

Effects of a Cool Environment on the Health of Female Office Workers and Students

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Abstract Objective: The aim of this study was to evaluate the effect of a cool environment on the peripheral skin blood flow and subjective thermal sensations of female office workers and female students.

Methods: The subjects were 26 female bank employees (mean age, 38 years) who worked in a cool environment and 10 female college students (mean age, 22 years). The peripheral skin blood flow was measured using a laser Doppler blood flow meter. In each bank employee, peripheral skin blood flow was measured at three time points during the workday in the medical treatment room at their workplace. In the college students, peripheral skin blood flow was measured every hour between 9:00 and 17:00 in a laboratory. In both the medical treatment room and the laboratory, the room temperature was controlled at 24–26°C with a relative humidity of 55±10%. The bank employees and students were each divided into those with hypersensitivity to cold (Group A) and those without hypersensitivity to cold (Group B).

Results: When the 10 college students were in the cool environment (24–26°C), their peripheral skin blood flow generally decreased over time. The rate of decrease of this blood flow was greater in Group A than in Group B.

In the female bank employees, the peripheral skin blood flow was the lowest at 12:00 (before lunch), was increased at 13:00 (after lunch), and then was decreased at 17:30. However, the degree of the increase from before lunch to after lunch in Group A was about half of that in Group B.

Conclusion: Among female office workers and students, a cool environment reduced the peripheral skin blood flow of individuals with hypersensitivity to cold to a greater degree than in those without hypersensitivity to cold. *J Physiol Anthropol* 27(3): 153–159, 2008 <http://www.jstage.jst.go.jp/browse/jpa2>

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Keywords: cool environment, skin blood flow, cooling disorder, health effect

Introduction

A number of studies on the arrangement of workplace environments have been conducted, and as a result they have improved workplace environments and allowed people to work in comfortable conditions (Miura, 1975; Tanaka, 1999; Takahashi et al., 1998; Ardeshtir and Ulla, 2005; Dear and Brager, 2001; Muzi et al., 1998). In particular, artificial control of room environments has been highly acclaimed as a method to reduce discomfort in the hot and humid summer conditions of Japan. On the other hand, unsuitable physical conditions, such as too much cooling with an air conditioner, may lead to the development of cooling disorder.

When the room temperature is lower than the outside air temperature by five degrees Celsius or more, a skin thermal receptor recognizes a change in temperature and activates the body temperature controlling mechanism. “Cooling disorder” is defined as an autonomic imbalance due to abnormal and continuous cooling stimulation by excessive air conditioning (Miura et al., 2001). Considering that females are more vulnerable to cold environments and that a greater number of females are sensitive to cold than males (Tanaka et al., 2003), symptoms associated with cold temperatures are intensified in females when they work in not only cold working environments but also cool offices, and indefinite health complaints by female workers are expected to increase. Therefore, the aims of this study were to survey the status quo of females working in cool environments and to elucidate the relationship between cooling and hypersensitivity to cold.

In a preliminary survey, the health conditions of 1200 working females in Saga Prefecture, Japan were examined, and it was found that more than half of the working females had some physical problems. Some females required clinical treatment. However, in other workers, their symptoms could be alleviated by an improvement in their life environment, including their work environment. Stiff shoulder, lumbago, chilling of the body, and fatigue are among the symptoms that can be alleviated by lifestyle changes. These symptoms were

found significantly more often among females working long hours in a cool environment.

Service providers such as banks and department stores are among workplaces that require long hours of work in excessively cool environments. In these workplaces, the temperature is set a little lower than normal to create an atmosphere where customers entering from the hot and humid outdoors with marked discomfort lose heat-associated discomfort and feel comfortable. Such a setting is expected to greatly affect the body condition of those who work long hours in such workplaces as opposed to general offices.

In the first part of the present study, a field survey of 26 females working at the office of a bank was carried out. This study was designated as Study 1. In the field survey, the hypersensitivity to cold of the females working at the bank, as well as subjective thermal sensations and peripheral skin blood flow were examined. To supplement this, ten female college students were examined in a laboratory, where the temperature, humidity, and airflow were adjusted to be the same as those at the office in the bank. This study was designated as Study 2.

The objectives of this study were to categorize the subjects based on the presence or absence of hypersensitivity to cold, and elucidate the influence of a cool environment on such hypersensitivity.

Subjects and Methods

Subjects

The subjects were 26 female bank employees aged 22–51 years (mean age, 38 years) and 10 female college students aged 21–25 (mean age, 22 years). Female college students often stay all day long in an air-conditioned environment. The characteristics of the subjects are summarized in Table 1. Written informed consent was obtained from all of the subjects after they were provided with an explanation of the background, purposes, and methods of the study and the method of publication of the study results.

The presence of hypersensitivity to cold was assessed as described in reports by Miyamoto et al. (1992, 1993, 1995). The bank employees and students were each divided into those with hypersensitivity to cold (Group A), in which the subject thought that she was vulnerable to cold, and those without hypersensitivity to cold (Group B), in which the subject did not

think that she was vulnerable to cold according to a questionnaire on lifestyle status. In subjects who answered that they did not know which was more appropriate, those who had three or more symptoms of hypersensitivity to cold (feeling of coldness in arms or legs during the summer, feeling of coldness in arms and legs during the winter, feeling of coldness in limbs in air-conditioned rooms during the summer, difficulty sleeping due to chilliness of limbs during the summer, difficulty sleeping due to chilliness of limbs during the winter) were categorized into Group A, while those who had two or fewer symptoms were categorized into Group B. As a result, among the 26 bank employees, Groups A and Group B comprised 16 and 10 employees, respectively. Among the 10 college students, Groups A and B consisted of 5 students each.

Study 1. Field survey of female bank employees

A field survey was conducted in the office of a bank in Saga City, Japan. The office was located in an eight-story office building and air conditioning was used in all areas. The temperature of the workplace was 24–26°C with a humidity of 55±10% RH and an airflow of 0.5 m/sec. The subjects were assessed in the medical treatment room. The room temperature of the medical treatment room was controlled at the same temperature and humidity. The physical activity index corresponded to 1.5 METs (light office work) (Ainsworth et al., 2000). The bank employees worked mostly at desks either from 9:00 to 17:30 or from 8:30 to 17:00.

Skin blood flow was measured three times: before lunch (11:30–12:00), after lunch (12:30–13:00), and after work (17:00–17:30). We did not impose any restrictions other than at the times of measurement, and the subjects worked a regular job. They ate lunch at the company's diner or their own box lunch in their break room, and there was no restriction on the intake of calories. From the menu, it was estimated that their lunch consisted of 450–550 kcal. The lunch break was 60 min.

At the times of measurement of skin blood flow, the subject was asked to sit on a chair and remain relaxed. Skin blood flow was measured by a Laser Doppler blood flow meter (AFL21D, Advance, Japan). A round probe of 10 mm in diameter was fixed at the cushion of the left big toe on the outer side and blood flow 1 mm deep from the skin surface was measured. Five minutes after placement of the probe, blood flow was measured over a one-minute period and the average was

Table 1 Physical characteristics of the subjects

	Age (yr)	Height (cm)	Weight (kg)	Body fat (%)	BMI (kg/m ²)
Female bank employees (n=26)					
Group A (n=16)	37.9±10.9	152.4±7.3	50.1±9.1	25.0±5.0	21.5±3.1
Group B (n=10)	38.4±10.6	153.8±7.9	51.6±4.7	25.8±4.3	21.9±1.2
Female students (n=10)					
Group A (n=5)	22.4±2.1	159.1±4.5	51.0±5.9	24.7±5.4	20.2±2.7
Group B (n=5)	22.1±0.8	160.1±5.9	48.1±6.7	21.1±2.7*	18.7±1.6

Group A (with hypersensitivity to cold) and Group B (without hypersensitivity to cold) were categorized according to the report of Miyamoto et al. Data are expressed as mean±SD. **p*<0.05 versus Group A in female students.

adopted.

The clothing of the bank employees consisted of a bra, shorts, stockings, and a uniform designated by the bank (a short-sleeve blouse: polyester 80% and cotton 20%; a skirt and a vest, polyester 80% and wool 20%). At the time of the pre-lunch measurement, the office temperature was evaluated on a seven-point scale: 1, very cold; 2, cold; 3, slightly cold; 4, comfortable; 5, slightly hot; 6, hot; and 7, very hot.

Study 2. Measurement of skin blood flow in the college students in the laboratory

The ten female college students were assessed in a laboratory of size $5.9 \times 10.5 \text{ m}^2$ (length \times width). Most studies on the relationship between the thermal environment and the human body have been conducted in a room where the room temperature and humidity are strictly controlled (Tanaka et al., 2003; Sadakata et al., 2000; Nishimura et al., 1993; Isaji et al., 2000; Yoneda, 1993; Hasebe and Iriki, 1993). In this study, however, changes mimicking the temperature and relative humidity in the office during the daytime working hours were evaluated, using a large room that would not cause feelings of claustrophobia.

The subject entered the laboratory at 8:50 and stayed there for the whole day. The first measurement of peripheral skin blood flow was performed at 9:00. After that, they were allowed to read and write except for an hourly measurement. The last measurement was made at 17:00. All of the students ate the same lunch (about 500 kcal) bought at a shop, and 500 ml of tea was supplied during the course of day. For clothing, they wore a shirt or blouse that provided thermal comfort (not hot or cold), a skirt, and a pair of stockings. They wore shoes with open toes.

For measurement of peripheral skin blood flow, the same apparatus and method was used as in Study 1.

Comfort was evaluated subjectively by assessing room temperature and thermal sensation of toes using in the sitting position and the seven-point scale in Study 1.

These measurements were repeated four times (on four separate days) in the 10 subjects, and the average values were used for analysis.

In all of the subjects, the percentage of body fat was measured by bioelectrical impedance analysis using a body fat analyzer (TBF-110, TANITA, Japan).

Statistical analysis

The physical characteristics of the subjects were analyzed by an unpaired t-test. Skin blood flow between the groups and its time-course changes within the group were analyzed by a two-way ANOVA with repeated measurement. When the interaction between the group and the time was found to be significant, a pair-wise difference was identified using an unpaired t-test at each time point. Subjective thermal sensations were compared by the non-parametric t-test. A p-value less than 0.05 was considered to be statistically significant.

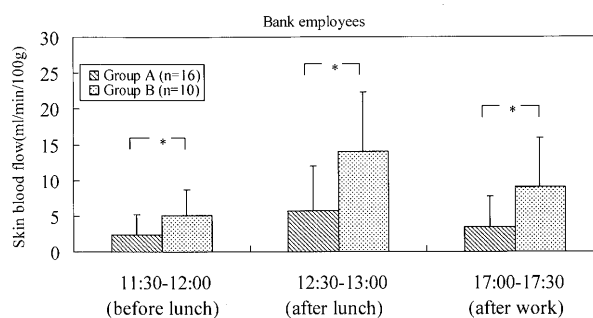


Fig. 1 Time course of changes in peripheral skin blood flow in 26 female bank employees in a cool environment. Values are mean \pm SD. * $p < 0.05$, Unpaired t-test compared with values for between Group A (with hypersensitivity to cold) and Group B (without hypersensitivity to cold).

Results

The changes in peripheral skin blood flow of the 26 female bank employees over time are shown in Fig. 1. A two-way ANOVA with repeated measurement revealed that the skin blood flow was significantly different between the groups ($p < 0.01$) and between the time laps ($p < 0.05$). Even though the interaction between the group and the time was not significant, the skin blood flow was greater in Group B than in Group A at all time points (unpaired t-test, $p < 0.05$).

Before lunch, the mean peripheral skin blood flow was 3.4 ml/min/100g. It increased to 8.9 ml/min/100g after lunch, although there was large inter individual variation. After work, the mean peripheral skin blood flow decreased to 5.5 ml/min/100g.

When Group A (with hypersensitivity to cold) and Group B (without hypersensitivity to cold) were compared among the bank employees, the mean peripheral skin blood flow before lunch was 2.4 ml/min/100g in Group A and 5.1 ml/min/100g in Group B, showing a significant difference. After lunch, blood flow increased in both groups, to 5.7 ml/min/100g in Group A and 14.0 ml/min/100g in Group B. The increase in Group A was about half of that in Group B, so there was a significant difference. From lunch to the end of work, the blood flow decreased in both groups, to 3.4 ml/min/100g in Group A and 9.0 ml/min/100g in Group B, with the difference between the groups becoming greater and reaching significance.

Cooling had a greater impact on skin blood flow in the group with hypersensitivity to cold than in the other group.

The time-course changes in skin blood flow exhibited a significant difference within Group B ($p < 0.01$), but not within Group A.

The thermal comfort of the room temperature in the workplace is shown in Table 2. The rating averaged 3.8 for all subjects; in Group B, it was evaluated as 4.1—"comfortable", whereas it was rated as 3.6 in Group A—"a little chilly". However, there was no significant difference between the two groups.

Table 2 Thermal rating of the room temperature at the workplace as evaluated according to the seven-grade scale by the 26 female bank employees

Time	Total (n=26)	Subgroup [†]		
		Group A (n=16)	Group B (n=10)	<i>p</i> value
11:30–12:00 (before lunch)	3.8±0.9	3.6±0.8	4.1±0.8	0.14

Data are expressed as mean±SD. [†], Group A: with hypersensitivity to cold, Group B: without hypersensitivity to cold. *p* value by non-parametric t-test.

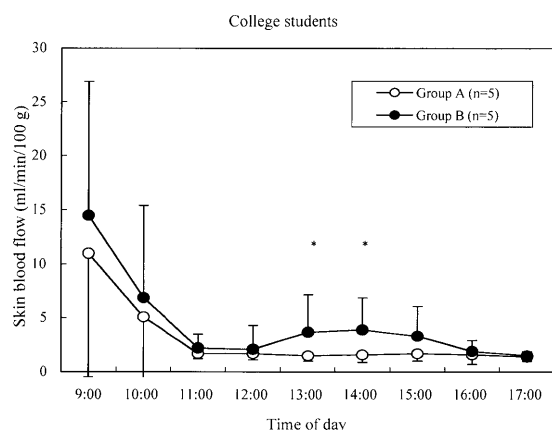


Fig. 2 The time-course of changes in peripheral skin blood flow in 10 female college students in a cool environment. Values are mean±SD. **p*<0.05, Unpaired t-test compared with values for between Group A (with hypersensitivity to cold) and Group B (without hypersensitivity to cold).

The time-course changes in peripheral skin blood flow in the ten female students are shown in Fig. 2. A two-way ANOVA with repeated measurement did not show any significant differences in the main effects and the interaction between the group and the time, but the skin blood flow was significantly greater in Group B than in Group A at 13:00 and 14:00 (unpaired t-test, *p*<0.05 in all cases).

When the presence or absence of hypersensitivity to cold was considered, the mean blood flow was 11.0 ml/min/100 g in Group A and 14.5 ml/min/100 g in Group B at 9:00, and then it decreased in both groups to 1.7 ml/min/100 g in Group A and 2.1 ml/min/100 g in Group B at noon before lunch. However, at 13:00 after lunch, it increased to 3.7 ml/min/100 g in Group B without hypersensitivity to cold whereas it remained low at 1.5 ml/min/100 g in Group A with hypersensitivity to cold, showing a significant difference. At 15:00 or later, it gradually decreased in Group B and it was 1.4 ml/min/100 g in Group A and 1.5 ml/min/100 g in Group B at 17:00, not showing a significant difference.

The time-course changes in the evaluation of subjective thermal feeling by the female students are shown in Fig. 3 (room temperature) and Fig. 4 (toes). For room temperature, Group A tended to be more sensitive to cold than Group B, but the difference was not significant. As to thermal feeling in the toes, Group A felt significantly chillier than in Group B at 11:00 and 16:00 (non-parametric t-test, *p*<0.05 in all cases).

In the summer, when the outside temperature exceeds 30°C,

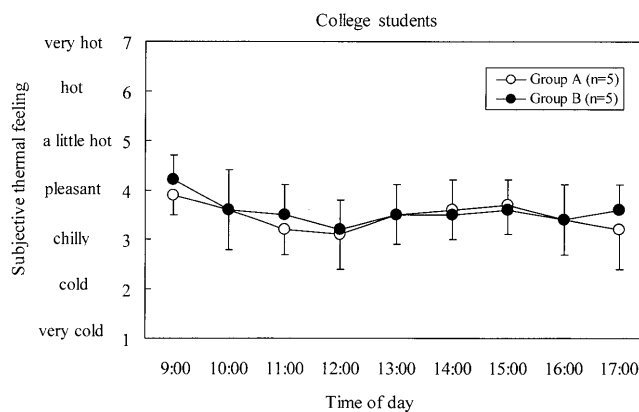


Fig. 3 The time-course changes in the evaluation of subjective thermal feeling by the female students (room temperature). Data are expressed as mean±SD. Group A (with hypersensitivity to cold); Group B (without hypersensitivity to cold). There were no significant differences between Groups A and B by non-parametric t-test.

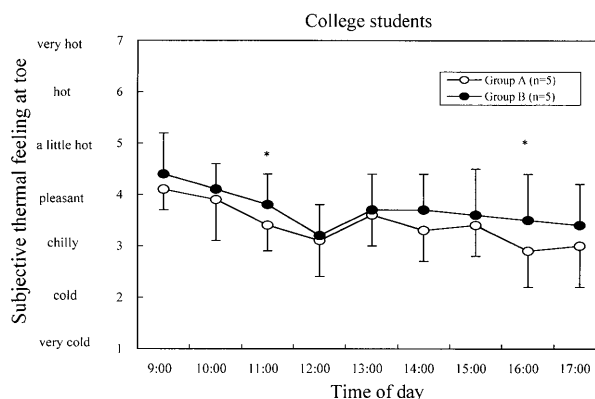


Fig. 4 The time-course changes in the evaluation of subjective thermal feeling by the female students (toes). Values are mean±SD. **p*<0.05, Non-parametric t-test compared with values for between A (with hypersensitivity to cold) and Group B (without hypersensitivity to cold).

those who stayed all day in a room with the temperature air-conditioned to 24–26°C felt comfortable only at 9:00 or at the beginning of work, and they felt a little cold or a little chilly during the rest of the day.

Discussion

Significance of skin blood flow measurement

Skin temperature and skin blood flow are important markers

for evaluating thermal reaction in humans. In a study on the objective assessment of sensitivity to cold, Sadakata et al. (2000) examined the validity of two parameters, “skin surface temperature” and “skin blood flow,” as objective biological indices of subjective symptoms of chilling. The skin surface temperature at 10 sites and at the umbilicus were found to provide useful information, but there was a problem in reproducibility because of inaccuracy in securing the same measurement sites. On the other hand, it was concluded that the extremities (hands and feet) were appropriate for measurement of skin blood flow, because the data obtained were stable.

As long as the environmental temperature is constant, skin blood flow is the major determinant of thermal temperature (Hasebe and Iriki, 1993; Nilsson, 1987), and a difference in skin blood flow is expected to cause differences in the peripheral skin temperature (Nishimura et al., 1993). Since skin blood flow has been reported to be the most important marker for the evaluation of comfort in a given environmental temperature (Hasebe and Iriki, 1993), it was considered appropriate to examine the thermal reaction in the office environment by measuring skin blood flow.

Status quo of females working in cool environments

The changes in skin blood flow in the female bank employees, who worked long hours in a cool environment (Study 1), were examined at three time points during an eight-hour work shift, and skin blood flow was found to be the lowest before lunch. Recovery of blood flow after lunch may be attributed to an increase in peripheral skin blood flow due to the energy intake. With the female college students (Study 2), skin blood flow changed in a similar manner as that in the bank employees before and after lunch and at the end of the workday. We were not permitted to make measurements in the bank employees at the beginning of work because it would disturb work at the bank. However, taking into account the results from the female college students, it is assumed that skin blood flow would be the highest at the beginning of work and gradually decrease throughout the day in the female bank employees.

As to thermal comfort in the workplace, the results in the female college students demonstrated that they felt that the room temperature was most chilly before lunch, when the cooling effect was largest, and a relationship with skin blood flow is indicated.

Relationship with the presence or absence of hypersensitivity to cold

As to skin blood flow and temperature, Group A (with hypersensitivity to cold) and Group B (without hypersensitivity to cold) were compared. However, it is first necessary to define “hypersensitivity to cold.”

In modern medicine, there is no disease term for “oversensitive to cold.” In Western medicine, “oversensitive to cold” corresponds to “hypersensitivity to cold” which

represents the condition of feeling cold in some parts of the body (Sadakata et al., 2000). In the present study, the subjects were divided into Group A (with hypersensitivity to cold) and Group B (without hypersensitivity to cold) according to the criteria used in previous studies (Miyamoto et al., 1995; Sadakata et al., 2000; Nagashima et al., 2002; Maeda et al., 2003), but there has been, to date, no definite method for categorization.

As shown in Fig. 1, when skin blood flow was compared during the daytime among the female bank employees, the peripheral skin blood flow was significantly lower before lunch, after lunch, and at the end of work in the group with hypersensitivity to cold than in the group without hypersensitivity to cold. Similar results were obtained among the female college students. In particular, among the college students, the skin blood flow after lunch was significantly lower in the group with hypersensitivity to cold than in the group without hypersensitivity to cold. In the group without hypersensitivity to cold, the peripheral skin blood flow decreased before lunch but increased after lunch, whereas the peripheral skin blood flow remained low after lunch in the group with hypersensitivity to cold. These results suggest that the group with hypersensitivity to cold is more susceptible to excessive cooling by air conditioning than the group without hypersensitivity to cold.

“Chilling” is a phenomenon that we feel as a physiological response when we are in cold environments, and blood vessels in the extremities contract to maintain core temperature and prevent a loss of body temperature. Consequently, the peripheral skin temperature decreases and chilling of the body is felt. In general, it is thought that this “chilling” reaction is attributable to the decrease in peripheral skin temperature because contraction of peripheral blood vessels causes the spasm of capillaries and local blood flow disturbance. In addition, when one is “oversensitive to cold,” time is required for the peripheral skin temperature to recover and there is a decrease in the temperature of the body trunk. As a result, autonomic nerve system disorder is induced. In the present study, skin blood flow decreased before lunch irrespective of the presence or absence of hypersensitivity to cold, but there was no sign of recovery of blood flow in Group A (with hypersensitivity to cold), unlike the case with Group B (without hypersensitivity to cold). In other words, it was established that in individuals with hypersensitivity to cold, it took many hours for the peripheral skin temperature to recover. It is assumed that continuation of this lifestyle would intensify symptoms of hypersensitivity to cold and aggravate the problem.

Relationship with percent body fat

When categorized by the presence or absence of hypersensitivity to cold, there were no significant differences in physical characteristics such as height, body weight, percent body fat, and BMI between Group A and Group B among the bank employees (Table 1). However, among the female college

students, the percent body fat was significantly higher in Group A than in Group B. Since it was expected that body fat was related to skin blood flow and hypersensitivity to cold, the college students were divided into two groups on the basis of their percent body fat. Students who had a percent body fat of 22% or higher were placed in the higher percent body fat group (Group O), while those who had a percent body fat of less than 22% were placed in the lower percent body fat group (Group L). Four out of the 5 students in Group A belonged to the higher percent body fat group (Group O), while 4 out of the 5 students in Group B were categorized into the lower percent body fat group (Group L). When Group O (percent body fat, $26.1 \pm 3.5\%$) and Group L (percent body fat, $19.5 \pm 2.2\%$) were compared, the skin blood flow volume tended to be larger in Group L than in Group O, although there was no significant difference.

Nishimura et al. (1993) reported a relationship between percent body fat and skin blood flow in males. They observed that as the percent body fat increased, the skin temperature in the body trunk decreased, and conversely the peripheral skin temperature increased. They explained that body heat emissions were physically inhibited by subcutaneous fat in the body trunk but were promoted in the peripheral body areas by physiological blood flow regulation to maintain a temperature balance in the entire body.

The results of the present study tended to be contradictory to those in the report by Nishimura et al. (1993). Compared with the current study, the background of the subjects in the report by Nishimura et al. (1993) was different in that the percent body fat in Group O ($19.5 \pm 2.2\%$) was much higher than that in Group L ($10.7 \pm 6.3\%$) and all of their subjects were male, and therefore simple comparison is difficult.

Even under the same percent body fat conditions, fat distribution was reported to be markedly different among individuals (Saito and Tamura, 1994), and detailed data such as distribution of body fat are required to fully discuss the relationship between percent body fat and hypersensitivity to cold. For this reason, the relationship between percent body fat and hypersensitivity to cold was not fully discussed with the data of the current study.

Summary

As the working environment, such as the room temperature of an office, has been arranged to improve the health and safety of employees, it has become possible to work in a comfortable atmosphere. However, the amenities provided to bank and department store customers include a comfortable feeling at the entrance of the facility; since the body temperature of customers is elevated by the outdoor heat during the summer, banks and department stores are cooled to a lower temperature than necessary. According to a report on the temperature in buses and trains in metropolitan areas, a comfortable temperature was 23°C in some trains. The temperature was set at 24°C in the office of the bank examined in the present study, which was markedly low. The low temperature in the bank is

an amenity to customers coming in from the outdoors as previously described. Therefore, for employees working all day long in a low-temperature environment, it is expected that too much chilling will cause some physical problems. The results of this study support this expectation. Furthermore, it became clear that a cool workplace environment during the summer greatly affects employees with hypersensitivity to cold.

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