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Circadian and gender differences in skin temperature in militaries by thermography

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HIGHLIGHTS

- We studied circadian and gender differences in skin temperature in militaries.
- In the morning, mean skin temperature was higher in men than in women.
- In the evening, mean skin temperature was similar in men and in women.
- The hands were the only body part having similar temperatures at both time points.
- Skin temperature was lower in the morning than in the evening in men and women.

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ABSTRACT

Aim: The purpose of this study was to determine gender differences in skin temperature (T_{sk}) for 21 regions of interest (ROIs) of the body throughout the day in a military sample using infrared thermography.
Methods: The T_{sk} of 20 male (23.2 ± 2.9 yr) and 20 female (20.5 ± 1.3 yr) Brazilian Air Force Military members were evaluated with four thermograms collected at 7:00 AM (T_{sk7}) and 7:00 PM (T_{sk19}) by a Fluke® thermal camera. The ROIs analyzed included the abdomen and bilateral anterior and posterior views of the hands, forearms, arms, thighs, and legs. Student's *t*-tests were performed on independent samples ($\alpha = 0.05$).
Results: With the exception of the hands, men's T_{sk7} was significantly higher than that of women ($p < 0.05$). However, in the late evening (T_{sk19}), only the temperatures of the posterior side of the thigh and leg were significantly lower ($p < 0.05$) in women.
Conclusions: In the early morning, men present a greater average T_{sk} than women across all evaluated ROIs; however, those differences disappear after 12 h, except for the posterior thighs and legs. The hands were the sole areas showing similar temperatures at both time points.

1. Introduction

It is well established that physiological differences in body temperature vary according to gender [1–4]. These differences have been related, in part, to higher body fat content in women [5], mechanisms for the sweating rate control [3,6], differences in body surface [3] and metabolic heat production [5,7,8], as well as by hormonal changes mediated by the menstrual cycle [9,10] and the use of oral contraceptives [3]. These factors complicate the assessment of women's thermal responses.

The control of human skin temperature can be evaluated with several techniques. However, each technique is characterized by normal ranges, and the measures may vary if they are evaluated from different procedures [11–13]. The major limitation of most techniques for detecting human skin temperature is that these methods record temperature at a single point in time. Conversely, infrared thermography (IRT) is a safe, non-invasive and non-ionizing technique that enables a rapid and non-contact

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detection of irradiated energy released from the body [14–16]. It has recently been shown that a high-resolution thermal image can provide detailed information about the complex systems underlying body thermoregulation [14,16]. The development of rapid and user-friendly IRT monitoring tools allowed to obtain thermal profile of humans for comparisons within different population groups [17]. Given that gender may influence thermal profile properties, it is necessary to determine how this factor may influence skin temperature (T_{sk}) measurements conducted with IRT.

In the military medical field, there are multiple applications of IRT. For example, exertional heat stress is one of the most dangerous threats in the military environment, and many studies have focused on this issue [18–22]. Exertional heat stress leads to an increase in body temperature [23], and IRT might be an alternative method for its evaluation. Furthermore, monitoring fevers caused by zoonotic infections [24], pathogens [25], or non-infectious inflammatory disorders [25] can also provide interesting applications for the IRT military field. The IRT has also been widely used in monitoring orthopedic injuries [26,27], with a potential military use for evaluating amputated limbs [28], as it can provide critical information during recovery processes. Finally, during military physical training, IRT has been proposed as a method for preventing injuries by trying to avoid side-to-side T_{sk} differences higher than 0.5 °C [29,30].

Regarding the use of IRT in the military field, the identification of T_{sk} differences between men and women is particularly intriguing because it facilitates a large number of applications in technological, medical or combat situations. In the technological field, the use of T_{sk} measurements by IRT can facilitate the study of heat production and dissipation [14,16,17,31], which is a key research issue in the military sector (i.e., for chemical protective clothing or bomb technician clothing, for diver's thermal protection, for battle dress uniforms and for ballistic vests). Military clothes are designed to facilitate heat loss, or its retention, depending on the amount of exercise and the weather conditions [18]. These special clothes are used to maintain body temperature in a thermo-neutral zone, which is a key factor for improving security and supporting appropriate physical and cognitive performance [2].

To the best of the authors knowledge, only few studies have used IRT in military environments for assessing T_{sk} [32,33]. However, none of these papers focused on both circadian and gender differences in T_{sk} in militaries. Studies performed on the civilian population [29,34,35] comparing IRT results by gender indicate that there are differences only in specific ROIs.

Therefore, due to the lack of information about circadian and gender differences in T_{sk}, the purpose of this study is to analyze gender T_{sk} differences in different time of day among young adult military subjects in 21 ROIs of the body.

2. Methods

2.1. Subjects

A convenience sample of 40 military subjects enlisted in the Brazilian Air Force School of Aeronautics, São Paulo, Brazil, including twenty males (age: 22.9 ± 3 yr; height: 178.3 ± 7.8 cm; body mass: 73.4 ± 8.2 kg; body composition: 19.6 + 3.5%) and twenty female (age: 20.5 ± 1.3 yr, height: 165.0 ± 4.7 cm, body mass: 62.2 ± 9.2 kg, body composition 20.8 ± 4.4%) volunteered in this study. All of the evaluated subjects were considered active because they performed military physical training sessions from moderate to high intensity four to five times per week for at least six months. This level of activity exceeds the standard recommendations for considering a sample to be "active" [36].

The exclusion criteria included the following: (a) Any bone, muscle or joint injury in the two months prior to data collection; (b) A history of renal problems; (c) Undergoing physiotherapeutic treatment; (d) Tobacco or drugs consumption (e.g., antipyretics, diuretics, or food supplements with potential interference with homeostasis or body temperature or water) in the previous two weeks; (e) Burns on the skin surface, regardless of their severity; (f) Performing any local treatment with creams, ointments or lotions; (g) Pain, symptoms of fever, or sleeping disturbances in the prior seven days; and (h) women in the ovulatory phase or alterations in the menstrual cycle (e.g., dysmenorrhea and oligomenorrhea). All the females considered were using contraceptives.

The male and female samples participated voluntarily and remained on the military base during the 32-h study period. After being informed about the goals of the study and its objectives, they signed consent forms to participate in the study and did not receive any financial compensation. The ethics committee of the Viçosa Federal University, Brazil, approved the study procedures (protocol number: 40928260540), which followed the principles outlined by the World Medical Assembly Declaration of Helsinki.

2.2. Procedures and study design

The data were collected over two days during the spring season, with an average external temperature of 25 °C for male and female data collections. The standardization of the evaluation conditions began the day before data collection. All subjects refrained from high intensity [37] physical exercises, and they were restricted to engaging in normal daily activities. After the evening meal held at the military base, the subjects retired to their respective rooms between 21:30 and 22:00 h for an 8 h sleep period.

Thermographic images were collected the next day at 7:00 (T_{sk7}) and 19:00 (T_{sk19}) hours. Subjects always remained in a hut and only engaged in sedentary activities with low energy consumption, such as watching TV, reading or playing cards (<1.6 METs) [37].

Subjects always ate soon after and at least 2 h before data collection. This schedule was maintained to minimize any thermogenic effects of food. The amount of food intake was standardized according to the controlled meals prepared in the military base cafeteria, and liquid consumption was restricted to water. The consumption of any other food or drink was forbidden, especially any products containing caffeine or alcohol, during the data collection period. Fig. 1 summarizes the study protocol.

The T_{sk} values of the body regions of interest (ROIs) were obtained from thermograms, according to the criteria described by the European Association of Thermology [38–40]. A room on the military base (4 × 6 × 2.6 m) with no natural light was prepared for testing, with a temperature of 23 ± 1 °C and humidity of 50 ± 5%. Environmental conditions were maintained in the room by an air conditioner, and airflow was not directed at the data collection area. Artificial lighting was provided by low-thermal radiation fluorescent lamps. All thermograms were performed by a single examiner using the same imager, which was positioned on a tripod 4 m from the subject.

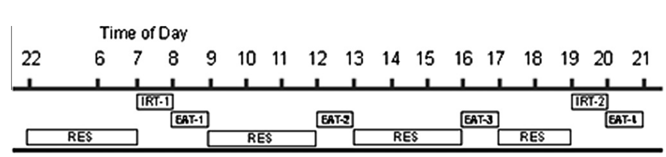

Fig. 1. Schedule of data collection (RES = Residence; IRT-n = Data collection number "n"; EAT-1 = Breakfast; EAT-2 = Lunch; EAT-3 = Snack; EAT-4 = Dinner).

Subjects arrived in the waiting room adjacent to the data collection room 15–20 min before the scheduled testing. The subjects remained seated at rest for five minutes. Then, men were instructed to change into a swimsuit or shorts, whereas women were asked to wear shorts and a sport bra. Then, subjects were directed to the data collection room where, after a minimum of 10 min of adaptation to the room conditions [41], the thermograms were obtained.

During the adaptation and data collection periods, the subjects were asked to abstain from making any types of movement, such as sitting, crossing legs or arms, or scratching, given that those actions can modify the local T_{sk} due to friction. After these preparatory steps, thermograms were obtained following the procedures described below. The subject was positioned standing in anatomical position (Fig. 2) and facing the imager. Four images were recorded, including the anterior and posterior views of the lower and upper limbs.

The analyzed ROIs included the anterior and posterior sides of the left and right hands, forearms, upper arms, thighs and legs. In addition, T_{sk} of the chest, abdomen, lower back and upper back were collected. The selection of ROIs was based on earlier work by Marins et al. (2014) [30]. The shape of each ROI analysis field (represented as rectangles) was determined with the use of the following anatomical landmarks: (a) hand: the junction of the 3rd metacarpal proximal phalanx with the 3rd ulnar styloid process; (b) forearm: cubital fossa and distal forearm; (c) arm: cubital fossa and axillary line; (d) abdomen (and low back): xiphoid process and 5 cm below the umbilicus; (e) thigh: 5 cm above the upper border of the patella and the inguinal line; and (f) leg: 5 cm below the lower border of the patella and 10 cm above the malleolus. The corresponding points on the posterior region of the body were marked using a tape measure held parallel to the ground. Fig. 2 shows an example of collected images of these ROIs.

2.3. Equipment

The thermographic imager was an IRT-25 camera (Fluke®, Everett, WA, USA) with a measurement range of −20 to +350 °C, an accuracy and sensitivity of ⩽0.1 °C at 30 °C target temperature (100 mK), infrared spectral bands from 7.5 μm to 14 μm, a refresh rate of 9 Hz and a resolution of 160 × 120 pixels (focal plane array, FPA). Images were obtained assuming a skin emissivity of 0.98 [42] and analyzed using Smartview®, version 3.1 (Fluke®, Everett, WA, USA). The temperature and humidity of the room were recorded with a thermohygrometer (ITHT-2200; ranges: temperature = 10–50 °C ± 1 °C, humidity = 20–90% ± 5%). An air conditioner (Consul® 10,000 BTU Hot/Cold CCO10B) was used to maintain the environmental conditions of the room.

2.4. Data analysis and statistics

The final temperature value of each ROI was calculated as arithmetic mean over the temperature value of all the pixels included in each ROI.

Upon confirmation of the normal distribution of the variables (Shapiro–Wilk test and graphical method) and the homogeneity of variances (*F*-test), descriptive statistics was used, including the mean and standard deviation, to present the data. General and

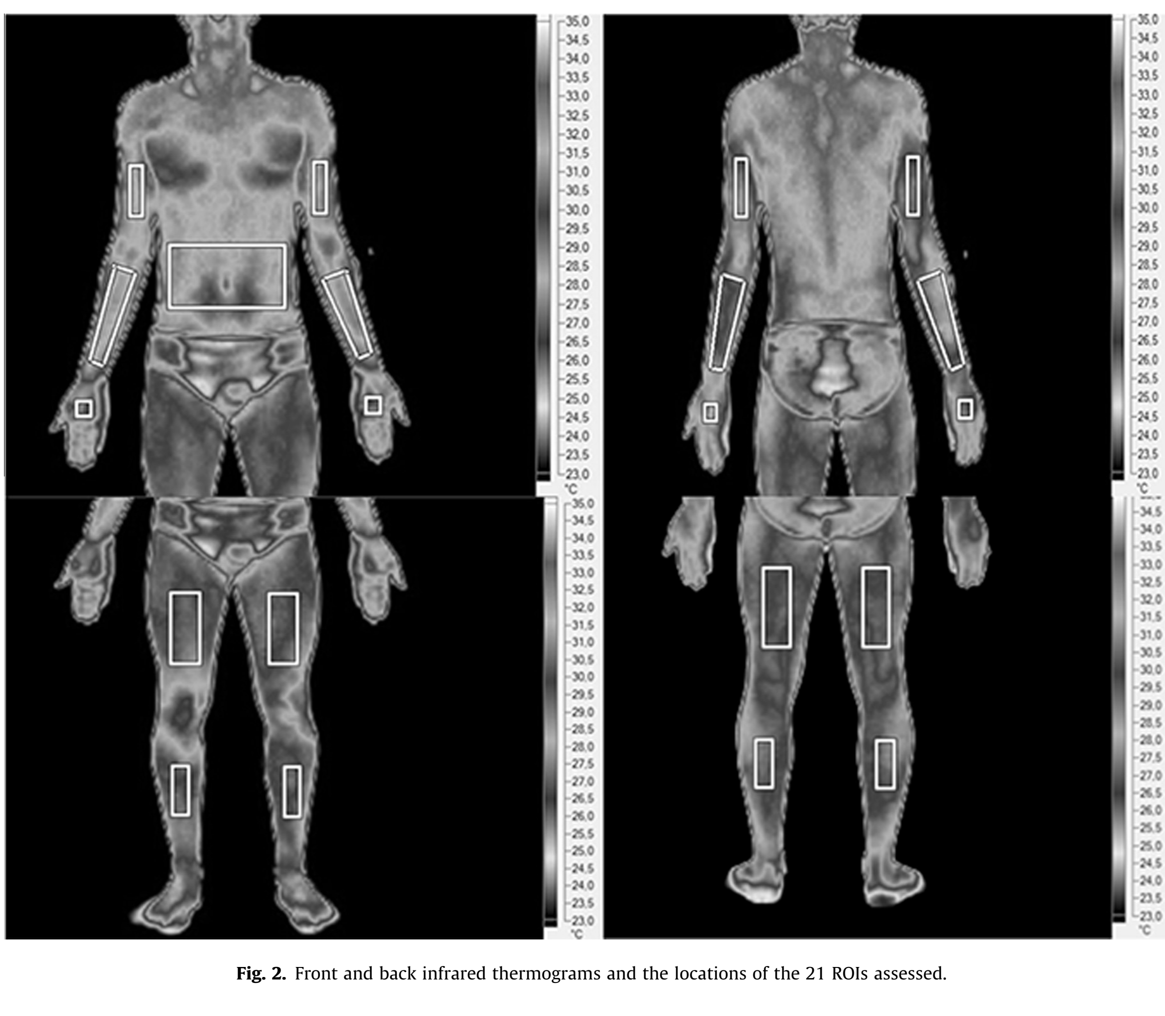

Fig. 2. Front and back infrared thermograms and the locations of the 21 ROIs assessed.

gender-specific regional absolute ΔT_{sk} were calculated for each ROI pair by subtracting the mean T_{sk}. Student's *t*-tests for related samples were used to compare paired data. A significance level of $\alpha = 0.05$ was established for statistical analyses using Sigma Plot 11.0 software.

3. Results

Table 1 shows the averages and standard deviations of the 21 ROIs evaluated in the 40 Brazilian Air Force Military subjects, organized by gender and with T_{sk} differences (ΔT_{sk}) compared by gender in both data collections.

Our results (Table 1) evaluate gender as a determining factor for T_{sk7} (Skin Temperature 7:00 h), given that 90% of the 21 ROIs showed significant gender differences at the $p < 0.05$ level. No significant differences were identified in the ventral and dorsal hand regions. However, gender should not be considered as a determining factor for T_{sk19} (Skin Temperature 19:00 h) because 80.9% of the 21 ROIs did not show significant gender differences. It appears that the time of the day differentially determines the thermal profiles of men and women.

Across all of the evaluated ROIs, the absolute differences between men and women were lower than 1.69 °C, which was obtained for the posterior surface of the arm (Table 1). On the posterior side, the highest observed ΔT_{sk} was at the arm and thigh regions, with values ≈ 1.5 °C lower in women. The evening thermal records (T_{sk19}) indicated a thermal balance between men and women, with differences lower than 0.5 °C in most of the evaluated ROIs. The exceptions included the posterior thigh (0.6 °C) and leg (1.2 °C).

Table 2 shows the temperature differences between T_{sk7} and T_{sk19} for men and women across ROIs. In all ROIs, the T_{sk19} was higher than the T_{sk7}. The lowest ΔT_{sk} was ≈ 0.40 °C in the anterior side of the arm in men, and the highest ΔT_{sk} was in the hands of both genders, with ΔT_{sk} values between 2.35 and 2.98 °C.

Table 3 shows the average contralateral ΔT_{sk} for the 10 bilateral ROIs assessed. In 95% of these ROIs, contralateral differences lower than 0.5 °C were registered. Only the posterior side of the women's hands showed more than a 0.5 °C contralateral difference. The upper limb areas (mainly the hands) showed higher contralateral differences than the lower limb areas in both genders.

Table 2
Temperature (°C) differences between Tsk_7 and Tsk_{19} for males and females for the evaluated ROIs.

ROI	Anterior side		Posterior side	
	Male	Female	Male	Female
Hand-R	2.79	2.35	2.92	2.35
Hand-L	2.84	2.46	2.98	2.46
Forearm-R	0.92	1.89	0.65	1.89
Forearm-L	0.98	1.86	0.71	1.86
Arm-R	0.38	1.41	0.71	1.41
Arm-L	0.41	1.46	0.65	1.46
Thigh-R	1.02	2.58	1.01	3.58
Thigh-L	1.15	2.22	0.94	2.42
Leg-R	0.94	1.36	1.09	1.36
Leg-L	1.11	1.3	1.12	1.3
Abdomen	0.64	2.06	–	–

Note: R = Right; L = Left.

4. Discussion

Strong evidence supports differences in thermal behavior between genders, regardless of the measurement techniques performed [1–3,12]. The thermographic analysis comparing men and women confirmed significant differences in skin temperature between gender [43], as well as our study reaffirmed this conclusion, but only in T_{sk7} (Table 1). The results from Niu et al. (2001) [29] paralleled our data, observing non-significant differences by gender in the dorsal hand at 7:00 and 19:00 h and in the abdomen at 19:00 h.

The systematically lower T_{sk7} observed in females for the 17 evaluated ROIs (with the exception of the hands) could be due to the following characteristics of males: higher metabolic activity, greater amount of lean body mass, which increases heat production, lower percentage body fat. Chudecka & Lubkowska (2015) [43] also found lower temperature values in women, and only the temperature of the chest area was significantly higher than that of the men. The higher percentage of body fat in women could act as greater thermal insulation to the skin in the morning, when the metabolic activity and the blood flow are low [43]. According to Savastano et al. (2009) [44], the hands are an important point of heat loss. Thus, the increased retention of body heat caused by

Table 1
Averages T_{sk} (°C) and standard deviations of the 21 ROIs that indicate contralateral and gender differences (ΔT_{sk}).

	ROI	SIDE	07:00 h		ΔT_{sk} (MvsF)	*p* Value	19:00 h		ΔT_{sk} (MvsF)	*p* Value
			Male	Female			Male	Female		
Anterior	Hand	R	27.58 ± 2.4	28.02 ± 1.8	0.44	0.570	30.37 ± 1.9	30.37 ± 1.5	0	0.993
		L	27.81 ± 2.4	28.37 ± 1.9	0.56	0.480	30.65 ± 1.8	30.83 ± 1.5	0.18	0.723
	Forearm	R	**31.51*** ± 1.0	30.57 ± 1.1	0.94	0.019	32.43 ± 0.8	32.46 ± 0.9	0.03	0.890
		L	**31.74*** ± 0.9	30.88 ± 1.2	0.86	0.034	32.72 ± 0.7	32.74 ± 0.8	0.002	0.957
	Arm	R	**32.51*** ± 0.6	31.07 ± 0.9	1.44	<0.001	32.89 ± 0.8	32.48 ± 0.5	0.41	0.082
		L	**32.72*** ± 0.7	31.45 ± 0.9	1.27	<0.001	33.13 ± 0.7	32.91 ± 0.4	0.22	0.363
	Thigh	R	**30.49*** ± 0.9	28.94 ± 0.6	1.55	<0.001	31.51 ± 0.9	31.52 ± 0.5	0.01	0.983
		L	**30.46*** ± 0.9	29.05 ± 0.8	1.41	<0.001	31.64 ± 0.8	31.47 ± 0.5	0.17	0.473
	Leg	R	**31.48*** ± 0.7	30.85 ± 0.9	0.63	0.010	32.42 ± 0.7	32.21 ± 0.7	0.21	0.314
		L	**31.35*** ± 0.8	30.8 ± 0.8	0.55	0.014	32.46 ± 0.7	32.1 ± 0.6	0.36	0.066
	Abdomen		**32.79*** ± 0.5	31.51 ± 1.2	1.28	<0.001	33.43 ± 0.5	33.57 ± 0.6	0.14	0.464
Posterior	Hand	R	27.59 ± 1.9	28.49 ± 1.4	0.9	0.179	30.51 ± 1.8	31.25 ± 0.9	0.74	0.078
		L	27.47 ± 2.0	27.98 ± 1.5	0.51	0.436	30.45 ± 1.6	31.17 ± 0.8	0.72	0.091
	Forearm	R	**31.45*** ± 0.8	30.46 ± 0.9	0.99	0.008	32.1 ± 0.8	31.96 ± 0.7	0.14	0.538
		L	**31.04*** ± 0.8	30.02 ± 0.9	1.02	0.003	31.75 ± 0.8	31.7 ± 0.6	0.05	0.842
	Arm	R	**30.61*** ± 0.7	28.92 ± 1.2	1.69	<0.001	31.32 ± 1.0	31.29 ± 0.7	0.03	0.925
		L	**30.29*** ± 0.5	28.77 ± 1.2	1.52	<0.001	30.94 ± 1.0	30.88 ± 0.7	0.06	0.818
	Thigh	R	**31.11*** ± 0.9	29.77 ± 1.0	1.34	<0.001	**32.12*** ± 0.7	31.52 ± 0.6	0.6	0.008
		L	**31.06*** ± 0.9	29.67 ± 1.2	1.39	<0.001	**32*** ± 0.7	31.4 ± 0.7	0.6	0.004
	Leg	R	**31.03*** ± 0.8	29.62 ± 1.0	1.41	<0.001	**32.12*** ± 0.7	30.89 ± 0.6	1.23	<0.001
		L	**30.91*** ± 0.8	29.53 ± 0.9	1.38	<0.001	**32.03*** ± 0.7	30.82 ± 0.6	1.21	<0.00

Note: R = Right; L = Left; M = Male; F = Female; ∗ Male significantly higher than female $P < 0.05$.

Table 3
Contralateral ΔT_{sk} (right – left side in °C) of the bilateral ROIs assessed.

	T_{sk7}					T_{sk19}				
	Hand	Forearm	Arm	Thigh	Leg	Hand	Forearm	Arm	Thigh	Leg
M AS	0.23	0.23	0.23	0.03	0.13	0.28	0.29	0.24	0.13	0.04
F AS	0.35	0.31	0.38	0.11	0.05	0.46	0.28	0.43	0.05	0.11
M PS	0.12	0.41	0.32	0.05	0.12	0.06	0.35	0.38	0.12	0.09
F PS	0.51	0.44	0.15	0.1	0.09	0.08	0.26	0.41	0.12	0.07

Note: R = Right; L = Left; M AS = Male Anterior Side; F AS = Female Anterior Side; M PS = Male Posterior Side; F PS = Female Posterior Side.

the greater body fat in women could be compensated for by the elevated temperature of the hands to regulate overall body temperature. This finding could explain why women sleeping in cold environments often require additional insulation to maintain the state of their thermoneutral zone (TNZ) [2].

The observed lower T_{sk7} in women is reinforced by a study by Savastano et al. (2009) [44], who concluded that the abdominal T_{sk} measured by IRT in an obese population (body index > 30 kg/m^2) had an average temperature of 31.8 ± 2.0 °C, which was significantly lower than the temperatures in subjects with normal weight (32.8 ± 0.3 °C). This value is very close to the values recorded in men in this study, which were slightly higher than the measures in women at 7:00 AM (Table 1).

During military activities, it is essential that soldiers are in the TNZ [2]. Many factors can influence the TNZ; however, clothing represents a decisive factor. In this study, the hands were characterized by no significant differences in temperature between males and females. This finding indicates that the manufacturing of gloves can be similar for both genders. Zimmermann et al. (2008) [45] established the criterion that the thermal comfort range of a glove should ensure maintenance of the hand T_{sk} at 15 °C. Moreover, the posterior thigh and leg regions were systematically different, with men having higher temperatures. In this case, the design of clothing should reflect this distinction by preferentially isolating these areas in cold environmental conditions.

The T_{sk19} measurements indicated no significant differences in most of the ROIs evaluated. These results agree with those of Agarwal (2010) [46], who could not discern an influence of gender when evaluating the T_{sk} of 50 healthy subjects (including 29 females and 21 males, with an average age of 32.8 years). It is not possible to find a clear explanation for the thermal behavior observed in the T_{sk19} of the posterior side of the thigh and leg, which comprised the only ROI with higher T_{sk} in men at 19:00 h. One possible explanation could be an accumulation of fat in this region in the studied sample of women; however, it is not possible to confirm this prediction because skin thickness was not measured in this study. It would be interesting to confirm this hypothesis in future studies.

These data suggest that only the hand T_{sk} would be a valid location for both men and women, independent of the time of day. Most of the ROIs recorded at 19:00 h yielded similar results in men and women; as a result, this time of day can be adopted as a single reference point for determining the thermal profiles of both men and women.

Regardless of gender, T_{sk} increased across the 21 ROIs when comparing the two times of day (T_{sk7} vs T_{sk19}) (Table 2). This increase may have been caused by the heat produced during regular daily activities, even when these are of low intensity, and by the incremental changes in metabolic rate throughout the day [47]. Our data indicate a slower thermal progression in men compared with women; this difference in thermal progression appears to be sufficient to explain the differences observed for T_{sk19} and T_{sk7}. A lower body temperature in the morning followed by an increase in the afternoon has also been observed by other authors using different methods for recording body temperature [48–51]. This finding demonstrates that IRT is also sensitive for monitoring daily temperature adjustments.

In both men and women, the abdominal region exhibited the highest temperatures of all 21 ROIs evaluated. These data reinforce the concept that the central body regions maintain a higher temperature than the peripheral regions [29], and the temperature decreases as the distance from the trunk increases toward the ends [43]. By contrast, the lowest temperature, which was found on the hands, confirms that the peripheral areas are characterized by cooler temperatures [29,34]. This difference in temperature helps control body temperature when it is necessary to increase heat loss or when the body is exposed to low temperatures. An interesting study on the effect of circadian rhythm described different values of T_{sk} depending on the body area examined. It was shown that the proximal area of the body followed the same circadian rhythm rectal temperature, while the T_{sk} of hands and feet (distal area) exhibited a opposite pattern [52]. Several metabolic adjustments may explain the lower temperature in the early morning compared to other times of the day: the sharp reduction in metabolic rate that occurs while the subject sleeps at night generates a decrease in body temperature [53], as well as the endocrine responses of melatonin and cortisol are also involved in this process [54]. The administration of melatonin normally leads to a reduction in the internal temperature under resting conditions [55], suggesting that the nocturnal secretion of melatonin may play a role in the diurnal variations of body temperature [56].

When the thermal contralateral behavior was analyzed (Table 3), both genders exhibited thermal equilibrium between body segments. This result was also found in a study that evaluated the local thermal regulation with soaking hands in cold water [57]. Thus, gender is not related to any type of thermal asymmetry. It has been suggested that the detection of asymmetries higher than 0.5 °C can be considered a symptom of local metabolic changes [29,58].

One limitation of this study was the lack of quantification of fat tissue thickness. This information would have facilitated our understanding of certain thermal skin responses on the lower limb areas. Further research about the influence of gender on T_{sk} measures is required to fully understand the thermal skin response and to define specific normative values for men and women.

It has been suggested that the garments used by soldiers could be similar throughout the day for men and women. However, the T_{sk7} assessments indicate that women's heat retention in cold environments must be considered. Furthermore, an excess of heat in men situated in hot environments during the early morning hours requires consideration, as well.

5. Conclusion

The lack of similar studies employing IRT throughout the day makes difficult generalizing our results. However the present study is valuable for establishing the differences and the parameters of the T_{sk} variations in two times of day using IRT technique. The

T_{sk} values of the ROIs show that, in the morning, men present higher temperatures than women; however, after 12 h, those differences are normalized, with the exception of the posterior side of the thighs and legs. The hands are the only ROIs with similar temperatures in men and women throughout the day. Our findings should stimulate further studies to investigate the thermographic profile of the skin during the day in different age groups and genders, considering that there are specific thermal responses.

Conflict of interest

The authors declare that there are no conflicts of interest.

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