Vibration Injury Network

Research Network on Detection and Prevention of Injuries due to Occupational Vibration Exposures

Normative thermal thresholds measured at five European test centres

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Task: To compare thermal thresholds measured on healthy subjects between three European test centers so as to determine causes of variability in normative data and to provide population and method specific data for use by health professionals.

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Summary

Objectives: To compare thermal thresholds measured on healthy subjects between three European test centers so as to determine causes of variability in normative data and to provide population and method specific data for use by health professionals.

Methods: Hot thresholds, cold thresholds and neutral zones were obtained for 36 men at Center 1, 85 men and 17 women at Center 2 and 88 men at Center 3. All centers used the method of limits to obtain the minimum discernable temperature increase and the minimum discernable temperature decrease from a reference temperature. Centers 1 and 2 used an *HVLab* Thermal Aesthesiometer with a fixed reference temperature (30°C, Center 1; 32°C, Center 2) and a rate of temperature increment and decrement of 1°C/s to measure thresholds at the finger tip. Center 3 used a Somedic Thermotest with the reference temperature set equal to the finger skin temperature, a rate of temperature increment of 1°C/s and a rate of temperature decrement of 3°C/s; thresholds were measured on the distal and medial phalanges combined. At Center 1, separate measurements were made on the index and ring finger of both hands whilst at Centers 2 and 3, thresholds were measured on the index finger of the right hand.

Results: The minimum discernable temperature increase and temperature decrease were greater at Center 1 than at Center 2 and greater at Center 2 than at Center 3. Thresholds measured at Center 2 showed 17 female white collar workers exhibited smaller minimum discernable temperature increases than the 37 male white collar workers. This may have been due to the effect of age; the men were significantly older than the women and the data shows a positive correlation between age and minimum discernable temperature changes. The 37 male white collar workers at Center 2 were compared with 48 male blue collar workers also from Center 2. The blue collar workers showed a significantly greater minimum discernable temperature decrease than the white collar workers. Measurements made at Center 1 were compared between test locations, the middle finger was better able to discern decreases in temperature than the little finger. No significant differences between the left and the right hand were observed. Within each homogeneous group of subjects, age tended to be positively correlated with the minimum discernible temperature increase and the minimum discernable temperature decrease. Finger skin temperature was shown to significantly effect measurements made at Center 3; the reference temperature at this Center was not fixed but set to the finger skin temperature of the subject. The data suggest increasing the reference temperature results in increasing the minimum discernable temperature change.

Conclusions: Thermal thresholds are greatly influenced by the measurement method. The thresholds are also dependent on the location of measurement, the reference temperature used, the age of the subject and the subjects occupation. Normative data for homogeneous groups of subjects are presented; these can be used to aide the diagnosis of peripheral neuropathy involving thermal sensation. It is not recommended that a variable reference temperature is used.

Introduction

Measurements of thermotactile thresholds on the fingers are currently used in several countries in Europe for assessing neurological dysfunction in workers exposed to hand-transmitted vibration (e.g. Lindsell and Griffin, 1999).

Various equipment and methods have been implemented for measuring vibrotactile thresholds. The different methods are unlikely to give similar thresholds due to differences in the applied thermal stimulus, the skin-stimulus contact conditions and the methods of calculating thresholds.

This study was conducted to investigate the variability in vibrotactile thresholds between three European laboratories. In addition to differences between centres, factors that affect thermotactile thresholds within centres (gender, occupation, age, measurement location and finger skin temperature) were also investigated.

Method

Thermal threshold data were obtained from three laboratories, one in the United Kingdom (Center 1), one in Belgium (Center 2) and one in Sweden (Center 3). All subjects for whom data were collated were healthy and of working age. No subjects were exposed to hand-transmitted vibration in the workplace. Subject characteristics that were obtained at each test center are shown in Table 1. Measurement methods differed slightly between locations. Table 2 shows the measurement parameters used at each center.

Table 1, Table 2

All subjects gave their consent before measurements were made and each of the centers obtained approval for making the measurements from their local safety and ethics committees.

Analysis

All centers reported data as absolute thresholds. However, since different reference temperatures were used at each center, and for each subject at Center 3, the minimum discernable temperature changes have been calculated. The minimum discernable temperature increase from the reference temperature was calculated as the hot threshold minus the reference temperature and the minimum discernable temperature decrease was calculated as the reference temperature minus the cold threshold.

Non-parametric statistics have been used throughout; minimum discernable temperature changes were not normally distributed (Kolmogorov-Smirnov statistic using a Lilliefors significance level; $p < 0.056$). Absolute thresholds and minimum discernable temperature changes have been described using the median as the measure of central tendency and the inter-quartile range (IQR) as the measure of spread. Neutral zones have been calculated as the the sum of the minimum discernable temperature increase and the minimum discernable temperature decrease from the reference temperature (or the difference between the hot threshold and the cold threshold).

The Kruskall-Wallis H test and the Mann-Whitney U test have been used to test for differences between groups and the Friedman test and the Wilcoxon signed ranks test have been used to test for differences within groups. Spearman’s correlation coefficient has been used to test for significant relationsbetween continuous variables. Data have been modelled using the Cox proportional hazards model. The application of the Cox proportional hazards model to non-parametric threshold data has been described elsewhere [1]. Briefly, the exponent of the coefficient (â) describes the risk of a subject with one value of an independent variable responding to a given stimulus relative to a subject with a reference value of the independent variable. A positive coefficient for a categorical variable indicates a greater likelihood of response to the stimulus relative to the reference category whilst a positive coefficient for a continuous variable indicates an increase in the covariate results in an increased risk of response to a given stimulus. The significance of the coefficient has been tested using the Wald statistic. A probablity of 5% has been chosen to indicate significance and 10% to indicate marginal significance in the analyses.

Results

Age, finger skin temperature, absolute thermal thresholds and minimum discernable changes from the reference temperature are shown in Table 3. Figure 1 shows box-and-whisker plots of the minimum discernable temperature increase and decrease from the reference temperature and the neutral zone for all measurements and for all measurements within each of the three centers.

Table 3, Figure 1

Differences between centers

The minimum discernable temperature increase and temperature decrease were greater at Center 1 than at Center 2 and greater at Center 2 than at Center 3. The absolute thresholds and neutral zone also differed between the three centers (Table 3).

To compare homogenous sub-groups between centers, data obtained from fingers innervated with the median nerve (index or middle finger) of the right hand were compared between the male blue-collar workers at Center 1 and the male blue-collar workers at Center 2 (Table 3). Measurements made at Center 1 indicated the minimum discernable temperature increases and decreases were greater and the neutral zones were wider than for measurements made at Center 2. The age and finger skin temperature did not differ between groups

Effect of gender

The 17 female white collar workers at Center 2 were compared to the 37 male white collar workers at Center 2. The minimum temperature discernable increase in temperature was greater for the men than the women (Table 3). The men were significantly older and exhibited significantly higher finger skin temperatures than the women. Cox’s proportional hazards model (Table 4) showed that within Center 2, there was no significant effect of gender when age, finger skin temperature and occupation were included.

Table 4

Effect of occupation

The 37 male white collar workers at Center 2 were compared with the 48 male blue collar workers from Center 2. The blue collar workers showed a significantly greater minimum discernable temperature decrease and a marginally wider neutral zone than the white collar workers. No other differences were shown between the two groups (Table 3). This difference between white collar and blue collar workers was also observed in the Cox's proportional hazards model (Table 4).

Effect of measurement location

Measurements made at Center 1 were compared between test locations. The minimum discernable temperature increase and the minimum discernable temperature decrease were both significantly different between the four locations, the neutral zones were marginally different between the locations (Table 3).

Data for all little finger measurements were compared to data for all middle fingers. The middle finger showed a significantly lower minimum discernable temperature decrease than the little finger and a marginally wider neutral zone. The minimum discernable temperature increase did not differ significantly between the middle and little fingers (Table 3). The data for both fingers of the left hand were combined and compared to the data for both fingers on the right hand. There were no significant differences between the two hands although the neutral zone was marginally smaller on the left hand than the right hand (Table 3). Cox's proportional hazards model indicated similar results (Table 4); the middle finger showed a greater ability to discern decreases in temperature than the little finger whilst there were no effects of the test hand.

Effect of age

Table 5 shows the Spearman's correlation coefficients for the relationship between age and thermal thresholds expressed as minimum discernable temperature changes. Generally, an increase in age resulted in an increase in the minimum discernable temperature change and a wider neutral zone.

Table 5

The effect was evident for the ability to feel a decrease in temperature amongst all sub-groups of male subjects but not amongst the female office workers. The effect of age on the ability to feel an increase in temperature was not so strong amongst the homogenous sub-groups; significant relationships were observed only for male white collar workers at Center 2 and for combined data at both Center 1 and Center 2.

Cox's proportional hazards models also shows the effects of age in minimum discernable temperature changes. In Center 1 and Center 2, increasing age resulted in a decreasing risk of responding to a given stimulus (both a temperature increase and a temperature decrease). In Center 3, however, The age effect was not observed for minimum discernable temperature increases and was only marginal for minimum discernable temperature deacreases.

Effect of finger skin temperature

Finger skin temperature was shown to have some effect on measurements made at each of the three centers (Table 4). When all data from Center 1 were combined, the minimum discernable temperature decrease tended to decrease as finger skin temperature increased, the neutral zone also narrowed. At Center 2, when all the data were combined an increase in finger skin temperature appeared to result in an increasing minimum discernable temperature increase. At both of these centers, the combined data indicated correlations between age and finger skin temperature; a negative correlation was observed at Center 1 and a positive correlation at Center 2. It is likely that the observed relationship between finger skin temperature and age resulted in the significant relationship between discernable temperature changes and finger skin temperature. This theory is somewhat supported by the Cox's proportional hazards model; within Center 1 and Center 2 finger skin temperature did not significantly alter the risk of responding to a given stimulus except for measurements of the minimum discernable temperature decrease obtained at Center 1 (Table 4).

Finger skin temperature was significantly correlated with both minimum discernable temperature increases and minimum discernable temperature decreases at Center 3 (Table 5). The reference temperature at this Center was not fixed but set to the finger skin temperature of the subject; the data suggest increasing the reference temperature results in increasing the minimum discernable temperature change. The results of the Cox's proportional hazards model also suggest this is the case (Table 4).

Conclusions

Thermal thresholds are greatly influenced by the measurement method. The thresholds are also dependent on the location of measurement, the reference temperature used, the age of the subject and the subjects occupation. Normative data for homogeneous groups of subjects are presented; these can be used to aide the diagnosis of peripheral neuropathy involving thermal sensation. It is not recommended that a variable reference temperature is used.

Acknowledgements

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References

1. Lindsell C J, Griffin M J (1999) Thermal thresholds, vibrotactile thresholds and finger systolic blood pressures in dockyard workers exposed to hand transmitted vibration. International Archives of Occupational and Environmental Medicine 72, 377 – 386.

Table 1 Characteristics of subjects at each of the three test centers

		Center 1 N=36	**Center 2** N=102	**Center 3** N=88
Age	Years (Median, IQR)	37 (12.8)	36 (15.3)	27 (4)
Occupation	White collar workers (N)	0	54	?
	Blue collar workers (N)	36	48	?
Gender	Male (N)	36	85	88
	Female (N)	0	17	0
Preferred Hand	Left (N)	0	0	5
	Right (N)	36	102	82
	Ambidexterous (N)	0	0	1
Finger skin temperature	°C (Median, IQR)	34.5 (1.6)	33.9 (3)	34.9 (1.4)

Table 2 Measurement methods used at the three test centers.

Parameter	Center 1	Center 2	Ceneter 3
Equipment	*HVLab* Thermal Aesthesiometer	*HVLab* Thermal Aesthesiometer	Somedic Thermotest
Measurement site	Fingertip	Fingertip	Distal and medial phalanges
Contact force	2 N	2 N	None specified
Phsycophysical method	Method of limits	Method of limits	Method of limits
Rate of temperature increment	1°C/s	1°C/s	1°C/s
Rate of temperature decrement	1°C/s	1°C/s	3°C/s
Delay at reference temperature	3 s ±10%	3 s ±10%	?
Number of judgements	3	6	6
Reference temperature	30°C	32°C	Finger skin temperature
Threshold calculation	Mean of second two judgements	Mean of four most similar judgements	?

Table 3 Age, finger skin temperatures and thermal thresholds (absolute thresholds and minimum discernable changes in temperature) for each subject grouping used in the analysis. Differences between the groups are shown.

Subject group		N	Age Years (Median, IQR)	Finger skin temperature °C (Median, IQR)	Hot threshold °C (Median, IQR)	Cold threshold °C (Median, IQR)	Neutral zone °C (Median, IQR)	Discernable change (Hot) °C (Median, IQR)	Discernable change (Cold) °C (Median, IQR)
All Center 1		144	37(12.8)	34.5 (1.6)	39.6 (4.5)	25.3 (3.6)	14.5 (8.2)	9.6 (4.5)	4.7 (3.6)
All Center 2		102	36 (15.3)	33.9 (3.0)	36.0 (3.3)	29.2 (2.2)	7.1 (6.2)	4.1 (3.3)	2.8 (2.2)
All Center 3 [a]		88	27 (4.0)**	34.9 (1.4)**	36.6 (1.9)**	33.1 (1.8)**	3.2 (1.2)**	1.8 (0.8)**	1.4 (0.6)**
Female white collar workers, Center 2		17	28 (9.0)	32.0 (8.0)	34.0 (2.8)	29.8 (2.4)	4.1 (5.4)	2.0 (2.8)	2.2 (2.4)
Male white collar workers, Center 2 [b]		37	35 (17.0)**	34.0 (2.0)**	35.5 (3.8)$^{+}$	29.3 (1.9)	6.3 (5.7)	3.5 (3.8)$^{+}$	2.7 (1.9)
Male Blue collar workers, Center 2 [c]		48	39.5 (11.0)	34.0 (3.9)	36.6 (2.7)	28.5 (2.6)*	8.0 (5.4)$^{+}$	4.6 (2.7)	3.5 (2.6)*
Male blue collar workers, Center 1	**Measurement location**								
	Middle finger, right hand [d]	36	37 (12.8)	34.5 (1.6)	38.7 (3.2)**	25.8 (3.2)**	13.5 (5.5)**	8.7 (3.3)**	4.2 (3.2)*
	Little finger, right hand	36	37 (12.8)	34.5 (1.6)	39.9 (4.1)	24.9 (3.4)	15.3 (8.1)	9.9 (4.1)	5.1 (3.4)
	Middle finger, left hand	36	37 (12.8)	34.5 (1.6)	39.8 (5.2)	25.8 (2.7)	14.5 (9.1)	9.8 (5.2)	4.2 (2.7)
	Little finger, left hand [e]	36	37 (12.8)	34.5 (1.6)	40.1 (5.2)**	24.6 (4.1)**	15.5 (11.1)$^{+}$	10.1 (5.2)**	5.4 (4.1)**
	Middle finger	72	37 (12.8)	34.5 (1.6)	39.1 (3.9)	25.8 (2.8)	13.8 (6.5)	9.1 (3.9)	4.2 (2.8)
	Little finger[f]	72	37 (12.8)	34.5 (1.6)	39.9 (4.8)	24.7 (4.1)**	15.5 (8.7)*	9.9 (4.8)	5.3 (4.1)**
	Right hand	72	37 (12.8)	34.5 (1.6)	40.0 (5.1)	25.3 (4.2)	15.2 (9.8)	10.0 (5.1)	4.7 (4.2)
	Left hand[g]	72	37 (12.8)	34.5 (1.6)	39.2 (3.8)	25.2 (3.2)	14.0 (7.1)$^{+}$	9.1 (3.8)	4.8 (3.2)

(a) Kruskall-Wallis H test to compare the three centers (b) Mann-whitney U test to compare female white collar workers and male white collar workers within center 2 (c) Mann-Whitney U test to compare blue collar workers and white collar workers within center 2 (d) Mann-Whitney U test to compare measurements made on the index finger of the right hand of blue collar workers between Center 1 and Center 2 (e) Friedman test to compare measurements made at the four different locations (f) Wilcoxon signed ranks test to compare measurements made on the litte finger to those made on the middle finger (g) Wilcoxon signed ranks test to compare measurements made on the left hand to those made on the right hand. $^{+}$ $p < 0.1$; * $p < 0.05$; ** $p < 0.01$.

Table 4 Cox's proportional hazards models showing the dependence of minimum discernable temperature changes on age, finger skin temperature, occupation, gender and measurement location. Reference categories were chosen arbitrarily.

	Dependent variable	Independent variable	Reference category	$e^{\hat{a}}$	Sig (â)
Center 1	Minimum discernable temperature increase	Age (years)		0.9698	0.0119
		Finger skin temperature (°C)		1.0388	0.3777
		Hand	Left hand	1.0801	0.6625
		Finger	Middle finger	0.9666	0.8476
	Minimum discernable temperature decrease	Age (years)		0.9461	0.0000
		Finger skin temperature (°C)		1.0986	0.0293
		Hand	Left hand	1.2289	0.2473
		Finger	Middle finger	0.6189	0.0074
Center 2	Minimum discernable temperature increase	Age (years)		0.9587	0.0016
		Finger skin temperature (°C)		0.9735	0.5219
		Ocupation	White collar workers	0.9573	0.8480
		Gender	Males	1.4006	0.3343
	Minimum discernable temperature decrease	Age (years)		0.9477	0.0001
		Finger skin temperature (°C)		1.0217	0.6226
		Ocupation	White collar workers	0.6345	0.0489
		Gender	Males	0.9637	0.9199
Center 3	Minimum discernable temperature increase	Age (years)		0.9359	0.1577
		Finger skin temperature (°C)		0.8687	0.0352
	Minimum discernable temperature decrease	Age (years)		0.9204	0.0715
		Finger skin temperature (°C)		0.8496	0.0223

Table 5 Spearman's correlation coefficients showing the relationship between age, finger skin temperature, minimum discernable temperature increase, minimum discernable temperature decrease and the neutral zone. Values in bold are significant at the 5% level and values in bold italic are significant at the 1% level.

			Finger skin temperature	Discernable change (hot)	Discernable change (cold)	Neutral zone
All		Age	-0.074	***0.518***	***0.602***	***0.592***
All		Finger skin temperature		0.005	-0.083	-0.042
All		Discernable change (hot)			***0.797***	***0.950***
All		Discernable change (cold)				***0.928***
Center 1	All	Age	**-0.170**	**0.178**	***0.391***	***0.360***
Center 1	All	Finger skin temperature		-0.073	***-0.210***	**-0.189**
Center 1	All	Discernable change (hot)			***0.456***	***0.822***
Center 1	All	Discernable change (cold)				***0.825***
Center 1	Middle finger, right hand	Age	-0.170	0.077	***0.411***	**0.369**
Center 1	Middle finger, right hand	Finger skin temperature		-0.034	-0.251	-0.202
Center 1	Middle finger, right hand	Discernable change (hot)			**0.282**	***0.777***
Center 1	Middle finger, right hand	Discernable change (cold)				***0.751***
Center 2	All	Age	**0.199**	***0.353***	***0.447***	***0.447***
Center 2	All	Finger skin temperature		**0.181**	0.063	0.143
Center 2	All	Discernable change (hot)			***0.670***	***0.904***
Center 2	All	Discernable change (cold)				***0.898***
Center 2	Female white collar workers	Age	0.082	0.120	0.261	0.272
Center 2	Female white collar workers	Finger skin temperature		-0.128	-0.411	-0.381
Center 2	Female white collar workers	Discernable change (hot)			***0.661***	***0.806***
Center 2	Female white collar workers	Discernable change (cold)				***0.953***
Center 2	Male white collar workers s	Age	0.196	**0.335**	***0.403***	**0.384**
Center 2	Male white collar workers s	Finger skin temperature		0.190	0.161	0.193
Center 2	Male white collar workers s	Discernable change (hot)			***0.787***	***0.972***
Center 2	Male white collar workers s	Discernable change (cold)				***0.890***
Center 2	Male blue collar workers	Age	0.039	0.172	***0.381***	***0.329***
Center 2	Male blue collar workers	Finger skin temperature		0.094	0.052	0.117
Center 2	Male blue collar workers	Discernable change (hot)			***0.533***	***0.813***
Center 2	Male blue collar workers	Discernable change (cold)				***0.893***
Center 3	All	Age	0.073	0.154	**0.187**	**0.226**
Center 3	All	Finger skin temperature		***0.322***	**0.244**	***0.315***
Center 3	All	Discernable change (hot)			***0.554***	***0.913***
Center 3	All	Discernable change (cold)				***0.820***

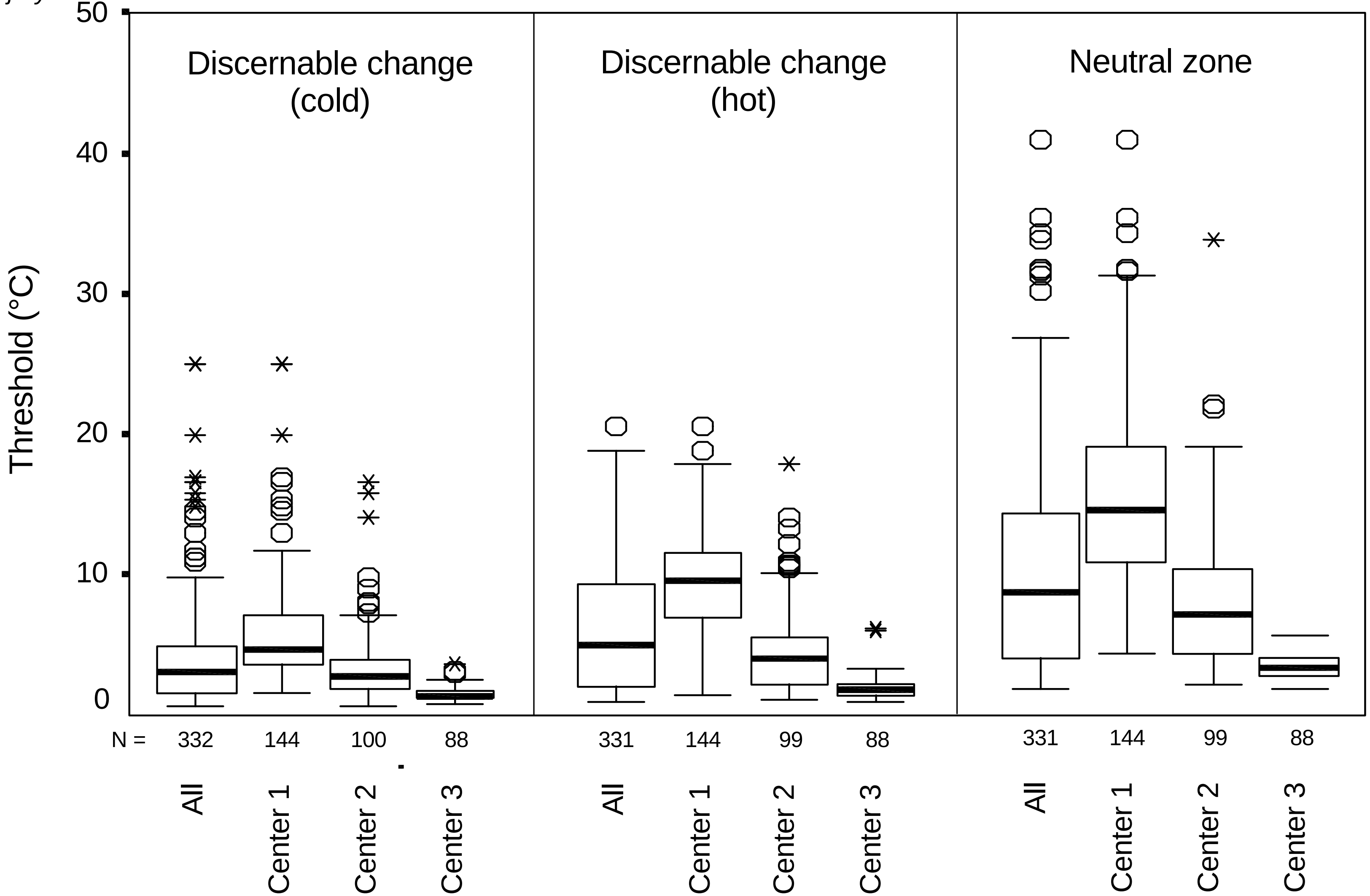

Figure 1 Box-and-whisker plots illustrating the median and interquartile range minimum discernable temperature decrease, minimum discernable temperature increase and neutral zones for all measurements and for all measurements at each center (Box = interquartile range; horizontal line within box = median; whiskers = minimum and maximum excluding outliers; = outliers; * = extremes).