REFERENCE TEMPERATURE DATA OF NORMAL KOREAN LOWER EXTREMITY

HY Zhang[1,2], TM Youk[1], KC Yoo[1], HK Lee[1], HJ Song[1], KY Yang[1], HY Lee[1], YE Cho[2], SH Noh[2], JB Choi[3], GH Nam[4]

1 Data Center for Korean Body Temperature of NCSRD, NHIS Ilsan Hospital, Korea
2 Department of Neurosurgery, Yonsei University College of Medicine, Korea
3 Department of Pain and Anesthesiology, Ajou University College of Medicine, Korea
4 National Center for Standard Reference Data, Korea Research Institute of Standards and Science, Korea

Introduction

Data Center for Korean Body Temperature (DC for KBT) was approved in the National Center for Standard Reference Data (NCSRD) No. 32 in 2016 by the Korean Agency of Technology & Standards under the Ministry of Trade, Industry and Energy. DC for KBT aims to make the reference standard temperature table by measuring the average temperature of each region of interest (ROI) made for each posture of infrared (IR) thermographic image of normal Koreans. The 2017 research goal is to create a reference temperature table for the normal adult's lower extremities. The purpose of this study is to present the production process and results of the reference body temperature data of the normal Korean lower limb.

Materials and Methods

In 2017, 517 normal adults were measured. The measurement posture of whole body is divided into 22 postures. The ROI of each posture is measured by using the IR thermographic images of the six among 22 postures corresponding to the lower extremity (Fig. 1). National Health Insurance Service (NHIS) Ilsan Hospital, Yonsei University Gangnam Severance Hospital and Ajou University Hospital participated in this study. The room temperature was kept constant at $24 \pm 1°C$. The selection of the normal person is the same as the distribution of the population in Korea from 20s to 60s. The criteria of normal adults should not be malformed in the face or limbs. There should be no scoliosis, kyphosis or lordosis, and the symmetry should be left and right as seen from the eyes. There should be no specific diseases as a result of national health check-up program. In addition, there are some cases of chronic diseases such as hypertension and diabetes which are controlled by medications and maintain normal levels. Some chronic diseases such as those who maintain normal liver function without liver cirrhosis are included as normal persons. The exclusion criteria are as follows. In IR thermography, when the temperature difference between left and right is more than 1°C due to operation wound, spine, hip, knee, ankle, or part of the lower extremity is identified. Spinal disease, peripheral arterial obstructive disease, varicose vein, diabetic foot, peripheral neuropathies. Some ROI exemptions are as also defined.

To obtain the uncertainty of the measurement, the following actions were performed. The reliability test was conducted on three IR cameras. First, we set the ambient temperature to 24 ° C and the temperature of the blackbody was measured from 15 to 40 °C in 3 °C increments. Secondly, the black body was fixed at 30 °C and the ambient temperature was measured at 20, 22, 24, and 26 °C, and the IR camera was measured at 1 minute intervals for 30 minutes at each temperature. The error between the black body and the IR camera was within ± 1 ° C. The manufacturer of the black body used for this test was Precision Infrared Calibrator (FLUKE/4180). Calibration certification report from the institution certified by Korean Laboratory Accreditation Scheme (KOLAS) of the black body had a measurement uncertainty of 1.7 °C and an emissivity of 0.95. Next, three IR cameras were received calibration certification report from the institutions certified by KOLAS for traceability and calibration.

Based on this, we made an uncertainty equation. The three institutions passed the institutional review board (IRB) of each institution for this study. Then we measured the ROIs of the lower extremities of 517 normal adults.

Results

The average temperature of the ROIs was measured at 6 postures. Posture of lower back & buttocks defined 42 ROIs, 21 on the left and 21 on the right. Posture of leg, posterior defines 40 ROIs, 20 on the left and 20 on the right. Posture of leg, anterior defines 30 ROIs, 15 on the left and 15 on the right. Posture of leg, right and posture of leg, left defined 20 ROIs respectively. Posture of sole defined 30 ROIs, 15 on the left and 15 on the right.

A reference temperature data base of normal Korean lower extremity was completed and divided into 20s, 30s, 40s, 50s, and 60s by age group, and 60 reference data were finally obtained by dividing into male and female.

Table 1 shows the reference temperature for female, age group 40s, and the posture of leg, anterior.

We calculated various uncertainty values by finding various uncertainty components. Type 1 uncertainty was standard deviation. Type 2 uncertainties were 1) Maximum uncertainty value among 10 times repeat measurement, 2) Resolving power of read indicator's value, 3) Combined Standard Uncertainty of calibration report of each IR Camera, and 4) Maximum uncertainty value of thermometer (for room temperature measurement).

For example, looking at the formula for calculating the uncertainty of female, age group 40s in ROI 1-1 of Table 1, we have

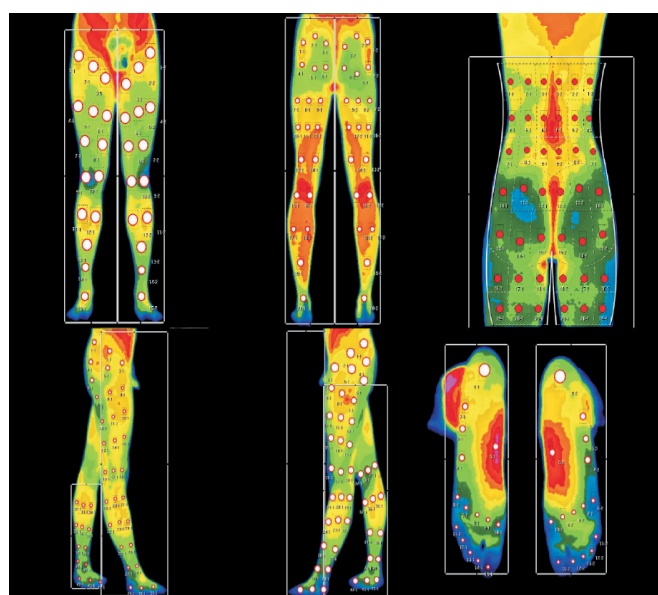Figure 1
Six postures and ROIs of temperature measurement.
1. Posture of leg, anterior. 30 ROIs.
2) Posture of leg, posterior. 40 ROIs.
3) Posture of lower back & Buttocks. 42 ROIs
4) Posture of leg, right. 44 ROIs
5) Posture of leg, left. 44 ROIs.
6) Posture of sole. 30 ROIs.

Table 1
Example of reference temperature of normal Korean lower extremity. Age group: 40s, Posture: Leg, anterior

ROI	Male						Female				
	N	Average	Standard Deviation	Average Lt(1)-Rt(2)	p		N	Average	Standard Deviation	Average Lt(1)-Rt(2)	p
1-1	54	32.96	2.07	4.25	-0.06		67	31.53	2.56	5.21	-0.19
1-2	54	33.02	2.08	4.27			67	31.72	2.52	5.13	
2-1	54	33.14	2.11	4.33	-0.04		67	31.65	2.51	5.11	-0.06
2-2	54	33.18	2.16	4.43			67	31.72	2.54	5.17	
3-1	54	33.30	2.41	4.92	-0.05		67	31.87	2.66	5.41	-0.15
3-2	54	33.35	2.39	4.88			67	32.03	2.59	5.27	
4-1	54	32.72	2.13	4.37	0.10		67	31.54	2.53	5.15	0.00
4-2	54	32.61	2.07	4.25			67	31.54	2.57	5.23	
5-1	54	32.71	2.05	4.22	-0.03		67	31.45	2.53	5.15	0.01
5-2	54	32.74	2.07	4.25			67	31.45	2.55	5.19	
6-1	54	32.95	2.15	4.41	0.08		67	31.34	2.53	5.15	-0.05
6-2	54	32.87	2.24	4.59			67	31.39	2.55	5.19	
7-1	54	32.07	1.98	4.08	0.10		67	30.98	2.29	4.68	0.04
7-2	54	31.97	2.01	4.14			67	30.93	2.32	4.74	
8-1	54	32.53	2.00	4.12	-0.17		67	31.39	2.40	4.90	-0.18
8-2	54	32.70	2.14	4.39			67	31.57	2.42	4.94	
9-1	54	31.99	1.95	4.02	0.18		67	31.18	2.14	4.39	0.25
9-2	54	31.81	1.87	3.87			67	30.93	2.18	4.47	
10-1	54	31.87	1.90	3.92	-0.27		67	30.63	2.13	4.37	-0.15
10-2	54	32.14	2.05	4.22			67	30.78	2.17	4.45	
11-1	53	33.97	2.14	4.39	-0.08		66	32.87	2.46	5.02	-0.14
11-2	53	34.05	2.25	4.61			66	33.01	2.42	4.94	
12-1	53	33.78	2.10	4.31	0.12		66	32.37	2.50	5.10	0.35
12-2	53	33.66	2.20	4.51			66	32.02	2.49	5.08	
13-1	53	32.94	2.15	4.41	0.24		67	32.03	2.39	4.88	0.08
13-2	53	32.70	2.21	4.53			67	31.95	2.31	4.72	
14-1	53	32.40	1.87	3.87	0.41		67	31.79	2.38	4.86	0.14
14-2	53	31.98	1.91	3.94			67	31.65	2.36	4.82	
15-1	53	31.31	2.04	4.20	0.21		67	30.08	2.45	5.00	-0.01
15-2	53	31.10	2.00	4.12			67	30.09	2.50	5.10	

Table 2
Summarized table of components of various uncertainties in this study. Age group: 40s, Sex: female, Posture: Leg, anterior, ROI 1-1

Name of uncertainty		Definition	Value
$u(T_{m,s})$		Standard deviation of measured value	2.56
$u(T_{m,rep})$		Maximum uncertainty value among 10 times repeat measurement	0.000
$u(t_{m,res})$		Resolving power of read indicator's value	$0.01/2\sqrt{3}$ = 0.003
$u(\delta T_{ref}) = \sqrt{\dfrac{N_1 u^2(\delta T_{ref1}) + N_2 u^2(\delta T_{ref2}) + N_3 u^2(\delta T_{ref3})}{N}}$, where $N = \sum_{i=1}^{3} N_i$	$u(\delta T_{ref1})$	Combined Standard Uncertainty of calibration report of IR Camera 1	0.333
	$u(\delta T_{ref2})$	Combined Standard Uncertainty of calibration report of IR Camera 2	0.327
	$u(\delta T_{ref3})$	Combined Standard Uncertainty of calibration report of IR Camera 3	0.369
$u(T_{env})$		Maximum uncertainty value of thermometer (for room temperature measurement)	0.349
Combined Standard Uncertainty $u_c(T) = \sqrt{u^2(T_{m,s}) + u^2(T_{m,rep}) + u^2(T_{m,res}) + u^2(\delta T_{ref}) + u^2(T_{env})}$			2.61
Expanded Uncertainty $U = k \cdot u_2(T)$ (95%, $k = 2$)			5.21

obtained various components of uncertainty and obtained their combined standard uncertainty. Based on this, expanded incertainty (U) was obtained (Table 2).

Table 3 shows the temperature measurement percentile for each ROI for female, age group 40s, and posture of leg, anterior.

Discussion

Institutions certified by KOLAS to measure the uncertainty of the IR camera are not yet traceable to the "real" temperature of the ITS-90, resulting in a calibration certification report of around 0.3°C. Since the long term stability is not secured, we will receive the calibration report annually as an alternative means.

Based on the two papers we published earlier, a reference standard temperature of at least 900 normal adults is required. Each year, 500 normal adults will be taken and measured for three years by IR camera in 22 postures. After three years, there will be 1,500 normal adults, and all referece standard temperatures in 22 postures will be made by 5 age groups. We made the reference temperture data of the lower limb at 2017, will add 1,000 legs and upper limbs at 2018, and we will have 1,500 lower limbs, upper limbs, face and trunk at 2019. In 2020, we will create a reference standard temperature for female breasts. Although 2017 was the first year of the temperature measurement and did not yet meet the reference standard data, continuing temperature measurements will yield good results in the future. It will also continue to add new uncertainty factors as they appear and will make continued efforts to reduce the uncertainty.

With reference standard temperature data, it will be easier and more precise to compare studies with thermographic images of specific patients. In addition, it can be used for the automatic detection of abnormal temperature region in accordance with the change of the artificial intelligence era and the judgment of the effect of the treatment.

Conclusion

In the year 2017, reference temperature data of the normal Korean lower extremity were made using temperature data of 500 normal adult subjects with 6 postures based on traceability and uncertainty. We will continue to add uncertainty factors in the future, and we will produce 22 reference standard temperature data using an IR camera for 1,000 adults in 2018 and 1,500 normal adults in 2019.

References

ISO/IEC. International vocabulary of metrology - Basic and general concepts and associated terms (VIM). 3rd eds, ISO/IEC GUIDE 99, 2007.

ISO/IEC. Part 3: Guide to the expression of uncertainty in measurement (GUM:1995) in Uncertainty of measurement; ISO/IEC Guide 98-3, 2008.

Kim YS, YE Cho, Zhang HY. Thermatomes of the lumbosacral nerve roots. J Korean Neurosurg Soc 1995; 24; 33-46.

Zhang HY, Kim YS, Cho YE. Thermatomal change is cervical disc herniations. Yonsei Med J 1999; 40; 401-12.

Table 3
Percentile of temperature for Posture of Leg, anterior in 40s female

ROI	N	1st percentile	5th percentile	10th percentile	25th percentile	50th percentile	75th percentile	90th percentile	95th percentile	99th percentile
1-1	67	25.52	25.89	27.59	29.73	32.24	33.44	34.20	34.37	35.97
1-2	67	25.70	26.17	28.27	30.24	32.40	33.58	34.27	34.59	36.32
2-1	67	25.58	26.24	28.08	30.39	32.22	33.51	34.14	34.79	35.91
2-2	67	25.35	26.01	28.15	30.50	32.30	33.71	34.28	34.69	36.43
3-1	67	24.74	26.38	28.07	30.07	32.38	33.85	34.69	35.39	36.96
3-2	67	25.34	26.33	28.92	30.25	32.46	33.82	34.98	35.62	36.62
4-1	67	25.24	26.05	27.78	30.25	32.11	33.45	34.23	34.78	35.39
4-2	67	25.40	25.90	27.79	30.05	32.13	33.47	34.39	34.80	35.82
5-1	67	25.25	26.15	27.64	29.87	32.16	33.36	33.97	34.60	35.32
5-2	67	24.82	26.20	27.68	30.32	32.19	33.42	34.11	34.40	35.67
6-1	67	24.85	26.12	27.75	29.73	31.96	33.44	33.74	34.16	35.28
6-2	67	24.85	26.13	27.75	29.95	32.17	33.33	33.95	34.25	35.36
7-1	67	24.80	25.74	27.67	29.84	31.75	32.58	33.30	33.48	34.32
7-2	67	24.19	25.92	27.26	29.48	31.81	32.40	33.23	33.60	33.87
8-1	67	24.93	26.04	28.03	30.58	32.53	32.89	33.80	34.12	35.09
8-2	67	24.83	26.16	27.79	30.43	32.52	33.23	34.02	34.28	35.47
9-1	67	25.39	27.30	27.95	29.69	31.74	32.82	33.50	33.79	35.66
9-2	67	24.53	26.67	28.04	29.76	31.30	32.35	33.61	33.94	34.79
10-1	67	24.67	26.47	27.70	29.54	31.10	31.95	33.13	33.70	34.09
10-2	67	24.70	26.22	27.13	29.80	31.25	32.33	33.24	33.37	34.14
11-1	66	25.14	28.14	28.88	31.60	33.54	34.48	35.49	35.75	37.12
11-2	66	25.95	28.55	29.19	32.05	33.40	34.78	35.63	35.81	37.82
12-1	66	24.78	27.74	28.61	31.01	32.98	33.98	35.26	35.51	36.88
12-2	66	25.01	27.56	28.31	30.57	32.54	33.84	34.93	35.29	36.28
13-1	67	25.67	27.05	28.00	30.77	32.48	33.57	34.62	35.37	35.86
13-2	67	26.01	26.90	28.44	31.26	32.20	33.55	34.64	34.96	36.16
14-1	67	25.78	26.89	28.39	30.22	32.15	33.60	34.61	34.75	35.57
14-2	67	25.17	27.33	28.11	30.35	32.18	33.34	34.42	34.74	35.69
15-1	67	23.61	24.95	25.94	28.70	30.45	31.87	33.12	33.55	34.22
15-2	67	23.57	24.64	26.53	28.94	30.36	31.75	32.99	33.59	34.46