SC	1.5	1.6	1.3	1.3	---	1.6
	Marching With Load	NC	1.4	0.9	0.9	0.9	---	1.4
		SC	1.8	2.4	5.8	2.6	---	5.8
	Running	NC	1.3	5.9	6.1	4.5	---	6.1
		SC	1.2	3.9	4.8	4.6	---	4.8
NC - Thermoneutral Condition; SC - Thermal Stress Condition								

Lactate concentrations rose in every test concerning both adaptation protocols, except for the running test in which the subject had adaptation to the SC. Another observation is that for running experiments, lactate concentrations were higher than in the marching tests.

Comparing both adaptation levels no conclusions can be drawn as there is no pattern in the behavior of this parameter.

3.5.5 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 36.

Table 36 - Body mass loss calculated through percentage and liters per hour (M07)

		Unacclimated subject		Acclimated subject	
		% of Body mass Loss (%)	**Body mass Loss (l/hour)**	**% of Body mass Loss (%)**	**Body mass Loss (l/hour)**
Marching With No Load	NC	0.32	0.20	0.16	0.10
	SC	1.65	1.03	1.57	1.00
Marching With Load	NC	0.88	0.55	0.32	0.20
	SC	1.89	1.18	1.42	0.90
Running	NC	0.81	0.50	0.64	0.40
	SC	1.67	1.06	2.04	1.30
NC - Thermoneutral Condition; SC - Thermal Stress Condition					

Through the analysis of the table is possible to say that body mass loss was higher from the comparison of NC with SC in every test.

These values were also higher concerning the severity of the performed experiment.

Comparing adaptation levels, body mass loss hit lower values from U to A condition.

3.5.6 Borg Rating of Perceived Exertion

The effort perception was also taken into consideration for the full experiment analysis; Table 37 summarizes the data for all experiments.

Concerning the unacclimated protocol, in the MNL tests effort perception was similiar for both thermal conditions. Despite not every data is available for MWL, it is possible to verify that this perception rose from NC to SC and in the running test, the effort perception was higher from NC to SC. In addition to that, the subject performed and extra stage in the NC.

For the acclimated subject protocol, in both marching tests, the exertion perception was higher from NC to SC, being the differences higher to MWL than to MNL. In the running test the perceived exertion was also higher from NC to SC and the individual, once again, performed an extra stage in the NC.

Table 37 - Summary of the RPE scale for every performed test (M07)

			Borg's Scale of perceived exertion							
			Warm up	**Stage 1**	**Stage 2**	**Stage 3**	**Stage 4**	**Stage 5**	**Stage 6**	**Stage 7**
Unacclimated subject	Marching With No Load	NC	2	2	3	3	3	---	---	---
		SC	2	3	3	3	3	---	---	---
	Marching With Load	NC	3	4	5	5	7	---	---	---
		SC	3	5	10	---	---	---	---	---
	Running	NC	2	2	3	4	5	10	---	---
		SC	2	3	4	6	10	---	---	---
Acclimated subject	Marching With No Load	NC	1	1	1	1	1	---	---	---
		SC	1	2	2	3	3	---	---	---
	Marching With Load	NC	1	3	4	5	5	---	---	---
		SC	3	5	6	7	7	---	---	---
	Running	NC	1	1	1	2	2	4	6	8
		SC	1	1	2	3	5	9	9	---
NC - Thermoneutral Condition; SC - Thermal Stress Condition										

3.6 M09 Performance

3.6.1 Core Temperature

The procedures for this parameter's data treatment were the same as the applied before. Table 38 summarizes the main results.

Table 38 - Core temperatures behavior summary (M09)

		Unacclimated subject		Acclimated subject	
		Initial Core Temperature (ºC)	Maximum Core Temperature (ºC)	Initial Core Temperature (ºC)	Maximum Core Temperature (ºC)
Marching With No Load	NC	---	---	---	---
	SC	---	---	37.74	38.26
Marching With Load	NC	---	---	37.11	37.85
	SC	---	---	37.42	38.76
Running	NC	36.73	38.42	36.43	37.93
	SC	37.17	38.91	37.71	38.86
NC - Thermoneutral Condition; SC - Thermal Stress Condition					

The core temperature increases from NC to SC in every comparable test: Running (with no adaptation), MWL and Running (with adaptation).

Comparing both adaptation levels the core temperature decreased from U to A.

3.6.2 Heart rate

Once again, applying the same procedures lead to Table 39.

In three of the tests (MWL_SC, Running_NC and Running_SC) the maximum possible heart rate was hit so the tests were interrupted.

Concerning MNL and MWL tests for the unacclimated protocol, no conclusions can be drawn, once there is no available data. However, in the running test (for the same protocol) heart rate decreased.

Table 39 - Summary of the main results for the heart rate component of the experiments (M09)

		Unacclimated subject			Acclimated subject		
		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 With No Load	NC	---	---	---	---	---	---
	SC	84	136	52	97	136	39
Marching With Load	NC	81	174	93	94	158	64
	SC	---	---	---	111	201	90
Running	NC	74	196	122	71	202	131
	SC	95	174	79	105	199	94
NC - Thermoneutral Condition; SC - Thermal Stress Condition							

In the acclimated protocol, no possible conclusions can be made for MNL test for the same reason but the other tests behave differently: in MWL heart rate rose from NC to SC and in Running it diminished.

Comparing both adaptation levels, with the exception of Running tests for the acclimated protocol, in every test heart rate decreased.

3.6.3 Maximal oxygen uptake (VO_2)

Concerning this parameter, marching and running protocols must be examined separately, as they have different calculation methodologies. Table 40 and Table 41 summarize the main results for each experiment.

Concerning average oxygen consumption, for the MNL in both adaptation protocols, the parameter rose from NC to SC. For the MWL in both protocols the oxygen consumption decreased from NC to SC.

Regarding the maximal oxygen consumption parameter in the running tests, oxygen consumption was lower from NC to SC in one protocol and higher the other.

Table 40 - Average oxygen consumptions for marching tests (M09)

		Average VO_2 **(ml/min)**	
		Unacclimated subject	**Acclimated subject**
Marching With No Load	NC	16.934	20.823
	SC	20.822	17.815
Marching With Load	NC	30.886	29.587
	SC	32.330	37.100
NC - Thermoneutral Condition; SC - Thermal Stress Condition			

Table 41 - Maximal oxygen consumption for running tests (M09)

		VO_2 max. (**ml/min**)	
		Unacclimated subject	**Acclimated subject**
Running	NC	46.150	50.775
	SC	37.965	54.088
NC - Thermoneutral Condition; SC - Thermal Stress Condition			

3.6.4 Lactate

As lactate values were directly measured they were put together in Table 42 concerning each and every test.

Lactate concentration rose from NC to SC in every test with the exception of MNL in the unacclimated protocol in which it is the same for both tests and Running (for the same protocol) in which it decreases.

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

Table 42 - Summary of the lactate concentrations for each experiment (M09)

			Lactate concentration (mml/L) 0'	3'	5'	7'	10’	Max. lactate concentration (mml/L)
Unacclimated subject	Marching With No Load	NC	1.5	1.1	0.9	0.9	---	1.5
		SC	1.3	1.3	1.5	1.5	---	1.5
	Marching With Load	NC	1.2	2.0	1.7	1.6	---	2.0
		SC	1.7	3.5	3.3	---	---	3.5
	Running	NC	1.1	1.15	6.1	8.8	6.7	8.8
		SC	1.6	6.8	5.9	6.3	4.7	6.8
Acclimated subject	Marching With No Load	NC	0.8	1.1	0.8	0.7	---	1.1
		SC	2.0	1.5	1.4	1.6	1.5	2.0
	Marching With Load	NC	0.7	1.0	1.0	1.0	---	1.0
		SC	1.5	1.9	1.9	---	---	1.9
	Running	NC	1.8	9.0	10.1	8.4	---	10.1
		SC	1.1	10.3	7.9	8.4	4.6	10.3
NC - Thermoneutral Condition; SC - Thermal Stress Condition								

3.6.5 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 43.

Table 43 - Body mass loss calculated through percentage and liters per hour (M09)

		Unacclimated subject		Acclimated subject	
		% of Body mass Loss (%)	Body mass Loss (l/hour)	% of Body mass Loss (%)	Body mass Loss (l/hour)
Marching With No Load	NC	0.28	0.20	0.35	0.25
	SC	---	---	1.13	0.80
Marching With Load	NC	0.64	0.45	0.45	0.33
	SC	1.48	1.02	1.47	1.05
Running	NC	0.46	0.33	0.49	0.35
	SC	1.11	0.77	1.56	1.10
NC - Thermoneutral Condition; SC - Thermal Stress Condition					

Body mass loss increases from NC to SC in every test with the exception of MNL (for both protocols) once it is not possible to compare the thermal condition tests.

Comparing both adaptation levels, body mass loss was lower from U to A, with the exception of MNL_NC and Running_SC.

3.6.6 Borg Rating of Perceived Exertion

The effort perception was also taken into consideration for the full experiment analysis; Table 44 summarizes the data for all experiments.

Concerning unacclimated subject protocol, for the MNL test, exertion perception rose from NC to SC despite during the “Warm up” stage it happened the opposite. For the MWL test, with regard to the available data, the perceived exertion was more a less the same and for Running, there was a rose in the perception of exertion from NC to SC.

For the unacclimated subject protocol, both MNL and Running tests showed that perceived exertion was higher from NC to SC and during the running experiment, the subject endured an extra stage. In the MWL experiment it happened the opposite: the effort perception was lower from NC to SC.

Table 44 - Summary of the RPE scale for every performed test (M09)

			Borg's Scale of perceived exertion							
			Warm up	**Stage 1**	**Stage 2**	**Stage 3**	**Stage 4**	**Stage 5**	**Stage 6**	**Stage 7**
Unacclimated subject	Marching With No Load	NC	2	1	1	1	2	---	---	---
		SC	1	1	2	2	2	---	---	---
	Marching With Load	NC	2	5	6	7	7	---	---	---
		SC	3	5	6	---	---	---	---	---
	Running	NC	3	3	4	5	6	8	---	---
		SC	2	4	6	6	---	---	---	---
Acclimated subject	Marching With No Load	NC	1	1	1	1	1	---	---	---
		SC	1	2	2	2	2	---	---	---
	Marching With Load	NC	3	4	6	7	7	---	---	---
		SC	2	4	4	5	7	---	---	---
	Running	NC	2	2	3	4	5	7	10	---
		SC	2	3	4	5	7	---	---	---
NC - Thermoneutral Condition; SC - Thermal Stress Condition										

4 DISCUSSION

Individuals may experience reasonable dehydration during prolonged high intensity exercise, which is thought to be responsible for the increase in some physiological parameters such as: core body temperature, heart rate and pulmonary ventilation (Golbabaei, Zakerian, Dehaghi, et al., 2014; Sawka et al., 1979), but this tendency also depends on individual's aerobic fitness (Wenger, 1997; Werner, 2010). Despite the adaptation protocol, or even environmental temperatures, all of the mentioned above were measurably observable during the experiments through primary observation of the Tables 1, 10, 17, 31 and 38 (core temperature), Tables 4 and 11 (heart rate) and Tables 5, 6, 33 and 34 (VO_2).

In hot environments there is a higher energy demand, thought to be one of the main contributes to the core body temperature increase (Dimri, Malhotra, Sen Gupta, Kumar, & Arora, 1980), noticeable in core body temperature Tables 1, 10, 17, 31 and 38. There is also an intensification of the oxygen consumption (Tables 5, 6, 33 and 34), explained by the decrease in the aerobic component of the oxygen supply (and consequent increase of the anaerobic one) (Dimri et al., 1980). It is important to state that ensuring the use of similar muscle groups during the different protocols, VO_2 is not overestimated, since some factors such as stress, ambient temperature and hydration increase heart rate, while having no effect on oxygen consumption (Dube et al., 2016). Despite thermal stress condition protocol triggered higher values for both parameters (HR and VO_2) these differences are, still, minimal concerning the oxygen uptake parameter. The growing tendency in the body oxygen demand in this set of conditions has correspondence in the increase of the heart rate, indicating a superior request on the circulation, caused by the blood flow to the skin, with the aim of controlling the thermoregulation process. Consequently, a higher heart rate is essential to preserve cardiac output (Dimri et al., 1980; Wenger, 1997), observable in Tables 4 and 11. Both oxygen demand and aerobic fraction also have an impact on lactate concentration, which rises due to the increase of work severity and thermal stress on the body (Dimri et al., 1980; Yoshida et al., 1986). That can be observable in Tables 14, 21, 28, 35 and 42 specially when comparing different tests: in the running tests, lactate concentrations were higher than in marching experiments. What is more, lactate threshold is around 4mml/L, so, for marching tests this value should be around 2mml/L or less, which does not happened in Tables 28, 35 and 42 in MWL tests for SC.

However for M06, no parallelism can be made because the lactate concentration behavior does not show a pattern (Table 7): it increased from NC to SC in the set of experiments where the individual was acclimated, and decreased from NC to SC in the tests in which the subject had no adaptation level whatsoever. Despite this, it was noticeable that during the running protocols lactate concentration decreased (acclimated subject protocol), which is coherent with the VO_2 consumption for the same protocol (it was greater, indicating higher exhaustion level). This may be due to the fact that the subject endured an extra stage during the thermoneutral protocol, increasing exertion.

Blood lactate variance, several factors have to be considered: muscle fiber composition, enzyme activity (glycolytic and lipolytic) and mitochondrial density (Faude et al., 2009).

Thermal stress increases energy necessities for human body during work, but also when it stays at rest, explained by the fact that thermoregulation requires a greater activity of the sweat glands and the increase of body temperature leads to biochemical reactions in the body (Dimri et al., 1980). Some studies also suggest that working out in the heat, leads to an increase in the core temperature of 0.21 ºC for each 1% of body mass lost from dehydration (Costa & Baptista, 2013; Pryor et al., 2015), however that did not happened for this individual (M06 - Table 45).

It is apparent that the actual rise in core temperature was higher than expected for every test. Considering this body mass lost in liters per hour (Figure 4 and Figure 5), in almost every experiment (except MNL NC for the unacclimated protocol) it rose above 1 l/h, what can be sustained for many hours, as well as higher rates for shorter periods (Wenger, 1997).

Table 45 - Rise in core body temperature put into perspective with bibliography

		Unacclimated subject		**Acclimated subject**	
		Expected core temperature rise (ºC)	Actual rise (ºC)	Expected core temperature rise (ºC)	Actual rise (ºC)
Marching With No Load	NC	0.10	0.56	0.11	0.63
	SC	0.25	1.08	0.35	0.65
Marching With Load	NC	0.10	0.70	0.14	0.81
	SC	0.21	1.45	0.34	1.16
Running	NC	0.14	1.17	0.14	---
	SC	0.20	1.26	0.26	1.76
NC - Thermoneutral Condition; SC - Thermal Stress Condition					

Water balance has a major role in thermoregulation so that high levels of dehydration can compromise this process: 1% of fluid loss is directly related with thirst, increasing at 2%, added by discomfort and loss of appetite. At 4% work capacity is reduced to 20-30% and at 5% subjects have difficulty in concentrating, headaches and sleepiness. Values of 10% body mass loss through dehydration are life-threatening (Grandjean, 2004).

Sweat rates in physically active individuals can reach 3-4 liter per hour; however this rate depends on factor such as duration and intensity of exercise, temperature, humidity and personal characteristics such as age, gender and training (Grandjean, 2004). For both calculations, Tables 8, 15, 22, 29, 36 and 43 can be analyzed.

The increase in heart rate and oxygen uptake is accompanied by an increase in the exertion perception (Habibi et al., 2014), detectable in Tables 9, 16, 23, 30, 37 and 44. In addition to that, tests which require higher effort lead to higher exertion perception values.

Uncompensable heat stress may result in the body's failure in the capacity of maintaining a steady temperature, increasing the risk of severe heat illnesses (Pryor et al., 2015). It is also important to clear that initial core temperature fluctuations (Table 1) can be due to individual circadian rhythms and to subject adaptation to heat (Derrick John Brake & Bates, 2002; Wenger, 1997).

Heat acclimatization produces changes in the physiological parameters which allow the body to perform better (Nielsen et al., 1993). The main differences observed usually are lower heart rate, lower core temperature, increase in sweat rate, increase in tolerance time, among other factors (Gupta, Swamy, Dimri, & Pichan, 1981; Nichols, 2014; Wenger, 1997). Nonetheless, not all studies report lower VO_2; better heat tolerance in acclimated individuals starts to decrease after 6 days without exposure to heat, but this adaptation is not totally lost after 34 days (Barnett & Maughan, 1993).

Concerning M06, no pattern can be drawn with regard to core temperature, heart rate and oxygen uptake: it decreased in some tests, but increased in others. Despite that, it must be considered that for this particular individual that the acclimation process did not occurred in the usual way due to calendar limitations. Nevertheless, observing Figure 4 and Figure 5 it is possible to say that sweat rate increased in almost every protocol, which can be explained due to the fact that sweating during the exercise stars earlier as a sweat glands' response, when the subject is acclimated (Wenger, 1997). Perceived exertion also decreased from unacclimated to acclimated protocol (Table 8). Also, considering the reference values listed at the ISO 9886 (2004), excepting one of the tests (U MNL for the thermoneutral condition) every other experiment has body mass losses above recommendation. However, it is crucial to remember that these values are applied for people working conventional shifts and heat in military settings may extend over time, having no resting periods; an example of such is troops on a mission (Nunneley & Reardon, n.d.).

After acclimation, almost all of the military (M02, M05, M06, M07 and M09) performed better, especially in the running protocol (NC) in which they accomplished extra stages when comparing to SC.

Even so, it should be noted not only particular conditions have direct consequence in the core body temperature and exercise, in general, causes core temperature to rise because of the heat-loss responses engendered by the body (Dimri et al., 1980; Wenger, 1997).

5 CONCLUSIONS

The results derived from the application of the protocols meet what was expected of them. When comparing thermoneutral condition with thermal stress condition, the body performed better while exposed to the neutral situation: core temperature was lower, heart rate showed less variation, oxygen uptake was also lower, individual’s exertion perception was not as high and body mass loss was not intense, despite acclimation level. Lactate parameters also met what was expected (higher values for higher physical effort). However, the military which was considered separately (M06) did not present a linear behavior for some of the parameters, such as lactate concentration. The sample of 6 military was not enough to better understand some of the behaviors that occurred.

Some of the found literature exhibited a pattern relating body mass loss with core temperature (Pryor et al., 2015) which was not coherent with the present results; the tested individual (M06) displayed a much higher temperature rise due to unknown reasons.

The first objective of this study was accomplished because the subjects’ performance study concerning two different environmental conditions was evaluated.

Thus far, when it comes to the comparison between the two adaptation situations (unacclimated and acclimated subject to thermal stress) there is huge gap left for one of the military (M06) probably because in his case it was not possible to link the two adaptation situations. Through the analysis of bibliography, it was possible to have an idea of what would happen to the body, however, it was not possible to draw a visible pattern for this individual’s body response behavior. If the two situations were put aside without the attempt of comparing them, they, separately, responded to what a thermal stress reaction would be (first part of the problem).

Considering the other individuals (M01, M02, M05, M07 and M09) the results met what was expected: they also reacted slightly better in the thermoneutral condition when comparing to the thermal stress condition and acclimation also lead to better performance status.

6 LIMITATIONS AND FUTURE WORK

Even though this kind of experiment is highly relevant for scientific knowledge purposes, this article only reports 6 case-studies so the conclusions cannot be largely applied. It would be interesting to extend these protocols to a bigger sample. One of the main reasons for this suggestion is the fact that the subjects sometimes reacted contrarily to expectations in some of the tests (especially M06); the causes are unknown and maybe a greater sample would explain the occurred behaviors. Also, a larger sample would provide greater power to the obtained conclusions.

Another limitation is that the studied activity concerning body mass loss does not fit in the ISO 9886 (2004) criteria as there is no defined work shift attached to Military (8h/day or 40h/week). Bearing this in mind, the presented values (token from the referred ISO) cannot be directly compared to the experimental data as they only serve the purpose of being a reference. This is the main reason why only one of the military's body mass loss (M06) was compared to the ISO. It would be interesting if some more studies would be performed in order to include all kind of occupational activities and maybe lead to the ISO's revision.

Some of the recommendations which can be made are: every protocols should be performed in the same period of the day, as personal circadian rhythms may have impact on the results and since the main purpose of this study was to evaluate the break in performance due to heat stress, some physiological stress indicators such as CK enzyme should be included in the blood sample analysis.

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