Bull. Tokyo Med. Dent. Univ., 18: 169-177, 1971.

EXPERIMENTAL STUDIES ON HUMAN REACTION TO COLD

—Vascular hunting reaction of workers to cold—

BY

Masatoshi TANAKA*1

ABSTRACT

This study was carried out to know the influence of environmental temperature, severely cold environment, and mild temperature on workers tested by the vascular hunting reaction.

Subjects were 14 males, from 21 to 53 years of age. One group consisted of 9 workers at the ice chamber who had worked in severe cold environment (about −20～−25°C) for 5 to 10 years. Another group consisted of 5 men working at a controlled temperature of about 15～18°C.

The left middle finger was immersed in water of 0°C for 30 minutes. Skin temperature of the nail bed of the finger was then measured during and after immersion. Room temperature was kept at 22～24°C.

Following results were obtained. Ice-chamber workers working in a severely cold environment showed a high "resistance index" to cold, that is, "mean skin temperature" and "temperature of the first rise after immersion" were higher and "time for the first temperature rise after immersion" became shorter on the average. Cool-room workers working in a room regulated at a mild temperature showed lower "resistance index". There were significant difference between the two groups in "resistance index" ($P<0.1\%$).

INTRODUCTION

Many factors are interrelated in the cold tolerance or cold reaction, and there are many methods to measure them; whole body reaction, that is, physiological measurement or biochemical measurement, and other local vascular reactions. The authors have previously examined the cold reaction of nude young men in a climate chamber at a temperature of about 12°C. The purpose of this study[1] was to compare the cold reaction of swimmers and a control group. There were some differences between the two groups; after exposure to cold, the increase of heat production of the swimmers was less than one-fourth of the control value. Both rectal and mean skin temperatures were lower in the swimmers but there was no clear difference between the groups in skin temperatures of fingers and toes.

*1 田中正敏: Department of Hygiene (Chief: Prof. H. KITA), School of Medicine, Tokyo Medical and Dental University (Tokyo Ika Shika Daigaku).
Received for Publication, May 29, 1971.

In the present study, we attempted to measure human reaction to environment by using the vascular reaction of the finger to cold as an index.

Method and Materials

When fingers and toes are exposed to extreme cold, their skin temperature falls steeply at first to a certain level and then fluctuates at that level. Basic studies on this temperature reacion was carried out by Lewis[2] and by Grant et al.[3] about 30 years ago. It was found that the reaction chiefly originated by intermittent dilatation of skin vessels, especially at the arterio-venous anastomoses.

Yoshimura et al.[4] have attempted to find a practcial method for measuring the reactivity of blood vessels to cold.

For comparison, the following three characteristics of the temperature curve were adopted[5] (Fig. 1):

T.F.R.=Temperature of the first rise after immersion
T.T.R.=Time of the first temperature rise after immersion
M.S.T.=Mean skin temperature (values during the first 5 minutes after immersion are rejected)

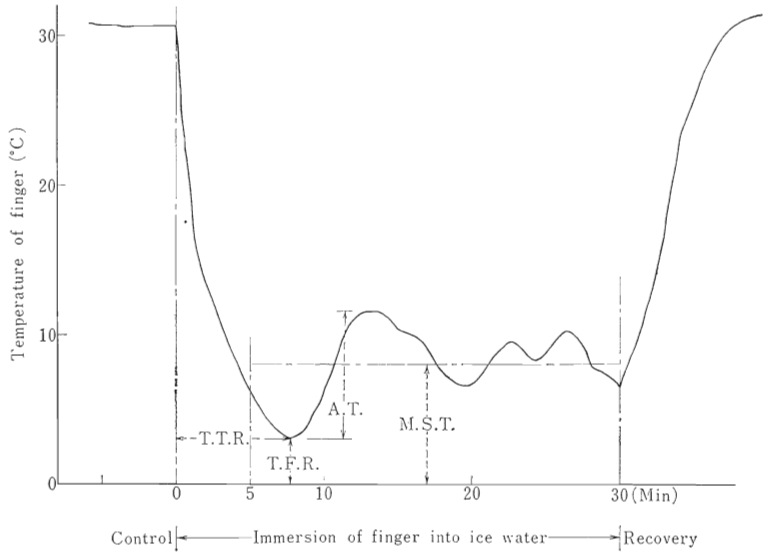

Fig. 1. Characteristics of temperature curve.
T.F.R. =Temperature of first rise after immersion.
T.T.R.=Time for first temperature rise after immersion.
M.S.T. =Mean skin temperature (values during the first 5 minutes after immersion were rejected).
A.T. =Amplitude of temperature reaction.

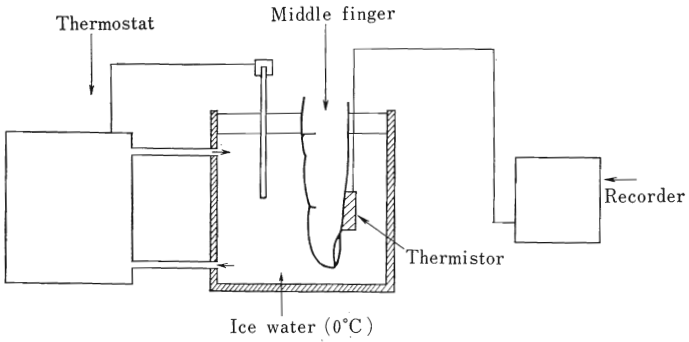

Fig. 2. Measurement of vascular reaction

To compare intensity of the temperature reaction, the resistance index is calculated from the values of each characteristic (T.F.R., T.T.R., and M.S.T.), a weak reaction is assigned a value of 1, while the strongest reaction is given a value 3. These values are given to T.F.R., T.T.R., and M.S.T., and they are added up to obtain the resistance index. Thus, the most severe resistance will have a maximum index of 9 and the weakest, 3.

Fig. 2 shows the method of the measurement. Nail bed of the left middle finger was chosen as the site of examination and the finger was immersed to its base in the water of 0°C for 30 minutes. Skin temperature of the nail bed of the finger then measured during and after immersion. Skin temperature was measured with a thermistor in this experiment. Throughout the experiment, the subjects were asked to be seated on a chair and dressed in everyday clothes, at 22~24°C ambient temperature. The subjects were 14 males from 21 to 53 years of age. One group consisted of 9 men working in the ice chamber of a fish market for 4 to 5 hours per day, 5 to 6 day per week, and they had been working for 5 to 10 years. Temperature of the ice chamber is from −20 to −25°C. Naturally, they work with heavy clothing to protect them against the cold and they do not work continuously for more than 1 hour. Another group consisted of 5 men working at a different part of the same fish market, where the temperature was controlled between about 15 and 18°C, and had been working for 5 to 10 years.

Data in this paper were assembled from the beginning of March to the beginning of April.

Results

Fig. 3 shows averages (± standard error) of finger temperatures of two groups at 60-second time intervals. Control values for the cool-room workers were slightly higher than those of the ice-chamber workers. Skin temperature

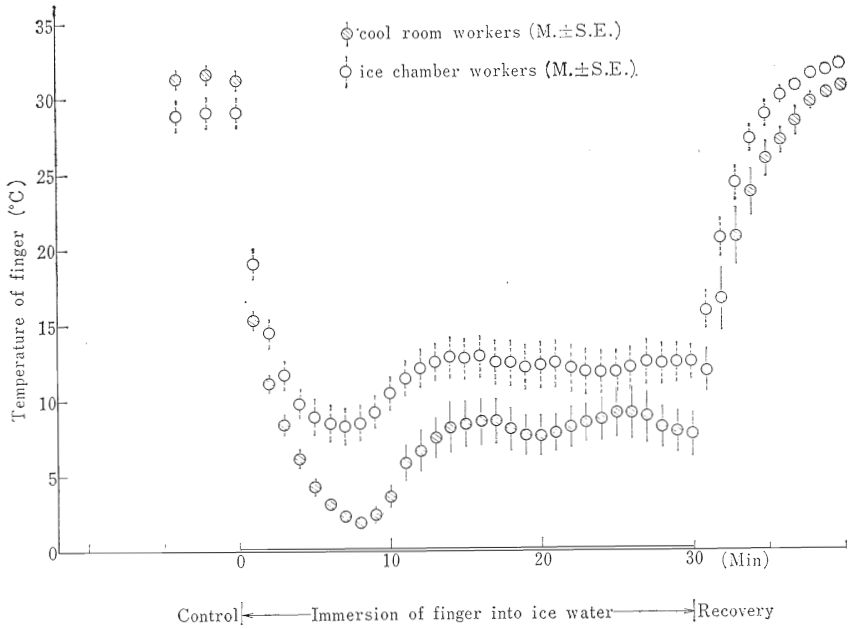

Fig. 3. Vascular hunting reaction of cool room workers and ice chamber workers. Finger temperature of two groups during the experiment. Each time interval is 1 minute. Each point is the average value of 9 subjects from ice-chamber workers and of 5 subjects from cool-room workers. Vertical lines and broken lines indicate standard errors.

of their finger fell steeply by immersion of the finger into ice water (0°C).

The curve for the cool-room group fell more steeply than that of the group of ice chamber workers. For the former group, T.F.R. was 1.94°C and T.T.R. 8 minutes. For the latter group, T.F.R. was 8.27°C and T.T.R. 7 minutes. Thereafter, the finger temperature tended to recover in an oscillating manner and amplitude of the first step of the temperature reaction of the group of ice-chamber workers was 4.56°C and that of the cool-room workers, 6.67°C, but the sustained level of the curve for the cool-room workers was lower than that of the ice-chamber workers. M.S.T. of the group of ice-chamber workers was 11.54°C and that of the other group, 6.89°C.

Table 1 shows characteristics of the temperature curve of each subject. T.F.R. was higher in the group of ice-chamber workers whose average of T.F.R. was 7.56°C. The range for individuals was from 4.95 to 12.95°C. In contrast, for the cool-room workers, average of T.F.R. was 1.68°C and the range for individuals was from 0.65 to 2.90°C.

T.T.R. values became shorter in the group of ice-chamber workers, whose average of T.T.R. was 6′40″ and the range for individuals was from

Table 1. Characteristics of temperature curve of each subject

Subject	Age (yrs)	Control value (°C)	T.F.R. (°C)	T.T.R. (min. sec)	M.S.T. (°C)	A.T. (°C)	R.I.	M.S.T./ A.T.
Cool room workers								
K.A.	21	32.40	2.90	8 00	7.79	8.60	6	0.91
N.E.	22	31.70	2.15	9 00	10.34	11.60	7	0.89
S.M.	27	32.70	0.65	8 00	4.05	5.75	5	0.70
H.T.	32	29.32	1.40	8 30	7.64	10.80	6	0.70
O.K.	53	30.00	1.30	11 00	4.49	6.55	5	0.69
M.±S.E.		31.22± 0.60	1.68± 0.35	8′54″± 30″	6.86± 1.04	8.66± 1.02	5.8± 0.33	0.78± 0.04
Ice chamber workers								
H.H.	22	32.10	11.90	4 00	17.54	6.30	9	2.78
K.E.	27	31.60	7.10	6 30	8.25	3.20	7	2.58
O.T.	27	27.70	5.80	7 00	7.06	2.40	8	2.94
S.A.	33	32.80	5.70	5 30	14.20	11.60	8	1.22
M.M	34	30.50	5.80	7 00	15.89	13.50	8	1.18
K.K.	39	30.40	5.75	6 00	6.18	2.75	8	2.25
S.K.	45	23.95	4.95	8 00	9.73	7.40	9	1.31
T.A.	48	25.30	8.05	7 00	11.54	7.10	9	1.63
S.T.	52	27.75	12.95	9 00	13.13	2.95	8	4.45
M.±S.E.		29.13± 0.97	7.56± 0.92	6′40″± 27″	11.50± 1.25	6.36± 1.27	8.22± 0.21	2.26± 0.34

4′00″ to 9′00″. For the cool-room workers, the average was 8′54″ and the range was from 8′00″ to 11′00″.

M.S.T. was higher in the group of ice-chamber workers, the average of M.S.T. being 11.50°C and range for individuals, from 6.18 to 17.54°C. For the other group, the average was 6.86°C and the range was from 4.05 to 10.34°C.

As the individual distribution of the control values (finger temperature before the immersion) was rather varied, R.I. (resistance index) was calibrated with the control value of each subject according to the Nagasaki University method.[6] For the ice-chamber workers, average R.I. was 8.22 and range for individuals was from 7 to 9. A value of 9 is the maximum value possible by using this index. For the cool-room workers, the range was from 5 to 7 and the average was 5.8.

A.T. is the amplitude of temperature reaction, i.e., difference between the temperature at the bottom of the first decrement and the top of the first restoring wave during immersion. Average A.T. for the cool-room

workers was greater than that for ice-chamber workers, but the maximum value was that of subject M.M. and individual range was rather varied.

Discussion

There are many factors affecting tolerance of finger to cooling under basal conditions[7]; diet[8], experience of cold exposition[9], seasonal change[4], age[9], etc.

In Table 1, younger subjects, H.H. in the ice chamber and K.A. and N.E. in the cool room, and elder subjects, K.E. and O.T. in the ice chamber and S.M. in the cool room have got their position in the same company of the fish market at the same time for each group after graduating from a junior high school. They have worked in the same place for a long time. They have no choice in their place of work. The company posted them to their position without any physical examination regarding their cold resistance. Their jobs were chosen purely by chance.

There was a remarkable difference between the group in this experiment as shown in Table 1. For the ice-chamber workers, the average values of T.F.R. and M.S.T. were higher, and T.T.R. value became shorter. Therefore, a R.I. of the ice-chamber workers became higher.

It was previously reported that the individual variation of R.I. was closely correlated with difference in their resistance against frost-bite[10].

The subjects who have worked in a room regulated to a mild temperature (about 15~18°C) had less resistance to cold than the subjects who have worked in a severely cold environment (about −20~−25°C) in the present study. The workers cannot work continuously for more than 1 hour in the ice chamber due to the severe cold. They can work in the cold only for short periods and must rest sometimes with a heater in another room. This may suggest an increase in the activity of blood vessels controlled by the vasomotor[4], which changes with the environmental temperature in the ice chamber workers, and ice-chamber workers keep the stronger value in the vascular reaction to cold.

Fig. 4 shows comparison of T.F.R., T.T.R., M.S.T., and R.I. of the two groups. There were significant differences between these groups. Resistance index (R.I.) was calibrated with the control values according to the Nagasaki University method[6]. The finger temperature before immersion affects the characteristics of the temperature curve and naturally the resistance index. The regression equation was calculated from about 200 subjects.

In the present experiment, this calibration method was used as the individual range of the finger temperature before the immersion was rather scattered as shown in Table 1. Without calibration, the average R.I. was

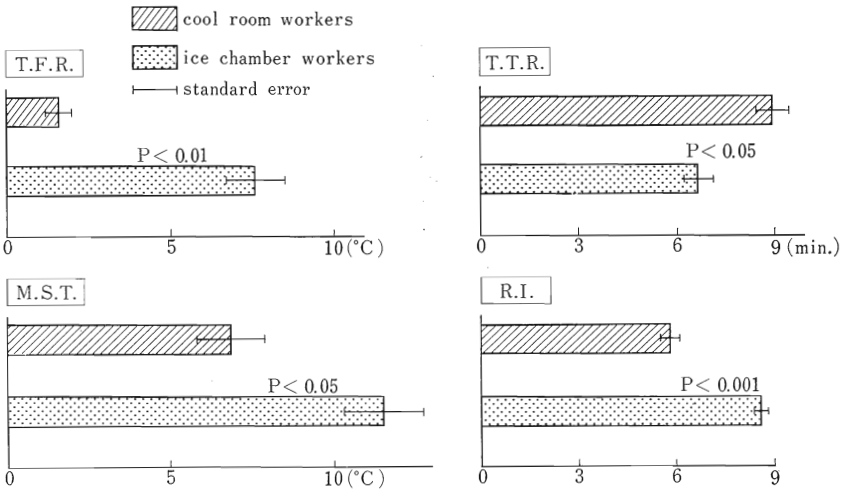

Fig. 4. Comparison of T.F.R., T.T.R., M.S.T., and R.I. of the two groups.

Table 2. Correlation coefficients between each item

Correlation coefficients / Significancy	T.F.R.	T.T.R.	M.S.T.	R.I.	M.S.T./A.T.
T.F.R		0.512	0.693	0.743	0.864
T.T.R	P<0.05		0.540	0.618	0.031
M.S.T.	P<0.01	P<0.05		0.697	0.328
R.I.	P<0.01	P<0.01	P<0.01		0.515
M.S.T./A.T.	P<0.001	(−)	(−)	P<0.05	

8.56±0.23 and the individual range was from 7 to 9 for the ice-chamber workers. For the cool-room works, average value was 5.40±0.46 and the range was from 4 to 7. The difference in R.I. between the two groups became greater.

Table 2 shows the correlation coefficient between each item (T.F.R., T.T.R., M.S.T., and R.I.). For the item A.T. (amplitude of temperature reaction), the maximum value was that of subject M.M., and the values of subjects N.E. and S.A. were rather high. Accordingly, the individual range was rather scattered as shown in Table 1. The index, M.S.T. devided by A.T., was 2.26 on the average and the range was from 1.18 to 4.45 for the ice-chamber workers. For the cool-room workers, the average was 0.78 and

the range was from 0.69 to 0.91, less than 1. For the ice-chamber workers, A.T. was smaller than M.S.T.

Conclusion

Although there are many methods used in determining individual cold resistance or cold reaction, it is important also to examine the local vascular reaction to cold which protects fingers or toes against frost damage. Studies on the influence of environmental temperature on the workers are important for occupational health.

The method of measuring the vascular hunting reaction is simple; it can be performed easily and in a short time.

There were individual difference in the vascular reaction to cold, and these differences should be evaluated by "resistance index" which can be objectively compared.

Workers in a severely cold environment showed a high "resistance index" in the present study. This fact may be due to the working condition, such as alternate heating and cooling the activity of local blood vessels. In contrast, workers in a mild temperature showed less cold resistance in vascular reaction to cold.

Acknowledgment

Grateful acknowledgment is made to Professor H. Kita for his cordial guidance and review of this manuscript and to Dr. T. Kubota, Assistant Professor of Hygiene, for his kind advice. The authors' deep gratitude is also due to Dr. K. Nakamura in the Department of Public Health and to the colleagues in the Department of Hygiene for their great assistance in this study.

This work was supported in part by a Grant-in-Aid for Scientific Research from the Ministry of Education.

An outline of this paper was read at the 16th International Congress on Occupational Health in Tokyo, 1969.

References

1) Tanaka, M. et al.: Reaction of swimmers to cold. Bull. Tokyo Med. Dent. Univ., 17: 217–226, 1970.
2) Lewis, H.: Observations upon the reactions of the vessels of the human skin to cold. Heart, 15: 177–208, 1930.
3) Grant, R. T., and Bland, E. F.: Observations on arteriovenous anastomoses in human skin and in the birds foot with special reference to the reaction to cold. Heart, 15: 386–407, 1931.

4) Yoshimura, H., and Iida, T.: Studies on the reactivity of skin vessels to extreme cold. Part 1. A point test on the resistance against frost bite. Japan. J. Physiol., 1: 147–159, 1950.
5) Hirai, K. et al.: Studies on effect of heat content on the vascular hunting reaction to cold, and the reaction of women divers. (in Japanese, English abstract). J. Physiol. Soc. Japan, 30: 12–21, 1968.
6) Nakamura, M. et al.: Some considerations on an estimation method for cold tolerance of local region in human being. (in Japanese). Japan. J. Hyg., 26: 106, 1971.
7) Eagan, C. J.: Local vascular adaptations to cold in man. Fed. Proc., 22: 947–952, 1963.
8) Yoshimura, H. et al.: Studies on the reactivity of skin vessels to extreme cold. Part III. Effects of diets on the reaction of skin vessels to cold. Japan. J. Physiol., 2: 310–315, 1952.
9) Yoshimura, H., and Iida, T.: Studies on the reactivity of skin vessels to extreme cold. Part II. Factors governing the individual difference of the reactivity, or the resistance against frost-bite. Japan. J. Physiol., 2: 177–185, 1952.
10) Iida, T.: Studies on the vascular reaction to cold. Part 1. (in Japanese). J. Physiol. Soc. Japan, 11: 73–78, 1948.