http://periodicos.sbu.unicamp.br/ojs/index.php/parc
http://dx.doi.org/10.20396/parc.v7n4.8648216

THERMAL PERCEPTION OF BRAZILIAN ELDERLY IN AN AIR-CONDITIONED ROOM: A FIRST APPROACH

A PERCEPÇÃO TÉRMICA DE IDOSOS BRASILEIROS EM SALA COM AR CONDICIONADO: UMA ABORDAGEM INICIAL

Fabiana Padilha Montanheiro[1]
Universidade do Sagrado Coração, Bauru, SP, Brasil, fpmontanheiro@yahoo.com.br

João Roberto Gomes de Faria [2]
Universidade Estadual Paulista, Faculdade de Arquitetura, Artes e Comunicação, Bauru, SP, Brasil, joaofari@faac.unesp.br

Abstract

Despite the aging of the population in general and in particular in Brazil, there is not yet research on the thermal perception of Brazilian elderly. The available information is based on studies conducted in climates very different from those in Brazil. This study's purpose was to evaluate if there are significant differences in the thermal perception of the elderly in comparison with younger subjects. In an air-conditioned room, the thermal variables were measured and a questionnaire was applied to a sample of elderly people who used the place. The answers to the questions about the reported thermal perception (TP), thermal comfort and preference, personal acceptability and tolerance, were related to the respective operational temperatures and with those calculated by the predicted mean vote (PMV) (reference for non-elderly population). The mean operative temperature for neutrality (TP = 0) was lower than those calculated by the PMV, i.e., smaller than preferred by non-elderly; furthermore, the range of operative temperature for thermal comfort for elderly was also wider than for non-elderly. These results diverge, in principle, from those found in the international literature, by finding lower comfort temperatures for the elderly than for the non-elderly, but they may be supported by more recent studies involving circadian thermometry. Other answers to the questions show that PMV is not a good predictor of thermal comfort conditions for the elderly. As this is the first work on the subject in Brazil, it opens a discussion and invites researchers to carry out similar studies to verify its validity.

Keywords: Thermal perception. Thermal sensation. Elderly. PMV.

Resumo

Apesar do envelhecimento da população de forma geral e, em particular, no Brasil, não há até o momento pesquisas sobre a percepção térmica do idoso no país. As informações disponíveis são baseadas em estudos realizados em climas diversos dos brasileiros. O objetivo do presente trabalho foi avaliar se existem alterações significativas na percepção térmica de idosos em relação à de indivíduos mais jovens. Numa sala com ar condicionado foram medidas suas variáveis térmicas e aplicado um questionário a uma amostra de idosos. As respostas a questões sobre percepção térmica relatada pelos sujeitos (PT), conforto e preferência térmica, aceitabilidade e tolerância pessoal foram relacionadas com as respectivas temperaturas operacionais e essas com as calculadas pelo PMV (referência para não idosos). A temperatura operativa média de neutralidade (PT = 0) foi menor que a calculada pelo PMV, ou seja, menor do que a preferida por não idosos; além disso, a faixa de temperatura operativa de conforto térmico de idosos é também maior que a de não idosos. Os resultados divergem, em princípio, dos encontrados na bibliografia internacional, ao encontrar temperaturas de conforto para idosos menores do que para não idosos, mas eles podem ser amparados em trabalhos mais recentes, os quais envolvem termometria circadiana. Outras respostas ao questionário mostram que o PMV não é um bom previsor de condições de conforto térmico para idosos. Como este é o primeiro trabalho sobre o tema no Brasil, ele abre uma discussão e convida pesquisadores a realizar estudos similares para sua validação.

Palavras-chave: Percepção térmica. Sensação térmica. Idosos. PMV.

How to cite this article:

MONTANHEIRO, Fabiana Padilha; FARIA, João Roberto Gomes de. Thermal perception of Brazilian elderly in an air-conditioned room: a first approach. **PARC Research in Architecture and Building Construction**, Campinas, SP, v. 7, n. 4, p. 202-210, dec. 2016. ISSN 1980-6809. Available at: <http://periodicos.sbu.unicamp.br/ojs/index.php/parc/article/view/8648216>. Date accessed: 08 may 2017. doi:http://dx.doi.org/10.20396/parc.v7i4.8648216..

Received in 31.01.2017 - accepted in 20.04.2017

Introduction

The elderly population grows faster than any other age group, and projections by Brazil (2013) indicate that in 2020 there will be 29.3 million people over 60 years old (14% of the population) for 37.8 million children (18% of the population). This is going to be due mainly to family planning, with the consequent fall in fertility rate, as well as the longevity of the population (MORAGAS, 2010).

The references regarding thermal comfort for this age group in Brazil are scarce. Our literature review found a single Brazilian study, quite preliminary, carried out in naturally-ventilated rooms (SATO; GONÇALVES; MONTEIRO, 2014). Professionals refer to studies normally developed in temperate climates; however, in doing so, differences in climate, dress, and lifestyle are not considered. Thus, this study aims to evaluate if there are differences between the thermal sensation and preference of elderly and non-elderly people in air-conditioned rooms in a Brazilian locality by means of a field research.

BACKGROUND

The physical and psychological changes that people experience when they grow old change their perception of the world (RIBEIRO; ALVES; MEIRA, 2009), including the thermal environment (NOVIETO; ZHANG, 2010). The main changes in thermal perception are summarized below.

Adult people have a loss of basal metabolism in the range of 1 to 2% per decade (RAVUSSIN; BOGARDUS, 1989). From the age of thirty, this reduction is around 3% per decade (SIMÕES, 1998). This loss is indicated as the main cause of the difference in the perception of thermal comfort in relation to the youngsters (VAN HOOF; HENSEN, 2006), because the reduction of the capacity of producing internal heat, initially, should lead to lower body temperatures, increasing the sensitivity to cold (WEINECK, 2005). In fact, experiments show that older people have preference for higher comfort temperature ranges compared to non-elderly (TSUZUKI; OHKUFU, 2002): the thermal sensation of elderly is in general 0.5 points (in the 7-point Bedford scale) lower than the sensation of youngsters in the same situation (SCHELLEN et al., 2010). The eventual preference of older people for lower temperatures compared to young people can be attributed to the use of clothing with higher thermal insulation (COLLINS; HOINVILLE, 1980).

On the other hand, such experiments show that there is no difference between the baseline internal body temperature levels in older and younger groups under thermal neutral conditions (SHIBASAKI; OKAZAKI; INOUE, 2013), and the range of comfort temperature is the same for elderly and young adults, but the first ones have higher temperature-discrimination threshold (COLLINS; EXTON-SMITH; DORÉ, 1981).

Attenuation of peripheral sensibility occurs in older people (USHIDA; TAMURA; IWASAKI, 2009) because of the skin aging combined with other factors (GUERGOVA; DUFOUR, 2011): the warm threshold increases and the cold threshold decreases (HUANG; WANG; LIN, 2010). Although both warm and cold sensitivity tends to decline, the warm threshold predominates, and the effect is more pronounced in the body extremities (GUERGOVA; DUFOUR, 2011). As a consequence, the comfort temperature range should be wider for the elderly than for non-elderly, but independent references show the opposite, the narrowing of the comfort temperature range from 6 K for youngsters (ENOMOTO-KOSHIMIZU et al., 1997, *apud* Van HOOF; JENSEN, 2006)[1] to 3 K for elderly (HESCHONG, 1979).

Therefore, the thermal sensation and preference of the elderly are not fully understood, with some controversial results, although most of them point out to the preference of older people for higher thermal comfort temperatures and a higher threshold of temperature discrimination than young.

Finally, studies indicate that the internal temperature of the body is affected by the environment temperature: the mean and the peak-to-tough circadian temperatures for elderly are noticeably higher in the summer (0.29° C in men and 0.34° C in women) than in the winter (0.20° C in men and 0.12° C in women) (TOUITOU et al., 1986). The core temperature (from rectal measures) increases from the morning up to midday, stays relatively high and stable at evening and falls toward night (EDWARDS et al., 2002). This means, at first, that thermal preference may vary throughout the day.

The predicted mean vote (PMV) is commonly used as a reference in assessing thermal comfort conditions for the general population in air-conditioned spaces (ASHRAE, 2013). Thus, it has also been used as a standard to check for possible changes in the thermal perception of the elderly (SCHELLEN et al., 2010). However, the results of this comparison should be analyzed with caution. PMV is calculated through six variables: two personals, metabolism and clothing, and four from the indoor environment (air temperature, mean radiant temperature, air velocity, and air humidity). All of them error prone, either due to the instruments, the measurement method (VAN HOOF, 2008) or the difficulty of estimating correct table values, or the inherent imprecision of their values, such as the thermal resistance of the dress or the metabolic rate (RUAS, 1999).

MATERIALS AND METHOD

The empirical basis of the work is composed by responses regarding the thermal sensations and preferences of a questionnaire applied to a group of elderly people in a room of a building having central air conditioning system. The operative temperatures related to the thermal sensations and preferences (standard for elderly) were compared to the ones related to the PMV ranges (standard for non-elderly).

Thermal characteristics of the site and sample outline

The study was carried out in the city of Bauru (SP, Brazil, Cwa climate according to Köppen climate classification), in an institution that congregates the largest number of elderly in social integration activities in the city, which facilitated the composition of the sample of subjects and the data collection. The surveys were conducted in a meeting room of the institution during the ordinary sessions of planning the activities of the groups. The researchers did not interfere on the thermostat adjustment during the surveys nor on the exposed situations of the institution quotidian.

The participants had full physical and mental abilities. The initial sample consisted of the largest number of people who participated in these activities, over sixty years old (BRASIL. PRESIDÊNCIA DA REPÚBLICA. CASA CIVIL. SUBCHEFIA PARA ASSUNTOS JURÍDICOS, 1994) and who agreed to participate in the survey by answering a questionnaire: 275 subjects, 47 men, and 228 women.

Measuring instruments and reference standards

The thermal characteristics of the room were raised with an Instrutherm TGD 100 set of digital thermometers (dry bulb, wet bulb, and globe) and a Lutron AM-4220 digital anemometer.

The thermal sensation of the subjects was raised from a questionnaire elaborated according to ISO 10551: 1995, which contains questions about thermal perception (TP, question 1), thermal comfort (question 2), thermal preference (question 3), personal acceptability (question 4) and personal tolerance (question 5) (JOHANSSON et al., 2014). Answers to the question 1 (TP) used a scale from cold (-3) to hot (+3), can be related to the empirical PMV scale.

The answers to the questions 2 to 5 were compared to the TP values and to the PMV classes according to the criteria in Table 1 to verify the consistency of the answers to question 1. This comparison also tested if both TP and PMV were good predictors of the answers, i.e., if elderly and non-elderly have the same thermal preferences.

Table 1 – Criteria to compare answers to the questions 2 to 5

Question 2	Do you find this environment ...?
Answer	**TP values and PMV classes**
Comfortable	0
Slightly uncomfortable	(-1) + (+1)
Uncomfortable	(-2) + (+2)
Very uncomfortable	(-3) + (+3)
Question 3	**Please state how you would prefer it to be now**
Answer	**TP values and PMV classes**
Much cooler	+3
Cooler	+2
Slightly cooler	+1
Neither warmer nor cooler	0
A little warmer	-1
Warmer	-2
Much warmer	-3
Question 4	**On a personal level, this environment is for me ...**
Answer	**TP values and PMV classes**
Acceptable	(-1) + 0 + (+1)
Unacceptable	(< -1) + (> +1)
Question 5	**Is it ...?**
Answer	**TP values and PMV classes**
Perfectly tolerable	0
Slightly difficult to tolerate	(-1) + (+1)
Fairly difficult to tolerate	(-2) + (+2)
Very difficult to tolerate	(-3) + (+3)
Intolerable	(< -3) + (> +3)

Source: The authors

Data collection and final delimitation of the thermal conditions and the sample

The data collection was carried out from February 4th to 6th, and 11th, and from March 3rd to 5th, 2015, always from 2PM to 3PM. During these data gathering period, the external air temperature varied from 25.4° C to 32.7° C. The sessions took place 30 minutes after the occupants arrived at the room, after a detailed explanation of the intentions of the research and the importance of the fidelity of the answers. Thus, the "steady-state" condition of ASHRAE 55-2013 (ASHRAE, 2013), required for the validity of the use of PMV, was guaranteed. The questionnaire was applied after the authorization of the subjects (if they did not want to participate, they would simply not respond to the questionnaire) and only once per person, according to the group's general request. Temperatures were measured at the beginning and end of the application of the questionnaire and the average value of the two measurements of each variable was considered. Likewise, the average air velocity (calculated by the instrument) was considered during the application of the questionnaire (which was always below 0.1 m/s, the instrument detection threshold).

A preliminary analysis of the data led to the adoption of criteria that best delineated the sample and the thermal environment, shown below:

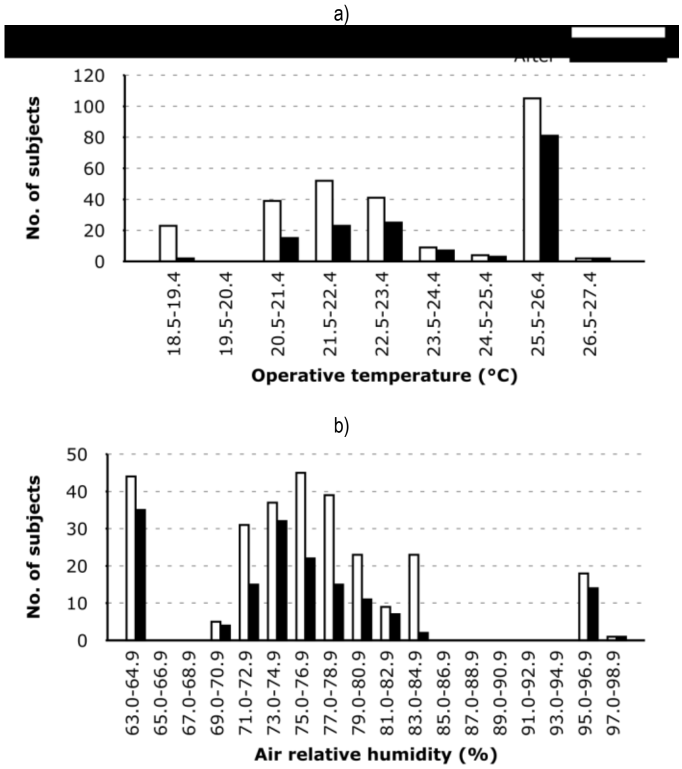
- Due to the heterogeneous temperature distribution during the surveys, the statistics of operative temperatures could not be made by absolute frequencies, but by relative frequencies double-normalized by TP values or PMV classes (integer values of PMV) and by operative temperature ranges themselves;

- Only people with appropriate clothing to the summer, i.e., with thermal resistance between 0.3 and 0.5 clo, according to Table B2 of ASHRAE 55-2013 (ASHRAE, 2013) were considered;
- TP and PMV pairs separated by more than one point of the scale were not considered;
- Because it was not possible to measure the metabolic rates; the reference value of metabolic rate from Appendix A - Activity Levels of ASHRAE 55-2013 (ASHRAE, 2013) for sedentary activity (1.1 met) was assumed, corrected by the DuBois area (due the variation of height and weight) and linearly corrected with the increasing age at a rate of 3% per decade, as suggested by Simões (1998).

Data processing

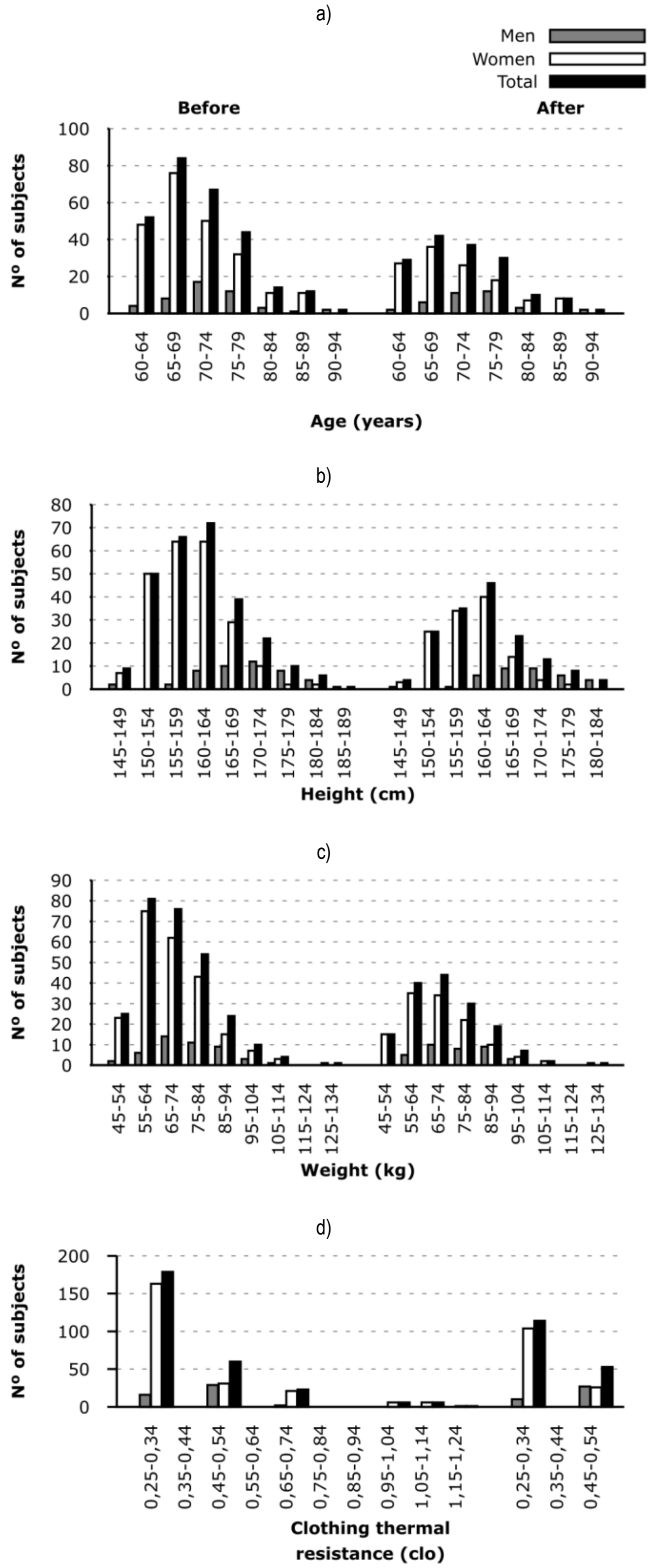
The results of applying these criteria are presented in Figures 1 and 2.

Figure 1 – Distribution of the of room's thermal characteristics to which the subjects were exposed before and after the application of the design criteria: a) operative temperature; b) air relative humidity (same key of a)



Source: The Authors

Figure 2 – Distributions of the sample characteristics before (left) and after (right) the application of the delineating criteria: a) age; b) height; c) weight; d) clothing thermal resistance (same key of a)



Source: The authors

The final sample was composed of 158 subjects, 36 men, and 122 women. Their distributions of age, height, and weight can be considered normal at confidence interval

95% according to the Kolmogorov-Smirnov test and the corresponding main descriptive statistics are shown in Table 2. This table also shows the respective minimum sample sizes (min N) so that the survey could be statistically relevant at confidence level 95% according to the t-Student test.

Table 2 – Statistics of the final sample's parameters

Statistical parameters	mean	s. d.	min N
Age (years)	71.9	7.2	201
Height (cm)	157.6	8.1	254
Weight (kg)	71.3	13.7	721

Source: The Authors

The distributions of pairs of TP and PMV (resulting from question 1) were compared with the Tukey test to verify if there were statistically significant differences between TP values. The hypothesis was that the PMV distributions for TP values were significantly similar at confidence interval 95%. Two groups of TP values (-1 and 0) and three of equivalent PMV classes (-2, -1 and 0) with statistically significant differences ($p < 5\%$) were identified.

Due to the heterogeneous distribution of operating temperature (as showed in Figure 1a), TP and PMV data were binned at 1° C operating temperature intervals. Linear regressions weighted by bin intervals were done with those distributions, which were used to calculate the thermal comfort temperature intervals.

The ranges of operative temperature were also distributed by answers to the questionnaire and for TP values and PMV classes according to the criteria from Table 1. The positional statistics of thermal comfort operative temperatures for subgroups were calculated from these data and the Tukey test at confidence level 95% was used to determine if the distributions were statistically different. Finally, the Kolmogorov-Smirnov test at confidence interval 95% was also applied to verify if the operative temperature distributions from TP and PMV were good estimators for the distributions of the same variable for the most favorable conditions for the questions 2 to 5 (answers "comfortable", "neither warmer nor cooler", "acceptable", and "perfectly tolerable", respectively).

Limitations

The meetings to organize the activities in the institution were carried out with different groups each day. This caused two problems to this study, as explained below:

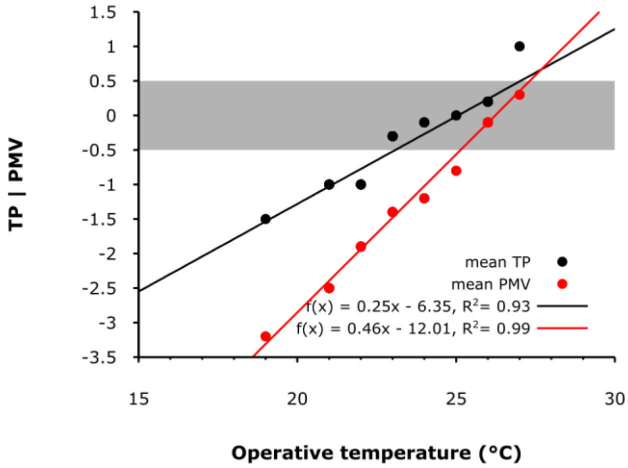
- Not all subjects were present in all environmental conditions, which makes it impossible to group by age for more detailed studies;
- Reduction of the amount of collected data, already limited by the number of participants. Thus, the study does not have statistical expressiveness. Results should be analyzed as a trend and grouped together with those of other future studies to provide an overview of the thermal perception of the Brazilian elderly population.

Another limitation is the clearly unbalanced sample in relation to genders (Figure 2); in this way, the results are more representative of women.

RESULTS

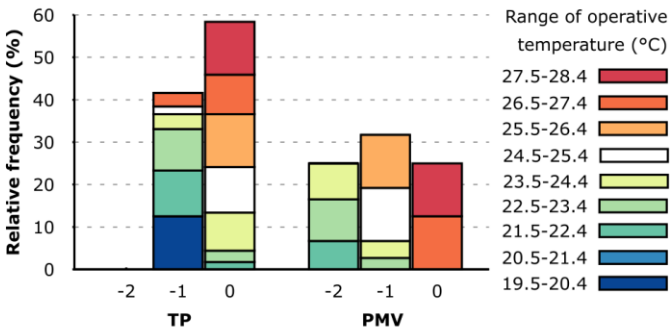
Figure 3 shows the distributions and the respective weighted linear regressions of mean TP and PMV by operative temperature bins. Both binned TP and PMV are strongly correlated with operative temperature. The distributions of operative temperature by answers to the questions and the respective TP values and PMV classes are shown in Figures 4 to 8.

Figure 3 – Mean TP and PMV binned by operative temperature and respective weighted linear regressions. The gray band is the TP and PMV range for thermal neutrality



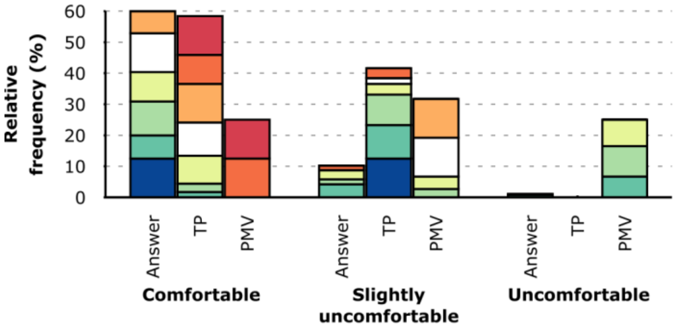
Source: The Authors

Figure 4 – Distributions of operative temperature by statistically different ($p < 5\%$) ranges of TP and PMV for the answers to question 1



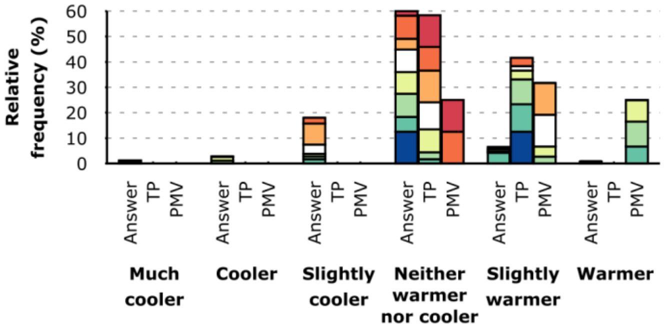
Source: The Authors

Figure 5 – Distributions of operative temperature by answers to the question 2 and by ranges of TP and PMV. The same key of the Figure 3



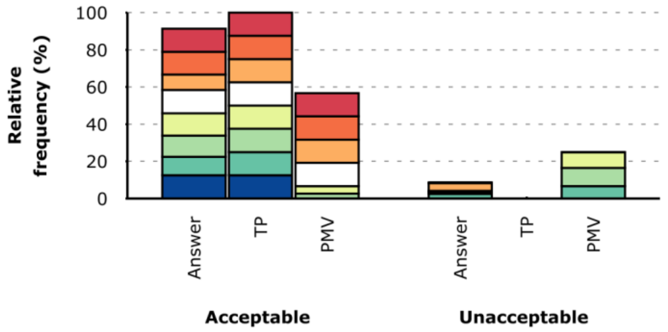
Source: The Authors

Figure 6 – Distributions of operative temperature by answers to the question 3 and by ranges of TP and PMV. The same key of the Figure 3



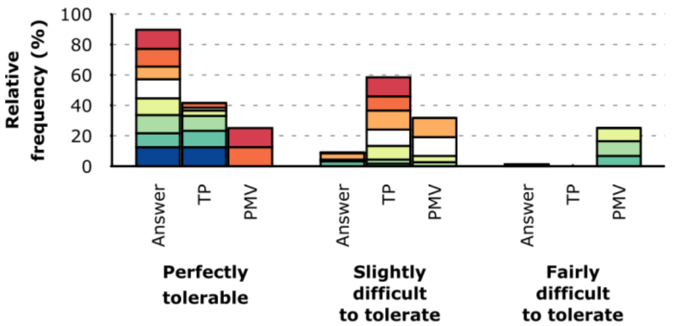
Source: The Authors

Figure 7 – Distributions of operative temperature by answers to the question 4 and by ranges of TP and PMV. The same key of the Figure 3



Source: The Authors

Figure 8 – Distributions of operative temperature by answers to the question 5 and by ranges of TP and PMV. The same key of the Figure 3



Source: The Authors

Statistics of operative temperatures for thermal neutrality (Table 3) were calculated with values from the data of the survey and by linear regression equation of Figure 3. The values obtained from TP are statistically different (p <5%) from the one obtained from PMV (Table 3) According to the Tukey test.

Table 3 – Statistics of operative temperature for thermal neutrality

Statistical parameters	TP	PMV
N	158	
range (°C) (–0.5 ≤ TP | PMV ≤ +0.5)[1]	23.0 ~~a~~ to 26.9	25.1 ~~a~~ to 27.3
neutral (°C)[1]	24.9	26.2
mean (°C)[2]	24.8	26.5
s. d. (°C)[2]	1.6	0.5

[1] From linear regression
[2] From the data of the survey
Source: The Authors

Application of the Kolmogorov-Smirnov test shows that the operative temperature distribution for TP = 0 is a good estimator to the same distribution for the most favorable conditions for the questions 2 to 5 ($p < 5\%$). The operative temperature distribution for $-0.5 \leq PMV \leq +0.5$ can adequately explain only the most favorable answer to the question 4 (Table 4).

Table 4 – Probabilities from the Kolmogorov-Smirnov test comparing the operative temperature distributions of thermal neutrally for TP and PMV, and the same distribution for the most favorable answers to the questions 2 to 5

Question	2	3	4	5
Answer	Comfortable	Neither warmer nor cooler	Acceptable	Perfectly tolerable
TP = 0	0.25	0.60	0.08	0.08
-0,5 ≤ PMV ≤ +0,5	0.02	0.02	0.25	0.02

Source: The Authors

Discussion

The main finding of this study is that there are statistically significant differences ($p < 5\%$) in the mean operative temperatures for thermal neutrality for the sampled elderly (TP = 0) and for not elderly ($-0.5 \leq PMV \leq +0.5$) (see Table 3). It contradicts, at first, the references used in this work. However, it should be remembered that it was observed the presence of larger body circadian thermal amplitudes in the summer (TOITOU et al., 1986) and that the highest level of the circadian cycle of temperatures occurs in the afternoon (EDWARDS et al., 2002). Generally, these changes in the body temperature are associated with the metabolism; however, there is not database with this relationship to serve as input into the PMV to verify if people in general, not only the elderly, need to expose themselves to cooler thermal conditions than the model indicates to cool down in this situation.

Other result is that the range of operative temperature for thermal neutrality is wider for the subjects of this study than for non-elderly (the angular coefficient for TP regression is bigger than for PMV in Figure 3, giving a wider range in Table 3; the range of operative temperatures are bigger for TP = 0 than for PMV = 0 in Figure 4). Despite these facts, the elderly thermal sensibility is lower than the young's are: they can distinguish only two TP points against 3 PMV points of the youngsters (Figure 4). These observations agree with other studies: the temperature discrimination threshold is higher for elderly (COLLINS; EXTON-SMITH; DORÉ, 1981); at the same time, the decreasing ability of temperature distinction leads to the identification of a smaller number of thermal sensation bands.

In the answers to questions 2 to 5, PMV generally demonstrated not to be a good estimator for the best thermal comfort conditions for the elderly (Figures 5, 6, and 8, and Table 4). TP better represents the best conditions for thermal comfort ("Comfortable", "Not hotter nor colder" and "Perfectly tolerable", answers respectively to questions 2, 3 and 5), but the equivalent operating temperature ranges may differ. They may include lower values in which subjects would remain "comfortable" (Figure 5) and feel that the best thermal environment would be "neither warmer nor colder" than the current one (Figure 6). At the same time, these intervals may include higher values than those present in the TP, which, however, are "perfectly tolerable" (Figure 8). The representativeness of TP for the best conditions of thermal comfort corroborates the thermal comfort temperature of the derivative. The highest operational temperature range for thermal comfort, neutrality or acceptability is in accordance with the highest standard deviation of the mean operating temperature for thermal comfort for the elderly relative to the value of that variable derived from the PMV (Table 3). In summary, this seems to indicate that PMV is not a good model for analyzing the thermal perception of the elderly. As the most recent literature suggests, perhaps the input parameters, especially the metabolic rate, need a finer adjustment.

CONCLUSION

This study was conducted to evaluate whether elderly people in air-conditioned rooms have different thermal perception than non-elderly, for which the reference was the PMV. It showed that yes, they have, but not in the same way described by the international literature: their preferred thermal environment for comfort is colder than for the second ones, as well as the range of operative temperatures for thermal comfort is also wider than for non-elderly. On the other hand, their range of thermal perception is narrower than that of the non-elderly. Therefore, PMV is not a good predictor for the elderly thermal preferences.

Recent studies involving circadian thermometry show that the core temperature has a day-to-night cycle and so the human body may exhibit different thermal demands along this period. However, it is outside the scope of this paper to attempt to explain these relationships, because the authors have not resources to do it, as well it is not possible to explain here whether climatic conditions or the lack of statistical representativeness influenced the trend or magnitude of the results by the same reason.

Thus, the work opens a discussion about the theme and invites researchers to carry out research in Brazil to better clarify the raised problems aforementioned.

Notes

(1) ENOMOTO-KOSHIMIZU, H; KUBO, H; ISODA, N; YANASE, T. Effect of the radiant heating on the elderly. In: TRIENNIAL CONGRESS OF THE INTERNATIONAL ERGONOMICS ASSOCIATION, 13, Tampere, Finland, 1997. **Proceedings…** Tampere, Finland, 1997, v. 5, p. 433-435.

References

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS. **ANSI/ASHRAE Standard 55-2013** - Thermal Environmental Conditions for Human Occupancy. Atlanta, GA, 2013.

BRASIL. Instituto Brasileiro de Geografia e Estatística (IBGE). **Projeções da população por sexo e idade: 2000-2060**. Disponível em: ftp://ftp.ibge.gov.br/Projecao_da_Populacao/Projecao_da_Populacao_2013/projecoes_2013_populacao_xls.zip. Acesso em: 03 mar. 2015.

BRASIL. PRESIDÊNCIA DA REPÚBLICA. CASA CIVIL. SUBCHEFIA PARA ASSUNTOS JURÍDICOS. Lei nº 8.842, de 4 de janeiro de 1994. Dispõe sobre a política nacional do idoso, cria o Conselho Nacional do Idoso e dá outras providências. **Diário Oficial [da] República Federativa do Brasil**, Brasília, DF, 4 de jan. 1994. Disponível em: http://www.planalto.gov.br/ccivil_03/leis/L8842.htm. Acesso em: 21 jan. 2014.

COLLINS, K. J.; HOINVILLE, E. Temperature requirements in old age. **Building Services Engineering Research and Technology**, v. 1, n. 4, p. 165-172, 1980. http://dx.doi.org/10.1177/014362448000100401.

COLLINS, K. J.; EXTON-SMITH, A. N.; DORÉ, C. Urban hypothermia: preferred temperature and thermal perception in old age. **British Medical Journal (Clinical Research Edition)**, v. 282, n. 6259, p. 175-177, 1981. https://doi.org/10.1136/bmj.282.6259.175.

EDWARDS, B.; WATERHOUSE, J.; REILLY, T.; ATKINSON, G. A comparison of the suitabilities of rectal, gut, and insulated axilla temperatures for measurement of the circadian rhythm of core temperature in field studies. **Chronobiology International**, v. 19, n. 3, p. 579-597, 2002. http://dx.doi.org/10.1081/CBI-120004227.

GUERGOVA S.; DUFOUR A. Thermal sensitivity in the elderly: a review. **Ageing Research Reviews**, v. 10, n. 1, p. 80-92, jan. 2011. http://dx.doi.org/10.1016/j.arr.2010.04.009.

HESCHONG, L. **Thermal delight in architecture**. Cambridge: MIT Press, 1979.

HUANG, H.-W.; WANG, W.-C.; LIN, C.-C. Influence of age on thermal thresholds, thermal pain thresholds, and reaction time. **Journal of Clinical Neuroscience**, v. 17, n. 6, p. 722-726, jun. 2010. http://dx.doi.org/10.1016/j.jocn.2009.10.003.

JOHANSSON, E.; THORSSON, S.; EMMANUEL, R.; KRÜGER, E. Instruments and methods in outdoor thermal comfort studies – The need for standardization. **Urban Climate**, v. 10, Part 2, p. 346-366, dec. 2014. http://dx.doi.org/10.1016/j.uclim.2013.12.002.

MORAGAS, R. M. **Gerontologia social**: envelhecimento e qualidade de vida. 3. ed. São Paulo: Paulinas, 2010.

NOVIETO, D. T.; ZHANG, Y. Towards thermal comfort prediction for the older population: a review of aging effect on the human body. In: IESD PHD CONFERENCE: ENERGY AND SUSTAINABLE DEVELOPMENT, 2010. **Proceedings....** Leicester, UK: Institute of Energy and Sustainable Development, De Montfort University, 2010, p. 35-48.

RAVUSSIN, E.; BOGARDUS, C. Relationship of genetics, age, and physical fitness to daily energy expenditure and fuel utilization. **The American Journal of Clinical Nutrition**, v. 49, n. 5, p. 968-975, 1989.

RIBEIRO, L. C. C.; ALVES, P. B.; MEIRA, P. Percepção dos idosos sobre as alterações fisiológicas do envelhecimento. **Ciência, Cuidado e Saúde**, v. 8, n. 2, p. 220-227, 2009. http://dx.doi.org/10.4025/cienccuidsaude.v8i2.8202.

RUAS, A. C. **Avaliação de conforto térmico**: contribuição à aplicação prática das normas internacionais. 1999. 78 p. Dissertação (Mestrado em Engenharia Civil) - Faculdade de Engenharia Civil, Universidade de Campinas, Campinas, 1999.

SATO, A. E.; GONÇALVES, F.; MONTEIRO, L. M. Resiliência às mudanças climáticas: conforto térmico de idosos em unidades residenciais. In: XV ENCONTRO NACIONAL DE TECNOLOGIA DO AMBIENTE CONSTRUÍDO, 15., Maceió, 2014. **Anais...** Maceió: ANTAC, 2014, p. 153-162. https://dx.doi.org/10.17012/entac2014.113.

SCHELLEN, L.; Van MARKEN LICHTENBELT, W. D.; LOOMANS, M. G. L. C.; TOFTUM, J.; de WIT, M. H. Differences between young adults and elderly in thermal comfort, productivity, and thermal physiology in response to a moderate temperature drift and a steady-state condition. **International Journal of Indoor Environment and Health**, v. 20, p. 273-283, aug. 2010. https://dx.doi.org/10.1111/j.1600-0668.2010.00657.x.

SHIBASAKI, M.; OKAZAKI, K.; INOUE, Y. Aging and thermoregulation. **Journal of Physical Fitness and Sports Medicine**, v. 2, n. 1, p. 37-47, 2013.

SIMÕES, R. **Corporeidade e terceira idade**. 3. ed. Piracicaba: Unimep, 1998.

TOUITOU, Y.; REINBERG, A.; BOGDAN A.; AUZÉBY, A.; BECK, H.; TOITOU, C. Age-related changes in both circadian and seasonal rhythms of rectal temperature with special reference to senile dementia of Alzheimer type. **Gerontology**, v. 32, p.110-118, 1986. http://dx.doi.org/10.1159/000212774.

TSUZUKI, K; OHFUKU, T. Thermal sensation and thermoregulation in elderly compared to young people in Japanese winter season. In: INDOOR AIR 2002 - INTERNATIONAL CONFERENCE ON INDOOR AIR QUALITY AND CLIMATE, 9. Monterey (CA), 2002. **Proceedings…** Rotterdam (Netherlands): In House Publishing, 2002, p. 659-664.

USHIDA, Y.; TAMURA, T.; IWASAKI, F. Changes in cold/warm thresholds with advancing age – the case of adult women aged from the 20s to the 80s. **Sen'I Gakkaishi**, v. 65, n. 5, p. 48-54, 2009. http://doi.org/10.2115/fiber.65.132.

VAN HOOF, J. Forty years of Fanger's model of thermal comfort: comfort for all? **Indoor Air**, v. 18, p. 182-201, 2008. http://dx.doi.org/10.1111/j.1600-0668.2007.00516.x.

VAN HOOF, J.; HENSEN, J. L. M. Thermal comfort and older adults. **Gerontechnology**, v. 4, n. 4, p. 223-228, 2006. http://dx.doi.org/10.4017/gt.2006.04.04.006.00.

WEINECK, J. **Biologia do esporte**. Barueri: Manole, 2005.

---

[1] **Fabiana Padilha Montanheiro**
Arquiteta. Mestre em Arquitetura e Urbanismo. Endereço postal: Rua Irmã Arminda, 10-50 - Jardim Brasil, Bauru, SP, Brasil, CEP: 17011-160

[2] **João Roberto Gomes de Faria**
Engenheiro. Livre-docente. Endereço postal: Avenida Eng. Luiz Edmundo Carrijo Coube, 14-01, Bauru, SP, Brasil, CEP: 17033-360