Korean Neutral Thermal Sensation Ranges in Urban and Beach Areas

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Ⅰ. Introduction

Outdoor human thermal sensation and comfort are important considerations in urban and landscape planning and design. Neutral temperature (NT) range is a range of equivalent air temperature that would produce the same neutral (comfortable) human thermal sensation and physiological response as does the composite climate. Thermal sensation votes (TSVs) measure human response.

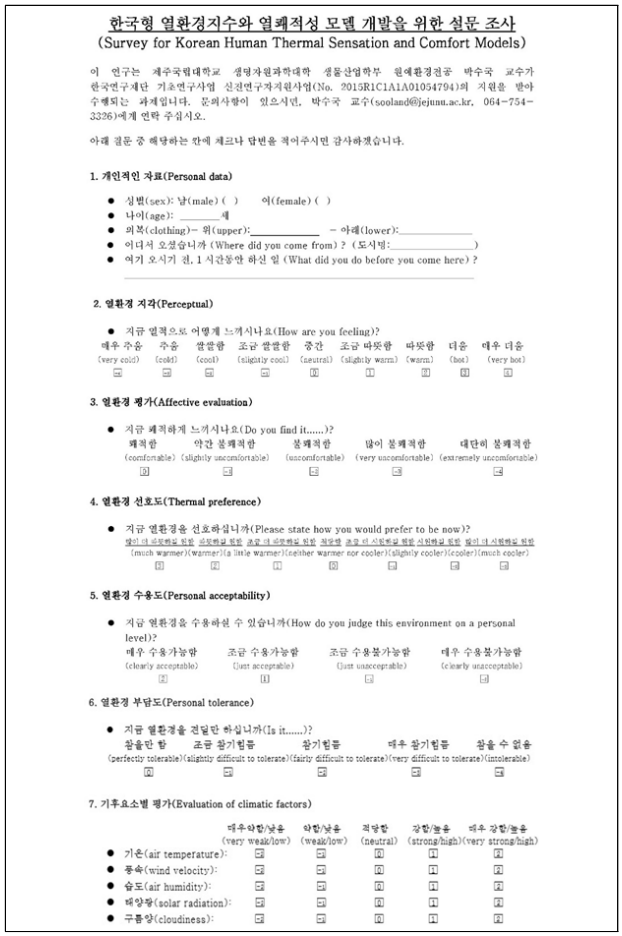
This study investigated Koreans' NT ranges in urban and beach areas.

Ⅱ. Materials and Methods

Microclimatic data measurements and 9-point human thermal sensation surveys from ISO 10551 were conducted together (Table 1 and Figure 1). Surveys occurred in two different years at each area and included a total of 2,172 subjects at the beach (spring and summer; 869 persons in 2015, 938 in 2016 and 365 in 2017) and 1,982 in the city (all seasons; 876 persons in 2012~2013, 768 in 2016 and 338 in 2017). NT range ($-0.5 \leq TSV \leq 0.5$) was taken as physiological equivalent temperature (PET) and universal thermal climate index (UTCI) values for neutral TSV responses. Four different methods were used to find NT ranges: comparison between (1) TSV and

Table 1. Instruments for microclimatic data measurements

Instruments			
Data	Name	Accuracy	Manufacture
Radiation	CNR4 Net Radiometer	≤ 1% (−40~80℃)	Kipp & Zonen Inc
Air temp. and relative humidity	HMP155A	· Air temp.: ±0.3℃ (−80~60℃) · Relative humidity: 2% (0~90%) 3% (90~100%)	Campbell Scientific Inc
Wind speed and direction	Met one 034B-L Windset	· Wind speed: ±0.1 ms^{-1} (≤ 10.1ms^{-1}) ±1.1% (≥ 10.1ms^{-1}) · Wind direction: ±4°	
Datalogger	CR1000	±0.06% (0~40℃)	



한국형 열환경지수와 열쾌적성 모델 개발을 위한 설문 조사

(Survey for Korean Human Thermal Sensation and Comfort Models)

이 연구는 제주국립대학교 생명자원과학대학 생물산업학부 원예환경전공 박수국 교수가 한국연구재단 기초연구사업 신진연구자지원사업(No. 2015R1C1A1A01054794)의 지원을 받아 수행되는 과제입니다. 문의사항이 있으시면, 박수국 교수(sooland@jejunu.ac.kr, 064-754-3326)에게 연락 주십시오.

아래 질문 중 해당하는 란에 체크나 답변을 적어주시면 감사하겠습니다.

1. 개인적인 자료(Personal data)

- 성별(sex): 남(male) ( ) 여(female) ( )
- 나이(age): _____세
- 의복(clothing)- 위(upper):_____ - 아래(lower):_____
- 어디서 오셨습니까 (Where did you come from) ? (도시명:_____)
- 여기 오시기 전, 1 시간동안 하신 일 (What did you do before you come here) ?

2. 열환경 지각(Perceptual)

- 지금 열적으로 어떻게 느끼시나요(How are you feeling)?

매우 추움 (very cold)	추움 (cold)	쌀쌀함 (cool)	조금 쌀쌀함 (slightly cool)	중간 (neutral)	조금 따뜻함 (slightly warm)	따뜻함 (warm)	더움 (hot)	매우 더움 (very hot)
				☑				

3. 열환경 평가(Affective evaluation)

- 지금 쾌적하게 느끼시나요(Do you find it.....)?

쾌적함 (comfortable)	약간 불쾌적함 (slightly uncomfortable)	불쾌적함 (uncomfortable)	많이 불쾌적함 (very uncomfortable)	대단히 불쾌적함 (extremely uncomfortable)
☑				

4. 열환경 선호도(Thermal preference)

- 지금 열환경을 선호하십니까(Please state how you would prefer to be now)?

(much warmer) (warmer) (a little warmer) (neither warmer nor cooler) (slightly cooler) (cooler) (much cooler)

☐ ☐ ☐ ☑ ☐ ☐ ☐

5. 열환경 수용도(Personal acceptability)

- 지금 열환경을 수용하실 수 있습니까(How do you judge this environment on a personal level)?

매우 수용가능함 (clearly acceptable)	조금 수용가능함 (just acceptable)	조금 수용불가능함 (just unacceptable)	매우 수용불가능함 (clearly unacceptable)
☑	☐	☐	☐

6. 열환경 부담도(Personal tolerance)

- 지금 열환경을 견딜만 하십니까(Is it.....)?

참을만 함 (perfectly tolerable)	조금 불기힘듦 (slightly difficult to tolerate)	불기힘듦 (fairly difficult to tolerate)	매우 불기힘듦 (very difficult to tolerate)	참을 수 없음 (intolerable)
☑	☐	☐	☐	☐

7. 기후요소별 평가(Evaluation of climatic factors)

	매우약함/낮음 (very weak/low)	약함/낮음 (weak/low)	적당함 (neutral)	강함/높음 (strong/high)	매우 강함/높음 (very strong/high)
● 기온(air temperature):	☐	☐	☑	☐	☐
● 풍속(wind velocity):	☐	☐	☑	☐	☐
● 습도(air humidity):	☐	☐	☑	☐	☐
● 태양광(solar radiation):	☐	☐	☑	☐	☐
● 구름양(cloudiness):	☐	☐	☑	☐	☐

Figure 1. Survey form

mean PET/UTCI (mean), (2) TSV and PET/UTCI (PET and UTCI), (3) aggregated (weighted) TSV and PET/UTCI (aPET and aUTCI) and (4) mean TSV and PET/UTCI (mPET and mUTCI). One-way ANOVA of SPSS 20 was used to find mean results, and linear regression analysis of Microsoft office excel 2016 were used to find the other NT ranges for comparison.

III. Results and Discussions

Neutral TSV responses were compared with 2 measures of human thermal sensation, PET and UTCI (Table 2).

The neutral temperature (NT) for TSV=0 in beach areas had higher results when mean PET and UTCI of the years were higher. The correlations between mean PET and UTCI of the years and NTs of PET and UTCI of the years in beach areas were very high: r^2=0.9823 and 0.9982, respectively. In urban areas, the NT for TSV=0 also increased as mean PET and UTCI of the years increased. However, the correlations between them were not high: r^2=0.6258 in PET and 0.5093 in UTCI.

NT ranges were also higher results when mean PET and UTCI of the years increased. The NT ranges were around 5~8℃ PET and 3~5℃ UTCI in beach and urban areas. The NT ranges for planning and design were 19~29℃ PET and 22~30℃ UTCI in beach areas; and 16~24℃ PET and 19~25℃ UTCI in urban areas.

The beach visitors/tourists seem to have a higher acclimatization, which may be from the psychological effects of looking for and expecting a warm environment, than the more consistent urban population.

Table 2. Koreans' neutral temperature ranges of thermal sensation vote (TSV) in urban and beach areas as physiological equivalent temperature (PET) and universal thermal climate index (UTCI)

Urban area								
	Mean	PET	aPET	mPET	Mean	UTCI	aUTCI	mUTCI
2012~13	21~25	16~24	16~24	17~24	22~24	19~24	19~24	18~23
r^2		0.4414	0.6364	0.7424		0.4534	0.672	0.7515
2016	19~23	17~22	17~22	17~22	22~24	19~23	19~23	18~23
r^2		0.6909	0.9354	0.902		0.6863	0.9098	0.8004
2017	26~28	19~24	19~24	17~23	27~28	21~25	21~25	21~25
r^2		0.3757	0.7919	0.6753		0.3956	0.7268	0.6541
Beach area								
	Mean	PET	aPET	mPET	Mean	UTCI	aUTCI	mUTCI
2015	25~27	24~29	24~29	23~28	27~28	27~30	27~30	26~29
r^2		0.6493	0.9552	0.9283		0.6627	0.956	0.9588
2016	22~27	20~25	19~24	20~25	25~28	23~27	22~26	23~27
r^2		0.6186	0.9415	0.9267		0.6187	0.948	0.9309
2017	24~26	21~27	21~27	20~26	25~27	23~27	23~27	22~26
r^2		0.5573	0.965	0.854		0.5564	0.9547	0.8587

IV. Conclusion

Koreans' neutral temperature ranges for creating thermally comfortable environments can be applied 16~24℃ PET or 19~25℃ UTCI in urban areas for urban and landscape planning and 19~29℃ PET or 22~30℃ UTCI in beach areas for tourism planning. The Koreans' NT ranges are similar with one of western/middle Europe for urban areas and broader than Tel Aviv and Nigeria (Table 3). The aggregated (weighted) mean method (aPET and aUTCI in this study) looks an appropriate way to find neutral temperature ranges of each region or country.

Table 3. Comparison of neutral temperature PET ranges between previous studies and Koreans

	PET (℃)						
	Western/ Middle Europe[1]	Tel Aviv[2]	Taiwan[3]	Nigeria[4]	Hungary[5]	Korea (urban areas)	Korea (beach areas)
Neutral temp. range	18~23	19~26	26~30	23~27	14~22	16~24	19~29

[1] Matzarakis and Mayer(1996); [2] Cohen *et al.*(2013); [3] Lin and Matzarakis (2008); [4] Omonijo and Matzarakis(2011); [5] Kántor *et al.*(2016)

참고문헌

1. Cohen, P., O. Potchter and A. Matzaraki (2013) Human thermal perception of coastal mediterranean outdoor urban environments. Applied Geography 37: 1-10.
2. Höppe, P.(1999) The physiological equivalent temperature-a universal index for the biometeorological assessment of the thermal environment. International Journal of Biometeorology 43: 71-75.
3. Kántor, N., A. Kovács and Á. Takács (2016) Seasonal differences in the subjective assessment of outdoor thermal conditions and the impact of analysis techniques on the obtained results. International Journal of Biometeorology 60(11): 1615-1635.
4. Lin, T. P. and A. Matzarakis(2008) Tourism climate and thermal comfort in Sun Moon Lake, Taiwan. Int J Biometeorol 52: 281-290.
5. Matzarakis, A. and H. Mayer (1996) Another kind of environmental stress: Thermal stress. WHO News 18: 7-10.
6. Omonijo, A. G. and A. Matzarakis(2011) Climate and bioclimate analysis of Ondo State, Nigeria. Meteorologische Zeitschrift 20(5): 531-539.