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Skin temperature evolution in an acclimation process

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Abstract: Hot and cold thermal environments interfere with the body's thermoregulatory system, which reacts to ensure thermal balance. The response to changes at room temperature occurs through a process of physiological adjustment to the new environmental conditions. This process plays a key role in human health risks prevention. This article aims to present some of the MeFinSA (Mental Fatigue in Sedentary Activity) project results related to changes in skin temperature, in a process of acclimation to different temperatures at the same relative humidity, in a sedentary activity. For this purpose, tests were performed in a climatic chamber with eight male volunteers.
The tests lasted one hour a day and were repeated by each volunteer during eight days, for each of two temperature conditions (20ºC and 32ºC) with a relative humidity of 60%. It has been found that there is a greater homogeneity in the temperature of the skin in warmer environments (32°C) when compared with colder environments (20°C). These results are consistent with those obtained by other researchers.

Keywords: Acclimatization, acclimation, hot, skin temperature, thermal environment.

A Evolução da temperatura da pele num processo de aclimatação

Resumo: Ambientes térmicos quentes e frios interferem com o sistema de termorregulação, o qual, reage para assegurar o equilíbrio homeotérmico. A reação às alterações da temperatura ambiente, ocorre através de um processo de ajuste fisiológico às novas condições ambientais. Este processo desempenha um papel fundamental na prevenção de riscos para a saúde. Este artigo tem como objetivo apresentar uma parte dos resultados do projeto MeFinSA (Mental Fatigue in Sedentary Activity) relativos à evolução da temperatura da pele, num processo de aclimatação a diferentes temperaturas mantendo a humidade relativa constante, numa atividade sedentária. Com este propósito, foram realizados ensaios com oito voluntários do sexo masculino numa câmara climática. Os testes, com duração de uma hora, foram repetidos por cada voluntário durante oito dias para cada uma de duas condições de temperatura (20ºC e 32ºC) com a mesma condição de humidade relativa (60% Hr). Verificou-se uma maior homogeneidade na temperatura da pele no ensaio em ambiente térmico quente (32°C) do que no ambiente térmico mais frio (20°C). Estes resultados são concordantes com os obtidos por outros autores.

Palavras-chave: Aclimatação natural, aclimatação artificial, calor, temperatura da pele, ambiente térmico.

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1. Introduction

Thermal environment is the set of variables that influence thermal heat exchange between the environment and the human body, so it is a factor that, directly or indirectly, acts on health, wellness and performing tasks. In thermal environment characterization two situations should be considered: one is thermal "stress" (cold or heat) and the other is thermal comfort. The first case is related to human body exposure to environments with extremes in temperature and humidity. The second is associated to values of temperature, humidity and air velocity that may cause discomfort.

All human activity is influenced by the environment where it is performed. In other words, in an economic perspective, it allows productivity control; in a sociocultural context, it reflects society customs and traditions; in a legal and political background it is expressed by the basic needs and, in a technological context, it can represent technological progress.

Over time, the organizations have progressively been giving more importance to the relationship between thermal environment, health problems and productivity. Productivity is conditioned by the comfort / discomfort level perceived by the affected individual. Some combinations of heat and humidity can be a health hazard. In fact it became increasingly clear that there are temperatures for which the work can become dangerous. According to several authors (Ribeiro, 2010; Radakovic et al., 2007), excessive heat exposure is related to heat stress that is injurious to health. The thermal environmental out of the comfort zone can affect the welfare, performance and individual`s health (Costa, Baptista & Diogo, 2012). The negative effect caused by high temperature is evidenced by changes in behaviour, mood, fatigue, motivation, reaction speed, increased absenteeism and stress. The study of the respective impact in the workplace has been undergoing an increasing importance. The growing complexity of work activities, associated with different environmental conditions, can lead to thermal stress situations. The influence of stress on human behavior due to extreme temperatures has been studied for several years, allowing the understanding of individual reactions in adverse working conditions. It is therefore essential to identify and monitor variables, in order to evaluate the performance under different environmental conditions. One of the most efficient ways human beings have to deal with stress by exposure to heat or cold, is by physiological adaptation. This process is known as acclimatization.

1.1. Acclimatization and Acclimation

Acclimatization and acclimation have the same goals and occur as consequence of cold exposure or heat exposure. They happen in different contexts: the acclimatization occurs in natural environment, while acclimation happens in a controlled environment (Ribeiro, 2010). Acclimatization impact in a workplace is a key subject to understand workers behaviour in different activities. In studies on thermal environment influence, a factor that needs to be controlled is the acclimatization state, due to the fact that the physiological response has transient characteristics during the adaptation time.

The acclimatization and its consequences were initially investigated by several authors as Oleson and Fanger (1973) and Parsons (2003). One of the more easily measured parameters in the acclimatization process is skin temperature. Skin temperature is influenced by thermal exchanges by conduction, convection, radiation and evaporation on the skin surface and, in addition, undergoes the influence of changes in skin blood flow and arterial blood temperatures. The skin being directly in contact with the external environmental conditions and being the more accessible part of the human body, it was hypothesized that it could provide one or more points that allow an expeditious measure of individual's acclimatization state.

Heat acclimatization improves tolerance to higher and lower temperatures and it is more effective when implemented in warm and humid conditions. In this case, a successful indicator is the decrease of the core temperature (t_c). Furthermore, cold acclimatization can minimize the risks of cold related injuries. Sawka et al. (2001) refer that human adaptation to heat or cold exposure tends to stabilize core and skin temperature, reducing physiological strain, improving work capabilities and consequently reducing the susceptibility to thermal injuries.

Children and adults have similar physiological adaptations during acclimatization to heat. These adaptations involve a lower heart rate, lower core and skin temperatures and a reduction of electrolytes loss in sweat (Naughton, 2008). Nevertheless, the acclimatization to heat may take a different course depending on the environment being dry or humid (Sawka, 2001; Naughton, 2008; Nielson et al., 1993).

1.2 Skin Temperature

Skin temperature is controlled by the sympathetic nervous system activity. Even when the entire skin surface is exposed to a constant ambient temperature, skin temperature is different on the different body areas. According to (Schlader et al., 2013) skin temperature plays an important signaling role in human thermoregulatory behavior.

The skin is the largest human body organ, and acts as the boundary between the body and the external environment. The skin controls the flow of heat and moisture with the surrounding environment, protects the body from the sun's rays and helps to keep a constant internal body temperature (≈37°C). Skin temperature also depends on climatic factors such as humidity, air temperature, wind chill, and exposure time to a particular environment. Skin temperature also changes over its own surface, especially in cold environmental conditions, in which the normal average skin temperature (t_{skm}) is about 33°C (91F) which can be referred to as its "set point" (Arens, 2006).

1.3 Objectives

This paper aims to present the first results of the project MeFinSA (Mental Fatigue in Sedentary Activity) relating to changes in skin temperature acclimation process.

2. Methodology

The tests were performed within a climatic chamber, where a sedentary activity is simulated supposedly provoking mental fatigue. Eight healthy volunteers participated in all the trials, aged between twenty and twenty seven years old who were asked to avoid coffee, alcohol, smoking and physical activity at least twelve hours prior to each test. Preliminary tests were carried on to test all the equipment and the reproducibility of trials. After that, all assays in the acclimation process were performed at the same time in the afternoon; this option aimed at minimizing the effects of circadian rhythms. All subjects had no significant disease. The protocol (with number *nº04/CEUP/2012)* was approved by the

Ethics Committee of the University of Porto. An informed consent was read and signed by each volunteer before its participation in the study. The subjects were fully informed of any risk and discomfort associated with the experiment. Prior to each test, the volunteers body mass (kg) and height (centimeters) were determined.

Each acclimation test lasted for one hour during which the subjects performed a set of four tests. The criteria to stop an assay was any of the following situations: a) finishing the four cognitive given tasks, b) feeling any symptoms such as dizziness, nausea and general malaise c) reaching 38.5 °C of internal temperature, measured by an ingestible thermometer *Equivital System*, d) reaching 165 bpm (beats per minute) of heart rate (measured with electrodes GE - Healthcare), e) feeling any other symptoms of heat stress, or if the volunteer, for any reason, decides to stop the task.

The skin temperature was recorded at 14 points according to ISO (9886:2004) standard. Assays were performed in two environment temperatures: 20 °C and 32 °C both with an air humidity of 60% Hr. A sedentary activity in a duly tested climatic chamber (Guedes et al., 2012) was simulated and appropriate parameters and equipment were selected according to (Costa & Baptista, 2013), as well as the procedure for measuring the internal temperature of the body (Costa et al., 2012a). In this situation, in addition to skin temperature (ISO 9886, 2004), other parameters were monitored, such as: intra-abdominal temperature via ingestible temperature sensors (TIS); brain activity through electroencephalography (EEG); electrodermal activity through (EDA), muscle activity through electromyography (EMG) and heart rate through electrocardiography (ECG). Furthermore, two questionnaires of subjective evaluation were also used, one for evaluation of thermal sensation, and another to evaluate workload NASA TLX (Hart & Staveland, 1988).

2.1 Equipment

For this study, the main equipment was the climate chamber within which all tests occurred. In Figure.1, all the equipment and instruments used can be observed (Costa & Baptista 2013).

2.2 Protocol

The assays were performed according to a protocol involving the following steps: first, the laboratory is shown and the research team is presented to the volunteer to whom the tests are explained (the volunteer does not do any test on the first day in lab). First, the volunteer is introduced to the research team who then lead him into the laboratory where all the tests to go through are explained in detail (on this first day no tests will take place).
Since the climatic chamber can take few hours to reach some of the intended "set points", for precaution, all tests are scheduled and prepared in advance. The first day of testing begins with 1) Questioning the volunteer on any doubts related with the test; 2) Reading and signing the informed consent, if the volunteer is going through this experience for the first time 3) Registration by the researcher in the individual test sheet (FIE n.1) of the temperature and humidity in the laboratory and inside the chamber, while the volunteer reads the Informed consent and / or is preparing himself for the test; 4) Register in FIE n.1 the weight of the volunteer.

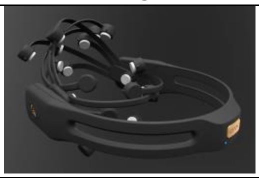
Computers	Climatic Chamber	Ingestible Temperature Sensors (Vital Sense)	Skin Temperature sensors tempPlux
			
Electrodermal activity sensors edaPlux	Electromyography sensors emgPlux	Electroencephalography EEG	Questionnaires
			
Medical Weighing Scales	Blood pressure metter	Flexible measuring tape	Battery of cognitive test
			PEBL: The Psychology Experiment Building Language 
Medical gloves	Scissors	Allergenic adhesive tape	Informed consent and questionnaires
			

Figure 1 - Different equipments and instruments used in the trials

Afterwards, all the protocols follow up. If the test requires measurement of internal temperature, the protocol PROT - IC001rev00 - Ingestion of capsules must be enabled; Place the skin sensors according to the protocol - PROT-TP002rev00, Sensors temPlux; Place the EDA sensors according to the protocol - PROT-EDA003rev00, Sensors edaPlux; Place the EMG sensors in accordance with the Protocol - PROT-EMG004rev00, Sensors emgPlux, and place the ECG according to the protocol - PROT-ECG005rev00 electrocardiogram. After that, the proceeding is the following:

- Stay twenty minutes sitting at rest, at constant temperature, before entering the chamber where he sites;
- The volunteer goes into the chamber and sits in front of the computer;
- Apply the blood pressure meter according to the protocol - PROT _ MT007rev00;
- Explain the questionnaires and NASA TLX thermal sensation, which must be filled informatically;
- Apply the sensors to measure the cognitive activity according to the protocol - 006rev00 - PROT - EEG , electroencephalogram;
- Ask the volunteer to stay as quiet as possible, while is doing the test, paying special attention to head motion;
- Complete the thermal sensation questionnaire before starting the cognitive test;

- The test should take about one hour, starting with a random sequenced battery of cognitive tests;
- Fulfill the thermal sensation questionnaire at the end of the test, after finishing the last test battery;
- Remove the blood pressure meter;
- Disconnect and remove the electroencephalogram (EEG) from the volunteer head;
- After removing the equipment (EEG) the volunteer leaves the chamber;
- After leaving the climatic chamber, the volunteer puts on a robe and waits at least 10 minutes out of the chamber until his blood pressure is stabilized.
- Remove the remaining sensors placed on the skin in the following order: a) SEM equivital (if applicable); b) ECG; c) Temperature sensors TempPlux; d) Electrodermal activity Sensors (EDA); e) EMG sensors.

Subsequently, the following steps are carried on: reweight the volunteer and record the value in (FIEn.1); collect the test battery; check if the data were stored according to the following checklist: a) Camera; b) BioPLUX number 29; c) BioPLUX number 37; d) ECG; e) Equivital; f) EEG; g) Blood pressure meter; h) Battery Tests; i) Thermal sensation questionnaire; j) NASA TLX questionnaire; k) Anthropometric data. Finally, the data are saved according to the specific protocol.

2.3 Skin temperature measurement

The skin temperature was monitored at 14 points all over the body as shown in Table 1. This monitoring was conducted in accordance with ISO9886 standard (International standard – Ergonomics Evaluation of Thermal Strain by Physiological Measurements) and some other studies (Ely et al., 2009; Yao et al., 2008; Costa & Baptista, 2013).

Table 1 - Skin temperature measurements (adapted from ISO 9886)

Numbers and locations of measured points
1- Forehead
2- Neck
3- Right scapula
4- Left upper chest
5- Right arm in upper location
6- Left arm in lower location
7- Left hand
8- Right abdomen
9- Left paravertebral
10- Right anterior thigh
11- Left posterior thigh
12- Right shin
13- Left calf
14- Right instep

The date acquired on the points indicated on the Table 1 is used to calculate the mean skin temperature, t_{skm}.

The skin temperature was measured with “Plux temperature sensors” colleted by *the system bioPLUXresearch.* These sensors were designed for applications involving continuous or intermittent temperature readings. This NTC (negative temperature coefficient) thermistor has been developed for biomedical applications with the possibility of being used in a temperature range from 0ºC to 50°C. The Plux temperature sensors are robust, stable, accurate and with low tolerance values. Its geometry and rapid response also provided an increased confidence on obtained results.

2.4 Core temperature measurement.

As already mentioned body temperature is a physiological parameter that changes according to the measurement point location and environmental temperature. It can be measured internally, and in this case, corresponds to “core temperature", t_c, or it can be measured more superficially (skin; axillary, tympanic, oral). In this last procedure, it is more influenced by room temperature, and is also less reproducible than core temperature (Ribeiro, 2010). In the present work, t_c was measured using an ingestible temperature sensor, *Vital Sense*. After a careful analysis, the use of ITS (Ingestible Thermal Sensors) (Costa et al, 2012), having less technical limitations and being less invasive, was chosen as the best option to measure t_c in the occupational environment.

2.5 EEG

Heat exposure may change cognitive performance. An excessive mental load combined with high temperature and humidity can lead rapidly to a state of fatigue. Electroencephalography (EEG) was used to study this parameter (Costa et al 2013) and to record electrical activity along the scalp. Recent technological advances allow real-time online processing of multi-channel EEG data using EEG devices (e.g., *Emotiv EPOC EEG headset*) (Bobrov et al., 2011).

2.6 Battery of cognitive tasks

A battery of psychological tests implemented in PEBL (Psychology Experiment Building Language) and distributed freely was used. These tests are used in psychological, neuropsychological research and clinical communities. The cognitive tests were: SRT – Simple Reaction Time - to detect the presence of a visual stimulus as quickly and accurately as possible; DSpan – Digit Span: to remember a sequence of digits; Satest – Situation Awareness Test: to watch a set of moving targets which respond to *probes* about their locations and identities; GoNoGo_Classic: for continuous performance of a task. All tasks were carried on with computer support. The test battery took approximately 60 min to perform (Costa et al., 2013).

3. Results Presentation

The evolution of skin temperature in an acclimation process and the data related to skin temperature of two individuals over eight days are presented. The tests were conducted to assess acclimation analyzing the evolution of physiological response. The tests were performed in two different conditions: 20ºC-60% Hr (considered fresh), and 32ºC-60% Hr (considered hot).

Table 2, lists the environmental variables related to the days of the tests and the anthropometric data of volunteers.

Five different analysis are emphasized in this study: 1) temperature changes over one hour test, which analyzes the initial and the final temperature for each day; 2) variation of skin mean forehead and neck temperatures over one hour test; 3) variation of the skin mean temperature, over 8 days of acclimation; 4) variation in the mean temperature of the neck and forehead over 8 days and 5) comparison of skin temperature variation measured on each place of the body.

Table 2 - Record of environmental variables and anthropometric data

Code	Set Point	Date	Hour	Height	Starting weight	Final weight	BMI	CO_2 inicial	CO_2 final
	ºC_%Hr	dd:mm:year		m	Kg	Kg		ppm	ppm
TR0010_2060_A1	20_60	19-Feb-13	16H00	1.71	66.900	66.650	22.9	457	1154
TR0011_2060_A2	20_60	20-Feb-13	15H00	1.71	67.705	67.705	23.2	461	1152
TR0012_2060_A3	20_60	21-Feb-13	15H00	1.71	67.720	67.705	23.2	601	719
TR0013_2060_A4	20_60	22-Feb-13	15H00	1.71	67.950	67.850	23.2	436	799
TR0014_2060_A5	20_60	23-Feb-13	15H00	1.71	66.700	66.600	22.8	498	765
TR0015_2060_A6	20_60	25-Feb-13	15H00	1.71	67.550	67.450	23.1	451	804
TR0016_2060_A7	20_60	26-Feb-13	15H00	1.71	67.350	67.350	23.0	621	683
TR0017_2060_A8	20_60	27-Feb-13	15H00	1.71	66.600	66.500	22.8	556	816
FJ0019_3260_A1	32_60	06-Mar-13	16H00	1.786	85.200	85.200	26.7	670	609
FJ0020_3260_A2	32_60	07-Mar-13	16H00	1.786	84.650	84.400	26.5	409	688
FJ0021_3260_A3	32_60	08-Mar-13	16H00	1.786	84,000	83.950	26.3	415	699
FJ0022_3260_A4	32_60	11-Mar-13	15H30	1.786	84.350	84.250	26.4	401	695
FJ0023_3260_A5	32_60	12-Mar-13	16H00	1.786	83.800	83.700	26.3	422	733
FJ0024_3260_A6	32_60	13-Mar-13	16H00	1.786	84,000	83.900	26.3	438.	764
FJ0025_3260_A7	32_60	14-Mar-13	16H00	1.786	84.750	84.700	26.6	426	711
FJ0026_3260_A8	32_60	16-Mar-13	16H00	1.786	84.300	84.100	26.4	610	686

Table 3 shows the anthropometric basic elements of the 8 volunteers, and their body mass index (BMI).

Table 3 - Anthropometric characteristics of the sample

	Age (Years)	Starting weight (kg)	Height (m)	BMI ($kg.m^{-2}$)
Mean	22.63	81.79	1.75	26.75
SD	3.11	22.07	0.04	7.11
Max	27.00	133.35	1.81	43.79
Min	20.00	62.00	1.71	20.96

3.1. Variation in skin mean temperature over one hour test

During the tests, it was found a different acclimation pattern between the hot (32°C) and cold environment (20ºC). In hot environment, there was a decrease of approximately 1°C in mean skin temperature (t_{skm}) in the beginning of the test between the first day (around 35ºC) and the eighth day of acclimation (around 34ºC). During the test, the temperature tends to reach the value prior to acclimation (Figure 2), an effect which was not so evident on the first day.

The opposite situation happened in the cold environment (Figure 3). In this case, the acclimation caused a rise in skin mean temperature by about 1°C verified at the beginning of the test. It was observed an adaptation to the new environment temperature over an hour. In the course of the test, this difference gradually fades, resuming the skin pre-acclimation values.

Throughout the trials, t_{skm} evolved to the values previous to acclimation. This phenomenon occurred in either hot or cold environment but not in an identical manner.

In the tests performed, it was observed that there was a need for more time for acclimation to cold environments than to warm ones.

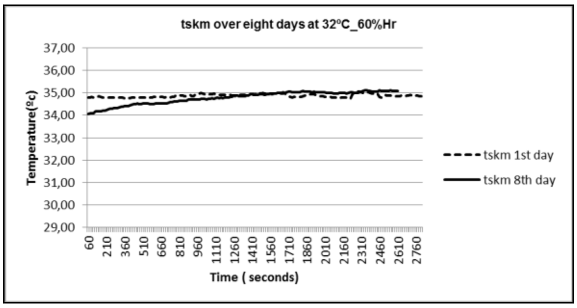


Figure 2 - Mean body temperature (t_{skm}) during acclimation to 32°C-60% rh

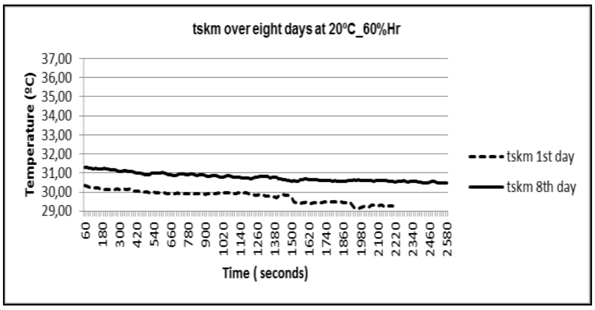


Figure 3 - Mean body temperature (t_{skm}) during acclimation to 20°C-60% rh

3.2. Variation in skin mean temperature on the forehead and neck over one hour test

When the analysis is performed separately for each one of the fourteen points of skin temperature measurement, it is observed that each one has a characteristic development that differs when environments are hot or cold.

In the search for a point of easy access and high reliability where the occurrence of acclimation could be verified, the results pointed to the head, particularly to the forehead and neck. On these two points, for the hot environment, it seems to be the neck that offers more reliability (Figure 4). For the cold environment, the forehead seems to be the most suitable (Figure 5).

3.3. Variation in skin mean temperature over eight days of acclimation test

Figures 6 and 7, show the variation in skin temperature over the eight days of acclimation at two different temperatures and humidity.

Figure 6, displays instability on the average of skin temperature, showing variations in different days. The difference between the maximum and minimum t_{skm} at 20ºC-60% Hr over 8 days of acclimation is 1.28ºC.

In Figure 7, it can be seen greater stability of mean skin temperature in warm temperatures. Significant differences during the trial are not verified. The difference between the maximum and the minimum t_{skm} value, at 32ºC-60% Hr over 8 days of acclimation was 0.41ºC.

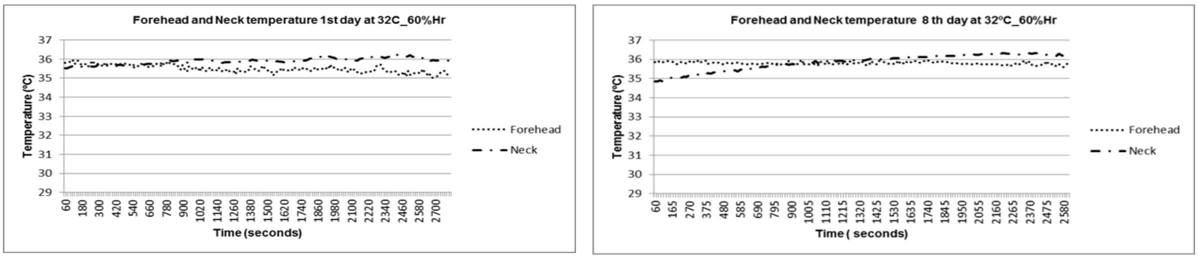


Figure 4 - Comparison of forehead and neck temperature between the 1st and 8th day of acclimation at 32°C-60% Hr

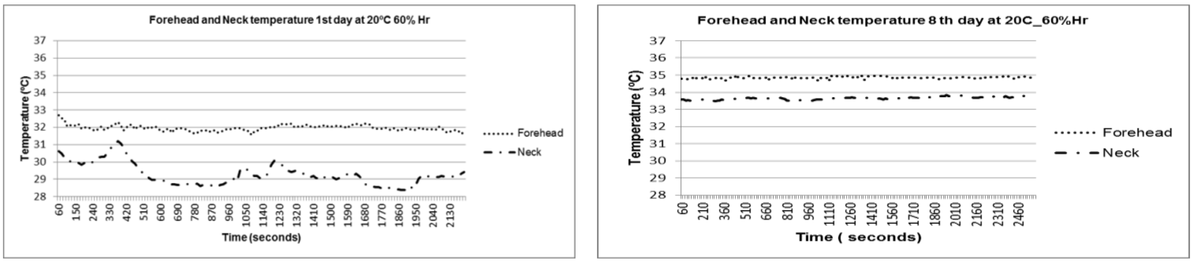


Figure 5 - Comparison of the forehead and neck temperature between the 1st and 8th day of acclimation at 20°C-60% Hr.

Analyzing these two situations, it is found that when in cold temperatures (Figure 5), the variability of t_{skm} is generically greater than when they are hot (Figure 4).

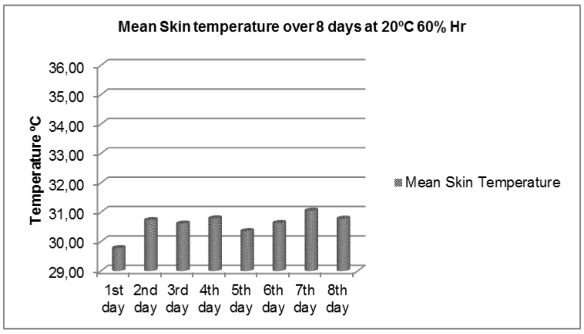


Figure 6 - Mean skin temperature over 8 days at 20ºC, 60% Hr in an acclimation process.

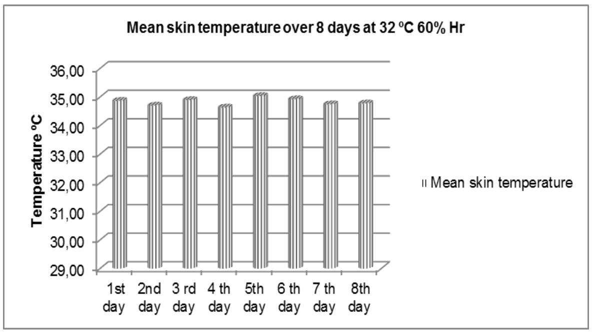


Figure 7 - Mean skin temperature over 8 days at 32ºC, 60% Hr in an acclimation process.

3.4 Variation in the mean temperature of the neck and forehead over 8 days.

In Figure 8, it can be seen the maximum and minimum temperature of the forehead for 32ºC and 20ºC. The same occurrence is visible in Figure 9, concerning the neck temperature.

The difference between the maximum and minimum mean forehead temperature at 32ºC is 0.64ºC while at 20ºC 60% Hr is 3.90ºC. Once again, a biger difference in cold condition was registered.

The difference between the maximum and minimum temperature in the neck mean temperature at 32ºC 60% Hr is 0.37ºC, while at 20ºC, 60% Hr is 5.18ºC. It also appears that there is less difference between the temperature of the forehead and neck in the case of hot environments and a greater difference between these temperatures in cold ones.

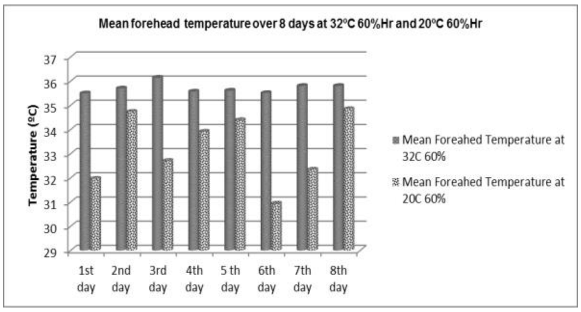


Figure 8 - Mean forehead temperature over 8 days at 20ºC-60%Hr and 32ºC-60% Hr

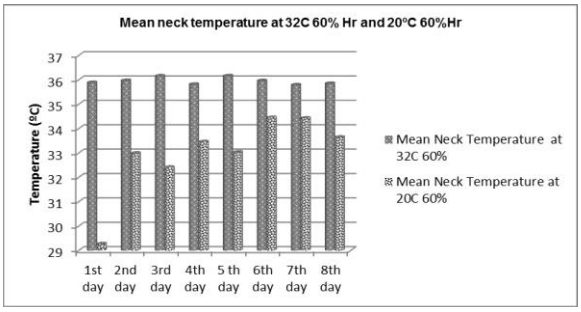


Figure 9 - Mean neck temperature over 8 days at 20ºC-60% Hr and 32ºC-60% Hr

Analyzing these two situations (Figure 8 and 9) it was once again verified a great difference between the maximum and minimum temperature in a cold environment. Between the neck and the forehead it was found that in hot conditions the temperature of the neck is slightly higher than the forehead temperature, and the difference between the maximum and minimum is smaller.

3.5. Comparison of variation of skin temperature on each part of the body

As it can be seen in Figures 10 and 11, there is a greater homogeneity in hot temperature than in cold temperature in all parts of the body where the measurements were performed.

4. Discussion of the results

4.1 Physiologic response to heat and cold environments

It is already known that the skin mean temperature (t_{skm}) has a good correlation with the feeling of comfort. However, there is still some concern about the correlation between the average temperature and other indexes. In order to verify to what extent the temperature of the skin is an effective indicator to assess the influence of thermal environment in sedentary activity, some points were found that can lead to the following information.

To describe the physiological response to heat and cold environments, the body is considered divided into two components: core and shell. The surface temperature is represented by the mean temperature of the skin, and core temperature is represented by the internal temperature. When the body is faced with challenges to neutrality (eg when in a state of hot or cold stress), strives to regain the thermal equilibrium through physiological adjustments. The two forms of physiological adjustments to different thermal environments are sweating and shivering.

In fact, the human body reacts to lower temperatures, mainly by constriction of peripheral blood vessels, and to high temperatures mainly by increasing the secretion of sweat. It is known that the physical regulation by constriction or dilation of blood vessels is essentially a change of heat conductivity between room temperature and internal body temperature and that the different body segments play different roles concerning heat removal.

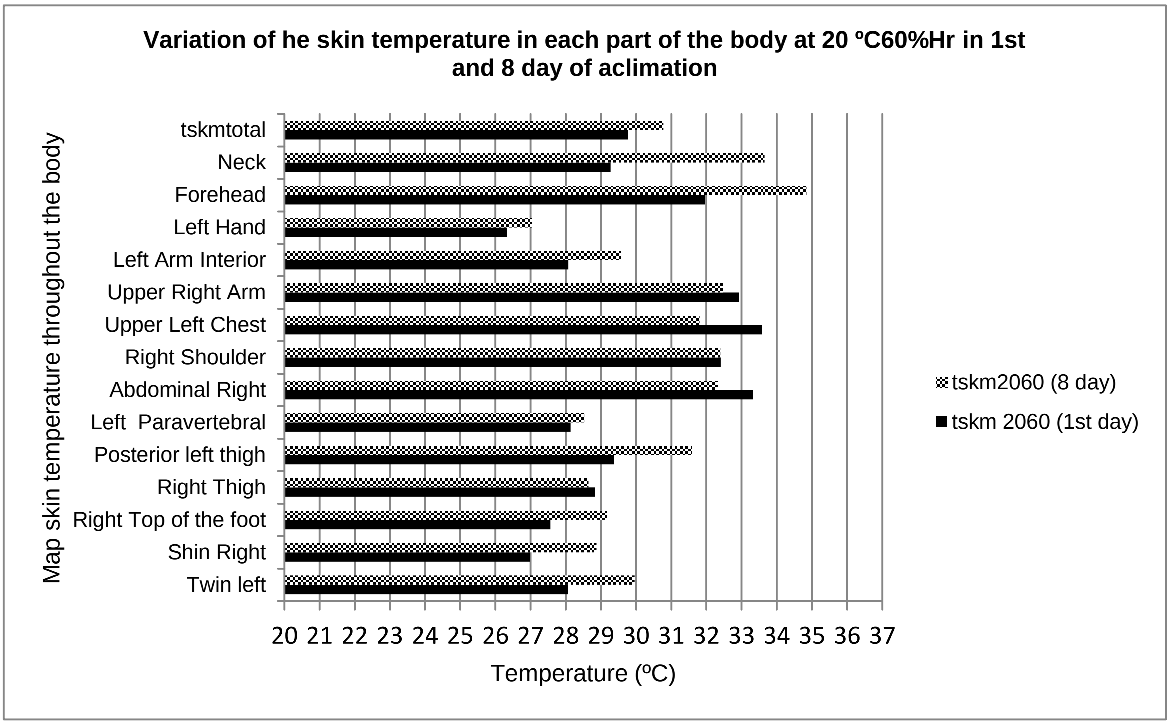


Figure 10 - Skin temperature in each part of the body at 20ºC, 60% Hr in the 1st and 8th day of acclimation.

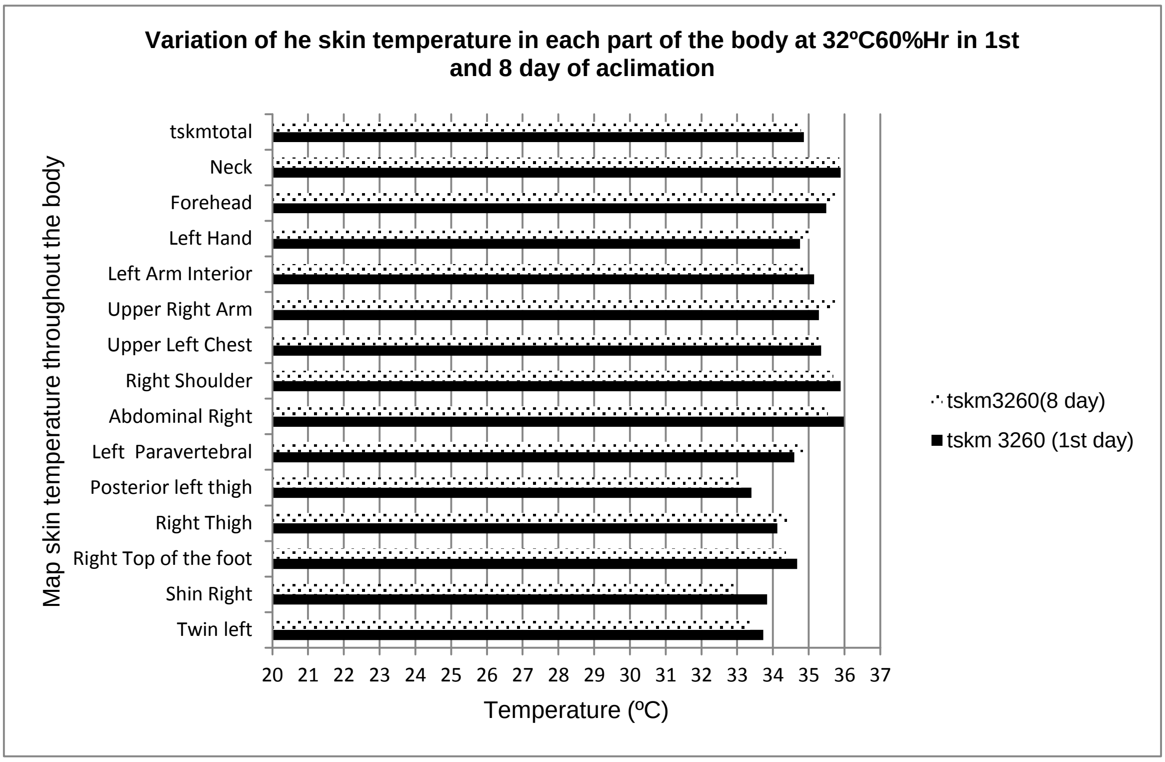


Figure 11 - Skin temperature in each part of the body at 32ºC, 60% Hr in 1st and 8th day of acclimation.

Skin temperature is an effective indicator for an objective evaluation of human thermal sensation, since it is controlled by the sympathetic system activity, which reflects the information processed by the brain (Kataoka, 1998). According to the standard ISO_9886, skin temperature varies over body surface, and especially in cold environmental conditions. For this reason there is a distinction between local skin temperature (t_{sk}) at a specific point on the surface of the body, and skin temperature over the entire surface of the body that can be estimated by a mean value (t_{skm}), considering a set of local skin temperatures, according to the characterizing area. Skin temperature alone is not sufficient to assess the physiological thermal stress, but an important criterion for evaluating thermal comfort.

Skin temperature depends on thermal exchanges by conduction, convection, radiation, evaporation, changes in blood flow, and arterial blood temperature which reaches each zone of the body. The heat losses from the body are caused precisely by variable thermal exchanges that cause temperature alterations along the body. When air temperature is close to skin temperature, around 31-33°C, heat losses from convection ceases and, under these conditions, the body becomes highly and almost totally dependent on the evaporative cooling for heat dissipation (Baker 1954).

Body temperature is also subjected to a circadian rhythm variation that can be up to about 1 °C over the day in a normal subject (Ribeiro, 2010).

4.2. The importance of acclimation

Heat acclimation is likely to confer an important advantage that is a decrease in core body temperature in the order of 0.3 - 0.5°C (Buono et al, 1989). The effects of acclimation were also studied by Radakovic (2007) on cognitive and physiological performance against heat stress in soldiers, when carrying out stress tests. Those 40 male soldiers were tested at temperatures of 20ºC (16ºC wet globe temperature), cold, and 40ºC (29ºC wet globe temperature) before and after acclimation for 10 days. Also Lee et al (2012) refer that in a warm and humid climate, a typical 10-day heat acclimatization program can improve work tolerance with 20.5 kg and 24.7 kg standard military load configurations in trained soldiers.

The physiologic adjustments of heat acclimation are: internal and skin temperature reduction, decreased heart rate and increased sweating rate. The main changes that occur with hot acclimation are: increased blood volume, increased blood flow, increased venous tone, increased sweating rate; earlier onset of sweating, production of more dilute sweat, sweat with lower sodium concentration, more widespread sweating, less cardiac frequency, lower metabolic rate, lower inner temperature, lower skin temperature, better hydric balance, increased thirst (Sawka et al., 2001).

On the other side, when exposed to cold environments, human body will respond with vasoconstriction to maintain core reduced heat loss from core to periphery by convection, and heat loss from periphery to environment, by radiation and convection (Yu, Cao, Cui, Ouyang, & Zhu, 2013).

Lower skin temperatures during cold air exposure following acclimation have two implications: (a) at a given air temperature, lower skin temperatures reduce thermal gradient for heat transfer between the skin and the air, which improves insulation; (b) in the cold exposure, the magnitude of the acclimation effect on the skin temperature is greater than the effect on core temperature. Therefore, the core-to-skin thermal gradient is higher. A higher thermal gradient, between the core and the skin, favors redistribution of body heat from the core to the subcutaneous muscular shell, while lower skin temperature due to enhanced cutaneous vasoconstriction will limit heat loss through the body's shell.

Individual physiological response to cold changes with age and physical fitness (Kaciuba-Uscilko & Greenleaf, 1989) depends on temperature and exposure time.

5. Conclusions

It is already known that the skin mean temperature (t_{skm}) has a good correlation with the feeling of comfort. However, there is still some concern about the correlation between the average temperature and other indexes. After this work/research, and in order to verify to what extent the temperature of the skin is an effective indicator to assess the influence of the thermal environment in sedentary activity, some points were found that can lead to such information and one of them will be the head, particularly in the forehead and neck. Regarding these two points, heat situations seem to be more noticeable in the neck and, in cold environments, the forehead. Other authors suggest that there is no correlation and direct connection between the skin temperature and performance.

The results clearly point to the existence of a differentiated acclimation when it comes to hot and cold environments. However, these results are not in line with many others found in the literature and in international organizations. Without discussing the results presented by other authors, as for example Oleson and Fanger (1973), but given the rigor placed on tests performed, it seems obvious that the process and acclimation time is different for hot and cold environments. It is important to check the influence of the differential between the starting temperature of acclimation and the time needed for the body's adaptation to new environmental conditions. This knowledge is of great importance for work world, particularly for occupations where working conditions require a good capacity for climate adaptation. Obvious examples are sectors such as metallurgical and glass industry, mineral underground exploitation, bakery and catering, among others. The need for acclimation also occurs in areas where there is the/ a intercontinental movement of workers or even for tourists.

6. References

Arens, E. & Zhang, H. (2006). The Skin's Role in Human Thermoregulation and Comfort. Thermal and Moisture Transport in Fibrous Materials, Woodhead Publishing Ltd, pp 560-602. Available in http://escholarship.org/uc/item/3f4599hx (accessed on Jan. 27, 2014).

Barker, L. M. & Taylor, W. M. (1954). The relationship under stress between changes in skin temperature, electrical skin resistance, and pulse rate. *Journal of Experimental Psychology*, 48 (Nº5), pp. 361-366

Bobrov, P., Frolov, A., Cantor, C., Fedulova, I., Bakhnyan, M. & Zhavoronkov, A. (2011). Brain-Computer Interface Based on Generation of Visual Images. *PLoS ONE* 6(6): e20674, pp. 1-12.

Buono, M. J., Heaney, J. H. & Canine, K. M. (1998). Acclimatization to humid heat lowers resting core temperature. *Am J Physiol.* pp-R1295-1299.

Costa E. Q., Baptista, J. S. & Carvalho, J. (2014). Skin temperature as an indicator of thermal environment's influence on cognitive response. *International Symposium on Occupational Safety and Hygiene-SHO 2014*, pp. 187-191

Costa, E. Q., Guedes, J. C., & Baptista, J. S. (2012). Core Body Temperature Evaluation: Suitability of Measurement Procedures. *Thermology International*, Vol. 22 (2012) nº Appendix 1 to Number 3, pp. 33-41.

Costa, E. Q. & Baptista J. S. (2013). Thermal Environment and Cognitive Performance: Parameters and Equipment. *International Symposium on Occupational Safety and Hygiene-SHO 2013*, pp. 267-272.

Costa, E. Q., Baptista, J. Santos, Couto, D., Costa, J. T., Diogo, M. T., Almeida, P., Chaves, P., Carvalho, J. & Leão, P. (2013). Test Protocol Validation For Thermal Environment and Cognitive Performance. *Proceedings 4th International Conference on Integrity, Reliability and Failure*, Ed. INEGI, pp. 667-668.

Costa, E. Q., Baptista, J. S., & Diogo, M. T. (2012). Thermal Environment and Productivity in Sedentary Activities. A Short Review. *International Symposium on Occupational Safety and Hygiene-SHO 2012,* pp. 478-483.

Ely, B. R., Ely, M. R., Cheuvront, S. N., Kenefic, R. W., DeGroot, D. W., & Montain, S. J. (2009). Evidence against a 40ºC core temperature threshold for fatigue in humans'. J *Appl Physiol* 107(5), pp. 1519-1525.

Guedes, J. C., Costa, E. Q. & Baptista, J. S. (2012). Using a Climatic Chamber to Measure The Human Psychophysiological Response Under Different Combinations of Temperature And Humidity. *Thermology International*, Vol.22 (2012) nº Appendix 1 to Number 3, pp.49-54.

ISO (International Organization Standardization) (2004) ISO 9886. Ergonomics: Evaluation of thermal strain by physiological measurements. Genève: ISO.

Lee, J. K. W., Nio, A. Q. X., Fun, D. C. Y., Teo, Y. S., Chia, E. V., & Lim, C. L. (2012). Effects of heat acclimatisation on work tolerance and thermoregulation in trained tropical natives. *Journal of Thermal Biology*, 37(5), pp. 366-373.

Kaciuba-Uscilko, H., & Greenleaf, J. E. (1989). Acclimatization to Cold in Humans. *NASA Technical Memorandum* 101012, pp. 1-42.

Naughton, G. A., & Carlson, J.S. (2008). Reducing the risk of heat-related decrements to physical activity in young people. *J. of Sc. and Medicine* in Sport, 11, pp. 58-65.

NIOSH (National Institute for Occupational Safety and Health) (1986). Criteria for a Recommended Standard - Occupational Exposure to Hot Environments - revised criteria. *Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health*, DHHS(NIOSH) pp. 86–113.

Nielsen B., Hales, J. R. S., Strange, N. J., Christensen, N. J., Warberg, J. & Saltin, B. (1993). Human circulatory and thermoregulatory adaptations with heat acclimatization and exercise in a hot, dry environment. *J Physiol*, 460, pp. 467-485.

Olesen, B. W. & Fanger, P. O. (1973). The Skin temperature distribution for resting man in contort. *Arch. Sci. Physiol*. (Paris); 27(4): 385-393.

Parsons, K. C. (2003). *Human thermal environments: the effects of hot, moderate, and cold environments on human health, comfort, and performance* (2nd ed.). London: Taylor & Francis.

Radakovic, S. S., Maric, J, Surbatovic, M., Radjen, S., Stefanova, E., Stankovic, N. & Filipovic, N. (2007). *Effects of acclimatization on cognitive performance in soldiers during exertional heat stress.* Belgrado, Serbia, Mil Med.

Ribeiro, B. (2010). *Calor, Fadiga e Hidratação*. Alfragide: Texto Editores.

Sawka, M. N., Castellani, J. W., Pandolf, K. B. & Young, A. J. (2001). Human Adaptations to Heat and Cold Stress. *RTO HFM Symposium on "Blowing Hot and Cold: Protecting Against Climatic Extremes"*, RTO-MP-076. pp.KN4-1-KN4.15.

Schlader, Z. J., Perry, B. G., Jusoh, M. R., Hodges, L. D., Stannard, S. R. & Mundel, T. (2013). Human temperature regulation when given the opportunity to behave. [Randomized Controlled Trial]. *Eur J Appl Physio*l.,113(5), pp.1291-301.

Staveland, L. E. & Hart, S. F. (1988). Development of NASA-TLX (Task Load Index): Results of Empirical and Theoretical Research. *Human Mental Workload*, pp. 239-250.

Yao, Y., Lian, Z., Liu, W., & Shen, Q. (2008). Experimental study on physiological responses and thermal comfort under various ambient temperatures. *Physiology Behaviour*, 93(1-2), pp. 310-321.

Yu, J., Cao, G., Cui, W., Ouyang, Q. & Zhu, Y. (2013). People who live in a cold climate: thermal adaptation differences based on availability of heating. *Indoor Air*, 23(4), pp.303-310.