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Effects of thermophysiological and non-thermal factors on outdoor thermal perceptions: The Tomebamba Riverbanks case

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ABSTRACT

Outdoor thermal comfort (OTC) is an indicator of urban-environmental sustainability. A better understanding of OTC requires exploring the effects of contextual, non-thermal and human-related factors on thermal sensation votes (TSV) in addition to the long-studied thermophysiological and microclimatic factors. In this research, the Socio-Ecological Model (SEM) structure was used for grouping thermophysiological and non-thermal factors in three environments: corporeal (level of physical activity, level of clothing, gender, age and skin tone), mental (perceived urban agreeability, perceived urban insecurity and perceived urban noise) and social (company, occupation and cultural background). Field surveys were performed in three representative weeks of the annual climate-type in Cuenca, Ecuador during the hottest month (January), a cooler month (July) and an intermediate month (April), surveying 2321 users of two urban sites located at representative areas of the Tomebamba riverbanks. Statistical descriptive analysis and inferential methods were employed for exploring the effect of these SEM factors on the TSV using the Physiological Equivalent Temperature (PET) calculated with RayMan1.2 from on-site measured data. The analytical results evidenced a low influence of all three SEM environments on the TSV. Additionally, differences in male and female OTC requirements were identified, and two local PET-TSV scales were calculated from (1) urban global radiation data and (2) mean radiant temperature, calculated according to ISO 7726 with Ø 150 mm black-globe-thermometer measurements. The main results show Acceptable Temperature Ranges (rTa) in Cuenca from 29 °C to 34 °C PET (1) and from 26 °C to 37 °C PET (2), for 85% acceptability.

1. Introduction

1.1. Background

Thermal comfort constitutes an inherent aspect of the environment built by humans, as it has historically manifested itself in the vernacular architecture developed over the centuries and under various environmental conditions that have conditioned the local construction systems [1]. All of this conditioning depends on each contextual example and the historical period in terms of sociocultural conditions, technical abilities, perceptual notions and aesthetic appreciations [2]. Hence, the climate, natural light, natural ventilation, architectural form and interior atmosphere have continually been managed to achieve indoor thermal comfort, during the modern architectural period of the 20th century [3].

Current scientific research regarding thermal comfort originated in the field of biometeorology, which studies the interactions of living organisms with their atmospheric environment [4]. As a consequence, the human balance of temperature and thermal perception has been studied in depth over the last sixty years [5], where thermal comfort is defined as the "*condition of the mind that expresses satisfaction with the environment.*" [6].

In this context, Ref. [7] developed the classic static model of the body-heat balance equation, designed for air-conditioned spaces and established the popular Mean Predicted Vote (PMV) and Predicted Percentage of Dissatisfied (PPD), for which he employed six variables, which are currently the fundamental ones in this area of study: metabolism, clothing, air temperature, air velocity, air humidity and the mean radiant temperature. This static model understands the subjective discomfort as the result of mere physiological reactions to the microclimate, considering the user as an entirely passive receiver of the thermal stimuli [8]. However, subsequent studies emphasized that

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users' contextual factors and thermal history modify their own expectations and thermal preferences. For example, the occupants of naturally ventilated buildings tolerate a wide range of temperatures, adjusting their behaviour and displaying psychological adaptations [9]. For this reason, an adaptive model emerged based on the principle that states *"if a change occurs such as to produce discomfort, people react in ways that tend to restore their comfort"* [10]. These reactions may involve physiological, psychological, social, technological, cultural and behavioural measures [10]. Thus, the static-adaptive quantification of interior comfort has been widely established during the past several decades, given that the interior microclimate is relatively stable and even controllable by means of active air conditioning systems, and adjustable to given requirements of human activity [11]. However, outdoor thermal comfort (OTC) requires a more complex quantification, since it is conditioned by rapid microclimatic variations (solar exposure and wind speed) and by a wide range of outdoor time-exposures [11].

OTC research in urban planning is essential to mitigate the heat-island effect and, consequentially, to contribute to climate change adaptation [12]. The initial absence of empirical studies at outdoor spaces allowed OTC methodology to be conceived directly from conventional indoors theory [13], displaying henceforth a) an experimental design, b) micro-meteorological measurements (instrumentation, air temperature and humidity, wind speed, mean radiant temperature), c) questionnaires (physical activity, clothing isolation, subjective perceptions, personal and cultural factors), and d) thermal indexes [14]. Moreover, the need for a general assessment framework linking thermo physiological factors (local microclimatic environment and physiology) with non-thermal factors (social, psychological and behavioural) has been reported [15]. Such an assessment framework has instated the research of practical roles of various non-thermal, corporeal and mental factors in contextual outdoor thermal perceptions, such as socio-economic [16], gender, age, skin tone, companionship, cultural background, position [17,18], length of residence, character and features of place and naturalness [19], considering also that there is still a lack of methodological consensus to analyse and compare OTC data for a consistent international dialog [12]. In so doing, the models and standards for OTC studies have been frequently adjusted to specific requirements of each research project and according to "*their ability to analyse the climate, microclimate and human characteristics*" of the selected built environment [11].

Recent OTC studies show diverse conclusions regarding corporeal and non-thermal factors. In regard to gender, at Rio de Janeiro, the role of this factor has been reported as statistically insignificant in outdoor thermal perceptions [18]. Likewise, in Melbourne [17], West Lafayette, Indiana, and Tianjin [20]. Conversely, in Teheran, a smaller female comfort zone has been found, suggesting a greater female sensitivity to the lack of comfort in winter [21]. Slightly lower female thermal sensation votes (TSV) were also found in Arizona [22], while on the contrary, in Wuhan, a criterion based on the average attendance to a space instead of subjective votes has been used, reporting a higher male comfort range [23].

In relation to age, according to Ref. [18] and [22] there is no statistical relevance on thermal sensation; Ref. [20] found an irrelevant difference between groups of older and younger than 30 years of age, whereas Ref. [17] report that age does have a statistical significance in thermal perception. Ref. [21] report that at a younger age both male and female users are more sensitive to colder conditions, while Ref. [23], on the contrary, observed that the younger the age is, the less the tolerance to cold is, with statistically significant differences being observed.

In reference to skin tone, Ref. [17] do not report a unique relationship of this factor with the perception of thermal comfort but in interaction with other factors the skin tone becomes significant in the general regression model. In contrast, Ref. [18] emphasize a considerable role of this factor in the outdoor thermal sensation and suggest investigating it, preferably based on local skin-tones databases.

As for the level of clothing (clo) and physical activity (Met), Ref. [22] report that previous activities and clo level do not significantly influence subjective thermal comfort. In contrast, Ref. [17] found that the level of clo is a function of the atmospheric state, and is statistically related to TSV but did not find a statistically significant relation between the level of physical activity and the thermal perception. In Melbourne, Ref. [24] in comparing seasons with and without heat waves, reported that during the latter, both local people and visitors use significantly less clothing, although locals show greater adaptation. Ref. [20] observed that older subjects compensated their lower metabolism with more clothing; and Ref. [23] identified different comfort ranges according to the level of physical activity.

In relation to company, occupation and cultural background, Ref. [17] found a significant effect on the TSV; Ref. [23] also found that social behaviour is positively altered through interventions of microclimatic improvement in public spaces, which echoes previous observations regarding the influence of culture-rules, norms and values on outdoor thermal perception [25,26].

Henceforth, the growing tendency in thermal comfort research, including OTC, is to develop *"an integral (systemic/holistic) research approach that may help to a better comprehension about sensation, perception and thermal comfort and its physiological and psychological dimension."* [27]

1.2. Main goal

In the Ecuadorian context, Ref. [28] performed a relevant study in Guayaquil, a tropical savannah Aw according to the Köppen climate map [29], exploring the influence of urban micrometeorological conditions on the subjective perception of users and comparing it with two thermal indexes: the Standard Effective Temperature (SET) and the Physiologically Equivalent Temperature (PET). In a similar way, this research was developed in Cuenca, classified as a highland subtropical climate (Cfb) according to Ref. [29], and was performed in line with two studies regarding behaviour, uses and non-thermal perceptions (mental factors) at Cuenca's Tomebamba riverbanks [30,31], which observed that perceptions of urban insecurity and noise are a statistically high concern for current riverbank users, while urban beauty is a low concern. The primary goals of this research were to explore the effects of thermophysiological and non-thermal factors on outdoor thermal perceptions; to identify differences in male and female OTC requirements; and to derive a custom TSV scale for the region of study, ultimately instigating scientific knowledge regarding OTC in the local urban context.

2. Methodology

2.1. Theoretical framework

The Socio-Ecological Model (SEM) is a theory for a multilevel understanding of the complex interrelations between an individual and the context in which he or she lives. SEM structures such interrelations in five subsystems or environments, nested as matryoshkas (Russian nesting dolls), namely: microsystems, mesosystems, exosystems, macrosystems and chronosystems [32]. These environments are also defined as: individual, interpersonal, organizational, community and policy [33]. SEM's promoter, Urie Bronfenbrenner, argues that *"in order to understand human development, one must consider the entire ecological system in which growth occurs."* [32].

SEM environments have been adapted in different disciplines, through studies seeking to highlight the human role in the interaction with the environment. For example, the study by Ref. [34] takes the SEM as a reference to categorize the complexity of social, cultural and environmental factors that influence eating habits in low-income populations, generating intrapersonal, interpersonal and organizational environments for that specific study. Ref. [35] in a study about physical activity interventions in childcare, deploy five environments: child, interpersonal, organizational, community and public policy. Ref. [36] studied how to reduce cyberbullying behaviour by analysing the characteristics of six SEM environments.

Similarly, the SEM has been used in the study of thermal comfort [37], being a model extrapolated effectively for the analysis of the effect of non-thermal and human-dependent factors on the subjective perceptions of OTC. For example, in Melbourne Ref. [17] classified the SEM model in individual (including level of physical activity, level of clothing, gender, age and skin tone) and social environments (including company, occupation and cultural background) in order to understand the role of these factors in outdoor thermal perception.

Thus, besides the antecedents mentioned in the introduction, this research takes as reference the study proposed by Ref. [17], adding the exploration of mental factors about local riverbank perceptions outlined by Ref. [30] and thereby applying the SEM model in three environments: corporeal (level of physical activity, level of clothing, gender, age and skin tone), mental (perceived urban agreeability, perceived urban insecurity and perceived urban noise) and social (company, occupation and cultural background).

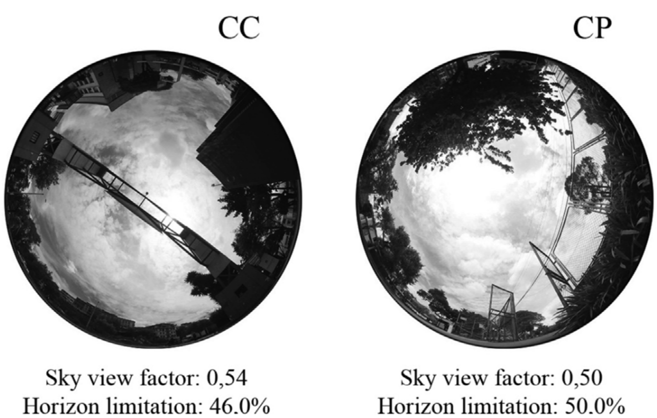

Fig. 1. Fish-eye images and SVF values in the two study sites.

2.2. Study sites

Urban riverbanks are relevant spaces for OTC studies, as they are “generators of urban biodiversity” and constitute “public spaces that contribute to social resilience and build urban identities” [30]. Consequently, two sites were chosen in Cuenca, both located in the Tomebamba riverbanks. The area designated “banks” are those found between the water river limit and the first built line within the “river protection margin” of 50 m stipulated in the local municipal standard [38]. These two sites were previously selected for uses and behavioural studies in Refs. [30,31].

The areas containing the selected sites are classified as an LCZ5 Open Midrise local climate type [39], with buildings between 3 and 9 floors, an abundance of pre-urban flora (minor vegetation and scattered trees), heavy construction materials (concrete, steel, stone, brick or block, glass), a residential-institutional land-use, and a sky view factor (SVF) between 0.5 and 0.8 (Fig. 1).

The first site is located at the “Central Campus” (CC) of the University of Cuenca, near the main entrance at 12 de Abril Avenue. This site is the river's most emblematic area because of its relation with the UNESCO World Heritage historic centre. The site has a high population density, a high percentage of land occupation and little vegetation coverage (compared to other river areas) because of significant bank-reduction by footpaths interventions. This river area also has the greatest integration (urban connectivity) and hence the greatest influx of people [31]. The main entrance to the CC is on the southern bank and on the northern bank is the historic centre ravine (Fig. 2). The SVF in CC is 0.54, and the horizon limit is 46% (Fig. 1).

The second site is on the “Paradise Campus” (CP) of the University of Cuenca, for which those entrance is also on 12 de Abril Avenue but further down-river. This site is located in a consolidated urban grid with a low population density, a medium percentage of land occupation and medium vegetation coverage compared to other river areas. The river's banks at this site are wide with accessible footpaths and contain no urban equipment [31]. The main entrance to CP is on the southern bank and at the northern bank a residential area is emplaced (Fig. 2). The

Fig. 2. Two study sites at Tomebamba Riverbanks.

SVF at CP is 0.50, and the horizon limit is 50%. The SVFs for both sites were calculated in RayMan 1.2, employing fish-eye photographs -with 180° vision-for each site, taken by a Canon EOS 5D Mark III camera with EF 8–15 mm f/4 L Fisheye USM lens, (Fig. 1).

2.3. Climatic conditions and study field

According to local weather stations (CEA University of Cuenca 2005 to 2015, Universidad Politécnica Salesiana, El Vecino, Yanuncay, 2004 to 2016, EMOV GAD Municipal Cuenca −2013 and 2015- and General Directorate of Civil Aviation- 1977 to 2015), the annual climate of Cuenca consists of a cold season (June, July, August and September), a warm season (November, December, January and February) and intermediate temperatures in the other months. In addition, the first semester of the year tends to have a higher relative humidity than the second. Therefore, three representative months were chosen: January (highest temperature), July (lowest temperature) and April as an intermediate month and representative of the semester with the higher relative humidity. During 2017, three rounds of simultaneous micrometeorological measurements were carried out at CC and CP, from the 23rd to the 29th January, the 17th to the 23rd April and the 3rd to the 9th July with concurrent questionnaires. The diurnal time-range of the highest temperature was selected, coinciding with a high use of public space; from 8:30 a.m. to 5:30 p.m. The measured data showed that July contained the coldest week (CC 18.3 °C, CP 18.4 °C) but also the one with the highest relative humidity (CC 53%RH, CP 56.1%RH), while the week in April turned out to be the hottest (CC 21.5 °C, CP 21.5 °C) followed by January (CC 20.1 °C, CP 20.5 °C), being also the driest one (CC 48.8%RH, CP 50.4%RH).

2.4. Sample size

Surveys were conducted by random sampling without replacement, performing a total of 2419 surveys of which 98 were discarded; 46 due to the absence of concurrent microclimatic measurements and 52 due to inconsistencies in clothing data. Of the remaining 2321, 58% (N = 1338) were collected in CC and 42% (N = 983) in CP. Of the total 46% were men (N = 1072) and 54% were women (N = 1249).

2.5. Instruments, questionnaires and thermal comfort assessment

Four in situ micrometeorological variables were measured: globe temperature (Tg °C), air temperature (Ta °C), relative humidity (RH%) and wind speed (Va m/s). Two Delta OHM HD 32.1 data loggers were employed, each with the TP3207, TP3275, AP3203 and HP3217R probes, (Fig. 3), (Table 1), with 1-min data recording intervals. Measurement ranges and instruments fidelity were in accordance with standards [6], [40] and [41]. The measurement used was *Class II*, where the variables for the calculation of the thermal index *"…Were collected at the same time and place as the thermal questionnaires were administered, but most likely only at one height of measurement"* [8]. Therefore, the instruments were adjusted to the height of the centre of gravity of a standing person, that is 1.1 m, according to the standards [40] and [6]. The measured Tg °C was employed to calculate the mean radiant temperature (Tmrt) according to the standard [40], equation (1): Tg (°C) = balloon temperature, Va (m/s) = wind speed, Ta (°C) = air temperature, εg = balloon emissivity and D = balloon diameter according to probe TP3275 (Table 1).

$$Tmrt = \left[(Tg + 273)^4 + \frac{1.1 \times 10^8 \times Va^{0.6}}{\varepsilon g \times D^{0.4}} (Tg - Ta) \right]^{1/4} - 273 \tag{1}$$

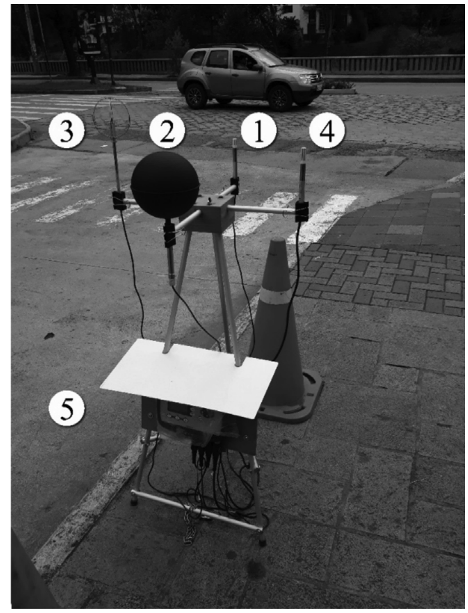

Fig. 3. 1) Temperature probe 2) Globe thermometer probe 3) Hot wire probe 4) Combined probe; temperature and relative humidity 5) Data logger.

Many studies have observed that the Ø 150 mm black globe thermometer is unsuitable for outdoor usage (having rapid changes in radiative fluxes and wind speed) due to a significant measurement time lag, being the Ø 40 mm grey-globe thermometer best suited for outdoors [14,42]. Nonetheless, Ø 150 mm black-globe thermometers are still employed in OTC research [19,43,44]. Ref. [45] observed that when integral radiation or global temperature measurements are not viable, global radiation (SR) measured at the urban site can be applied, and even when the latter is also missing, rural SR is still a valid option for estimating Tmrt in OTC research. Therefore, for the purpose of comparison, two local TSV-PET-scale calculations were performed (Scale1 & Scale2); the first with SR from the local university Politécnica Salesiana Yanuncay-CTS (located near another Cuenca urban riverbank), and the second with the TP3275 probe's on-site measured data. Aside from the TSV-PET-scales, only PET values generated with SR were considered for exploring the effect of the SEM factors on the TSV and for identifying male and female OTC requirements.

The questionnaire was structured and performed in an Open Data Kit (ODK) (alternatively in KoBoToolbox) in four sections:

1) Thermal evaluation (seven sections) complying with the standard of Ref. [46]. Thus, for TSV, a symmetric scale of two poles and 7 points was used, from −3 (very cold) to +3 (very hot), where 0 is "neither hot nor cold" (Fig. 4).
2) Use, perception and spatial behaviour (six sections). It includes the level of physical activity, also using as a reference Ref. [30] and [31] (Fig. 4).
3) Personal details (six sections). It includes age, height and weight, based on Ref. [17] (Fig. 5).
4) Observation of supplementary data, based on Ref. [17]: gender, company, posture, clothing, and skin tone according to a Latin American skin-tone scale [47] (Fig. 5).

Each survey took less than 5 min and was geo-referenced with

Table 1
Detail of the measurement instruments.

Probe[a]	Measured parameter	Description	Uncertainty of measurement	Measurement range
Delta OHM TP3207	Tw (°C)	Temperature probe Sensor type: Pt100 thin film.	Class 1/3 DIN	−40 ÷ 100 °C.
Delta OHM TP3275	Tg (°C)	Globe thermometer probe Ø = 150 mm according to ISO 7243 - ISO 7726 Sensor type: Pt100 thin film.	Class 1/3 DIN	−10 ÷ 100 °C.
Delta OHM AP3203	Va (m/s)	Omnidirectional hot wire probe. Sensor type: NTC 10Kohm	± 0,02 m/s (0,05 ÷ 1 m/s) ± 0,1 m/s (1 ÷ 5 m/s)	0,05 ÷ 5 m/s 0 °C ÷ 80 °C
Delta OHM HP3217R	Ta (°C), RH (%)	Combined probe temperature and relative humidity. It is used in the measurements of environmental comfort indexes. Type sensors: - Pt100 of thin film for temperature - Capacitive sensor for relative humidity.	Temperature: 1/3 DIN Relative humidity: ± 2.5%	Temperature: −10 °C ÷ 80 °C Relative humidity: 5% RH ÷ 98% RH
Microclimatic station[a]				
Delta OHM HD 32.1 Thermal Microclimate	Pr (hPa)	Data logger. Microclimatic station manufactured to study, measure and check the microclimate.		

[a] Two of these were used simultaneously in each site during the 3 weeks of measurement.

Outdoor Thermal Comfort Questionnaire (transcription from the Spanish-digital ODK format)

1. THERMAL PERCEPTION EVALUATION

1.1 How do you feel at this precise moment? Choose a point on the scale

cold	cool	slightly cool	neutral	slightly warm	warm	hot
-3	-2	-1	0	+ 1	+ 2	+ 3

1.2 At this precise moment, do you find it the...?

a. Temperature ☐ pleasant ☐ unpleasant
b. Sunlight ☐ pleasant ☐ unpleasant
c. Wind speed ☐ pleasant ☐ unpleasant
d. Humidity ☐ pleasant ☐ unpleasant

1.3 On a scale of 1 to 5, where 1 is "uncomfortable" and 5 is "comfortable" Right now how do you find the weather on this site?

Uncomfortable — Comfortable
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

1.4 At this precise moment, in this site:

a. Would you prefer... ☐ A colder temperature ☐ no changes ☐ warmer temperature
b. Would you prefer... ☐ more sunlight ☐ no changes ☐ more shade
c. Would you prefer... ☐ more wind ☐ no changes ☐ less wind
d. Would you prefer... ☐ more humidity ☐ no changes ☐ less humidity

1.5 On a personal level, how do you judge the local climate at this riverbank?

☐ generally acceptable ☐ generally unacceptable

1.6 On a scale of 1 to 5, where 1 is "intolerable" and 5 is "tolerable", habitually the climate at this riverbank is...

Intolerable — Tolerable
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

1.7 What measures would you take right now to feel more comfortable?

☐ Use a parasol or a hat
☐ Use an umbrella
☐ Use more clothing
☐ Use less clothing
☐ Move to shade
☐ Move to sunlight
☐ No changes

2. USE, PERCEPTION AND SPATIAL BEHAVIOUR

2.1a What activity were you performing during the last 30-60 minutes?

☐ Exercising ☐ Standing ☐ Reclining
☐ Walking ☐ Seated ☐ Sleeping

2.1b Fifteen minutes ago you were...?

☐ Indoors ☐ Outdoors in shade ☐ Outdoors in sunlight

- If you were outdoors: What time in minutes has it been since you are outside?

☐ less than 5 ☐ 5 to 10 ☐ 10 to 30 ☐ more than 30 minutes

2.2 How often do you come by here?

☐ First occasion ☐ Few times a month ☐ Many times a week
☐ Rarely ☐ Few times a week ☐ Daily

2.3 What activity have you come to do at this riverbank?

☐ Tourism ☐ Sports ☐ Work ☐ Eat a snack
☐ Walking ☐ Study ☐ Take a break ☐ Make a picnic

2.4 How do you perceive this urban environment on the riverbank?

☐ pleasant ☐ safe ☐ calm
☐ unpleasant ☐ unsafe ☐ noisy

2.5 For you, the mobility to reach this place is...

☐ Easy access ☐ Difficult to access

- Usually how do you move here?

☐ Walking ☐ Bicycle ☐ Car-Motorcycle ☐ Public transport

2.6 Do you consider that in this riverbank environment...

- Trees providing shade should... ☐ Increment ☐ Keep without changes
- The benches and covered spaces should ... ☐ Increment ☐ Keep without changes
- The green areas and gardens should... ☐ Increment ☐ Keep without changes
- Business and local commerce should... ☐ Increment ☐ Keep without changes

Fig. 4. Questionnaire, part 1 and 2.

date-time info linked to each smartphone device and performed next to each microclimatic station. One researcher and six architecture students were required during the measurement period in both sites (Fig. 2).

PET (Physiological Equivalent Temperature) and UTCI (Universal Thermal Climate Index) are both notable OTC indexes [45]. PET is based on human comfort and UTCI is based on human physiological strain, but with a high correlation coefficient between them (r = 0.96) [48]. However, PET presents a particularly high employment in different climate-zones [14]; hence, this index was used in order to facilitate an international comparability of results. PET is defined as the physiological equivalent temperature at any given place (either inside or outside), for example: a person in an outdoor sunny spot with a PET value of 43 °C will experience the same heat sensation as if he were inside a room at 43 °C; if that person moved from that sunny spot towards the shadow (exterior), the PET value would be reduced 14 K to 29 °C [49]. In other words, PET evidence "*great sensitivity to variation in the human–biometeorological parameters*" [50], which makes it applicable to different climates of the world and throughout the year [49]. Consequently, the PET thermal scale and neutral sensation vary

3. PERSONAL DETAILS

3.1a Do you reside in Cuenca since your birth?

Yes☐ No☐

3.1b If not, since when do you reside in the city of Cuenca?

_____years _____months____days
... (if you were not born in Cuenca) What is your place of birth? ________________

3.2 What is your age?

- Between 13 - 17 years old... ☐
- Between 18 - 39 years old... ☐
- Between 40 - 65 years old... ☐
- More than 65 years old... ☐

3.3 How tall are you?

____

3.4 How much do you weigh?

____

3.5 What is your level of education?

- School ☐
- High School ☐
- Graduate ☐
- Master degree ☐
- Ph.D. ☐
- No studies ☐

3.6a What is your current daily activity?

- Study ☐
- Work ☐
- Study & Work ☐
- Retired ☐
- Housewife ☐
- Unemployed ☐
- Other (please specify)... __________

3.6b On a scale of 1 to 5 where 1 is "dissatisfied" and 5 is "satisfied" How do you feel now with your main daily activity?

1☐ 2☐ 3☐ 4☐ 5☐

4. SECTION FOR THE INTERVIEWER

4.1 The respondent was...

☐Man ☐Woman

4.2 The respondent was...

☐Alone ☐With more people

4.3 The respondent was...

☐Under shade ☐Under sunlight

4.4 The respondent's position was...

☐Standing ☐Reclining ☐Seated

4.5 Skin tone...

☐Very light ☐Light ☐Medium ☐Dark

4.6 Mark the necessary options to describe the respondent's clothing pattern... (options according to typical local arrangements and understandings)

T-shirts
☐Short sleeve ☐Long sleeve

Shirt or blouse
☐Short sleeve ☐Long sleeve

Sweater
☐Lightweight ☐Normal ☐Heavy ☐Vest

Jackets
☐Lightweight ☐Normal ☐Coat

Pants
☐Of cloth ☐Jeans ☐Shorts ☐Sports

Skirts
☐Lightweight ☐Heavyweight

Shoes
☐Thin sole ☐Thick sole ☐Boots

GEOREFERENCED LOCATION, (DIGITAL)

Thank you for your kind collaboration.

Fig. 5. Questionnaire, part 3 and 4.

according to the climate, being necessary to validate its simulations with measurements and questionnaires in situ [11].

2.6. Data analysis

PET values were calculated using RayMan1.2 [51]. In the PET index, the clothing (clo) and the activity (W) are standardized for indoors in sedentary mode (0.9c, 80 W), since the variation of clothing and activity does not lead to significant differences in PET values [49]. That was verified in RayMan1.2 with the present study; even the height, weight, age and sex only slightly impacted the PET value (between 0.1 °C), and when introducing the Sky view factor (Fig. 1), the PET was not altered either. For this reason, studies without thermal questionnaires assume the program's default (PET standard for clo and W) [50], otherwise sample size averages have been used [17,52]. Therefore, from the 2321 surveys, the average values obtained were clo (0.8), height (1.63 m), and weight (61.5 kg), and the mode was taken for age (early adult, N = 1996, 86%), W (sitting 60 W, N = 1083, 47%) and sex (female, N = 1249, 54%). Aditionally, in the "Data file" the measured data also included: date, time, Ta (°C), RH (%), Va (m/s), global radiation (W/m^2) for Scale1, and Tmrt (°C) calculated by equation (1) for Scale2. Finally, the "Geographic data" for Cuenca-Ecuador was included.

PET values were grouped by 1 °C intervals (PETbin) [53], and the TSV was averaged obtaining the mean TSV (MTSV) for each PETbin. Then, the effect of the SEM factors in thermal perception was explored according to the statistical procedure described by Ref. [17]; using the TSV in the ordinal logistic regression as the dependent variable, in conjunction with the co-variable (PET) to evaluate the SEM factors. IBM SPSS Statistics Version 23 and Microsoft Excel 2013 were used for calculations and graphics.

3. Results

3.1. Effects of the corporeal SEM factors on the TSV

The W value was obtained from Ref. [6] for each physical activity according to question 2.1a (last 30–60min) (Fig. 4), and the clo values were assigned based on the standards of Ref. [6] and [41] according to question 4.6 (Fig. 5). For the ordinal logistic regression analysis, both clo and Met (Fig. 6 A–B) were categorized into intervals with a similar number of elements to ensure the representativeness of all the standard assigned values within the analysis. The first ordinal estimate of the corporeal SEM factors indicates a statistical influence on the TSV of the level of clo and Met (CLO A-C). The overall ordinal regression model improved by 2,3% in the prediction ability on the TSV, when the statistically significant corporeal-SEM factors on the TSV were included (Table 2). Therefore, for this case study the corporeal SEM environment has a low influence, according to Nagelkerke's Pseudo-R^2 (Pseudo-R^2 > 0.099 = very strong influence, Pseudo-R^2 > 0.066 = strong influence, Pseudo-R^2 > 0.033 = medium influence, Pseudo-R^2 ≤ 0.033 = low influence).

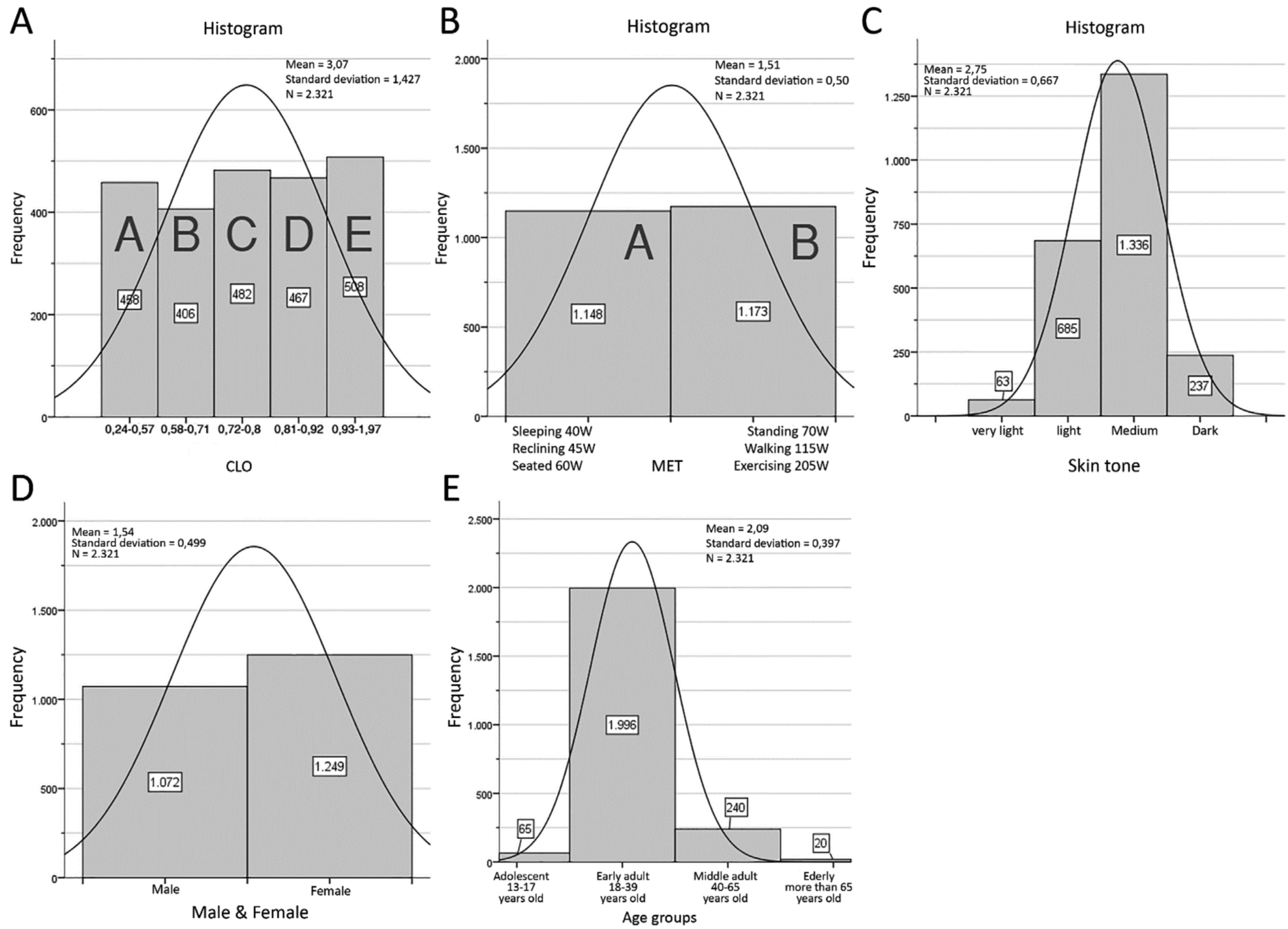

Fig. 6. A) clo, B) Met, C) skin tone, D) gender, E) age.

The non-significant categorical variables were gender, age and skin tone (Table 2, Fig. 6, C-E). Unlike the gender categorical variable, the age sample was highly heterogeneous. For the latter, four categories were directly structured in the survey: adolescent (13–17 years old), early adult (18–39 years old), middle adult (40–65 years) and elderly (over 65 years old), these categories were defined by considering their approximate correlations with the basic activities of an average person in Ecuador: college, university (undergraduate or graduate), work and retirement; and were based on Erik Erikson's Theory of Psychosocial Development, stating that psychosocial development progresses with age but depends on individual training [54]. Conversely, skin tone should be analysed with local scales [18]; therefore the Latin American scale developed in Ref. [47] was employed, with four categorical skin-tones: very light, light, medium and dark [55]. Each interviewer was previously visually familiarized to this scale, since the human eye is the most efficient tool for evaluating human skin tone [56].

Aditionally, a one-way ANOVA analysis was performed, showing a statistically significant difference between male and female clothing patterns at $P < 0.05$ ($F1, 2319 = 54.044293$, $P < 0.001$). In addition, the mean clo (MCLO) was calculated for each PETbin, and when performing a second-degree polynomial regression, a direct relationship of higher temperature with lesser clothing was evidenced ($R^2 = 0.742$), reaching a point where clo tends to increase again (Fig. 7).

3.2. Effects of the mental SEM factors on the TSV

The first ordinal estimate of mental SEM factors indicates a statistical influence on the TSV of perceived urban insecurity and perceived urban noise. The non-significant categorical variable was the perceived agreeability (Table 3) (Fig. 8 A–C). Nonetheless, the overall ordinal regression model improved only by 0.3% in the prediction ability on the TSV when the statistically significant mental-SEM factors were included (Table 3). Hence, for this case study, the mental SEM environment has a low influence according to Nagelkerke's Pseudo-R^2.

3.3. Effects of the social SEM factors on the TSV

The cultural background was evaluated according to the Köppen climate map [17], assigning four categories (tropical, arid, temperate and cold) to each foreign respondent according to their place of birth. For nationals, the classification of climatic zones by provinces was used according to INER data [57] and an equivalence was made with Köppen: tropical (very hot humid - hot humid), arid (not applicable in INER), temperate (continental rainy - temperate continental) and cold (cold and very cold) (Fig. 8 F). The first ordinal estimate of social SEM factors indicates a statistical influence on the TSV of the cultural background (temperate and cold). The overall ordinal regression model

Table 2
Ordinal estimates for the prediction of the TSV in the corporeal SEM factors.

		Estimate	Std. error	Sig.		95% confidence interval	
						Lower limit	Upper limit
Threshold	TSV = −3	0.644	0.446	0.148		−0.229	1.518
	TSV = −2	1.937	0.444	0.000		1.066	2.807
	TSV = −1	3.216	0.447	0.000		2.341	4091
	TSV = 0	4.880	0.453	0.000		3.992	5.768
	TSV = 1	6.097	0.460	0.000		5.195	6.999
	TSV = 2	7.686	0.477	0.000		6.751	8.621
Location	PET°C	0.136	0.005	0.000		0.126	0.147
	MET A	−0.330	0.076	0.000		−0.480	−0.181
	MET B	0[a]					
	CLO A	0.789	0.122	0.000		0.550	1.028
	CLO B	0.292	0.121	0.016		0.055	0.529
	CLO C	0.268	0.116	0.021		0.040	0.495
	CLO D	0.196	0.116	0.091		−0.031	0.423
	CLO E	0[a]					
	Male	0.026	0.077	0.737		−0.125	0.177
	Female	0[a]					
	Adolescent	−0.063	0.461	0.891		−0.966	0.839
	Early adult	−0.138	0.405	0.732		−0.932	0.655
	Middle adult	−0.167	0.418	0.689		−0.987	0.652
	Elderly	0[a]					
	Very light skin	0.329	0.256	0.199		−0.173	0.831
	Light skin	0.194	0.136	0.153		−0.072	0.460
	Medium skin	0.061	0.127	0.630		−0.187	0.310
	Dark skin	0[a]					

Summary of the overall logistic regression model for the corporeal SEM factors:

		Estimate	Std. error	Sig.	Nagelkerke pseudo-R^2	95% confidence interval	
						Lower limit	Upper limit
Threshold	TSV = −3	0.675	0.146	0.000		0.389	0.960
	TSV = −2	1.964	0.142	0.000		1.685	2.243
	TSV = −1	3.242	0.150	0.000		2.949	3.536
	TSV = 0	4.906	0.168	0.000		4.576	5.235
	TSV = 1	6.122	0.186	0.000		5.757	6.487
	TSV = 2	7.710	0.224	0.000		7.270	8.149
Location	PET°C	0.136	0.005	0.000	28.70	0.126	0.147
	MET A	−0.332	0.075	0.000	29.50	−0.479	−0.184
	MET B	0[a]					
	CLO A	0.791	0.120	0.000	31.00	0.556	1.025
	CLO B	0.297	0.120	0.014		0.061	0.533
	CLO C	0.269	0.114	0.019		0.045	0.493
	CLO D	0.195	0.115	0.090		−0.031	0.420
	CLO E	0[a]					

Link function: Logit.
[a] This parameter is set to zero because it is redundant.

improved only by 0.15% in its prediction ability on the TSV when the statistically significant social-SEM factor was included (Table 4). Hence, for this case study, the social SEM environment has a low influence according to Nagelkerke's Pseudo-R^2.

The non-significant categorical variables were company and occupation (Table 4) (Fig. 8 D–E). CC and CP are also at the entrance of university campuses; therefore the high frequency occupation for "student" (N = 1540), question 3.6a (Fig. 5), was compensated by creating only two intervals: students and non-students (Fig. 8 E), for a better analysis of habitual and non-habitual users.

3.4. Male and female OTC requirements: neutral temperature (Tn), neutral temperature range (rTn) and acceptable temperature range (rTa)

Neutral Temperature (Tn): is defined as the temperature of a neutral thermal sensation, neither heat nor cold, resulting from "*a linear regression between mean thermal sensation vote (MTSV) and temperature*" [12], even if this method considers the ordinal TSV variable as a continuous one, it does not affect the results in a significant manner [53]. It should be noted that for each PETbin, the male and female MTSV were averaged independently. Thus, by solving each linear equation for zero (equation (2) and (3)) the male neutral PET temperature is 27.78 °C and the female one is 29.10 °C (Fig. 9 A–B). For the general neutral temperature the total MTSV for each PETbin was averaged, obtaining 30.22 °C PET according to equation (4) (Fig. 9 A–B).

Male (Tn):

$$y = -2.5 + 0.09x \; (R^2 = 0.831) \tag{2}$$

Female (Tn):

$$y = -2.91 + 0.1x \; (R^2 = 0.850) \tag{3}$$

General (Tn):

$$y = -2.72 + 0.09x \; (R^2 = 0.878) \tag{4}$$

The Neutral Temperature Range (rTn) is frequently assumed as the temperature range in a linear regression plotting the TSV against the PET, comprised between ± 0.5 TSV [12]. Thus, the male PET temperature range in Cuenca is 22.11–33.22 °C and the female one is

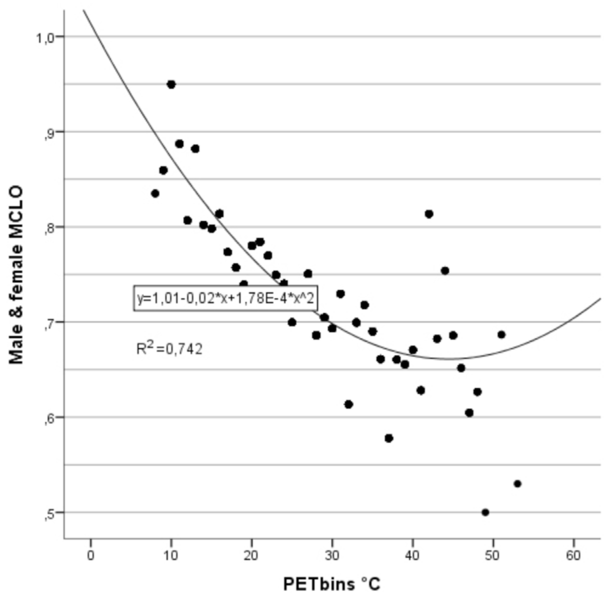

Fig. 7. Average clo value of all respondents in the 3 weeks.

24.10–34.10 °C (Fig. 9 C–D). Likewise, the general PET rTn for Cuenca is 24.67–35.78 °C (Fig. 9 C–D).

Male (rTn):

$$y=-2.49 + 0.09x\ (R^2 = 0.257) \tag{5}$$

Female (rTn):

$$y=-2.91 + 0.1x\ (R^2 = 0.293) \tag{6}$$

General (rTn):

$$y=-2.72 + 0.09x\ (R^2 = 0.276) \tag{7}$$

In regards to the Acceptable Temperature Range (rTa), the acceptability reported by respondents for each PETbin is usually averaged, establishing a linear or quadratic polynomial regression, then the equation is solved for 80% or 90% acceptability [12]. It has also been considered to solve for 70% acceptability for the outdoors, due to the more complex thermal conditions [17]. The survey in this study was conducted according to the standard [46] with the acceptability question 1.5 (Fig. 4) referring to the local climate (generally speaking). However, outdoors rTa calculation requires question 1.2a (Fig. 4), referring to the current atmospheric state [12]. Additionally, during January 2017 a week of microclimatic measurements and test surveys was performed, evidencing that in the local context question 1.2 is best understood in Spanish as "pleasant-unpleasant" rather than "acceptable-unacceptable." As such, male and female acceptability was independently averaged for each PETbin. Next, equations (8) and (9) were solved for 80% acceptability, obtaining a PET range of 23.05–42.95 °C and a 27.53–32.47 °C for acceptable temperatures for male and female, respectively (Fig. 9 E–F). The general rTa for 80% acceptability is 24.05–39.73 °C (equation (10)) (Fig. 9 E–F).

Male (rTa):

$$y=20.6 + 3.96\,x- 0.06x^2\ (R^2 = 0.426) \tag{8}$$

Female (rTa):

$$y=-27.27 + 7.2\,x- 0.12x^2\ (R^2 = 0.705) \tag{9}$$

Table 3
Ordinal estimates for the prediction of the TSV in the mental SEM factors.

		Estimate	Std. error	Sig.		95% confidence interval	
						Lower limit	Upper limit
Threshold	TSV = −3	1.016	0.209	0.000		0.605	1.426
	TSV = −2	2.293	0.207	0.000		1.887	2.699
	TSV = −1	3.556	0.213	0.000		3.138	3.974
	TSV = 0	5.189	0.227	0.000		4.744	5.635
	TSV = 1	6.386	0.241	0.000		5.913	6.858
	TSV = 2	7.952	0.271	0.000		7.420	8.483
Location	PET°C	0.141	0.005	0.000		0.130	0.151
	Pleasant	0.324	0.169	0.055		−0.007	0.655
	Unpleasant	0[a]					
	Safe	0.183	0.090	0.043		0.005	0.360
	Unsafe	0[a]					
	Calm	−0.174	0.077	0.023		−0.324	−0.024
	Noisy	0[a]					

Summary of the overall logistic regression model for the mental SEM factors:

		Estimate	Std. error	Sig.	Nagelkerke pseudo-R^2	95% confidence interval	
						Lower limit	Upper limit
Threshold	TSV = −3	0.740	0.151	0.000		0.444	1.037
	TSV = −2	2.014	0.147	0.000		1.725	2.303
	TSV = −1	3.275	0.154	0.000		2.972	3.577
	TSV = 0	4.907	0.173	0.000		4.569	5.245
	TSV = 1	6.105	0.190	0.000		5.732	6.478
	TSV = 2	7.673	0.227	0.000		7.228	8.119
Location	PET°C	0.141	0.005	0.000	28.70	0.130	0.151
	Safe	0.209	0.090	0.020	28.83	0.033	0.384
	Unsafe	0[a]					
	Calm	−0.161	0.076	0.035	29.00	−0.311	−0.011
	Noisy	0[a]					

Link function: Logit.

[a] This parameter is set to zero because it is redundant.

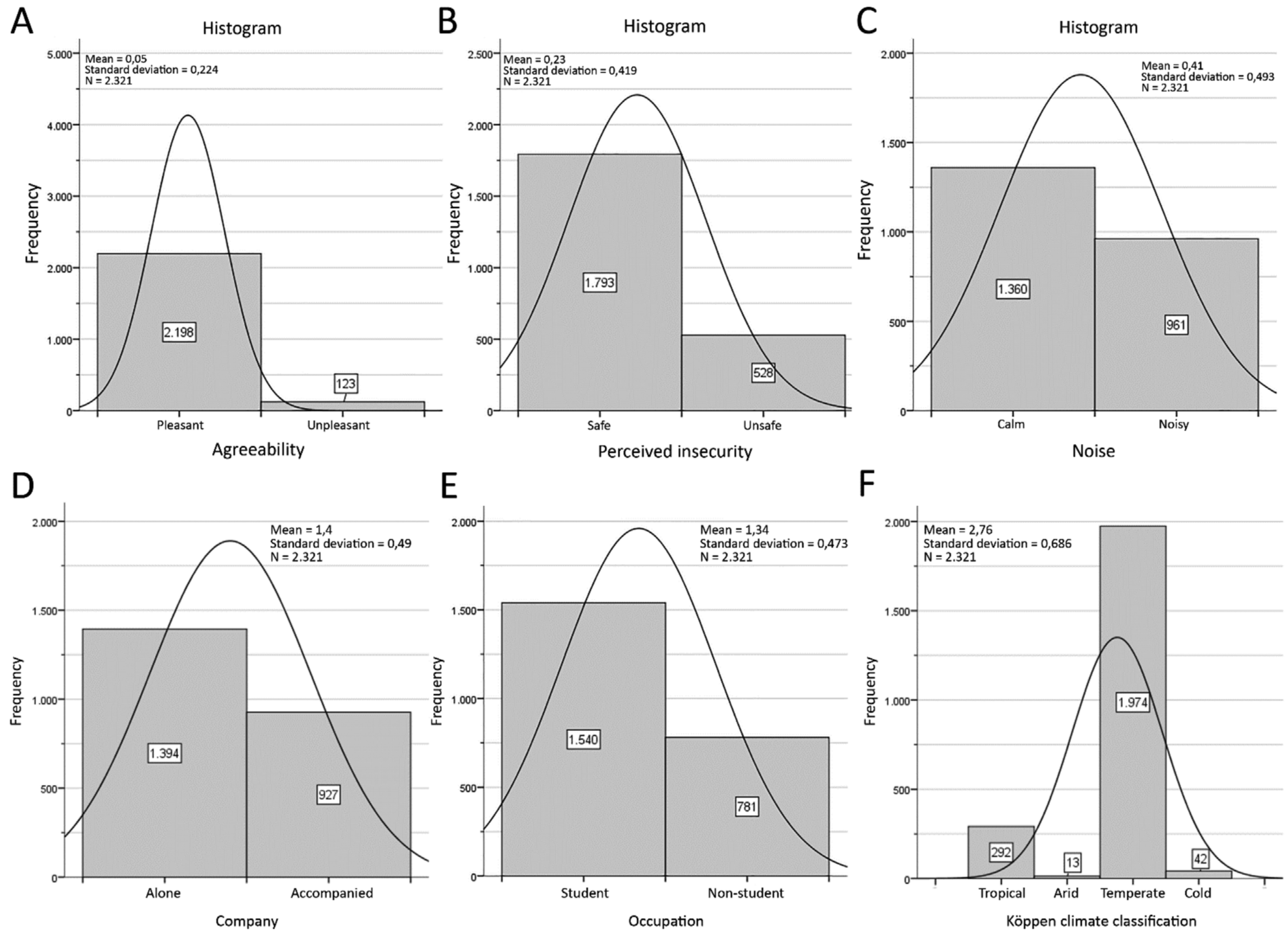

Fig. 8. A) agreeability, B) perceived insecurity, C) noise, D) company, E) occupation, F) Köppen climate classification.

General (rTa) (Scale1):

$$y = -5.99 + 5.74\,x - 0.09x^2\ (R^2 = 0.706) \tag{10}$$

3.5. Custom PET-TSV scale for cuenca

Based on the methodology proposed by Ref. [58]; in order to obtain a better comfort-range precision, a higher, general 85% acceptability was chosen for rTa, then the ranges for “slightly cool”, “cool”, “cold” and “slightly warm”, “warm” and “hot” through a 4 °C decrease and increase of the “neutral” range were obtained, respectively. Two sets of PET values were generated with RayMan1.2, producing two PET-TSV scales:

Scale1 (equation (10)): using measured urban global radiation data from the Politécnica Salesiana University CTS-weather-station, obtaining PETbin values between 8 and 53 °C; and Scale2 (equation (11)) using the TP3275 probe (Tg °C) measured data for the Tmrt calculation, obtaining PETbin values between 10 and 47 °C.

The results are shown in Table 5 alongside PET ranges for Singapore, Changsha (during the summer) [59], Taiwan (T. P. [60], Western/Middle Europe (A. [61], Tel Aviv [62], the Lingnan area (during the summer) [52], Belo Horizonte and Kassel/Freiburg [63].

General (rTa) (Scale2):

$$y = -49.6 + 8.80\,x - 0.14x^2\ (R^2 = 0.805) \tag{11}$$

4. Discussion

4.1. Effect of the corporeal SEM factors on the TSV

Both Met and clo are statistically significant regarding thermal perceptions, except for clo values higher than 0.8 (Table 2) (Fig. 6). These results support the discrepancy reported between different geographic zones regarding the role of these two factors in thermal perceptions, as reported in the introduction of this research. For instance [17] do not find a significant effect of Met on the TSV but do find one for clo, along with age, skin tone and exposure to the sun, inside the same SEM environment, with medium Pseudo-R^2 influence.

4.2. Effect of the mental SEM factors on the TSV

This research proposed the inclusion of some mental factors in the analysis of non-thermal effects on outdoors TSV, based on relevant statistical data regarding uses, perceptions and behaviours of Tomebamba riverbanks users [30]. Henceforth, the perceived urban agreeability, insecurity and noise were analysed, finding a statistical significance of these last two on the TSV, with a low Nagelkerke's Pseudo-R^2 influence and a low prediction ability on the TSV (Table 3). The results are consistent with findings by Ref. [30] where perceptions of urban insecurity and noise display a statistically high concern for current riverbank users, while urban beauty is a low concern. The exponential estimates' (expβ) “odd ratio” of perceived urban insecurity and noise in the overall logistic regression model (Table 3) were

Table 4
Ordinal estimates for the prediction of the TSV in social SEM factors.

		Estimate	Std. error	Sig.	Nagelkerke pseudo-R^2	95% confidence interval	
						Lower limit	Upper limit
Threshold	TSV = −3	1.157	0.312	0.000		0.545	1.769
	TSV = −2	2.430	0.311	0.000		1.821	3.039
	TSV = −1	3.689	0.315	0.000		3.072	4.306
	TSV = 0	5.320	0.325	0.000		4.683	5.957
	TSV = 1	6.518	0.335	0.000		5.861	7.175
	TSV = 2	8.087	0.358	0.000		7.386	8.789
Location	PET°C	0.141	0.005	0.000		0.131	0.152
	Alone	−0.048	0.076	0.530		−0.197	0.102
	Accompanied	0[a]					
	Student	−0.070	0.079	0.374		−0.226	0.085
	Non-student	0[a]					
	Tropical	0.479	0.296	0.106		−0.101	1.060
	Arid	0.578	0.569	0.310		−0.538	1.694
	Temperate	0.565	0.280	0.043		0.017	1.114
	Cold	0[a]					
Summary of the overall logistic regression model for social SEM factors:							
		Estimate	Std. error	Sig.	Nagelkerke pseudo-R^2	95% confidence interval	
						Lower limit	Upper limit
Threshold	TSV = −3	1.229	0.304	0.000		0.632	1.826
	TSV = −2	2.502	0.303	0.000		1.908	3.096
	TSV = −1	3.760	0.307	0.000		3.158	4.362
	TSV = 0	5.391	0.318	0.000		4.769	6.014
	TSV = 1	6.590	0.328	0.000		5.946	7.233
	TSV = 2	8.158	0.352	0.000		7.469	8.847
Location	PET°C	0.141	0.005	0.000	28.70	0.131	0.152
	Tropical	0.469	0.296	0.113	28.85	−0.111	1.049
	Arid	0.583	0.569	0.305		−0.532	1.699
	Temperate	0.559	0.280	0.046		0.010	1.107
	Cold	0[a]					

Link function: Logit.
[a] This parameter is set to zero because it is redundant.

analysed: people perceiving urban safeness would have a 1.23 times higher probability of reporting a lower TSV than people perceiving urban insecurity; and people perceiving urban calmness would have a 1.17 times higher probability of reporting a higher TSV than people perceiving urban noise, yet with considerably wide confidence-interval ranges (Table 3). Different studies could support a theoretical relationship for these findings, mainly that emotion, empathy, feelings and thermography have significant correlations [64], to the point that emotions (for instance joy, fear, anger, disgust or sadness) can be correctly diagnosed in a person through thermal analysis [65]. For noise related to emotions, a significant relationship between noise levels and mood (anxiety or pleasure) have been found [66,67].

4.3. Effects of the social SEM factors on the TSV

Company, occupation and cultural background were analysed, being the last one the only factor having statistical influence on the TSV but only on two out of four categories (temperate and cold) (Fig. 8 F), and with a low Nagelkerke's Pseudo-R^2 influence and a low prediction ability on the TSV (Table 4). This SEM environment including the same factors, also has a low influence on the TSV in the case of Melbourne, though in that case all three factors are statistically significant as well as all four categories for cultural background [17].

4.4. Differences in male and female OTC requirements

Male and female PET Tn values in Cuenca are 27.78 °C and 29.10 °C, respectively. Additionally, male rTn is wider than female but 0.9 °C PET lower in the upper limit (Table 5). Male acceptable temperature range is also wider but encompasses higher temperatures than the female rTa range. Henceforth, in global terms there is a greater female intolerance to lower temperatures (Table 5) as also reported by other studies [21,22].

4.5. Local PET-TSV scale

PET-TSV Scale1 and Scale2 have the same neutral point. Nonetheless, Scale1 is narrower, with a 3 °C difference in the upper and lower ranges (Table 5). Scale2 could not be calculated for the "very hot" range, as the PET values did not reach those temperatures with its corresponding input data. Ultimately, Scale1 is endorsed, given the certified data employed for it [14,42,45].

Outdoor acclimatization occurs in approximately 30 min of being outside [68], yet that time reflects not the short term utilization most users usually give to outdoor spaces [19]. For instance, in this research 63% of visitors were acclimatized to indoor conditions at the moment of the survey (Fig. 10 A). Additionally, in local architectural practice in a high

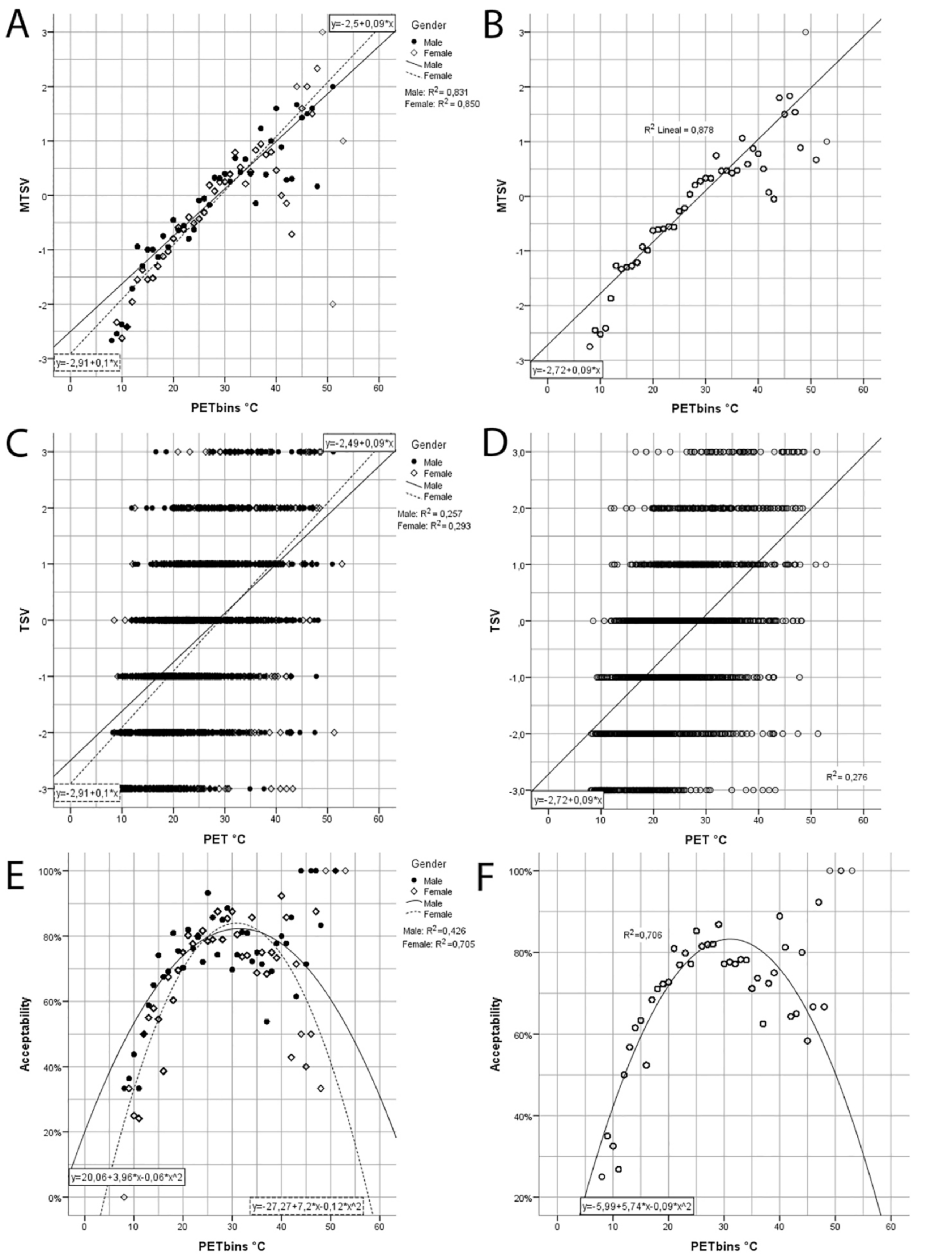

Fig. 9. A) male and female neutral temperature, B) general neutral temperature. C) male and female neutral temperature range, D) general neutral temperature range. E) male and female acceptable temperature range, F) general acceptable temperature range.

Table 5
Differences in male & female OTC requirements in Cuenca - Ecuador.

A [42]. reference scale:	Thermal perception	PET (°C)								
		Tn Male	Tn Female	Tn General	rTn Male	rTn Female	rTn General	rTa Male 80% acceptability	rTa Female 80% acceptability	rTa General 80% acceptability
< 4	Very cold									
4–8	Cold									
8–13	Cool									
13–18	Slightly cool									
18–23	Neutral				22.11					
23–29	Slightly warm	27.78				24.10	24.67	23.05	27.53	24.05
29–35	Warm		29.10	30.22	33.22	34.10			32.47	
35–41	Hot						35.78			39.73
> 41	Very hot							42.95		

TSV scales (°C PET):

Thermal perception	Cuenca (Scale1) 85% acceptability	Cuenca (Scale2) 85% acceptability	Western/ Middle Europe	Tel Aviv	Belo Horizonte	Kassel/ Freiburg	Taiwan	Singapore	Changsha (summer)	Lingnan area (summer)
Very cold	< 17	< 14	< 4	< 8			< 14	–	–	–
Cold	17–21	14–18	4–8	8–12		< 8	14–18	–	–	–
Cool	21–25	18–22	8–13	12–15	< 12	8–12	18–22	–	–	–
Slightly cool	25–29	22–26	13–18	15–19	13–15	13–17	22–26	20–24	20–24	–
Neutral	29–34	26–37	18–23	19–26	16–30	18–28	26–30	24–30	24–31	31–33
Slightly warm	34–38	37–41	23–29	26–28	31	29–34	30–34	30–34	31–35	33–38
Warm	38–42	41–45	29–35	28–34	32–35	35–38	34–38	34–38	35–39	38–43
Hot	42–46	> 45	35–41	34–40	> 36	> 38	38–42	38–42	39–43	38–41
Very hot	> 46		> 41	> 40			> 42	> 42	> 43	> 41

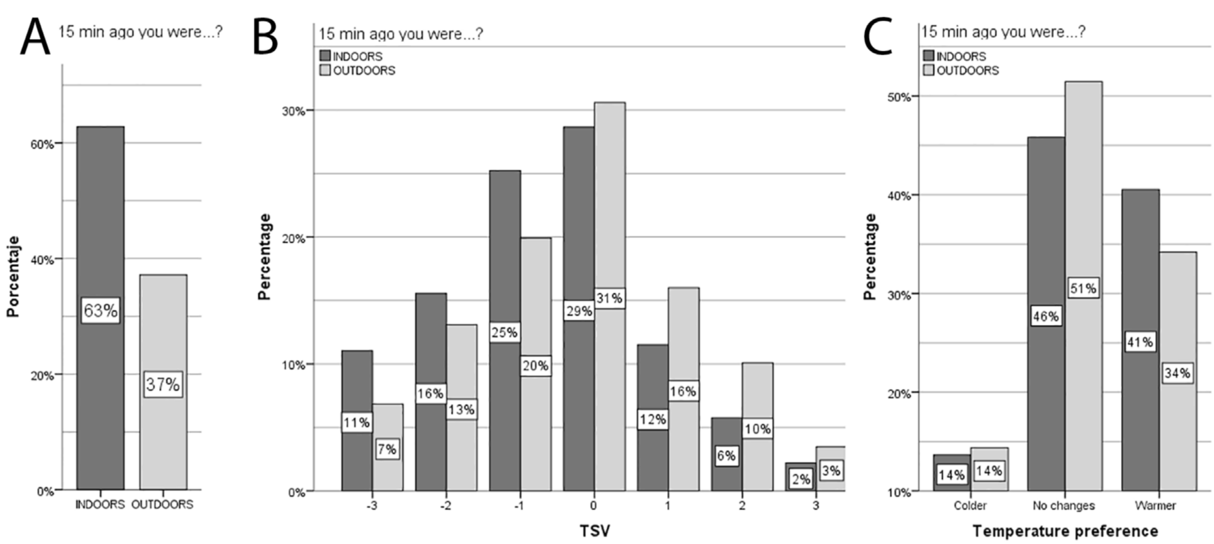

Fig. 10. Users reporting being at indoors/outdoors 15min prior to survey.

mountain climate the indoor thermal comfort is not considered in the design process, so users tend to accept rather low indoor operative temperatures [69]; hence, they consistently prefer higher outdoor temperatures when going outside (Fig. 10 C). This phenomenon has conditioned PET-TSV scales to reach high value ranges in the local context, since (for the same microclimatic conditions, Fig. 11 A) indoor-acclimatized subjects indicated a lower TSV (corresponding to discomfort) than the remaining 37% of outdoor-acclimatized visitors (Fig. 10 B). This weight is clearly displayed in the disaggregated Tn with a categorical MTSV for each PETbin (Fig. 11), where the highest value corresponds to indoor-acclimatized subjects (31 °C PET) (Fig. 11 A), clearly influencing the general Tn (30.22 °C PET) (Fig. 9 B). From this disaggregation it is also evident that Cuenca Tn is the lowest during hot and dryer seasons (27,29 °C PET), and the highest during cold and humid seasons (29,17 °C PET) (Fig. 11 B). These results are consistent with a lower 25.7 °C PET Tn obtained for a hot humid climate in Guayaquil [28], where the subjects acclimatized to colder air-conditioned indoors were only 30% of the sample, these ones also reporting higher thermal index values (30.5 °C SET) than those who were exposed to the sun (28 °C SET).

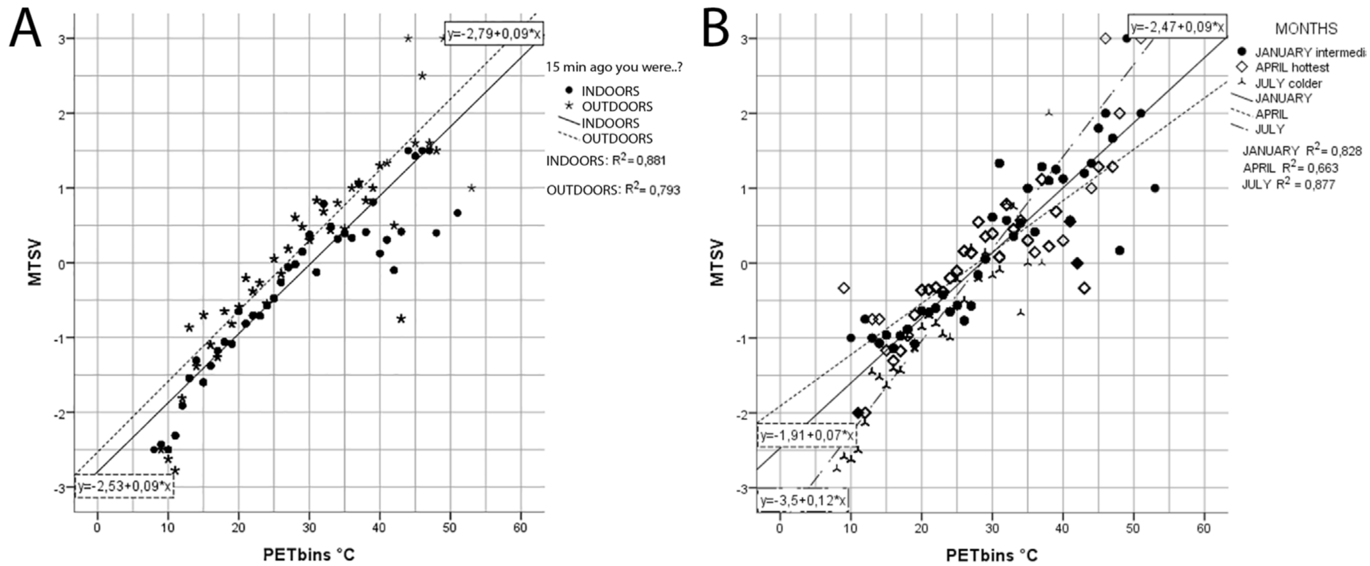

Fig. 11. A) Neutral Temperature (Tn) indoor/outdoor acclimatization, B) Tn for the three survey weeks.

5. Conclusions

This research was conducted during three representative weeks of the annual climate of the city of Cuenca, in two sites of significant zones of the Tomebamba riverbanks. The effects of corporeal, mental and social SEM factors on the TSV were explored according to a random sample without replacement of 2321 users, as well as identifying differences in male and female OTC requirements and deriving a custom TSV scale for the region of study.

The effects of physical activity, level of clothing, gender, age and skin tone were explored on the TSV. Neither gender, age or skin tones were significant in this research. As such, the corporeal SEM environment displays a low influence on the TSV (Nagelkerke's Pseudo-R^2) including only clothing and physical activity levels. These results in Cuenca corroborate the role of Met and clo in OTC, as in the static model of the body-heat balance equation. The effect of the perceived urban agreeability, insecurity and noise were also explored, obtaining a mental SEM environment with a low influence on TSV, including only perceived urban insecurity and noise. Findings referenced in the discussion relate perception, mind-set and corporeal thermal expression, thus supporting a theoretical relationship between the significant mental factors and thermal perceptions; as such the relationship of a perceived urban insecurity and noise with the TSV has not been disregarded primarily as a spurious relationship, although neither such possibility can be cast-off until more studies are performed focusing on perceptive, emotional and mental factors interacting with outdoor thermal perception. In relation to the effects of the social SEM environment on the TSV, its significance has a direct relationship with the climatic zone of the local population, displaying a low influence on the TSV. Regarding the differences in male and female OTC requirements, there is a greater female intolerance to lower temperatures in Cuenca. Finally, an Acceptable Temperature Range between 29 and 34 °C PET was obtained within the local PET-TSV scale generated, with supplementary analysis revealing an association of this scale's thermal ranges with climatic and cultural specificities of the local context, suggesting further exploration of customized local outdoor thermal indexes, which may be more suitable for contextual Latin American outdoor environments.

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