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Original Article

Skin temperature of physically active elderly and young women measured using infrared thermography

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Abstract
The aim of this study was to compare the skin temperature (Tsk) of old and young women, both physically active, using thermography, and observe the Tsk variation between body sides of each group evaluated. Sixty physical active women, thirty young Physical Education students (young group = YG; age: 21.8 ± 2.3 yrs.) and thirty older women (aged group = AG; age: 71.0 ± 7.5 yrs.) were selected to participate in the study. Tsk was measured using an infrared camera in 22 regions of interest (ROI). The results showed that in 15 of 22 of ROI compared, the older group had higher skin temperature than the people of the young, representing 68% of the analyzed areas. Regarding the differences between contralateral sides of the body, in 10 of the 20 analyzed ROI were obtained significant differences ($p<0.05$). In conclusion, regardless of age group there is a bilateral thermal symmetry usually less than 0.5°C both in young and elderly women. Elderly women show higher Tsk values than young women in most ROI mainly in distal regions of the limbs.
Key Words: infrared thermography, young, elderly, women, skin temperature

Introduction

Age is a key factor that influences the blood flow of the human skin, since this is controlled by the sympathetic nervous system innervation, which is greatly affected by the aging process (Kenney & Munce, 2003). An early effect of aging in the body, even in the absence of any disease, is the alteration of the cutaneous vasodilation and vasoconstriction adjustments that modifies peripheral blood flow and affect the individual thermal response of the body, thus impacting the skin temperature (Tsk) regulation (Kenney & Munce, 2003; Ring & Ammer, 2000). The control of the Tsk response can be objectively analyzed without any contact by infrared thermography (IRT). This technique is characterized by use of a thermal imager which detects the infrared radiation released by the body, converting it to a temperature measurement (Ring & Ammer, 2000). The development of IRT technology allows us to compare human thermal profiles from different populations (Marins, Fernandes, Cano, et al., 2014; Marins, Fernandes, Moreira, et al., 2014). These thermal profiles are very important to understand the mechanisms involved on thermoregulation and factors related to Tsk (Ammer, 2015).

The Tsk distribution in the central and peripheral regions of the body can be altered by adverse conditions. Evidence using IRT showed that the distribution of the Tsk patterns changes in presence of vascular problems (Vainer, 2005). In addition, other studies using IRT showed changes in the thermal pattern under conditions typical of the aging processes, such as diabetes (Ring, 2010), osteoarthritis, arthrosis, and fibromyalgia syndrome (Vargas et al., 2009), cancer (Acharya, Ng, Tan, & Sree, 2012) or spinal injuries (Ammer, 2010). These changes in Tsk are related to the specific conditions imposed by each disease, where inflammation generates hyperthermia while the degenerative process can cause hypothermia patterns (Hildebrandt, Raschner, & Ammer, 2010). It is also very common to find women with advanced age who express episodes of menopausal hot flushes due to hormonal imbalances (Sturdee, 2008), which may have an effect on Tsk values recorded by IRT altering the normal thermal profile that could be expected in young women. Hence, considering regular physical activity as a influencing factor on Tsk, due mainly the

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improvements on vasoconstrictor and vasodilatation systems (Kenney & Munce, 2003), it appears reasonable comparing only physical active women in order to isolate the age factor.

The growing interest in the development and application of IRT for medical purposes stimulated the production of various surveys in order to determine reference Tsk values. Such values are required for a correct interpretation of the thermograms, since normal Tsk can vary greatly depending on factors such as sex, age and sample characteristics (Ammer, 2015; Fernández-Cuevas et al., 2015). Recent studies leaded by Vardasca (2011) and Marins, Fernandes, Cano, et al. (2014) identified gender differences in Tsk, but only adults were analyzed. Earlier, Zhu and Xin (1999) had included elderly patients (> 60 years) in their sample, but they performed only a general descriptive analysis of the data without any comparison by age. On the other hand, Niu et al. (2001) investigated the Tsk of Taiwanese men and women (young and old) and identified lower temperatures in elderly, but both sexes were included on the analysis by age. At the present data, this was the only work containing Tsk reference data using IRT found in the database PubMed. Thus, it is not possible to establish how the age factor in women can change the Tsk reference values in young women facing the elderly women, both physically active. This could contribute to the interpretation of thermal images, to identify possible thermal changes that may be related to some type of vascular disease, muscle or tendon. Thus the aim of this study is to compare the Tsk of old and young women, both physically active, using thermography, and observe the Tsk variation between sides of the body of each group evaluated. We hypostatized that the physically active old sample have a lower Tsk in comparison of younger on same physical condition.

Material & methods

Participants

The inclusion criteria during the selection process were: a) the sample of university students were women aged 18 to 30 and physically active according to the criteria of the American College of Sports Medicine (Garber et al., 2011); b) the older sample consisted of women over 60 years old, enrolled in regular physical activity programs with a minimum frequency of three times per week and a minimum duration of 30 minutes per session. The participants fill in a questionnaire and excluded those with a history of vascular disease including Raynaud's disease; injuries in one of limbs, hypertension, fibromyalgia, arthritis, diabetes, smoking and continuous use drugs that could change the Tsk.

After application of inclusion and exclusion criteria's, this study measured a total of 60 women, 30 young Physical Education students (young group = YG; age: 21.8 ± 2.3 yrs., wt.: 58.5 ± 6.5 kg; ht.: 164 ± 0.6 cm; Body Fat: 29.0 ± 5.4%; body mass index: 21.8 ± 5.4 kg/m^2) and 30 older women (aged group = AG; age: 71.0 ± 7.5 yrs., wt.: 61.4 ± 8.6 kg; ht.: 153 ± 0.5 cm; body fat: 28.1 ± 7.0%; body mass index: 26.8 ± 3.4 kg/m^2) participated in University exercise group for Seniors. The volunteers were previously informed about the procedures of the study and signed a consent form before the data collection. This study followed the local legislation for human studies and the Declaration of Helsinki.

Procedures

According to the recommendations of Ring and Ammer (2000), participants were instructed in the period of 24 hours prior to collection to avoid practice of any vigorous exercise, using tight clothes, exposition to the sun, receive any massage procedure, applying any gel or cream on the skin and intake any product with caffeine or alcohol. Body mass (weight scale ID-M, Filizola®, São Paulo, Brazil), height (wall stadiometer Sanny®, São Bernardo do Campo, Brazil) and skinfold thickness (Cescorf®, Tristeza, Porto Alegre, Brasil) were measured by one trained research in accordance with the recommendations of the International Society for the Advancement of anthropometry (ISAK) (Marfell-Jones, Olds, Stewart, & Carter, 2006).

The study used the same daily routine in order to standardize the procedure. All samples were taken in the morning, covering the period between 8:00 and 10:00 am, at the Human Performance Laboratory. The clothing was standardized for preventing any influence on the Tsk measurements: shorts and top during the period that the sample was in the laboratory for the thermograms measurement (Moreira et al., 2017). Upon arrival at the laboratory, evaluated went to the locker room to put the standardized clothes were led to an acclimatized room equipped with fluorescent lights and air conditioning equipment (Komeco®, Hi-wall Split) that kept stable the environmental conditions [room temperature: 22.7±0.7°C, relative humidity 61.2±5.1% and air flow ≅0.2 m/s, digital weather station and anemometer (Instrutherm®, AD-250)] (Bain & Jay, 2011). These environmental conditions were in accordance with the accepted recommendations by Moreira et al. (2017). Before performing the thermographic collection subject stood 10 minutes without crossing arms, rubbing their hands or making any sudden movements for an appropriate acclimatization and stabilization of Tsk, as it was determined in a previous study (Marins, Moreira, et al., 2014).

After acclimatization, the participants were positioned on a platform at a distance of 4.0 m for recording the thermographic images. The TIR-25 Imager (Fluke®, Everett, USA) with a measurement range of -20 to +350°C±2°C; sensitivity ≤ 0.1°C, an infrared spectral band from 7,5 µm to 14 µm, refresh rate of 9 Hz and FPA

System (Focal Plane Array) 160 x 120 pixels, it was used to obtain the thermal images. We record four thermographic images accompanying the points for the analysis (the anterior and posterior views of lower limbs and the upper limbs). The body regions of interest (ROI) analyzed included hand, forearm, upper arm, abdomen, back, thigh and leg. These ROI were selected as a rectangle with the SmartView software version 2.1, identifying average temperatures from the thermographic images, following the criteria described by Ring and Ammer (2000).The skin emissivity value adopted for the thermal data collection was set in the imager at 0.98 (Anbar, 1998).

Some anatomical reference points were determine to select the ROIs from the thermograms: a) hand: the junction of 3rd metacarpal with the 3rd proximal phalanx and the ulnar styloid process; b) forearm: 1st distal third of the forearm and cubital fossa; c) arm cubital fossa and axillary line; d) abdomen and lower back: xiphoid and 5 cm below the navel; e) leg: 5 cm above the upper border of the patella and the inguinal line; f) leg: 5 cm below the lower border of the patella and 10 cm above the malleolus. The corresponding points of the posterior region of the body were marked using a measure tape located parallel to the floor, making a circumference on the analyzed region. An example of the location of the ROI analyzed can be seen in Figure 1.

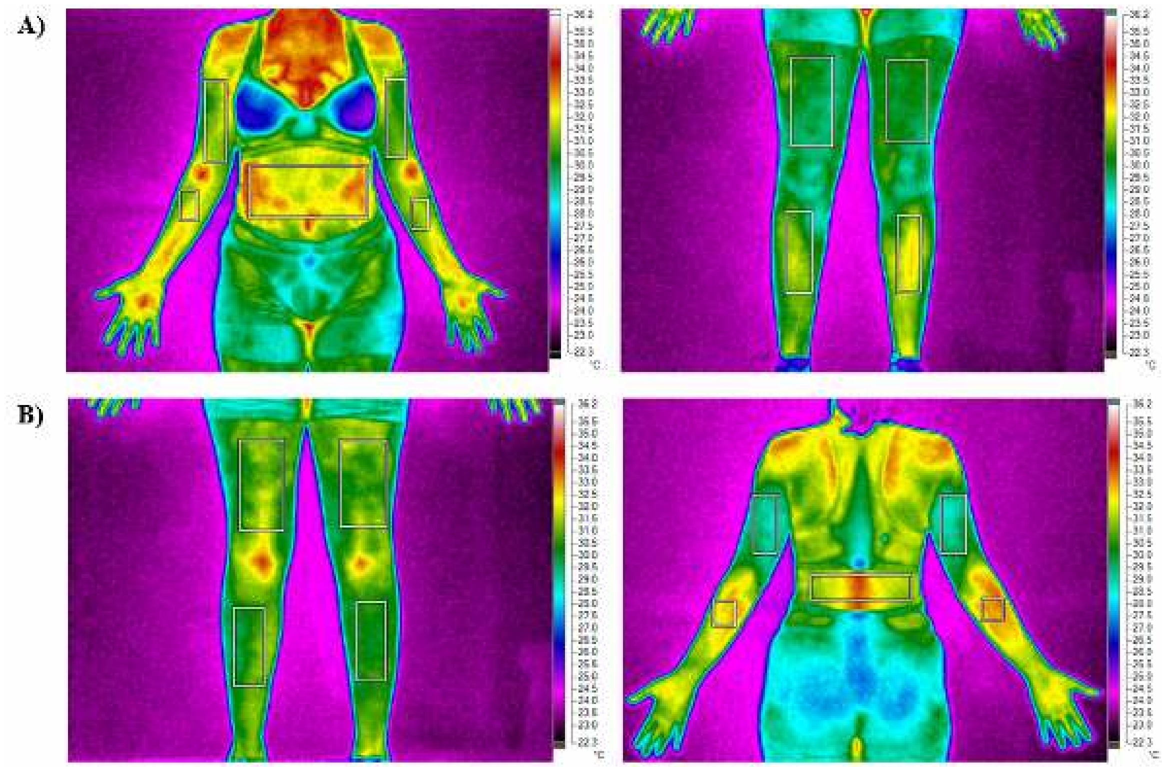

Figure 1. **Thermographic images with ROI evaluated by software, in anterior (A) and posterior (B) views.**

Statistical analyze

The sample size was determined using the GPower 3.1.9.2 software (Faul, Erdfelder, Lang, & Buchner, 2007) selecting the t-test for independent measurements with a power of 0.95. The Shapiro-Wilk test was used to assess the normality of the data. To compare the obtained Tsk in each ROI of the young and elderly groups the Student t test was used. To compare the Tsk between contralateral ROIs it was used the paired t test. Analyses were performed SPSS (Version 21.0, Chicago, USA). The significance level was set at α=0.05. All data are expressed as mean±Standard Deviation (SD).

Results

Table 1 show the behavior of Tsk observed in the 22 examined ROIs, comparing the body regions between young and old, and the left and right limbs. The results showed that in 15 of 22 of ROI compared, the older group had higher skin temperature than the people of the young, representing 68% of the analyzed areas. Only in the temperature region of the abdomen of young was significantly warmer than older women, while in 6 ROIs there were no significant differences ($p<0.05$) by the age group.

Table 1. **Tsk results for young and aged women.**

		Right	Left	Dif Right-Left	
ROI	**Group**	**T_P**	**T_P**	**ΔT_P**	***p***
Anterior Arm	Y	30,37 ± 0,99	30,50 ± 0,90	0,13	0,232
	A	30,50 ± 0,92	30,57 ± 0,87	0,07	0,226
	Dif Y-A (*p*)	0,13 (0,600)	0,07 (0,737)	---	---
Posterior Arm	Y	27,84 ± 1,12	27,65 ± 1,15	0,19	0,055
	A	28,36 ± 0,84	28,34 ± 0,90	0,02	0,787
	Dif Y-A (*p*)	0,52 (0,050)	0,69 (0,012*)	---	---
Anterior Forearm	Y	30,22 ± 1,10	30,32 ± 1,09	0,10	0,226
	A	30,89 ± 0,90	31,14 ± 0,86	0,25	0,003*
	Dif Y-A (*p*)	0,67 (0,013*)	0,82 (0,002*)	---	---
Posterior Forearm	Y	30,12 ± 0,94	29,86 ± 1,01	0,26	0,013*
	A	30,49 ± 0,78	30,31 ± 0,81	0,18	0,008*
	Dif Y-A (*p*)	0,37 (0,099)	0,45 (0,060)	---	---
Anterior Hand	Y	28,28 ± 2,04	28,52 ± 2,05	0,24	0,003*
	A	30,44 ± 2,58	30,57 ± 2,62	0,13	0,044*
	Dif Y-A (*p*)	2,16 (0,001*)	2,05 (0,001*)	---	---
Posterior Hand	Y	28,06 ± 1,49	27,83 ± 1,51	0,23	0,020*
	A	30,04 ± 2,50	29,48 ± 3,13	0,56	0,001*
	Dif Y-A (*p*)	1,98 (0,001*)	1,65 (0,012*)	---	---
Anterior Thigh	Y	27,90 ± 0,70	28,11 ± 0,79	0,21	0,001*
	A	29,42 ± 1,20	29,40 ± 1,16	0,02	0,856
	Dif Y-A (*p*)	1,52 (0,001*)	1,29 (0,001*)	---	---
Posterior Thigh	Y	28,85 ± 0,75	28,72 ± 0,79	0,13	0,036*
	A	30,17 ± 0,87	30,07 ± 0,90	0,10	0,119
	Dif Y-A (*p*)	1,32 (0,001*)	1,35 (0,001*)	---	---
Anterior Leg	Y	29,64 ± 0,98	29,74 ± 1,03	0,10	0,096
	A	31,57 ± 0,66	31,64 ± 0,73	0,07	0,412
	Dif Y-A (*p*)	1,93 (0,001*)	1,90 (0,001*)	---	---
Posterior Leg	Y	28,80 ± 0,85	28,66 ± 0,93	0,14	0,011*
	A	30,53 ± 1,01	30,61 ± 0,93	0,08	0,423
	Dif Y-A (*p*)	1,73 (0,001*)	1,95 (0,001*)	---	---
Abdomen	Y	30,60 ± 0,97	---	---	---
	A	28,82 ± 1,30	---	---	---
	Dif Y-A (*p*)	1,78 (0,011*)	---	---	---
Low Back	Y	30,54 ± 0,73	---	---	---
	A	30,39 ± 1,37	---	---	---
	Dif Y-A (*p*)	0,18 (0,590)	---	---	---

ROI = Region of interest; Y = Young; A = Aged; Dif Y-A = Difference Young – Aged. * Significant differences (*p*<0.05).

Regarding the differences between contralateral sides of the body, in 10 of the 20 analyzed ROI were obtained significant differences (p<0.05). In 4 ROI Tsk was higher for older women (anterior forearm, posterior forearm, anterior hand and posterior hand) and in 6 ROI higher for young women (posterior forearm, anterior hand, posterior hand, anterior thigh, posterior thigh and posterior leg). Despite the differences, the largest variation between contralateral sides in the older women did not exceed 0.56°C in the posterior hand, while in young women the greater variation was found to be 0.26°C in the posterior forearm.

Discussion

This study produced the first reference data to compare the Tsk of old physically active women compared to young adult women measured with IRT. Using the concept of body asymmetry between limbs used in other studies (Marins, Fernandes, Cano, et al., 2014; Marins, Fernandes, Moreira, et al., 2014), it was possible to provide new knowledge about Tsk distribution patterns in the 22 analyzed ROI. The main findings of this study can be summarized as: (1) older women had higher Tsk than young people, (2) the largest differences between young and old women were concentrated in peripheral regions of the body such as the hands, (3) the body symmetry between the limbs is similar in both young and elderly (Table 1).

Initially, it was expected lower Tsk in elderly because aging is usually related to the loss of muscle mass, thereby reduced metabolism may limit the heat generation and the thermoregulatory adjustments (American College of Sports et al., 2009; Holowatz, Thompson-Torgerson, & Kenney, 2010; Kenney & Munce, 2003). However, the average age of the older group, 71.0±7.5 years, may explain the fact that the registered Tsk for the elderly women is higher in this study, disagreeing with the previous data of Niu et al. (2001). The average age of 71 years far exceeds the average age of menopause in the population in Brazilian women (~51 years) (Pedro, Neto, Paiva, Osis, & Hardy, 2003). At this age is common to have hot flushes, usually caused by hormonal imbalances produced by an altered hypothalamic function and hence an inefficient thermoregulation (Sturdee, 2008). Tsk data recorded with IRT in menopausal women showed that during hot flashes, Tsk can change 1-5ºC depending on the body area (Sturdee & Reece, 1979). These data suggest that menopause may change Tsk and thus influence the thermal results. Another possible explanation for the higher Tsk values in older women is and increased blood flow in the skin caused by a deficit in the venous return. It is known aging affects the mechanisms of peripheral circulation, being impaired the vasoconstriction and vasodilatation reflexes (Holowatz et al., 2010). Thus, these losses can impact the blood circulation, especially in the distal parts of the body where blood can accumulate and cause greater Tsk values in elderly people. The study of Borisov and Lin (2014), which compared the Tsk of young and old people in daily activities using contact thermocouples, also found higher Tsk values in older people, contradicting the hypothesis that young people have warmer limbs than elderly. These results indicate that the elderly tend to have higher Tsk than young people, especially in the distal parts of the limbs; however, the mechanisms of this process need to be studied.

The regions with the greatest differences in Tsk found among older women and young people were in the hands, with a difference on the anterior side of 2.16°C in the right hand, and 2.05°C in the left hand, and 1.98°C on the right hand and 1.65°C in the left hand in the posterior side (Table 1). It is interesting to note that the greatest differences in Tsk found between young and older occurred in the more peripheral regions of the body, both in the front side as the back side. Hands are an important point of heat loss of body (Zhu & Xin, 1999), so this may mean an adaptation mechanism in older women in order to lose heat thus helping to control body thermogenesis. It should also be considered that under cold weather conditions, the hands should be covered in order to prevent an excessive heat loss in elderly women.

Regarding the symmetry between contralateral sides of the body, the highest average difference found for young women was 0.26°C in the posterior forearms (Table 1). In relation to older women, the results showed a maximum variation of 0.56°C in the Tsk of the posterior hand. Despite having found significant differences in 10 of the 20 analyzed ROIs, those variations between both sides possessed little amplitudes below 0.3°C. These results are in agreement with the values obtained found by Niu et al. (2001), consisting of 57 healthy Taiwanese adults, 22 women and 35 men, whose ages ranged from 24 to 80 years.

An interesting aspect during an assessment by thermography is to observe the differences between contralateral sides of the body. An asymmetry of 0.5ºC is considered as a maximum difference value for a symmetric ROI (Niu et al., 2001; Uematsu, Edwin, Jankel, Kozikowski, & Trattner, 1988). In the present study only the posterior hand region obtained a difference greater than 0.5°C in elderly. This suggests that the Tsk registered for young and elderly in our study agrees with the symmetry values found in other studies (Marins, Fernandes, Cano, et al., 2014; Niu et al., 2001; Uematsu et al., 1988). Despite differences higher than 0.5°C are associated with a thermal abnormality (hyperthermia or hypothermia) on one side of the body since the thermoregulation system tries always to balance the thermal values (Zhu & Xin, 1999), this small change of Tsk above the proposed limit in just one of the 22 analyzed ROIs (i.e. posterior hand = 0.56°C) does not imply problem from the clinical point of view (Hildebrandt et al., 2010).

The symmetry between sides of the body has shown differences depending on the population studied. The study Kolosovas-Machuca and Gonzalez (2011) assessed Tsk on 42 points and registered Tsk differences up to 0.7°C on the limbs in children. In the study conducted by Marins, Fernandes, Cano, et al. (2014) the average asymmetry difference recorded was 0.3°C in young adults, while Niu et al. (2001) obtained up to 0.5°C difference in adults. These results agree with the data of this study and suggest that normal Tsk differences between contralateral sides of the body ranging from 0.3 to 0.7°C depending on the population studied.

The abdominal region was the exception in which the young women had a Tsk higher than the elderly. The highest concentration of subcutaneous fat in these regions in older women may have influenced the results, since the subcutaneous fat layer plays a role of a thermal insulator and prevents heat transfer by conduction (Savastano et al., 2009). A limitation of this study was not having performed the measurement of the thickness of body fat by a tomographic technique in the abdominal area, which could assist in the interpretation of these results. Additionally, the higher activity of the reproductive organs, with higher blood supply in some phases of the menstrual cycle, could also have a slightly positive influence in a higher abdominal temperature of some analyzed young women. Another limitation of this study was a lack of internal temperature measures to control hot flashes in the older group, and does not delimitate the age groups in the elderly population. Therefore, it is interesting to speculate what would be necessary to expand the sample in the group of elderly women in order to establish normal Tsk values for women in several post-menopausal age groups.

Conclusions

According to the established aims and methods applied, the obtained results do not allow to conclude that regardless of age group there is a bilateral thermal symmetry usually less than 0.5°C both in young and elderly women. Elderly women show higher Tsk values than young women in most ROI mainly in distal regions of the limbs.

Conflicts of interest - The authors declare that there is no conflict of interests regarding the publication of this paper.

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