Study on Association Between Indoor Thermal Environment of Residential Buildings and Cerebrovascular Disease in a Cold Climatic Region of Japan

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Abstract

Purpose / Context - The aim of this study was to determine whether the quality of the indoor thermal environment during winter could increase the risk of cerebrovascular disease.

Methodology / Approach - An epidemiological survey of approximately 200 elderly persons living in a cold climatic region of Japan was conducted. The survey was divided into three phases, and the investigated areas were three rural towns with different rates of death due to cerebrovascular disease.

Results – Results indicate that feeling a draft in the living room while operating heating equipment and the style of bathtub were positively associated with an increased rate of death due to cerebrovascular disease. The bathroom with a traditional type bathtub tends to be cold, and its indoor thermal environment during winter is poor.

Key Findings / Implications – Poor quality of the indoor environment during winter could increase the risk of cerebrovascular disease.

Originality – The fidings of this study will contribute to accumulate the knowledges showing the associations between indoor thermal environment and health.

Keywords - Cerebrovascular disease, Indoor thermal environment, Questionnaire survey

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1. Introduction

According to statistical data reported by the Japanese government, 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 (UK Department of Health, 2009). 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 bathroom, corridors, and lavatory can be larger 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. Yoshino et al. (Hasegawa and Yoshino, 1985) investigated indoor themal environment in houses of Yamagata prefecture, which is included in Tohoku region, during heating season and the death rate of cerebrovascular disease in 1983 and 1984. As a result, the temperature difference between the heated living room and the unheated rooms was found to be great. Also it was revealed that If the lavatory temperature was low or the bedroom was not heated, the occupants living in such houses statistically tended to be susceptible to cerebral vascular accident.

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) and these areas are same as the investigated areas 30 years ago. 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. This paper describes the results obtained from this questionnaire and presents the characteristics of the indoor thermal environment and occupants' lifestyle habits during winter. Moreover, an association between the increase in rate of death due to cerebrovascular disease and factors that influenced the indoor environment of houses is examined using multivariable logistic regression analysis.

2. Materials and Methods

Table 1 presents the demographics of Towns A, B and C. These towns are located in Yamagata Prefecture, which has a population density of 120 persons/km^2 (2015). The rate of death in Town A due to cerebrovascular disease is approximately 1.6 times higher than the national average, and the rates in both Towns B and C are half of the national average. The heating degree days based on 18 ^{o}C of these areas is approximately 3,000, and the mean outdoor temperatures are –1 to 2 ^{o}C and 24 to 25 ^{o}C for January and August in Town A, B and C, respectively.

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).

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 the 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 the questionnaire survey and a statistical analysis of the results through Phase 1.

Table 2: Number of questionnaires distributed and response rate for Phase 1

Town	No. of distributed questionnaires (N)	No. of respondents (N)	Response (%)
A	99	78	78.8
B	33	32	97.0
C	100	78	78.0
Total	232	188	81.0

In Phase 1, which lasted from January to February 2015, questionnaires were distributed by mail to the 232 households that agreed to participate during the preliminary survey. The completed questionnaires were returned by post within 2 weeks. The total response rate for Phase 1 was 81.0%, as shown in Table 2. The self-reported questionnaire included questions on: (1) respondents' characteristics (gender, age, smoking status, occupation, etc.); (2) housing characteristics (housing location, housing type, finishing materials of building, frequency of heating equipment use, etc.); (3) indoor thermal environment during winter; and (4) indoor temperatures (measured using a liquid crystal thermometer for 1 week during the study period).

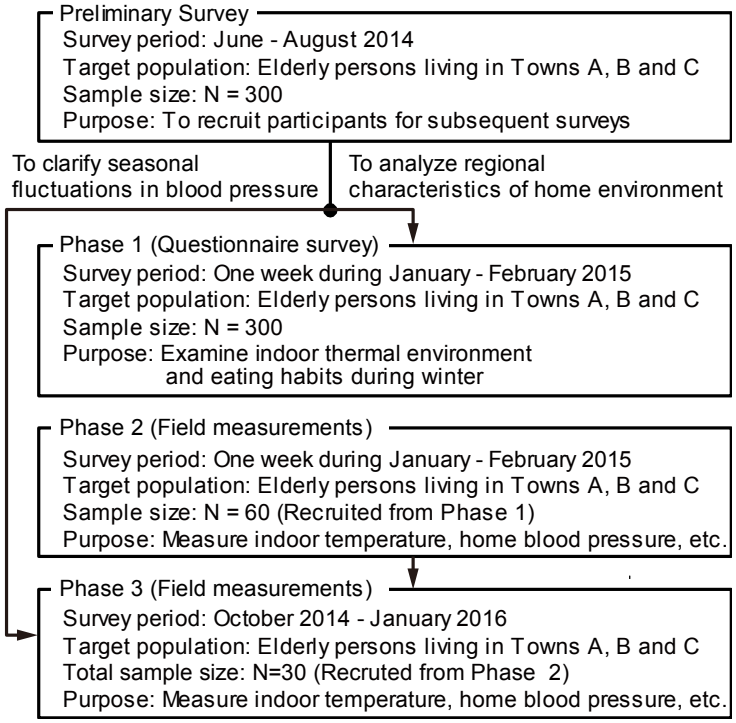

Figure 1 Flowchart of survey

Table 3 shows the characteristics of participants and houses in the three towns.

Male participants accounted for 73.1%, 81.3% and 20.5% of total participants in Towns A, B and C, respectively. There was a greater number of female participants in Town C.

Half of the respondents were in their 70s in Town A, 60s in Town C, and 80s in Town C. There was a clear difference in ages among the participants in the three towns.

Most of the participants in each area were not current smokers.

Approximately 30% of the houses in each area were built after 1990, and half of all of the houses were built between 1965 and 1990. Approximately 82.1% and 78.2% of building envelopes in Towns A and C, respectively, had thermal insulation. Based on the time the houses in these towns were constructed, the thermal performance of the buildings was judged to be low. A single window with a single pane of glass was a popular characteristic of homes, with approximately 60% of the houses in each area having this style of window.

Vented kerosene heaters were used in more than 20% of houses in each area. However, an un-vented kerosene heater was still being used in nearly 60% of houses. Of all respondents in Towns A and C, 16% used air-conditioning units for space heating during the winter. Use of an electric ‘kotatsu’ heater is very popular in the towns studied, and approximately 30% of respondents used this type of heater in combination with a space heater. The electric ‘kotatsu’ heater uses a heating element mounted under a low table that is covered with a quilt.

Heated toilet seats are also very popular in Japan, and most of the respondents reported using one during the study period.

More half of participants in Town A and B felt slightly cold when they moved to the bathroom from the living room where was heated. Approximatly 40% participants in Town C felt slightly cold. Participants felt neutral were more in Town C than Town A and B.

33.3% of participants in Town A were < 1.00 clo and they were thinly dressed compared to Town B and C.

Table 3: Characteristics of participants and houses in the three towns included in the study

Items	Town A [N=78]	Town B [N=32]	Town C [N=78]
Gender of respondents			
Male	57 (73.1)	26 (81.3)	17 (20.5)
Female	20 (25.6)	6 (18.8)	66 (79.5)
Age of respondents			
60s	22 (28.2)	18 (56.3)	10 (12.0)
70s	39 (50.0)	9 (28.1)	30 (36.1)
80s	15 (19.2)	4 (12.5)	43 (51.8)
≥90	2 (2.6)	1 (3.1)	0 (0.0)
Smoking status of respondents			
Yes	5 (6.4)	4 (12.5)	2 (2.4)
No	71 (91.0)	27 (85.4)	81 (97.6)
When house was constructed			
Before 1965	7 (9.6)	3 (7.4)	14 (18.2)
1965–1990	44 (57.1)	19 (61.3)	34 (43.6)
After 1990	26 (33.3)	10 (31.3)	27 (34.6)
Thermal insulation			
Yes	64 (82.1)	25 (78.1)	61 (78.2)
No	13 (16.7)	6 (18.1)	16 (20.5)
Window style			
Single pane	46 (59.0)	21 (65.6)	47 (60.3)
Double pane	31 (39.7)	9 (28.1)	29 (37.2)
Triple pane	1 (1.3)	0 (0.0)	1 (1.3)
Heating equipment in living room			
Vented heater	18 (23.4)	8 (25.8)	17 (21.7)
Unvented heater	51 (66.2)	20 (64.5)	50 (64.1)
Electric *kotatsu*	28 (36.4)	9 (29.0)	22 (28.2)
Air conditioner	13 (16.9)	2 (6.5)	13 (16.7)
Use of a heated toilet seat			
Yes	72 (92.3)	26 (84.4)	70 (91.0)
No	6 (7.7)	5 (15.6)	7 (9.0)
Thermal sensation when moving the living room to the bathroom			
Neutral	23 (29.5)	5 (15.6)	27 (34.6)
Slightly cold	50 (64.1)	17 (53.1)	30 (38.5)
Cold	8 (10.3)	7 (21.9)	16 (20.5)
Clothing when staying at home			
> 1.25 clo	5 (6.4)	7 (21.9)	13 (16.7)
1.00 – 1.25 clo	45 (57.7)	18 (56.3)	47 (60.2)
< 1.00 clo	26 (33.3)	5 (15.6)	14 (17.9)

3. Results and Discussion

The association between different rates of death due to cerebrovascular disease and indoor environmental factors and occupants' eating habits in the investigated areas is presented in Fig. 2(a–d). These figures present the proportions for each answer to questions regarding the quality of the indoor environment and eating habits according to the three investigated towns. The rate of death due to cerebrovascular disease in Town A was higher than the rates in the other towns, and factors that influenced the rate of death due to cerebrovascular disease were expected to be revealed by comparing the house characteristics and occupants' living habits between each area. Regarding the style of bathtub, a greater number of traditional style bathtubs were used in Town A than in Towns B and C (Fig. 2(a)). There was also a higher frequency of feeling a draft in the living room during the winter in Town A (Fig. 2(b)). Approximately 60% of participants felt some draft in the living room. More participants in Town C did not drink alcohol during the week than in Towns A and B (Fig. 2(c)). This is likely because of the higher number of female participants in Town C (approximately 80%). A high salt diet may contribute to high blood pressure and could therefore cause the onset of cerebrovascular disease. Many Japanese people customarily have ‘miso’ soup with every meal, and ‘miso’, a traditional Japanese seasoning made from soybeans, has a high salt content. The ratio of participants having ‘miso’ soup two or three times a day was the highest in Town A. These eating habits may increase the risk of death due to cerebrovascular disease.

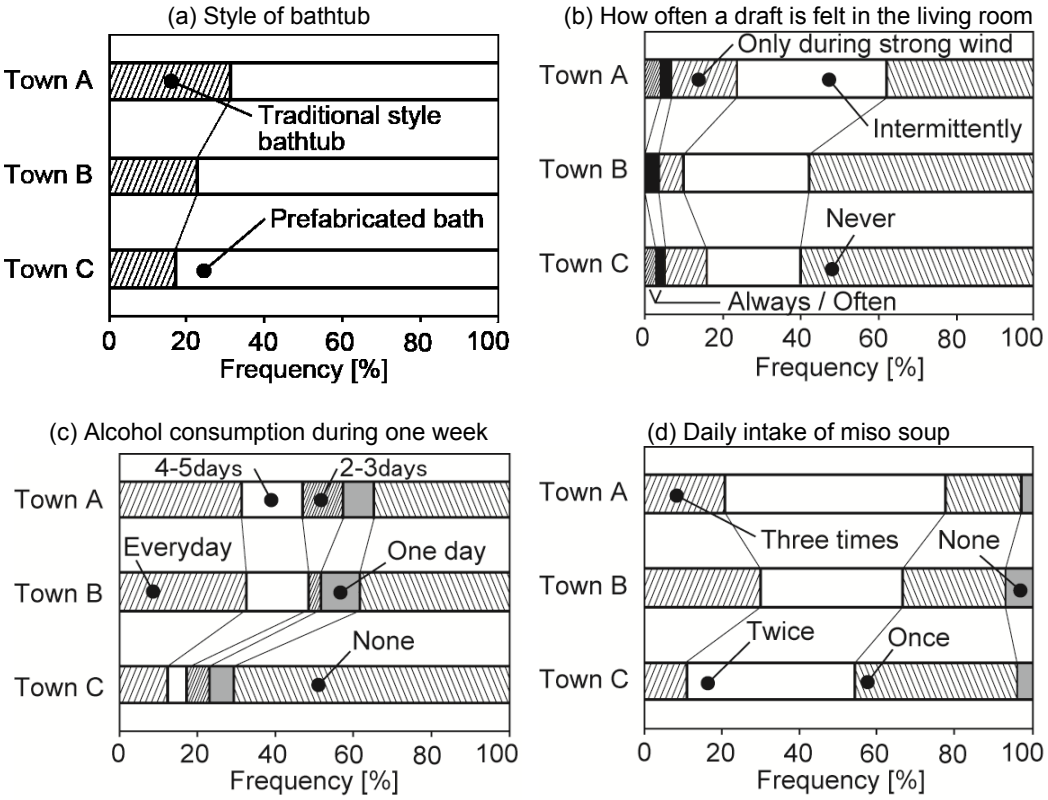

Figure 2 Proportions for each answer to questions regarding the quality of the indoor environment and eating habits (a) Style of bathtub, (b) How often a draft is felt in the living room, (c) Alcohol consumption during one week, (d) Daily intake of *miso* soup

Table 4: Adjusted ORs for Town A, which has a death rate higher than the national average

Items	Frequency	Adjusted OR[a]		95% CI
Style of bathtub				
Prefabricated bath	107	1.00		-
Traditional style bathtub	32	4.85***		1.48–15.94
How often a draft is felt in the living room				
Never	74	1.00		-
Intermittently	44	8.74***		1.68–45.57
Only during strong wind	21	5.78***		1.83–18.29
Daily intake of *miso* soup				
Once	50	1.00		-
Twice	67	3.86		0.83–18.01
Three times	22	2.57		0.90–7.35
Thermal sensation when moving from the living room to the bath-room during winter				
Neutral	47	1.00		-
Slightly cold	73	0.97		0.20–4.62
Cold	19	0.23**		0.07–0.76
Clothing when staying at home				
>1.25 clo	16	1.00		-
1.00–1.25 clo	87	6.78**		1.10–42.01
<1.00 clo	36	7.15**		1.36–37.69

[a] Adjusted by age and gender. ** P<0.05; *** P<0.01. CI = Confidence interval.

The association between the difference in the rate of death due to cerebrovascular disease (Towns A and C) and factors related to the quality of the indoor thermal environment and occupants' living habit was estimated using multivariate logistic regression analysis with adjustment for age and gender of participants. Adjusted odds ratios (ORs) were estimated including the 95% confidence interval (CI). Potential risk factors with a significance level of $P < 0.2$ in the single regression analysis were included in a stepwise logistic regression analysis to identify independent risk factors for significant indoor environmental conditions. Data were analyzed using the Statistical Package for the Social Sciences (SPSS, version 23).

The adjusted ORs for Town A are presented in Table 4. The adjusted OR for a traditional style bathtub (OR = 4.85, 95% CI = 1.48–15.94) was statistically significant for Town A, which had a high rate of death due to cerebrovascular disease. Bathrooms with a prefabricated bath tend to be well insulated thermally. On the other hand, houses with a traditional style bathtub are usually old, and their indoor thermal environment during winter is poor. The adjusted ORs for feeling a draft both intermittently and when a strong wind is blowing (OR = 8.74 and 5.78, $P < 0.01$) were significant for Town A. These results indicate that a poor indoor thermal environment may contribute to an increase in the rate of death due to cerebrovascular disease. A high salt diet may contribute to the onset of cerebrovascular disease. However this statistical model doesn't present the significant associations with daily intake of '*miso*' soup. When participants moved from a living room to a bathroom during winter, they reported feeling thermal sensations, such as 'warm', 'neutral' and 'cold'. The adjusted OR for 'cold' when entering a bathroom (OR = 0.23, 95% CI = 0.07–0.76) was significant for Town A. These results indicate that participants in Town A did not feel cold, although the temperatures of bathrooms in Town A (average: 8.1°C, standard deviation: 4.2°C, maximum: 17.9 °C, minimum: 2.0 °C) and Town C (average: 7.8°C, standard deviation: 3.1°C, maximum: 20.0 °C, minimum: 3.1 °C) were similar. The adjusted OR for light clothing when staying at

home was significant for Town A. Participant in Town A were thiny dressed during heating season. Therofore they may be more readily exposed to a cold indoor environment than those in Town C.

4. Conclusions

To clarify the association between the indoor environment of residential buildings and cerebrovascular disease, an epidemiological survey of 188 elderly persons living in three areas of Japan that have different rates of death due to cerebrovascular disease was conducted. Results indicate that feeling a draft in the living room while operating heating equipment and the style of bathtub were positively associated with an increased rate of death due to cerebrovascular disease. The bathroom with a traditional type bathtub tends to be cold, and its indoor thermal environment during winter is poor. This poor quality of the indoor environment during winter could increase the risk of cerebrovascular disease.

5. Acknowledgement

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