Climatic Effects on Human Thermal Comfort: Preliminary Survey in Korea

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INTRODUCTION

Climatic effects on outdoor human thermal comfort are one of the most important considerations in urban and landscape planning and design. Several human thermal sensation and comfort models were developed, i.e. COMFA, MENEX, OUT-SET*, PMV, PET, PT and UTCI. However, a few studies for the comparison between different climatic zones have been conducted (Cohen et al., 2013; Lin and Matzarakis, 2008; Matzarakis and Mayer, 1996; Omonijo et al., 2013). Moreover, how seasonal climatic factors such as air temperature (*Ta*), wind speed (*u*), relative humidity (*RH*) and solar radiation (*SR*) affect human thermal sensation and comfort has never been studied before.

This study investigated seasonal effects of four climatic factors (*Ta*, *u*, *RH* and *SR*) on human thermal sensation and comfort with surveying in Korea. Also, Korean human thermal sensation levels in PET were compared with previous studies.

MATERIALS AND METHODS

The survey was conducted in summer, fall and winter in 2012-2013 at university campuses, downtown and parks of southern Korean cities, Changwon and Daegu, in 9 times between 12:00 and 15:00 on clear days (Fig. 1). The total participants were 876 people (male, 53.2 %; female, 46.8 %) (Fig. 2), and the survey form was prepared using ISO 10551. In the survey, five major questions were asked to participants about thermal environment: perceptual, affective evaluation, thermal preference, personal acceptability and personal tolerance with the four climatic effects on the questions. Also, four important microclimatic factors for estimating human thermal sensation were also collected *in situ*: *Ta*, *u*, *RH* and short- and longwave radiation (Table 1).

The *Ta* was 17.2-23.9 ℃ in fall, 4.6-6.5 ℃ in winter, 27.2-29.5 ℃ in early summer and 33.6-34.3 ℃ in summer. *RH* was 26.3-42.6 % in fall, 18.4-38.9 % in winter and 45.1-53.3 % in early summer and summer. *u* was around 1.0 ms^{-1} in all the seasons (Table 2). Radiation varied by the season and location.

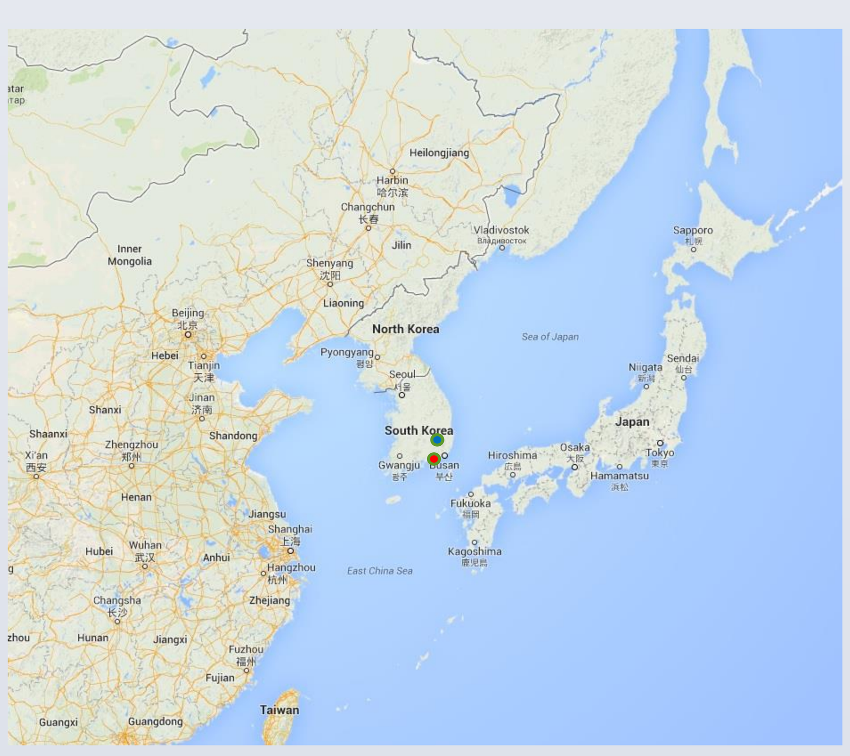


Figure 1. Study sites: ● Changwon, ● Daegu

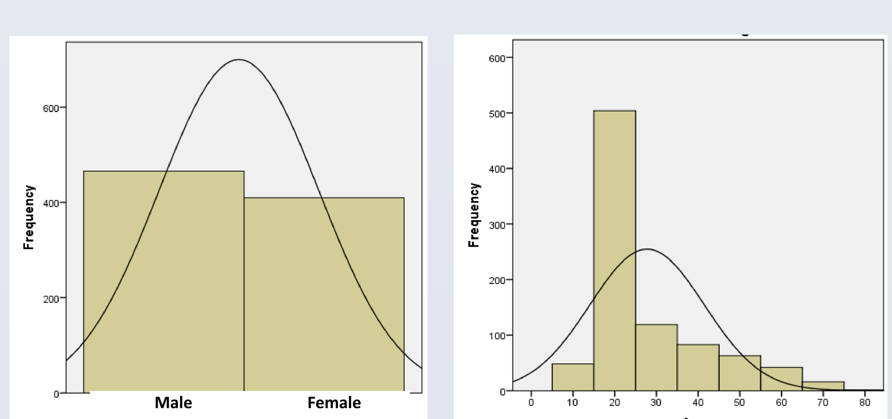


Figure 2. Frequencies of participants' sexes and ages

Table 1. Instruments for microclimatic data

	Instruments	
Radiation	CNR4 Net Radiometer	Campbell Scientific Inc.
Air temp. and Relative humidity	HMP155A	
Wind speed and direction	Met One 034B-L Windset	

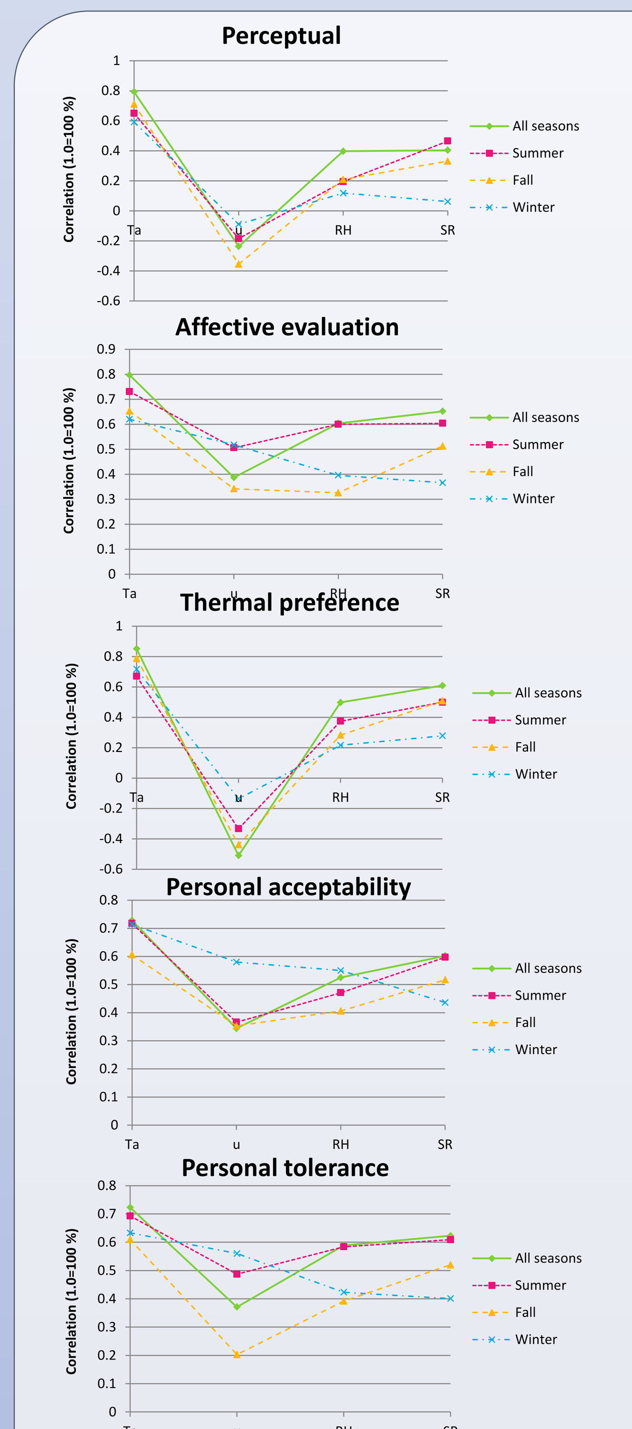
Table 2. Seasonal study sites and microclimatic factors

	Season								
	Fall			Winter		Early summer		Summer	
	Changwon Univ. campus (Oct. 18)	Changwon downtown (Oct. 19)	Changwon Yongji park (Oct. 21)	Changwon downtown (Jan. 18)	Changwon Yongji park (Jan. 19)	Changwon downtown (June 6)	Changwon Yongji park (June 5)	Kyeongbook Univ. (Aug. 15)	Kyeongbook Univ. (Aug. 16)
Air temperature (℃)	17.2±0.8	20.6±0.7	23.9±0.9	4.6±0.8	6.5±0.6	29.5±0.7	27.2±1.6	33.6±0.6	34.3±0.9
Relative humidity (%)	26.3±1.2	42.6±2.8	40.0±2.9	18.4±1.9	38.9±1.1	45.8±3.3	53.3±3.4	47.7±1.7	45.1±2.8
Wind speed (ms^{-1})	2.1±1.0	0.4±0.3	0.4±0.3	0.6±0.3	1.3±0.7	1.1±0.5	0.8±0.5	1.6±0.6	1.4±0.5

RESULTS AND DISCUSSIONS

Ta was shown as the most effective climatic factor in all five major questions, which was between the lowest 59.2 % of correlation (*R*) in winter in the perceptual and the highest 79.7 % in all seasons in the affective evaluation (Fig. 3). *SR* was the second effective one, around 40-60 % of *R*. People thought *SR* was a very effective factor in summer but less important in winter. The effects of *RH* and *u* were thought more important in winter than in summer and fall.

The PET had high *R*s with the results of the perceptual and the thermal preference, 66.5-67.9 % (Table 3). Also, the *R*s between the perceptual and the thermal preference and between the personal acceptability and the personal tolerance were high, 73.5 % and 60.2 %, respectively. Koreans' neutral range was 21-25 PET ℃ and thermal acceptable range was 8-26 PET ℃ when 5 thermal sensation levels (warm, slightly warm, neutral, slightly cool and cool) were included (Table 4). Moreover, Koreans' PET ranges for the heat stresses were very similar with those in Tel Aviv.



Perceptual
❑ How are you feeling?
very cold -4, cold -3, cool -2, slightly cool -1, neutral 0, slightly warm 1, warm 2, hot 3, very hot 4

	very weak/low			neutral			very strong/high
▪ air temperature	-3	-2	-1	0	1	2	3
▪ wind velocity	-3	-2	-1	0	1	2	3
▪ air humidity	-3	-2	-1	0	1	2	3
▪ solar radiation	-3	-2	-1	0	1	2	3

Affective evaluation
❑ Do you find it......?
comfortable 0, slightly uncomfortable -1, uncomfortable -2, very uncomfortable -3, extremely uncomfortable -4

	comfortable				extremely uncomfortable
▪ air temperature	0	-1	-2	-3	-4
▪ wind velocity	0	-1	-2	-3	-4
▪ air humidity	0	-1	-2	-3	-4
▪ solar radiation	0	-1	-2	-3	-4

Thermal preference
❑ Please state how you would prefer to be now?
much warmer 3, warmer 2, a little warmer 1, neither warmer nor cooler 0, slightly cooler -1, cooler -2, much cooler -3

	prefer much higher/stronger			neutral			prefer much lower/weaker
▪ air temperature	3	2	1	0	-1	-2	-3
▪ wind velocity	3	2	1	0	-1	-2	-3
▪ air humidity	3	2	1	0	-1	-2	-3
▪ solar radiation	3	2	1	0	-1	-2	-3

Personal acceptability
❑ How do you judge this environment on a personal level)?
clearly acceptable 2, just acceptable 1, just unacceptable -1, clearly unacceptable -2

	clearly acceptable			clearly unacceptable
▪ air temperature	2	1	-1	-2
▪ wind velocity	2	1	-1	-2
▪ air humidity	2	1	-1	-2
▪ solar radiation	2	1	-1	-2

Personal tolerance
❑ Is it......?
perfectly tolerable 0, slightly difficult to tolerate -1, fairly difficult to tolerate -2, very difficult to tolerate -3, intolerable -4

	perfectly tolerable				intolerable
▪ air temperature	0	-1	-2	-3	-4
▪ wind velocity	0	-1	-2	-3	-4
▪ air humidity	0	-1	-2	-3	-4
▪ solar radiation	0	-1	-2	-3	-4

Figure 3. Correlation between climatic factors and results of the five questions

Table 3. Correlation between variables
[*. Correlation is significant at the 0.05 level (2-tailed);
**. Correlation is significant at the 0.01 level (2-tailed)]

	Sex	Age	PET (℃)	UTCI (℃)	Perceptual	Affective evaluation	Thermal preference	Personal acceptability	Personal tolerance
Sex	1	-.014	-.018	-.033	.008	.034	.029	.013	.024
Age		1	-.070*	-.113**	.036	.278**	.120**	.218**	.196**
PET (℃)			1	.980**	.665**	-.498**	-.679**	-.302**	-.320**
UTCI (℃)				1	.673**	-.550**	-.705**	-.341**	-.359**
Perceptual					1	-.464**	-.735**	-.267**	-.327**
Affective evaluation						1	.573**	.568**	.574**
Thermal preference							1	.393**	.405**
Personal acceptability								1	.602**
Personal tolerance									1

Table 4. Comparison of thermal sensation PET ranges between previous studies and Koreans
[[1] Matzarakis and Mayer (1996);
[2] Cohen et al. (2013);
[3] Lin and Matzarakis (2008)
[4] Omonijo and Matzarakis (2011) and Omonijo et al. (2013)]

Thermal sensation	PET range				
	Western/Middle Europe[1]	Tel Aviv[2]	Taiwan[3]	Nigeria[4]	Korea
Very cold					
	4	8	14	11	17
Cold					
	8	12	18	15	18
Cool					
	13	15	22	19	19
Slightly cool					
	18	19	26	23	21
Neutral					
	23	26	30	27	25
Slightly warm					
	29	28	34	31	27
Warm					
	35	34	38	36	34
Hot					
	41	40	42	42	40
Very hot					

CONCLUSIONS

Universally applicable human thermal sensation or comfort models cannot exist because of different human body area factors, physical aspects (e.g., clothing and metabolic rate), physiological aspects (e.g., sweating rate) and psychological aspects (e.g., experience and expectation). They should be modified for each climatic or cultural zone when used to assess the local effects of specific planning options. Therefore, human biometeorologists/bioclimatologists and urban planners have to make an effort to create their own thermal sensation and comfort models applicable to their history, climate and culture.

REFERENCES

Cohen P, Potchter O, Matzarakis A. 2013. Human thermal perception of Coastal Mediterranean outdoor urban environments. Applied Geography 37: 1-10

Lin TP, Matzarakis A. 2008. Tourism climate and thermal comfort in Sun Moon Lake, Taiwan. Int J Biometeorol 52: 281-290

Matzarakis A, Mayer H. 1996. Another kind of environmental stress: thermal stress. WHO News 18: 7-10

Omonijo AG, Matzarakis A. 2011. Climate and bioclimate analysis of Ondo State, Nigeria. Meteorologische Zeitschrift 20(5): 531-539

Omonijo AG, Adeofun CO, Oguntoke O, Matzarakis A. 2013. Relevance of thermal environment to human health: a case study of Ondo State, Nigeria. Theor Appl Climatol 113: 205-212

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