Field Measurements of Indoor Temperatures and Blood Pressure of Elderly Persons

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Abstract

Purpose / Context – To clarify the association between the indoor environment of residential buildings and cerebrovascular disease, an epidemiological survey of elderly persons living in three areas of Japan that have different rates of death due to cerebrovascular disease was conducted.

Methodology / Approach – This paper describes field measurements of indoor temperatures and blood pressure of 30 elderly persons during one year.

Results – In almost all houses in Japan, indoor temperature differences between a living room and non-heated spaces, such as the bedroom, corridors and lavatory, during heating times are large, and the indoor temperature at daybreak can be as low as the outdoor temperature.

Key Findings / Implications – The systolic blood pressure of elderly persons is positively associated with exposure to temperatures lower than 15°C.

Originality – The findings of this study will contribute to the knowledge regarding the association between the indoor thermal environment and health.

Keywords – Cerebrovascular disease, Indoor thermal environment, Blood pressure of elderly persons, Field measurement

Hasegawa, K. DOI: http://dx.doi.org/10.4225/50/58107c1c7e46e
HealthyHousing2016: Proceedings of the 7th International Conference on Energy and Environment of Residential Buildings, November 2016, edited by Miller, W., Susilawati, C. and Manley, K. Brisbane: Queensland University of Technology, Australia. DOI: http://dx.doi.org/10.4225/50/58107c8eb9c71

1. Introduction

The major causes of death for Japanese people are cancer, heart disease and cerebrovascular disease. The incidence rate of cerebrovascular disease in particular is higher during winter than summer. One possible reason for this seasonal difference is that exposure to cold temperatures can cause fluctuations in blood pressure. In houses with poor thermal insulation, indoor temperature differences between heated and non-heated spaces, such as the bedroom, corridors, and lavatory, can be large during winter. Many houses in the Tohoku region have a poor thermal environment during winter, and the incidence rate of cerebrovascular disease in this area is the highest compared to other areas in Japan.

To clarify the association between the indoor environment of residential buildings and cerebrovascular disease, an epidemiological survey of approximately 200 elderly persons living in Yamagata Prefecture in the Tohoku region of Japan was conducted. The specific areas investigated included three rural towns (Towns A, B and C). The demographics of these towns are shown in Table 1. The survey was divided into three phases. The first phase (Phase 1) was a cross-sectional questionnaire on housing characteristics related to the indoor thermal environment and occupants' lifestyle habits among 188 elderly persons. The second and final phases (Phase 2 and Phase 3) comprised field measurements of the indoor thermal environment and blood pressure of selected subjects from Phase 1. This paper describes the results obtained from indoor temperature and blood pressure measurements of 30 elderly persons during one year. An association between blood pressure and exposure to indoor temperatures in elderly persons in particular is analyzed statistically.

Table 1: Demographics of the towns in Yamagata Prefecture surveyed in the present study

Items	Town A	Town B	Town C
Population*1 (persons)	6,519	9,059	8,770
Number of households*1 (N)	1,904	2,330	2,311
Population density*1 (persons/km^2)	31.9	83.7	44.6
Number of elderly persons*1 (persons)	2,148	2,687	2,798
Rate of aging*1 (%)	32.9	29.6	31.9
Standardized mortality ratio*2 (%)	164.2	50.6	61.6

*1: Statistical data from 2014. *2: 3-year average (2011–2013).

2. Materials and Methods

2.1 Study design

This survey was divided into three phases, as shown in Figure 1. A preliminary survey was conducted before these phases to ask elderly residents if they would be willing to participate in subsequent surveys. Phase 1 was a cross-sectional questionnaire on housing characteristics related to the indoor thermal environment and occupants' lifestyle habits among 188 elderly persons. The second phase (Phase 2) was conducted over a week during winter, and included field measurements, measurements of indoor temperatures in a living room, bedroom, lavatory and other rooms, and home blood pressure measurements of 55 elderly persons. The final phase (Phase 3) included long-term field measurements of indoor and outdoor temperatures and home blood pressure measurements of 30 elderly persons. This paper presents the results from field measurements during the final phase and a statistical analysis of the results through Phase 3.

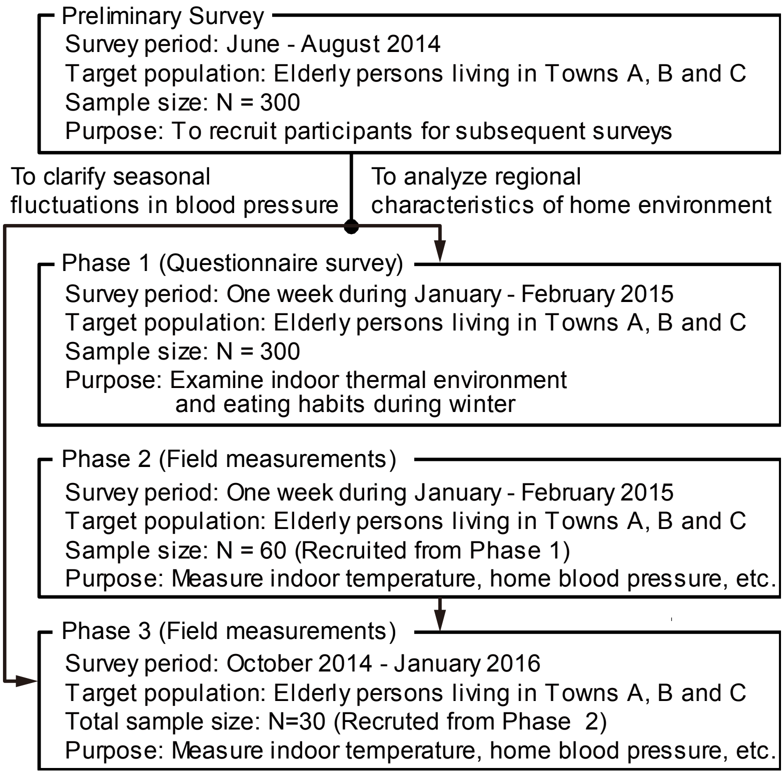


Figure 1 Flowchart of survey

2.2 Outline of field measurements in final phase

The final phase (Phase 3) included measurements of temperature and home blood pressure. A data logger with temperature and humidity sensors was used for the measurements of the indoor environment. At the beginning of long-term measurements, a data logger was placed near the center of the living room (1.1 m above the floor) in each house. Outdoor temperature and humidity were measured at one house in each area (i.e., Town A, Town B and Town C). The temperature and humidity were measured from October 2014 to January 2016 every 20 min during the measurement period. The subjects participating in the final phase measured blood pressure on their own using a blood pressure manometer. Participants recorded systolic blood pressure, diastolic blood pressure and pulse count every week during the measurement period. According to the guidelines for self-monitoring of blood pressure at home (The Japanese Society of Hypertension, 2011), the subjects measured their blood pressure within one hour after waking up and before going to bed every week.

2.3 Description of measured houses and subjects

Measurements were conducted in the houses of those who agreed to participate after the questionnaire survey in the first phase (n = 232). The measurements were conducted in 30 houses in three areas for at least one year. These 30 houses were detached houses with wood construction, and were inhabited by elderly person(s) more than 65 years old. Most of the houses lacked sufficient thermal insulation on the building envelopes. During winter, the heating equipment was operated intermittently, and the heating space was limited to just the living room.

Table 2 shows a description of the subjects that participated in the field measurement. Ten subjects from each area were included. There were more male than female subjects, and all subjects in Town B were male. The age of subjects ranged from 66 to 87 years; the median age was 71.5 years. Approximately one-third of the subjects were taking antihypertensive medication daily. These subjects had been diagnosed with hypertension by a medical doctor.

Table 2: Description of subjects in each survey area

No.	Town A			Town B			Town C		
	Sex	Age	Taking antihypertensive medication	Sex	Age	Taking antihypertensive medication	Sex	Age	Taking antihypertensive medication
1	Male	70	No	Male	73	Yes	Female	87	No
2	Female	82	Yes	Male	66	Yes	Female	67	Yes
3	Male	81	No	Male	68	Yes	Male	75	No
4	Male	81	Yes	Male	74	Yes	Male	68	No
5	Female	78	Yes	Male	67	No	Male	68	No
6	Male	71	No	Male	68	No	Male	74	No
7	Male	75	No	Male	70	No	Male	74	No
8	Male	79	No	Male	68	No	Female	75	Yes
9	Male	67	No	Male	75	No	Female	67	No
10	Male	71	Yes	Male	69	No	Male	72	Yes

3. Results and Discussion

3.1 Indoor temperature profile during heating season

An example (house of subject No.3 in Town A) of room temperature profiles during winter are presented in Figure 2. An unvented kerosene heater was used in the living room of this house. The room temperatures over a week during the heating season were averaged. The living room temperature at a point 1.1 m above the floor was maintained at approximately 18°C during the evening after supper. However, after the heater was turned off, the room temperature decreased rapidly, and was 5°C by daybreak. The living room temperature at a point 10 cm above the floor was approximately 6°C lower than the temperature at 1.1 m. The global temperature (i.e., radiant temperature) was approximately 1°C lower than the room temperature during the heating time. The temperatures of a bedroom, washroom and corridor remained between 2°C and 5°C throughout the day. The temperature differences between a living room and unheated spaces, such as the washroom during the evening after supper was approximately 20°C. The occupants living in this house were exposed to large temperature differences when moving to unheated spaces from the living room during the heating time.

3.2 Indoor temperature and blood pressure

Figure 3 presents the relationship between the systolic blood pressure of a subject (No. 5 in Town B) and the indoor temperature over the course of blood pressure measurements. These data were measured during the measurement period over one year. The systolic blood pressures within one hour after waking up and before going to bed are presented in this figure. The blood pressure within one hour after waking up ranged from 110 to 170 mmHg, and the blood pressure before going to bed was lower than 150 mmHg. These data indicate a morning surge in blood pressure. The systolic blood pressure tended to depend on the room temperature, even if it was in the morning. Furthermore, blood pressure greater than 160 mmHg was measured when subjects were exposed to temperatures less than 10°C.

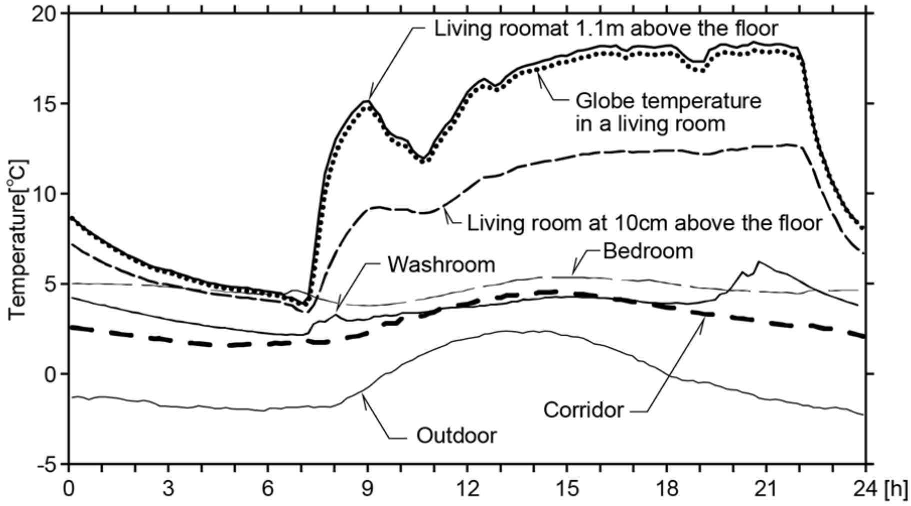


Figure 2 Indoor temperature profile of house of subject No. 3 in Town A

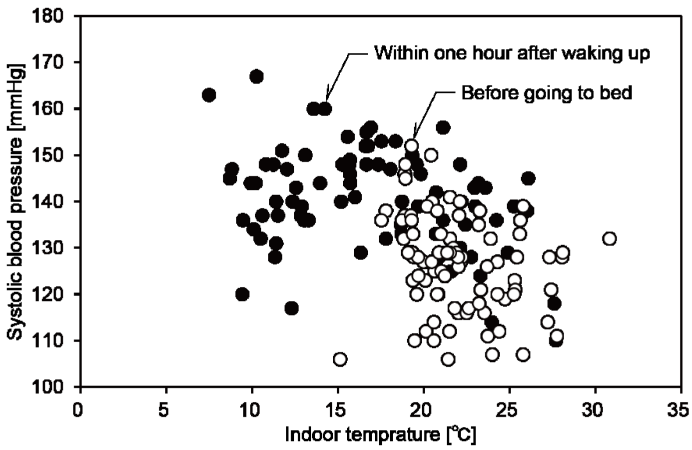


Figure 3 Indoor temperature and systolic blood pressure

3.3 Monthly profiles of systolic blood pressure

Figure 4 presents monthly profiles of systolic blood pressure in each town. The monthly data represent the median blood pressure for subjects in each town and all subjects for each month during the measurement period. A total of 30 values each month were used to calculate the median. There were seasonal changes in the median blood pressure of subjects from the three towns. The blood pressure tended to be higher during the heating season (i.e., from October to March) and lower during summer. The increased blood pressure during the heating season could be one of the risks for elderly persons to develop cerebrovascular disease. In general, the incidence rate of cerebrovascular disease was higher during winter than summer. In houses with poor thermal insulation, indoor temperature differences between heated and non-heated spaces are larger during winter, and occupants could be exposed to colder temperatures often even in indoor spaces.

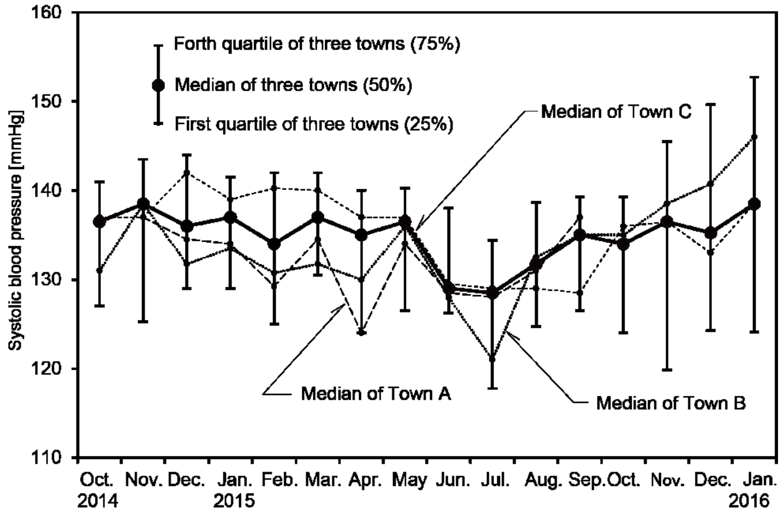


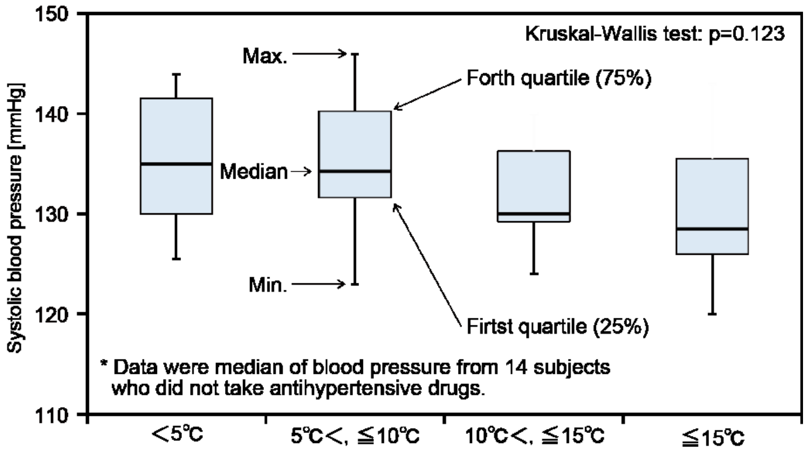
Figure 4 Monthly profiles of systolic blood pressure

3.4 Association between indoor temperature and blood pressure

Figures 5(a) and (b) present the statistical values of systolic blood pressure for outdoor and indoor temperature ranges, respectively. Both outdoor and indoor temperatures were classified into four ranges from below 5°C to more than 15°C, at intervals of 5°C. The values in every temperature range include the median systolic blood pressure from 14 subjects who were not taking antihypertensive medication.

For the outdoor temperatures, the median blood pressure was higher at lower temperature ranges. This tendency was not statistically significant, but supports the results of the monthly blood pressure profiles, as presented in Figure 4. On the other hand, for the indoor temperatures, the median blood pressure at indoor temperatures below 15°C was significantly higher than that at indoor temperatures over 15°C ($p<0.05$, Kruskal–Wallis test). The difference in systolic blood pressure between indoor temperatures below 10°C and over 15°C was 10 mmHg. Furthermore, median blood pressure increased to approximately 140 mmHg when elderly persons were exposed to indoor temperatures below 15°C. These results indicate that the systolic blood pressure of elderly persons is positively associated with exposure to temperatures lower than 15°C.

(a) Outdoor temperature range



(b) Indoor temperature range

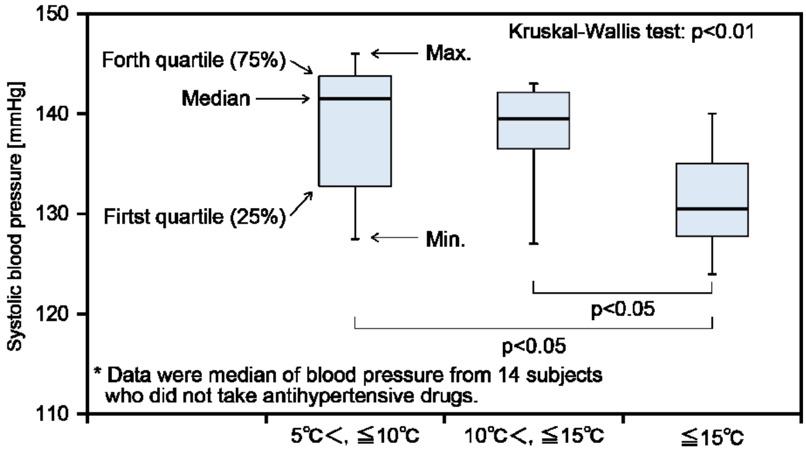


Figure 5 Systolic blood pressure at different temperatures

4. Conclusions

To clarify the association between the indoor environment of residential buildings and cerebrovascular disease, an epidemiological survey of elderly persons living in three areas of Japan that have different rates of death due to cerebrovascular disease was conducted. The survey was divided into three phases. This paper describes the results obtained from the final phase, which included field measurements of indoor temperatures and blood pressure of 30 elderly persons during one year. Results indicate that in most houses, indoor temperature differences between a living room and non-heated rooms, such as a bedroom, corridor and lavatory, during heating times are large, and that the indoor temperature at daybreak can be as low as the outdoor temperature. The systolic blood pressure of elderly persons was shown to be positively associated with exposure to temperatures lower than 15°C.

5. Acknowledgments

The authors would like to thank the residents who were involved in this study for their cooperation. This survey was supported partly by Grants-in-Aid for Scientific Research from the Ministry of Education, Culture, Sports, Science and Technology in Japan.

6. References

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