Intervention Study of Home Insulation Retrofit and Blood Pressure for the Prevention of Cardiovascular Diseases

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Intervention Study of Home Insulation Retrofit and Blood Pressure for the Prevention of Cardiovascular Diseases

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Abstract of Ph.D. Dissertation

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Cardiovascular diseases (CVDs), the world's leading cause of death, cause 17.9 million deaths each year. Mortality due to CVDs rises in winter, a phenomenon known as "Excess winter mortality (EWM)". The rise is especially sharp in cold homes. EWM is partially explained by cold exposure-induced hypertension. Nevertheless, existing countermeasures for the prevention of hypertension and CVDs place emphasis only on improving lifestyle habits. While diet, physical activity, alcohol consumption, and smoking are included in existing policies, housing environment is not because the scientific evidence is insufficient. Therefore, we aim to examine the preventive effects of improving housing environment on the incidence of CVDs. In particular, this study focuses on the relationship between thermal environment inside houses and blood pressure, which is a widely used risk factor for CVDs. This dissertation consists of the 8 chapters summarized below.

Chapter 1 describes the background, motivations and objectives of the study.

Chapter 2 summarizes domestic and foreign policies and previous research on housing and health.

Chapter 3 introduces the field surveys which became the basis of the nationwide survey in the next chapter. The results from the field surveys reveal 1) the impact of bedroom temperature on blood pressure variability in the early morning, and 2) the causal correlation between a rise in room temperature and a drop in blood pressure when subjects moved to houses with high thermal insulation. Issues associated with implementing the nationwide survey are summarized according to these results.

Chapter 4 outlines the before-and-after insulation retrofit surveys conducted throughout Japan (SWH survey: Smart Wellness Housing survey). The research question, study design, intervention, and measurement items are described, and the ethical issues and online registration are summarized. Furthermore, the number of participants and baseline characteristics of participants are summarized.

Chapter 5 describes findings on 1) the relationship between home blood pressure and room temperature, and 2) the sensitivity of home blood pressure to changes in room temperature, obtained in the baseline survey (before insulation retrofit). In addition, the nationwide survey was used to identify the areas with low indoor temperatures and the attributes of the residents who live in cold homes.

Chapter 6 describes the results of comparative analysis between the "insulation retrofit group" and the "control group". The results were used to determine the causal relationship between a drop in blood pressure and insulation retrofit intervention.

Chapter 7 shows the results of comparative analysis of health exam data between warm houses (indoor temperature ≥18°C) and cold houses (indoor temperature <18°C). A cross-sectional analysis is used to examine whether the risk of "arteriosclerosis" and "electrocardiogram abnormality", indices strongly related to CVDs, increases in cold houses.

Chapter 8 summarizes the achievements of the present research. In addition, this chapter suggests the need to verify the long-term health effects of housing environment using a long-term cohort study.

論文要旨

－循環器疾患の予防に向けた
住宅の断熱改修と家庭血圧の関連に関する介入研究－

循環器疾患は、毎年約 1,790 万人が命を落とす世界の死因第一位の病である。循環器疾患による死亡は冬季に増加し、「Excess Winter Mortality (EWM)」と称される。EWM は特に寒冷な住宅で顕著であり、寒冷への曝露に伴う血圧上昇によりその一部が説明できる。にもかかわらず、現状の高血圧及び循環器疾患対策は生活習慣改善のみに重点が置かれている。食事や運動、飲酒、喫煙の対策は政策に取り入れられている一方で、科学的エビデンスが不足している住環境は取り入れられていない。従って、住環境改善による循環器疾患予防効果を検証することを本研究の目的とする。特に循環器疾患の危険因子とされ、測定が広く普及している「血圧」に焦点を当て、「住宅内温熱環境と血圧の関係」の分析を行う。本論文は、以下に示す全 8 章から構成される。

第 1 章では、序論として、本研究の背景と意義、目的を示す。

第 2 章では、住宅と健康に関する国内外の政策及び先行研究についてまとめる。

第 3 章では、第 4 章以降の全国調査のベースとなった実態調査を紹介する。結果の一部として、1) 寝室の室温が早朝血圧変動に及ぼす影響、2) 高断熱住宅への転居による室温上昇と血圧低下の因果関係、の 2 点に触れ、全国調査を実施するにあたっての課題点を整理する。

第 4 章では、日本全国で実施した住宅の断熱改修前後調査（スマートウェルネス住宅研究）の概要を述べる。リサーチクエスチョン、調査デザイン、介入内容、調査項目について解説するとともに、倫理的問題、調査のオンライン登録について触れる。更に、調査対象者数並びにベースライン調査時点の調査対象者の属性を整理する。

第 5 章では、断熱改修前のベースライン調査から得られた成果である、1) 家庭血圧と室温の関係、2) 室温変化に対する家庭血圧の感度分析、の 2 点をまとめる。加えて、全国調査の強みを活かし、寒冷な住宅で暮らしている地域や居住者の属性（ハイリスク居住者）を明らかにする。

第 6 章では、断熱改修を行った「断熱改修群（介入群）」と、断熱改修を行わなかった「対照群」の比較分析により、断熱改修の介入による血圧低下の因果関係の検証を行う。

第 7 章では、温暖な住宅（室温 18℃以上）と寒冷な住宅（室温 18℃未満）の比較分析を行い、健康診断データから得られた循環器疾患との関連が強い指標である「動脈硬化」や「心電図の異常」が寒冷な住宅で助長されるのか、を断面分析により検討する。

第 8 章では、本研究の成果を総括するとともに、長期コホートスタディにより、住環境による健康影響を長期的な視点で検証する必要性を述べる。

Intervention Study of Home Insulation Retrofit and Blood Pressure for the Prevention of Cardiovascular Diseases

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Abbreviations

General terms

ABPM	Ambulatory blood pressure monitoring
AIC	Akaike's information criterion
ANCOVA	Analysis of covariance
BMI	Body mass index
BP	Blood pressure
CAD	Coronary artery disease
CBP	Clinic blood pressure
CI	Confidence interval
CV	Coefficient of variation
CVD	Cardiovascular disease
DBP	Diastolic blood pressure
EWM	Excess winter mortality
HBP	Home blood pressure
HDBP	Home diastolic blood pressure
HDD	Heating degree-day
HDL	High-density lipoprotein
HR	Hazard ratio
HSBP	Home systolic blood pressure
IHD	Ischemic heart disease
LDL	Low-density lipoprotein
RCT	Randomized control trial
RH	Relative humidity
SBP	Systolic blood pressure
SD	Standard deviation
SE	Standard error
$Temp_{Br}$	Bedroom temperature
$Temp_{Cr}$	Changing room temperature
$Temp_{Lr}$	Living room temperature
$Temp_{In}$	Indoor temperature
$Temp_{Out}$	Outdoor temperature
ΔTemp	Temperature disparity between the living room and bedroom

Proper nouns

ACC	American College of Cardiology
AHA	American Heart Association
BRE	Building Research Establishment
CASBEE	Comprehensive Assessment System for Built Environment Efficiency
CWP	Cold Weather Plan
ESC	European Society of Cardiology
ESH	European Society of Hypertension
HHI	Healthy Housing Index
HHSRS	Housing Health and Safety Rating System
ICMJE	International Committee of Medical Journal Editors
ISH	International Society of Hypertension
JNC	Joint National Committee on Detection, Evaluation, and Treatment of High Blood Pressure
JSBC	Japan Sustainable Building Consortium
MLIT	Ministry of Land, Infrastructure, Transport and Tourism
MHLW	Ministry of Health, Labour and Welfare
NICE	National Institute for Health and Clinical Excellence
SWH	Smart Wellness Housing
USA	United States of America
UK	United Kingdom
WHO	World Health Organization
WUNZ:HS	Warm Up New Zealand: Heat Smart

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Those senior to me in the Ikaga Laboratory, who have already graduated, provided me with guidance regarding general laboratory activities and ways to advance my research from the time I joined the laboratory. In particular, my seniors on the research team, Mr. Takashi Shinozuka, Ms. Reina Yamamoto, and Ms. Mai Miura supported my research activities and laboratory life in every way. I am where I am today thanks to them. I would like to extend my gratitude to them all.

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Finally, I would like to extend my appreciation to my father, my mother, and my brother for warmly looking after me while I spent my days completing this research. I will never forget how you listened to me when I expressed that “I wanted to aim for a doctorate, while continuing to work in the company,” the positivity with which you discussed how to realize this with me, and how you worried about my health. I hope to show this feeling of appreciation not just in words, but also in my actions.

Although still in progress, I want to report here, along with my appreciation and gratitude to all associated personnel, that I have completed my doctoral dissertation. I intend to devote myself in the future, with new conviction, to reducing as many health injuries and accidental deaths in the household as possible.

February 13, 2019

Chapter 1

Introduction

1.1 Efforts to prevent cardiovascular diseases and hypertension around the world

Cardiovascular diseases (CVDs) are the number one cause of death globally [1] (Fig.1-1). An estimated 17.9 million people died from CVDs in 2016, representing 31% of all global deaths. Of these deaths, 85% were due to heart attack and stroke [2]. Estimations predict that deaths due to CVDs will increase to 23.6 million in 2030 [3], making prevention of CVDs an urgent issue.

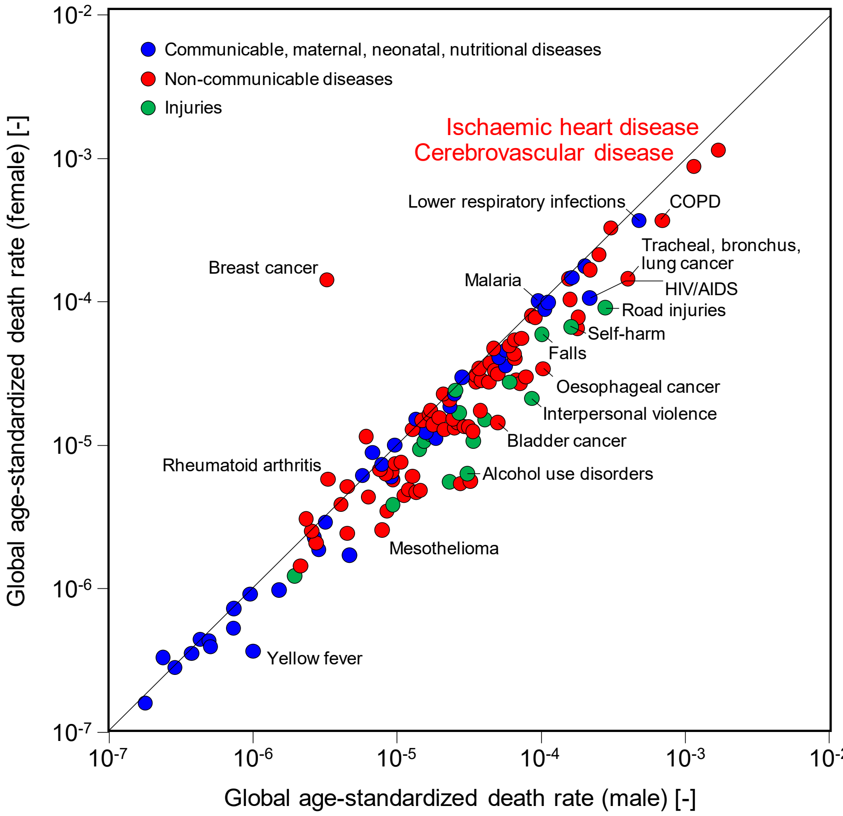
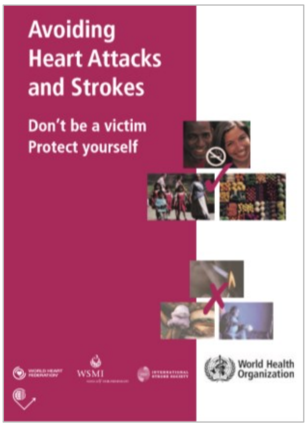
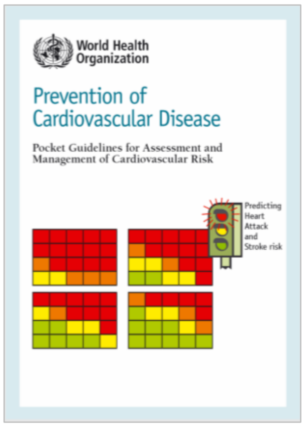
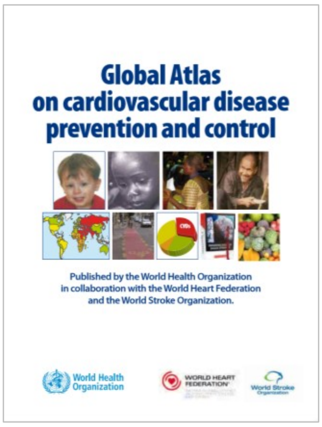
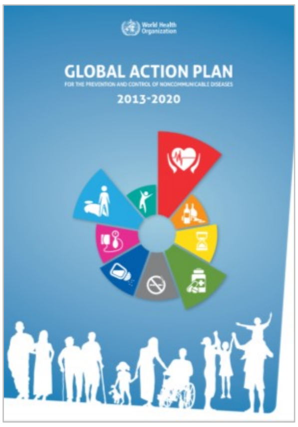


Fig.1-1 | Global age-standardized death rates for males versus females, 2015 [1]

The World Health Organization (WHO) has issued various reports on the prevention of CVDs (Table 1-1). These reports highlight four important risk factors for CVDs: (1) unhealthy diet, (2) physical inactivity, (3) tobacco use, and (4) harmful use of alcohol. These inappropriate lifestyle habits cause four intermediate risk factors: (1) hypertension (increase in blood pressure), (2) diabetes (increase in blood glucose level), (3) hyperlipidemia (increase in blood lipids), and (4) obesity (increase in body weight), which lead to CVDs. Based on these risk factors, the WHO depicted the 10-year probability of onset of CVDs in a risk chart (Fig.1-2). Additionally, in 2016, WHO launched the "Global Hearts Initiative" and campaigns to promote changes to improve lifestyle habits such as reducing salt intake (SHAKE [4]) and improving smoking habit (MPOWER [5]).

Table 1-1 | Publications focusing on prevention of cardiovascular diseases by WHO

Integrated management of cardiovascular risk [6]	Avoiding heart attacks and strokes [7]	Prevention of cardiovascular disease [8]
		
Global atlas on cardiovascular disease prevention and control [9]	Global action plan for the prevention and control of NCDs 2013−2020 [10]	Global status report on noncommunicable diseases 2014 [11]
		

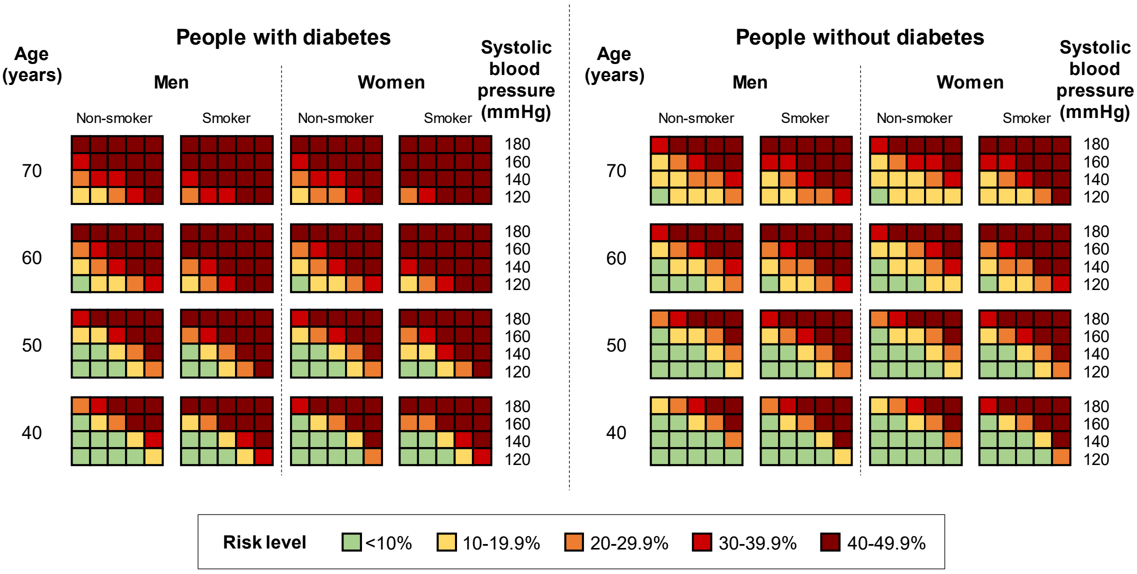


Fig.1-2 | WHO and ISH cardiovascular risk prediction chart [8]

Our knowledge of the risks associated with CVDs has improved following advances from early research methods. In particular, the Framingham Heart Study [12], launched in 1948 in the town of Framingham, Massachusetts, in the eastern United States, is considered the pioneer study in cardiovascular clinical epidemiology around the world. The study aimed to prevent CVD, which accounted for 80% of deaths in the United States at the time. It was the first study to bring epidemiology, which was then regarded as an infectious disease research method, to the field of CVD. This study is widely regarded as a representative epidemiological research study, and halved the incidence of CVD in the United States in 30 years as a result of pursuing the cause of coronary heart disease. Findings from this research are the basis for the reports in Table 1-1 and the development of the risk chart for CVDs in Fig.1-2.

The Framingham Heart Study set the following 11 hypotheses [13]: 1) coronary heart disease increases with age and occurs earlier and more frequently in males; 2) persons with hypertension develop coronary heart disease at a greater rate than those who are normotensive; 3) elevated blood cholesterol level is associated with an increased risk of coronary heart disease; 4) tobacco smoking is associated with an increased occurrence of coronary heart disease; 5) habitual use of alcohol is associated with increased incidence of coronary heart disease; 6) increased physical activity is associated with decreased development of coronary heart disease; 7) an increase in thyroid function is associated with decreased development of coronary heart disease; 8) a high blood hemoglobin or hematocrit level is associated with an increased rate of developing coronary heart disease; 9) an increase in body weight predisposes a person to coronary heart disease; 10) the rate of development of coronary heart disease is increased in patients with diabetes mellitus; and 11) the incidence of coronary heart disease is increased in patients with gout. By proving these hypotheses, the study identified the risk factors of CVD, including age, high blood pressure, high cholesterol, and tobacco smoking.

The relationship between CVD and high blood pressure based on 61 prospective observational studies, including the Framingham Heart Study, is summarized in Fig.1-3. These studies indicate that high systolic blood pressure is associated with a high incidence of stroke and ischemic heart disease [14].

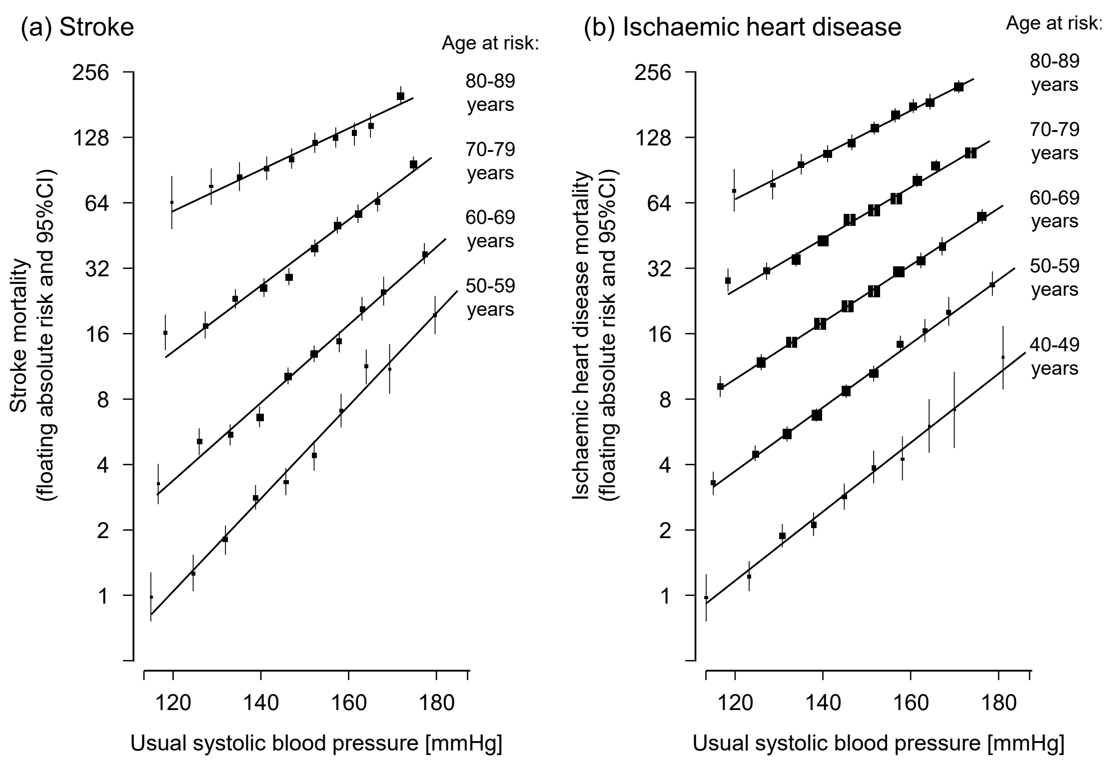


Fig.1-3 | (a) Stroke mortality rate in each decade of age versus usual SBP. (b) Ischaemic heart disease mortality rate in each decade of age versus usual SBP [14]

Among the four intermediate risk factors for CVDs (hypertension, diabetes, hyperlipidemia and obesity) identified in these previous studies, management of hypertension is considered the most important for preventing CVDs. Accordingly, WHO has released an independent report on the prevention of hypertension [15]. This report highlights the main factors contributing to the development of high blood pressure, with "housing" identified as a social factor. However, housing was absolutely treated as "hotbeds of inappropriate lifestyles," and its direct impact on high blood pressure has not been demonstrated (Fig.1-4).

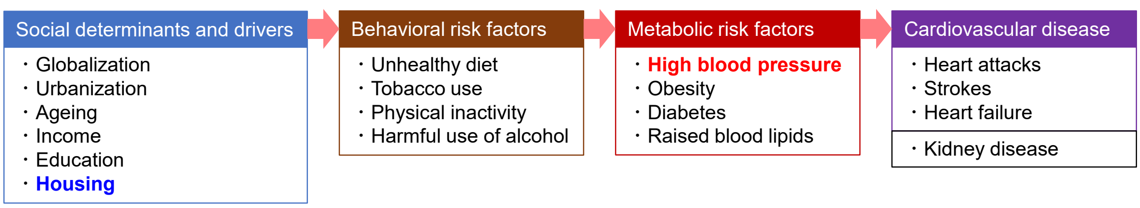


Fig.1-4 | Main factors that contribute to the development of high BP and its complications [15]

1.2 Efforts to prevent cardiovascular diseases and hypertension in Japan

1.2.1 Medical and nursing care financial crisis

Japan is one of the first countries to be confronted with the problems associated with an aging population. The number of people aged 65 years or older reached a record 34.59 million, or 27.3%, among a total population of 126.93 million in 2016. The proportion of people aged 65 years or older was 1 in 10 in 1985, 1 in 4 in 2010, and is estimated to increase to 1 in 2.5 in 2060 [16] (Fig.1-5).

As a consequence of this increase, medical and nursing care expenditure are also increasing, causing severe strain on government finances. Medical and nursing care expenses reached 37 and 8 trillion yen in 2010, and are expected to double to 68 trillion yen and triple to 24 trillion yen, respectively, by 2025 [17−19] (Fig.1-6).

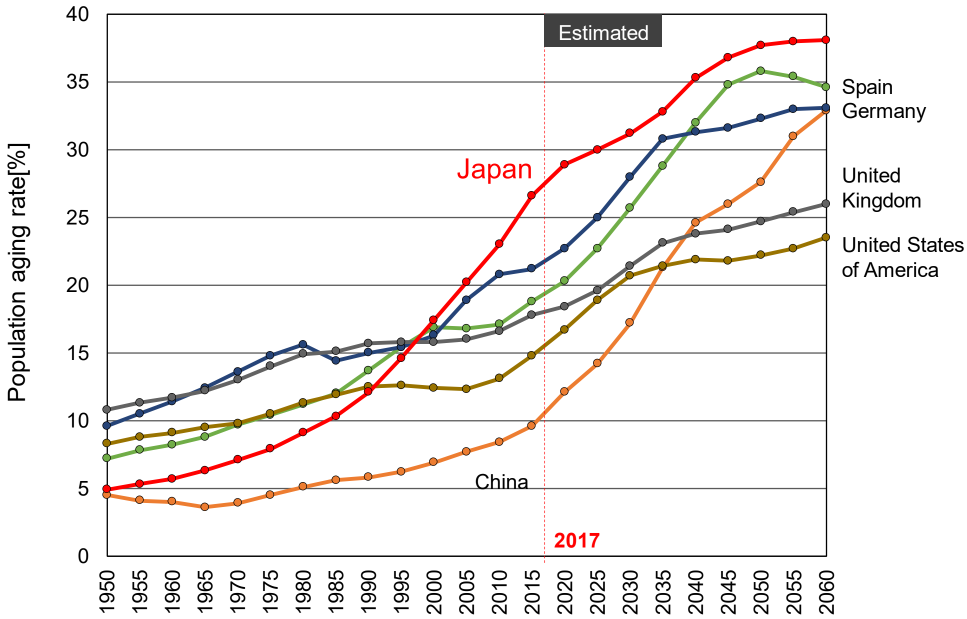


Fig.1-5 | Aging rate of countries around the world (graphed using data from [16])

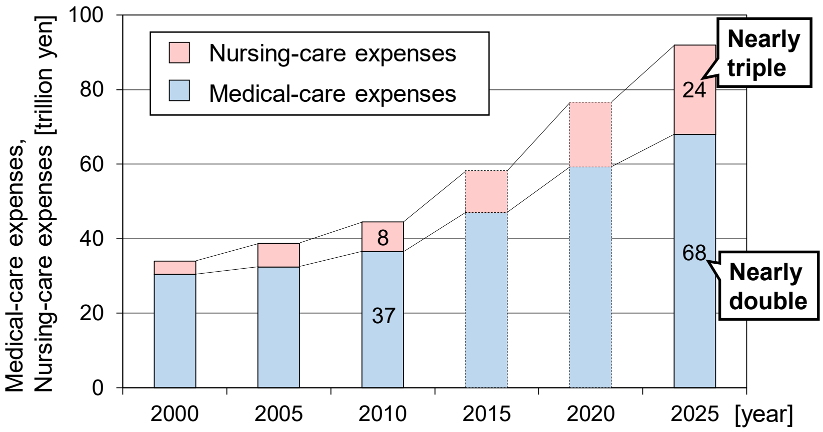


Fig.1-6 | Prospects for medical and nursing care expenses in Japan (translated from [19])

Factors associated with the medical and nursing care financial crisis can be identified by breaking down medical costs reported in yearly surveys conducted by the Ministry of Health, Labour and Welfare by age and disease (Fig.1-7). According to these surveys, the proportion of costs due to CVDs is the largest among people aged 65 years or older, accounting for about a quarter of total medical expenditure [20]. There is therefore concern that medical expenses will increase as the aging population rises. Meanwhile, cerebrovascular disease and heart disease were the second and sixth most prevalent among diseases that cause patients to require nursing care, respectively. Moreover, among cases of dementia, the most prevalent disease to cause patients to require nursing care, 30% were caused by cerebrovascular disease (Fig.1-8). These findings indicate that CVDs account for more than a quarter of nursing care cases [21, 22]. Therefore, as suggested above, an effective measure for the prevention of CVDs is needed to reduce these expenditures.

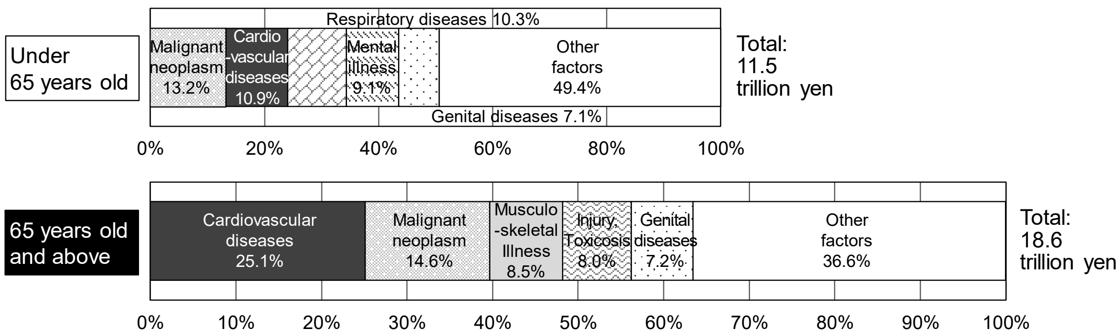


Fig.1-7 | Breakdown of medical costs by age and disease (translated from [20])

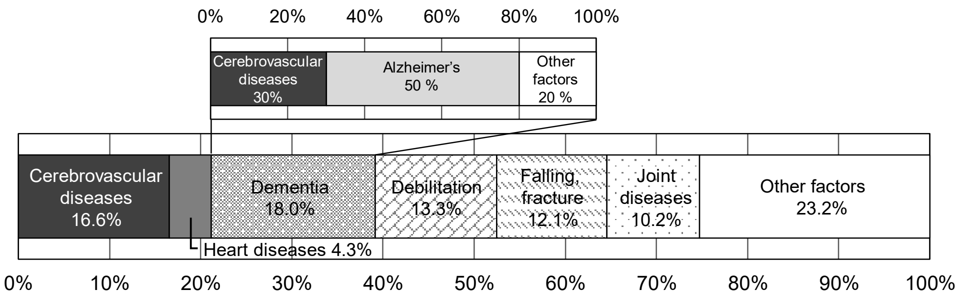


Fig.1-8 | Breakdown of diseases that cause patients to require nursing care (modified and translated from [21, 22])

Several studies have identified the risk factors for CVDs in Japan, which include hypertension, diabetes, hyperlipidemia and tobacco smoking [23]. Among these, hypertension has the greatest population-attributable risk ratio for the onset of CVDs and death from CVDs [23−25]. This suggests that prevention of hypertension will lead to a reduction in the risk of death due to CVDs. Some of the studies that have verified the relationship between CVDs and hypertension in Japan are summarized below.

(1) Hisayama Study

The Hisayama Study began with the aim of clarifying the actual state of stroke, which was the leading cause of death in Japan in 1961 [26]. A prospective cohort survey was conducted in residents over 40 years old in the town of Hisayama, Kasaya-gun, adjacent to Fukuoka City. The study is characterized by a high follow-up accuracy, with a participation rate of 99% in the cohort survey. Analysis of data from 588 males and females aged over 60 years who were followed for 32 years suggested that high blood pressure was associated with a higher incidence of stroke, even after adjusting for gender and age [27] (Fig.1-9).

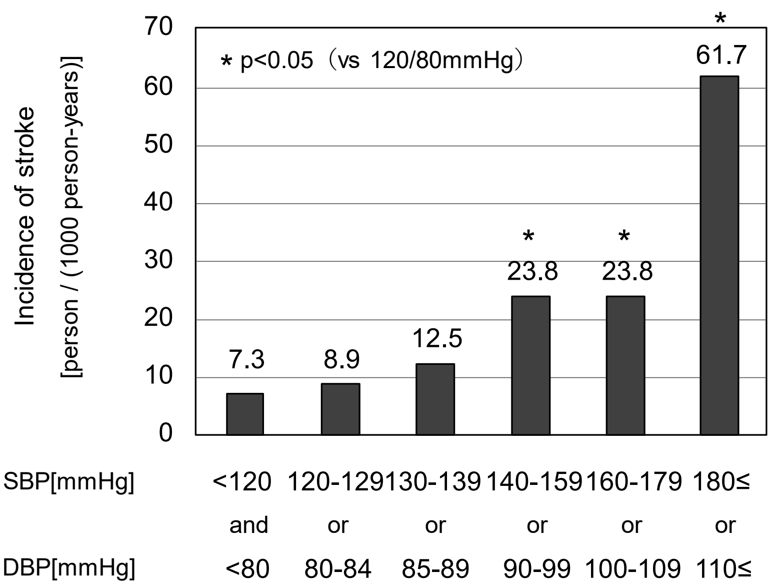


Fig.1-9 | Age- and sex-adjusted incidence of stroke by type according to BP category [27]

(2) Ohasama Study

The Ohasama Study was a prospective cohort study started in 1986 on hypertension and CVDs in residents in the town of Ohasama, Iwate Prefecture [28]. It was the world's first epidemiological study to use blood pressure indices obtained in non-medical environments, such as 24-hour ambulatory blood pressure and home blood pressure (self-measured blood pressure at home). These results based on ambulatory blood pressure in 1,500 people and home blood pressure in 2,000 people over the age of 40 years were recognized globally. The study was cited in a description on the clinical significance of ambulatory blood pressure and home blood pressure in “The Sixth Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure [29]” in 1997, the “1999 WHO/ISH Guidelines for the Management of Hypertension [30]” and the “2003 ESH - ESC guidelines for the management of arterial hypertension [31].”

(3) NIPPON DATA

NIPPON DATA 80 was a follow-up study of subjects of the Third National Survey on Circulatory Disorders, conducted in 1980. It examined the relationship between the risk factors for CVD and the risk of death. Similarly, NIPPON DATA 90 was a follow-up study of subjects of the Fourth National Survey on Circulatory Disorders, conducted in 1990 [32]. NIPPON DATA 80 followed 9,638 men and women for 19 years, and their data were used to develop risk assessment charts of the 10-year probability of death due to coronary heart disease, stroke and CVD. These risk charts have been released as a health education tool to improve lifestyle habits [33] (Fig.1-10).

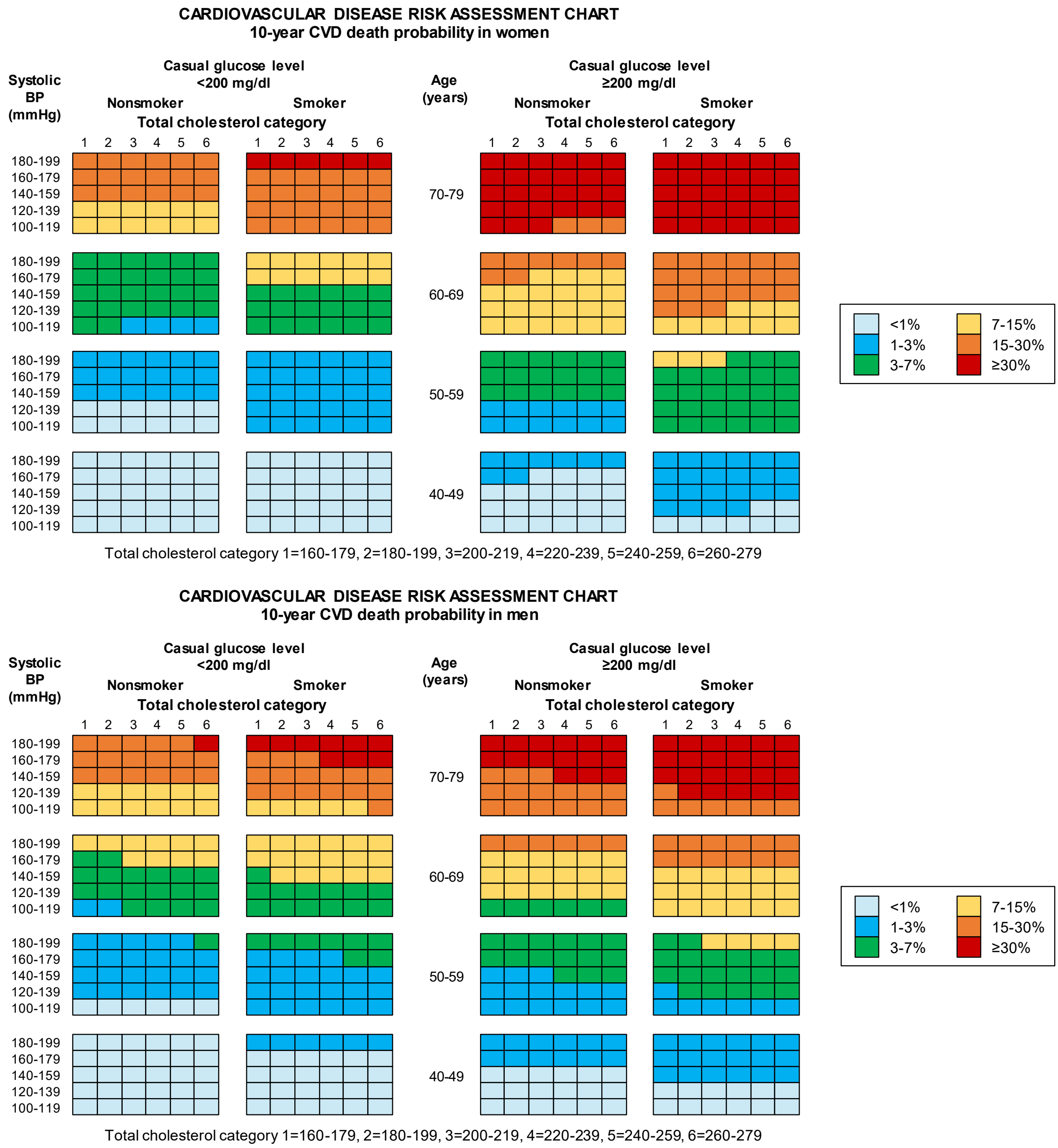
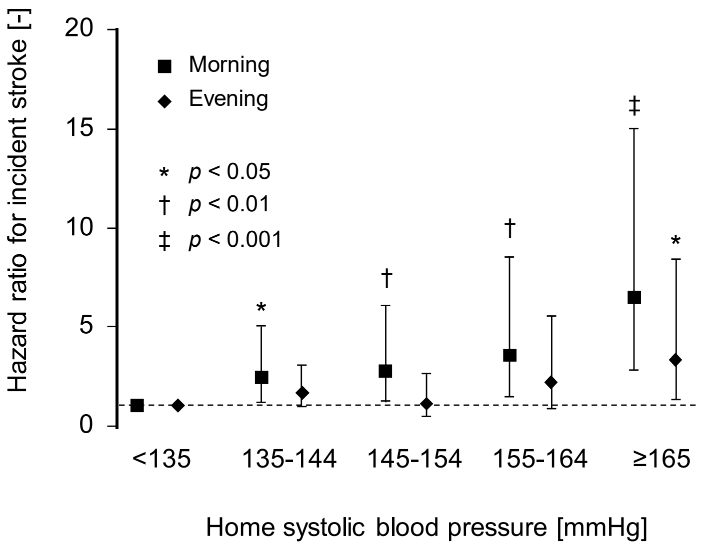


Fig.1-10 | Risk assessment chart for 10-year probability of death due to all CVDs [33]

(4) J-HOP Study

The J-HOP (Japan Morning Surge - Home Blood Pressure) Study began in 2005 as a prospective observational study that evaluated the "prognostic ability of home blood pressure for cardiovascular disease events" in about 4,500 people nationwide [34]. Blood pressure measurements were conducted at home for 2 weeks. The results showed that blood pressure measured at home in the morning was a better prognostic factor for stroke than that measured in the evening [35] (Fig.1-11).



Event number/ Total number	<135	135-144	145-154	155-164	≥165
(Morning)	12/1,958	20/1,044	16/687	11/342	15/247
(Evening)	35/2,851	20/787	7/366	6/177	6/97

Fig.1-11 | Stroke and coronary artery disease risks according to morning or evening home systolic blood pressure categories [35]

(5) HONEST Study

The HONEST (Home blood pressure measurement with Olmesartan Naive patients to Establish Standard Target blood pressure) Study was a prospective observational study started in 2009 which aimed to examine the association between home blood pressure and CVD events during follow-up [36, 37]. It is regarded as the world's biggest study of its kind, conducting follow-up surveys for over 2 years in 21,591 hypertensive patients who were administered antihypertensive drugs. The study showed that blood pressure measured at home in the morning was associated with the risk of cerebrovascular and heart disease [38] (Fig.1-12). In addition, even when clinical blood pressure was controlled to <130 mmHg, the hazard ratio for CVD events increased to 2.47 when home blood pressure was poorly controlled (145 mmHg or more) [39] (Fig.1-13).

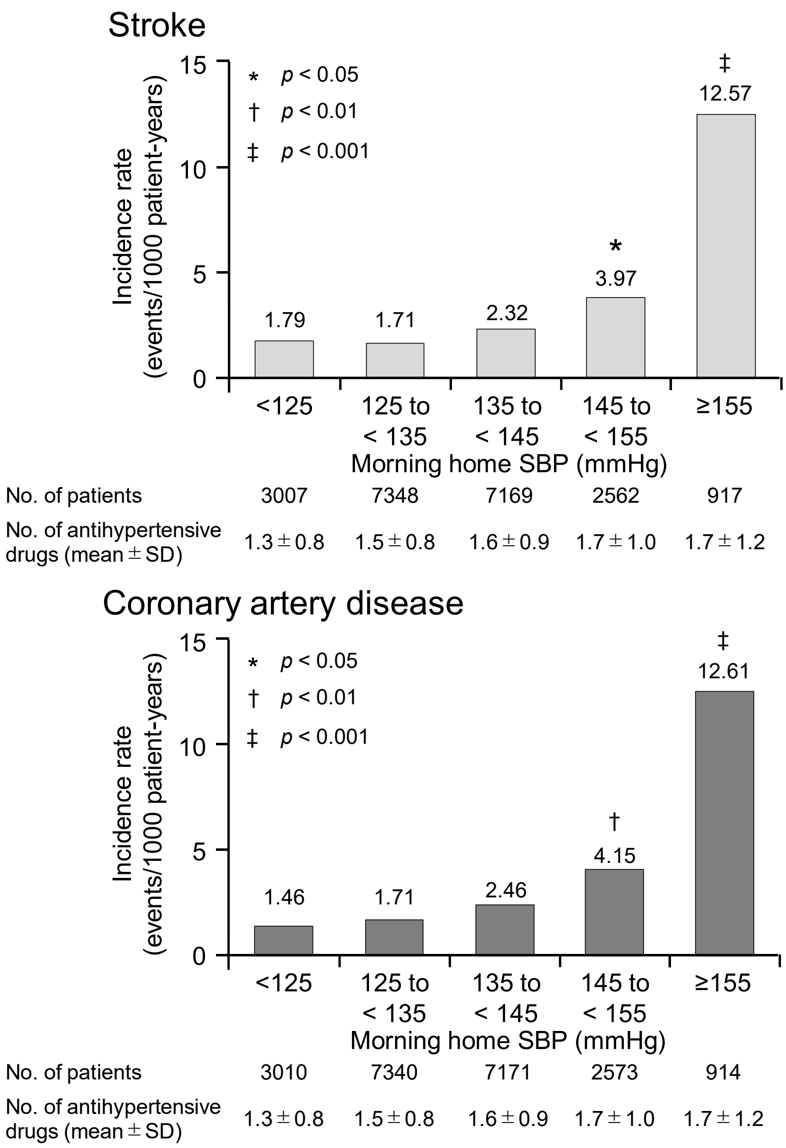


Fig.1-12 | HSBP and incidence rate of stroke and CAD events during follow-up [38]

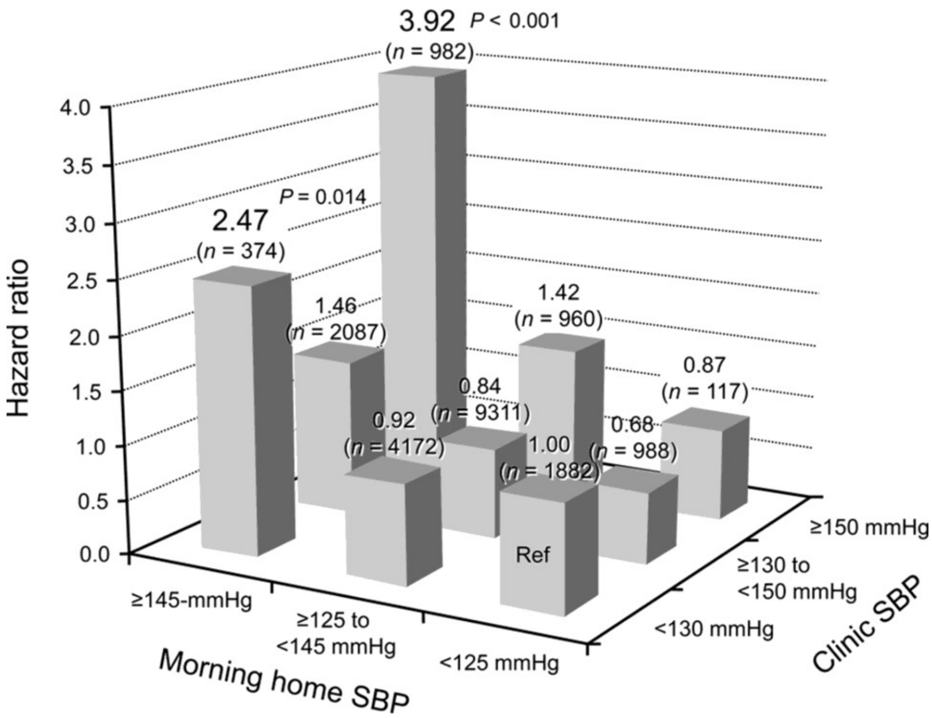


Fig.1-13 | Relationship between the primary end point (CVD events) and SBP divided into 9 categories [39]

1.2.2 Policies for preventing cardiovascular disease

From 2000 to 2012, the Ministry of Health, Labor and Welfare in Japan set guidelines aimed at improving strategies for the prevention of CVDs, such as "The first term of the National Health Promotion Movement in the Twenty-First Century" (Health Japan 21 (the first term)). Health Japan 21 focused on "primary prevention: prevent diseases in advance" rather than "secondary prevention: early detection and early treatment." Specific targets for 2010 were set for 80 items in nine fields, namely nutrition, physical activity, rest, smoking, alcohol consumption, dental health, diabetes, CVDs and cancer. One of the items under CVDs was improvement of hypertension, specifically to reduce the average systolic blood pressure by 4.2 mmHg over the next decade [40].

Additionally, Health Japan 21 (the second term) was established in 2012 and set a target to minimize the incidence of hypertension by reducing the average systolic blood pressure by 4 mmHg over the next decade through lifestyle modification [41]. According to Healthy Japan 21 (the second term), reducing the average systolic blood pressure (SBP) of Japanese aged 40 to 89 years by 4 mmHg (men: 138→134 mmHg, women: 133→129 mmHg) will prevent an estimated 14,000 deaths from CVDs each year in Japan, including 9,300 deaths from cerebrovascular disease and 4,700 from ischemic heart disease (Fig.1-14). Therefore, prevention of hypertension is considered critical to the prevention of CVDs.

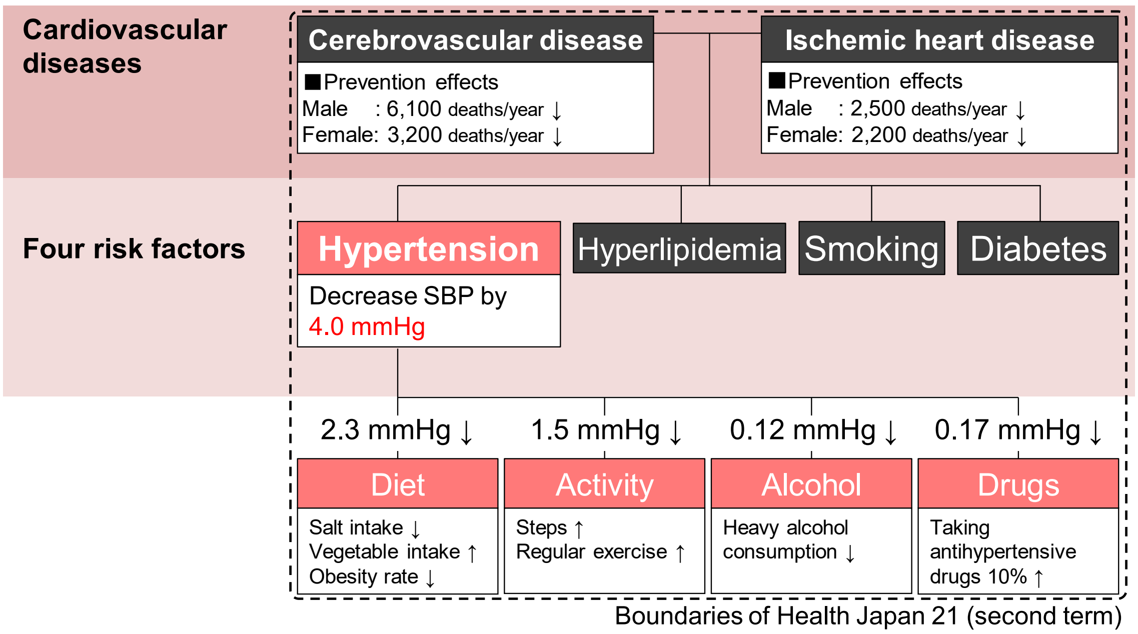


Fig.1-14 | Hierarchical structure of Health Japan 21 (the second term) for prevention of CVDs (translated from [41])

1.2.3 Present status and efforts for preventing hypertension

A 2014 survey of hospital patients released by the Ministry of Health, Labor and Welfare estimated that there were 10.11 million hypertensive patients in Japan [42]. However, because hypertension is an asymptomatic disease, also known as a “silent killer”, a large number of patients with hypertension do not visit a hospital. In fact, it is estimated that there are actually 43 million hypertensive patients [43] (Fig.1-15), which is equivalent to about one-third of the population. Moreover, the incidence of hypertension increases with age, suggesting that the number hypertensive patients will increase with the aging population in the future.

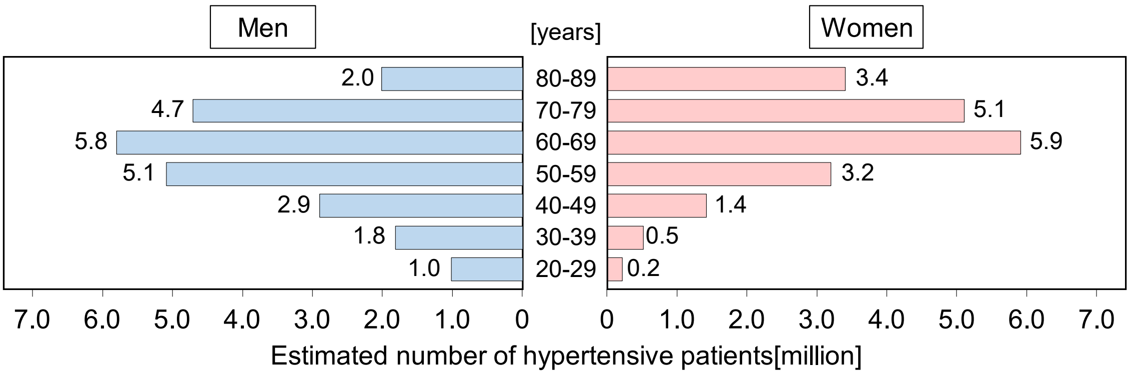


Fig.1-15 | Estimated number of hypertensive patients in Japan [43]

To prevent hypertension, the Japanese Society of Hypertension published "Guidelines for the management of hypertension 2014 (JSH 2014)" [44]. The guideline lists "lifestyle modification items for prevention of hypertension" (Table 1-2), and summarizes the "recommended grade" (Table 1-3) and "evidence level: the strength of evidence obtained so far" (Table 1-4) for each item. Among the lifestyle modification items, cold protection is classified under "Other". The guideline states that cold temperatures raise blood pressure, which leads to a rise in blood pressure in winter months. Moreover, mortality rate in winter due to CVDs rises sharply when heating or cold protection is insufficient. Therefore, hypertensive patients should use heating during winter, including in toilets, bathrooms, and changing rooms in Japan, which are often overlooked. Although these descriptions indicate the importance of heating, including in non-living rooms, the evidence in support of this is scarce, and has only been obtained from cross-sectional studies. The recommended grade was therefore set as C and the evidence level as IVb, indicating that scientific evidence is insufficient.

Table 1-2 | Lifestyle modification items for prevention of hypertension (translated from [44])

Item		Goal	Recommended grade	Evidence level
(1) Salt reduction		Salt intake less than 6 g/day	A	I
(2) Diet	Vegetables/ fruit	High consumption of vegetables and fruit	B	II
	Lipids	Avoid intake of cholesterol and saturated fatty acids High consumption of fish or fish oil		
(3) Weight loss		Body mass index (Weight [kg]/Height [m]^2) less than 25.0	A	I
(4) Exercise		For hypertensive patients without CVD: periodic exercise by mainly doing aerobic exercise (at least 30 minutes every day)	A	I
(5) Elimination of alcoholism		In men, less than 20–30 mL/day ethanol In women, less than 10–20 mL/day ethanol	A	I
(6) Elimination of smoking		Promotion of anti-smoking and prevention of passive smoking	A	IV
(7) Other		Cold protection, management of emotional stress, Improvement in sleep, bathing in water that is not too hot	C	IV

Table 1-3 | Recommended grade for prevention of hypertension (translated from [44])

Recommended grade	Description
A	There is strong scientific basis, it is strongly recommended.
B	There is scientific basis, it is recommended.
C1	Although scientific basis is insufficient, it is recommended.
C2	Scientific basis is insufficient, it is not recommended.
D	There is scientific basis, so it is not recommended.

Table 1-4 | Evidence level in medicine (translated from [44])

Evidence level	Description
I	Systematic reviews or meta-analysis of randomized controlled trials
II	Randomized controlled trials
III	Non-randomized controlled trials, sub analysis or post hoc analysis of randomized controlled trials
IVa	Epidemiological research (cohort studies, meta-analysis of cohort studies)
IVb	Epidemiological research (case-control studies, cross-sectional studies)
V	Descriptive study (case reports and case series)
VI	Opinion of technical committees and experts

1.3 Excess winter mortality

Excess winter mortality (EWM) is a phenomenon in which the mortality rate increases sharply in winter [45−49] and is predominantly caused by cardiovascular and respiratory diseases [50−52]. A paradoxical relationship in which EWM is higher in areas with milder winter climates has been observed in Europe [53, 54] (Fig.1-16), the USA [55] and Asia [56, 57]. This is attributed to houses in these areas being less prepared for the winter season, resulting in lower than recommended indoor temperatures. In fact, lower indoor temperatures have been reported in areas with higher outdoor temperatures [45], and EWM is higher in colder houses than warmer houses [49] (Fig.1-17).

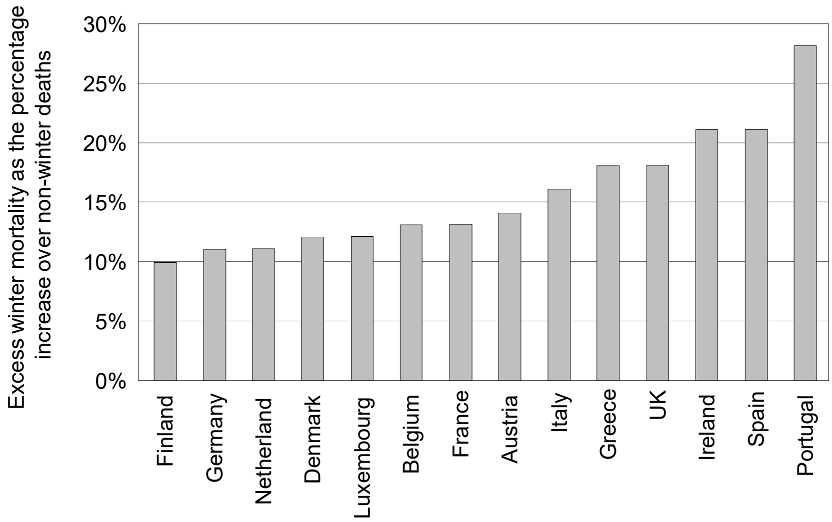


Fig.1-16 | Coefficient of seasonal variation in mortality in Europe [47]

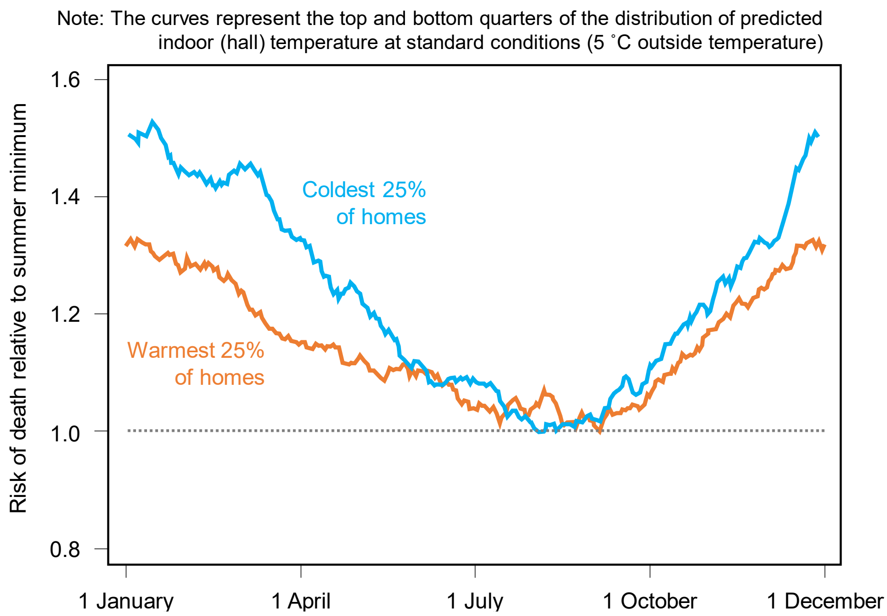


Fig.1-17 | Seasonal fluctuation in CVD mortality in cold and warm homes [49]

This paradoxical relationship has been observed in Japan [58] (Fig.1-18), which experiences both temperate and subarctic climates due to the orientation of the long axis of the Japanese landmass, which extends north to south.

Studies on deaths inside houses indicate that CVDs, such as heart diseases and cerebrovascular diseases, are the leading cause of death, despite being the second and fourth overall leading cause of death after malignant neoplasm in Japan [59] (Fig.1-19). In particular, there is a substantial increase in the number of deaths due to CVDs in winter, to a level more than twice that in summer. The thermal environment inside houses may be associated with deaths due to CVDs because the increase in the number of deaths in winter is greater in houses than in hospitals, which generally have appropriate temperature control [59].

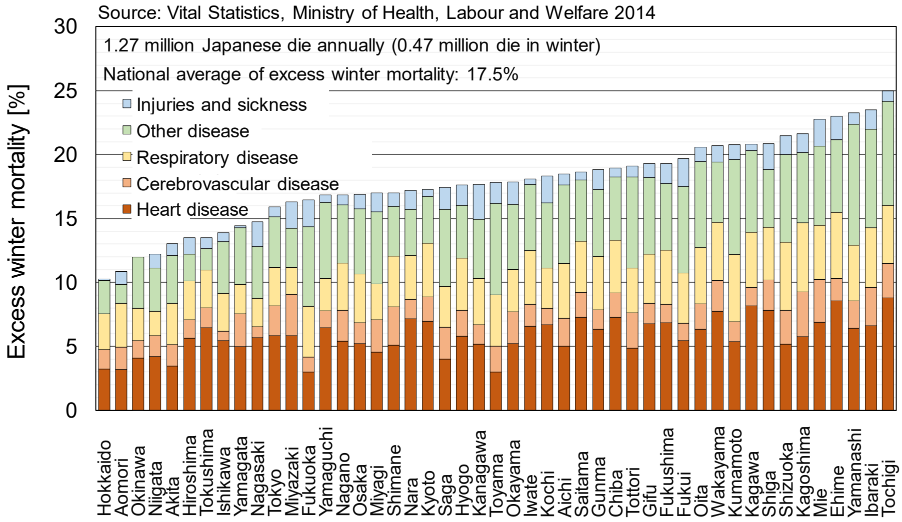


Fig.1-18 | Coefficient of seasonal variation in mortality by prefecture in Japan (graphed using data from [58])

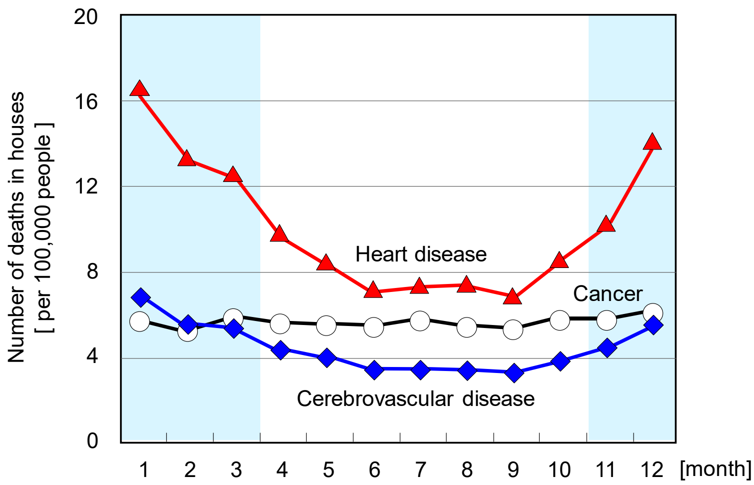


Fig.1-19 | Seasonal fluctuation in mortality inside houses by disease (modified and translated from [59])

Additionally, people in modern society spend between 60% and 70% of their time at home [60−62]. This is even higher among elderly people, who have declining physiological function, and children, whose physiological function is underdeveloped [63]. This indicates the importance of the impact of the thermal environment inside houses on health. Moreover, Japan is aiming to establish the Community-based Integrated Care System by moving from hospital-based- to region-based-style care to enhance home medical care and home medical care support [64] (Fig.1-20). The importance of housing conditions is therefore expected to continue to attract attention in the future.

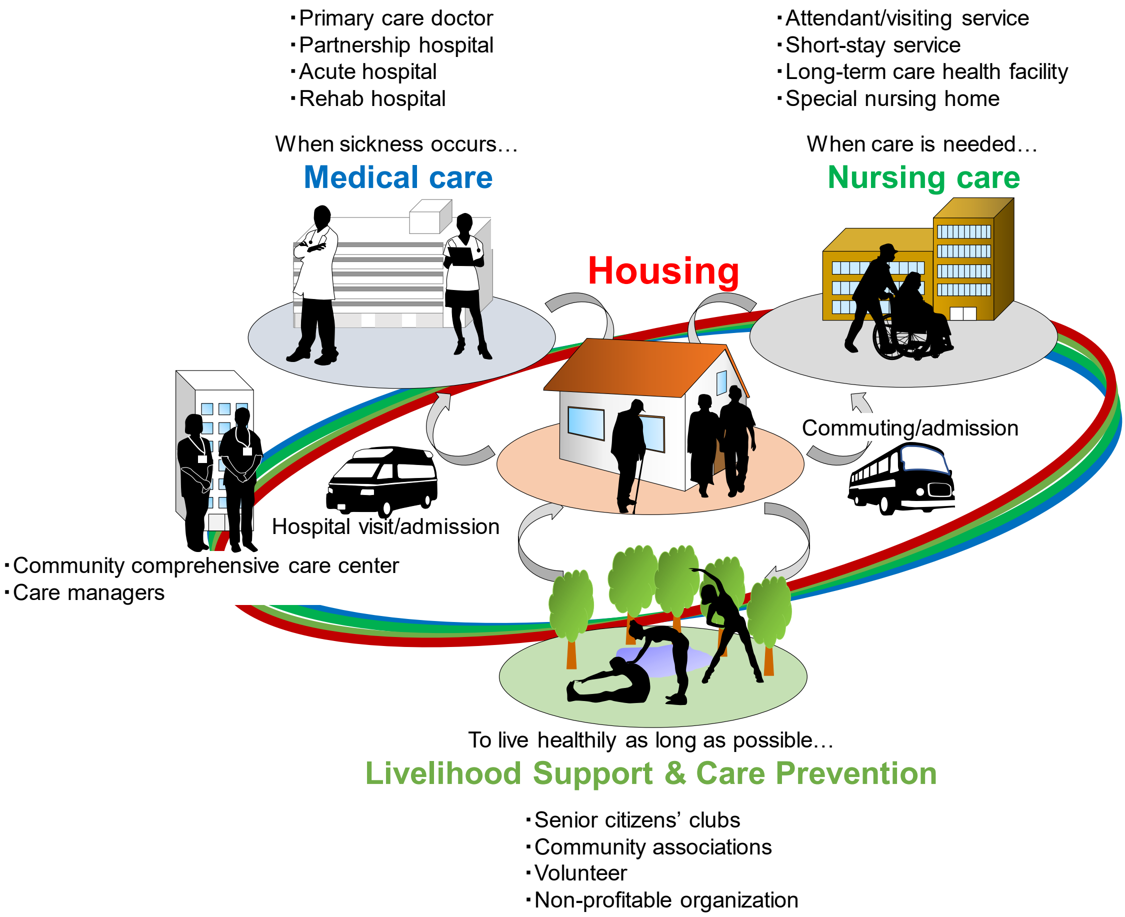


Fig.1-20 | Conceptualization of community-based integrated care systems in 2025 (modified and translated from [64])

1.4 Necessity of improving the thermal environment inside houses in Japan

In 2017, there were a total of 60.63 million dwellings in Japan. The number of occupied dwellings (places in which people usually live) was 52.10 million, accounting for 85.9% of the total number of dwellings. Among occupied dwellings, 54.9% were detached houses, about 90% of which were wood-frame houses. In contrast, 42.4% of occupied dwellings were apartment buildings, among which 12.5% were wood-frame buildings and more than 70% were made of other materials such as steel or reinforced concrete [65]. Uninsulated houses were estimated to account for 39% of existing dwellings, and 37%, 19%, and 5% of houses complied with the 1980, 1992, and 1999 adiabatic level standards, respectively [66] (Fig.1-21). Therefore, there are still many houses with low thermal insulation in Japan.

Standards for the average heat transmission coefficient for the outer skin (U_A-value) and the heat transmission coefficient for windows (U_W-value) have been compared internationally [67]. These parameters are indicators of the adiabatic level, with lower values indicating lower transmission and therefore higher heat retention. Findings indicate that even according to 2013 standards (current standards), the U_A-value in Tokyo is about twice as high as that in the U.S. state of California, which shares the same climate category as Tokyo (Fig.1-22). In addition, the U_W-value is 2.33 W/m^{2}K in Hokkaido and 4.65 W/m^{2}K in Tokyo, which markedly exceeds the 1.0 to 2.0 W/m^{2}K range of values in European and American countries (Fig.1-23).

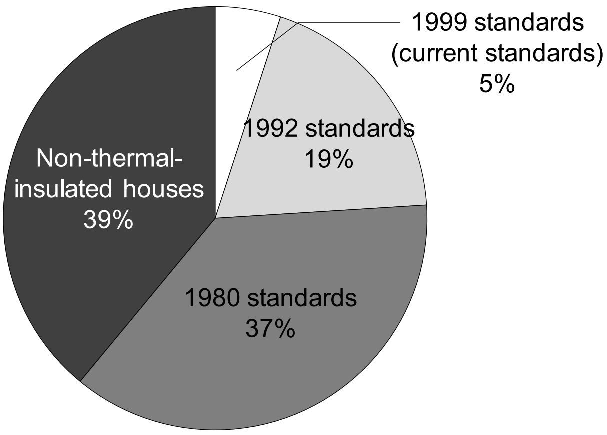


Fig.1-21 | Adiabatic level of existing dwellings in Japan (translated from [66])

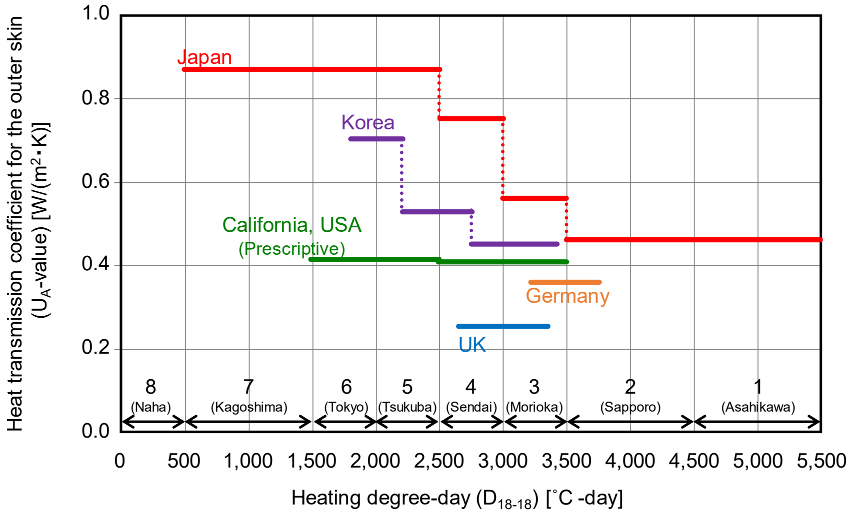


Fig.1-22 | Standards for the average heat transmission coefficient for the outer skin (U_A-value) of the main countries (modified from [67])

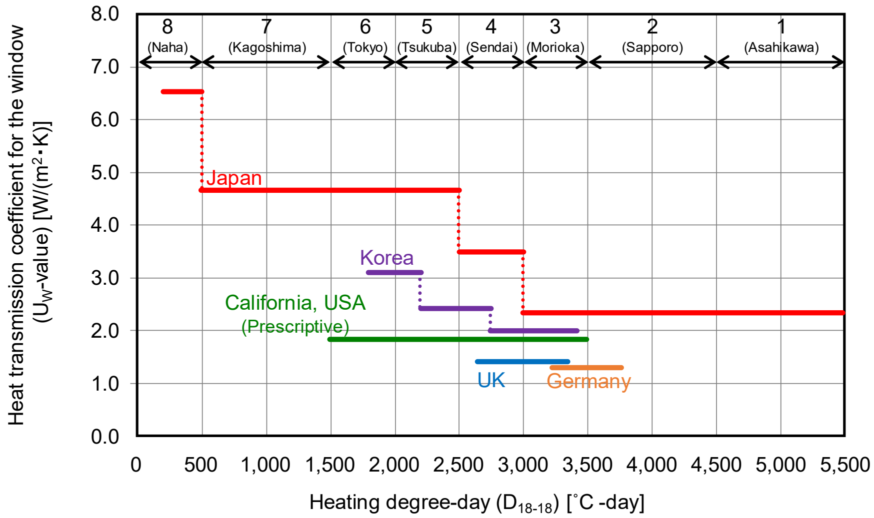


Fig.1-23 | Standards for the heat transmission coefficient for windows (U_W-value) of the main countries (modified from [67])

Residential energy consumption in Japan is also very low compared to European and American countries, with energy used for heating being only one-quarter of that in Western countries [68] (Fig.1-24). This is because while intermittent heating in only the living room is standard practice in Japan, European and American countries commonly perform continuous heating throughout the entire building. As a result, room temperatures are lower in Japan than in other countries. A survey of indoor environments in 602 houses throughout Japan indicated that the average room temperature in winter was 17°C [69]. This is below the minimum room temperature of 18°C recommended by WHO [70] and the UK government [71, 72], and there is concern that this may greatly affect health (Table 1-5).

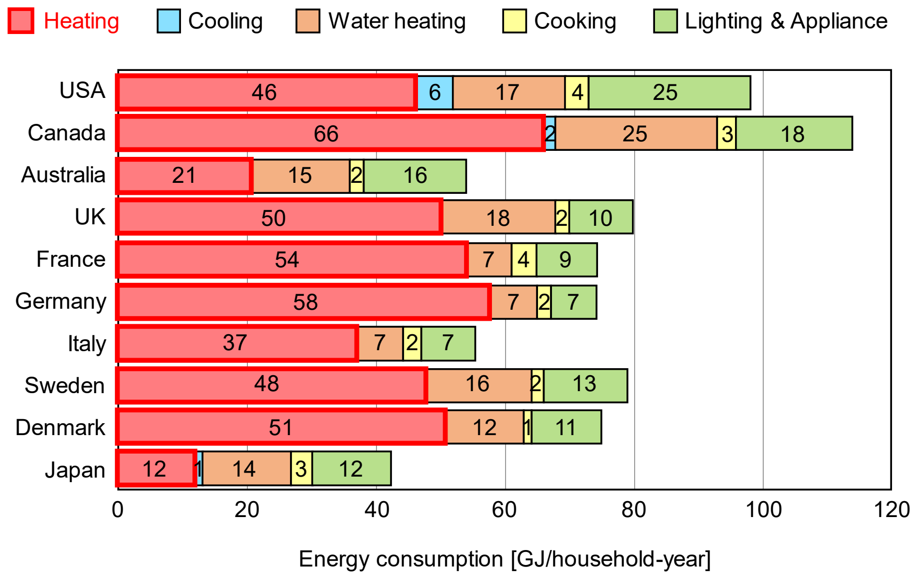


Fig.1-24 | Annual national average of residential energy consumption of the main countries [68]

Table 1-5 | Recommendations for minimum room temperature (modified from [71, 72])

Heating homes to at least 18˚C (65˚F) in winter poses minimal risk to the health of a sedentary person, wearing suitable clothing.	
For people over 65 years or with pre-existing medical conditions	
Daytime	The 18˚C (65˚F) threshold is particularly important. Having temperatures slightly above this threshold may be beneficial for health.
Overnight	Maintaining the 18˚C (65˚F) threshold overnight may be beneficial to protect the health. They should continue to use sufficient bedding, clothing and thermal blankets or heating aids as appropriate.
For healthy people (aged 1–64 years)	
Daytime	The 18˚C (65˚F) threshold also applies to healthy people. If they are wearing appropriate clothing and are active, they may wish to heat their homes to slightly less than 18˚C (65˚F).
Overnight	Overnight, the 18˚C (65˚F) threshold may be less important for healthy people if they have sufficient bedding, clothing and use thermal blankets or heating aids as appropriate.

1.5 Hypotheses on the effects of cold exposure on cardiovascular events

In the field of cardiovascular medicine, the synergistic resonance hypothesis proposes that cardiovascular events occur when peaks in blood pressure fluctuations from various time periods (yearly, seasonal, day-by-day, diurnal, and beat-by-beat) overlap and cause a dynamic surge in BP [73] (Fig.1-25). Based on this hypothesis, we predict that there are main two effects of cold temperatures: (1) acute effects, and (2) chronic effects. The specific questions these prediction raise are: (1) Does blood pressure rise due to cold exposure and trigger cardiovascular events? and (2) Does the state of hypertension due to chronic cold exposure damage vascular endothelial cells and promote vascular aging? Given that a long time span is required to answer question (2), we will aim to answer question (1) in this thesis.

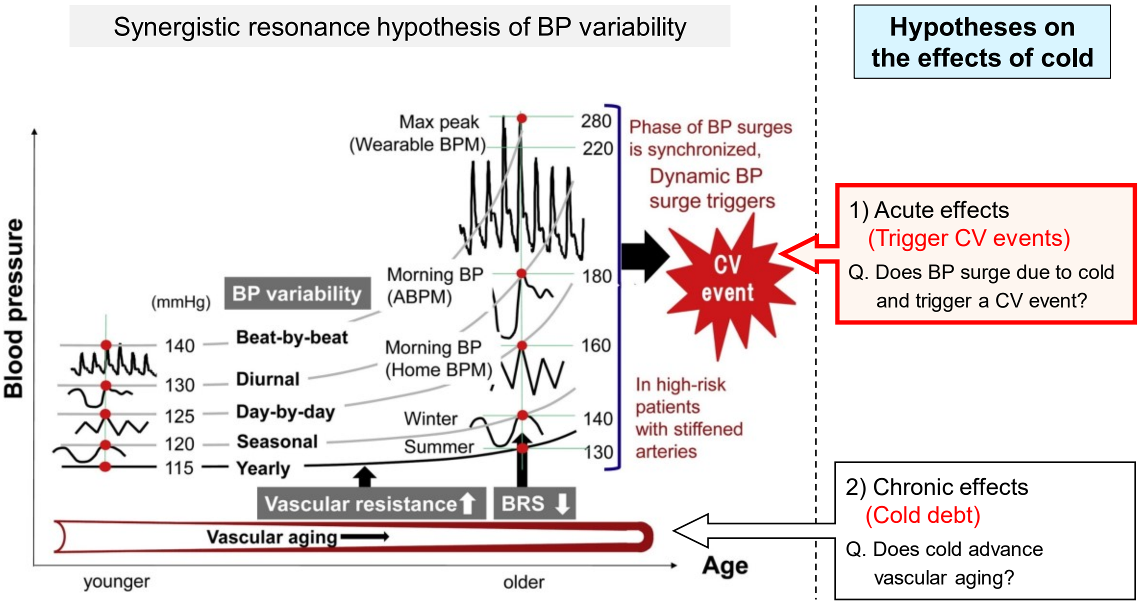


Fig.1-25 | Synergistic resonance hypothesis on blood pressure variability and the effects of cold (modified from [73])

ABPM, ambulatory blood pressure monitoring; BPM, blood pressure monitoring; CV, cardiovascular; BRS, baroreceptor sensitivity

1.6 Purpose of this research and the structure of this thesis

The purpose of this research was to examine the preventive effects of improving housing environments on the incidence of CVDs. In particular, surveys were conducted on blood pressure, which is a widely used risk factor for CVDs, and the relationship between the indoor thermal environment in houses and blood pressure was analyzed. This study was based on the hypothesis that low room temperatures in houses with a poor thermal environment lead to high blood pressure and large fluctuations in blood pressure (e.g. morning surge), while these outcomes are suppressed in houses with a sufficient thermal environment, and that improving the indoor thermal environment may contribute to the prevention of CVDs (Fig.1-26).

By quantitatively evaluating these relationships based on objective data, this study aims to show the degree to which the incidence of CVDs can be reduced by improving the thermal environment inside houses, and the importance of improving the indoor thermal environment. The main goals of this study are:

(1) To collect data to enable the establishment of optimum room temperature recommendations for the prevention of hypertension.

(2) To provide evidence for the incorporation of "housing environment" as a countermeasure for the prevention of CVDs into domestic and international policies (Fig.1-27).

Ultimately, this research aims to improve Japan's adiabatic level, which is lower than that of European and American countries.

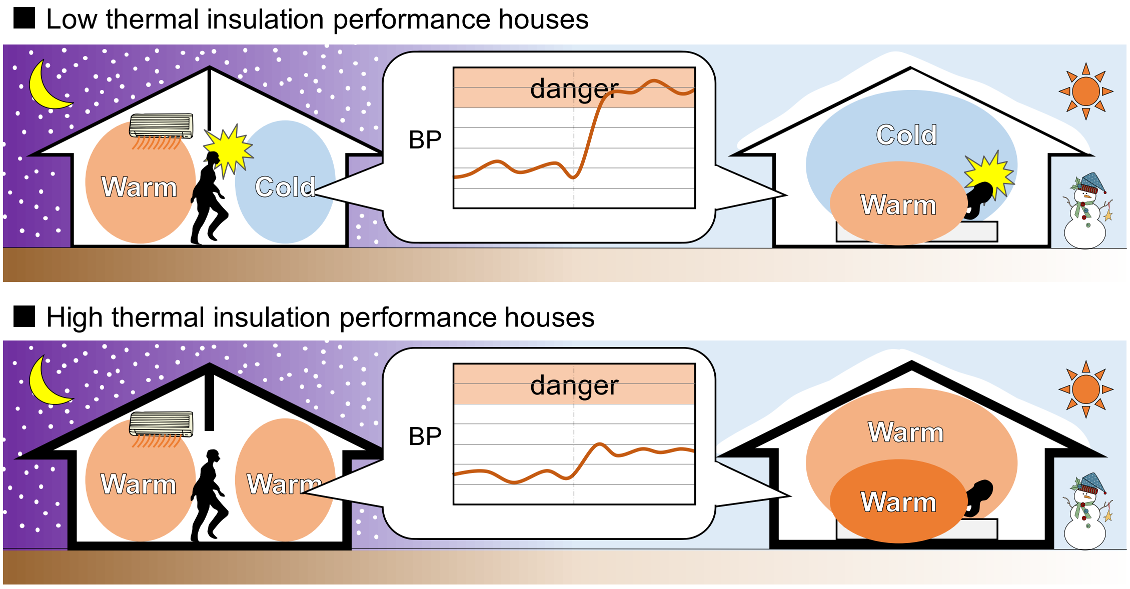


Fig.1-26 | Hypothesis of Ph.D. dissertation

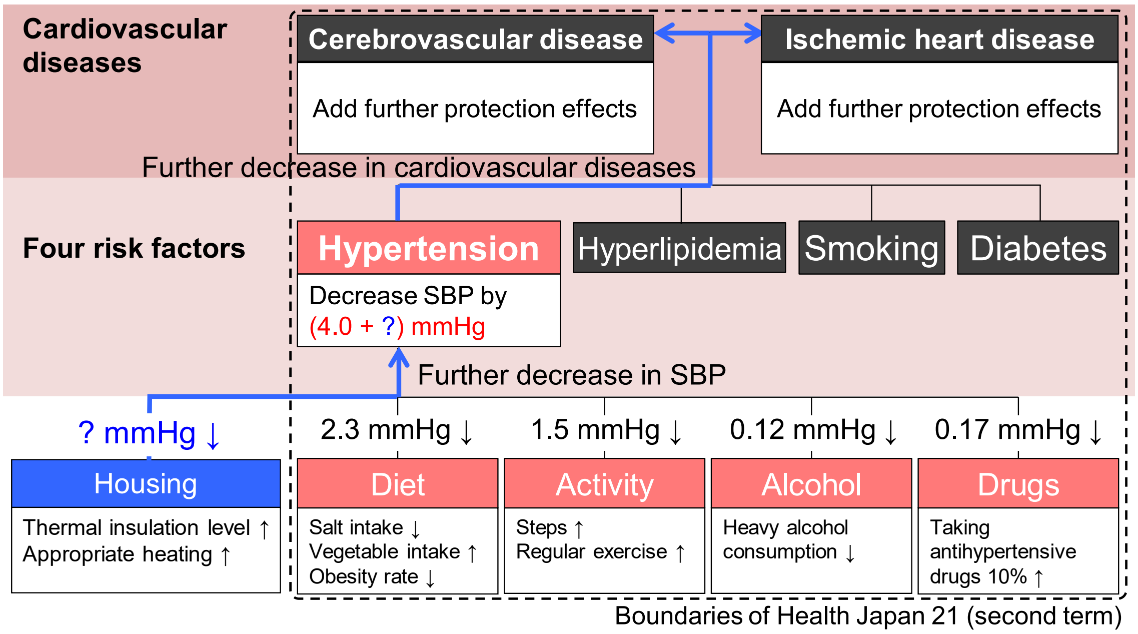


Fig.1-27 | Suggested hierarchical structure for prevention of CVDs including housing (modified and translated from [41])

Chapter 1 summarizes the motivations for preventing CVDs and the global problem associated with EWM. The chapter also discusses the possibility of preventing CVDs by improving the thermal environment inside houses. In addition, this chapter also describes the significance of preventing hypertension, which is considered the main risk factor for CVDs, and the basis of this research.

Chapter 2 summarizes domestic and foreign policies on housing-health relationships. Examples are mainly extracted from studies from the UK and New Zealand, which are leading countries in this field. The chapter will also introduce clinical trials that examined the relationship between the living environment and hypertension and CVDs, and studies that examined the relationship between room temperature and blood pressure. The position of the present research will be clarified based on issues identified in previous studies.

Chapter 3 outlines the field surveys conducted by several researchers from the Laboratory of Toshiharu Ikaga, which became the basis of a nationwide survey. The results from measurements conducted in the field surveys reveal 1) the impact of bedroom temperature on blood pressure variability in the early morning, and 2) the causal correlation between a rise in room temperature and a drop in blood pressure when subjects moved to high thermal insulation performance houses. Issues associated with implementing the nationwide survey are summarized according to these results.

Chapter 4 outlines the before-and-after insulation retrofit surveys conducted throughout Japan (SWH survey: Smart Wellness Housing survey). The research question, study design, intervention, recruitment, determination of sample size, and measurement items are described and the ethical issues and online registration in accordance with the International Committee of Medical Journal Editors (ICMJE) recommendations are summarized. Furthermore, the number of participants and baseline characteristics of participants and their homes are summarized.

Chapter 5 describes findings on 1) the relationship between home blood pressure and room temperature, and 2) the sensitivity of home blood pressure to changes in room temperature, obtained in the baseline survey (before insulation retrofit). These results are useful for determining optimum room temperature recommendations for the prevention of hypertension. In addition, the nationwide survey was used to identify the areas with low indoor temperatures and the attributes of the residents who live in cold homes.

Chapter 6 describes the results of comparative analysis between the "insulation retrofit group", which conducted two measurements before and after insulation retrofit, and the "control group", which conducted two measurements without insulation retrofit. The results were used to determine the causal relationship between decreases in blood pressure and insulation retrofit intervention.

Chapter 7 shows the results of comparative analysis of health exam data from participants living in warm houses (indoor temperature ≥18°C) compared to cold houses (indoor temperature <18°C). A cross-sectional analysis is used to examine whether the risk of arteriosclerosis and abnormalities in electrocardiogram findings, indices strongly related to CVDs, increases in participants living in cold houses.

Chapter 8 summarizes the achievements of the present research. In addition, this chapter suggests the need to verify the long-term health effects of housing environment using a long-term cohort study.

The structure of this paper is shown in Fig.1-28.

Chapter.1 Introduction

Background, hypothesis, purpose, structure of Ph.D. thesis

↓

Chapter 2. Domestic and international trends and research on housing and health

Efforts to prevent reduced health due to cold, review of previous research

↓

Chapter 3. Field surveys on housing thermal environment and blood pressure

Outline of field surveys, relationship between room temperature and blood pressure

↓

Chapter 4. Outline of the before and after insulation retrofit survey in Japan (SWH survey)

Research question, study design, intervention, measurement items

↓

Chapter 5. Relationship between indoor temperature and home blood pressure

Results of analysis of baseline data from SWH survey

↓

Chapter 6. Effect of insulation retrofit on home blood pressure

Results of analysis of before-after insulation retrofit data from SWH survey

↓

Chapter 7. Relationship between indoor temperature and biomarkers of CVD

Results of analysis of health exam data from SWH survey

↓

Chapter.8 Conclusions and future studies

Need for a long-term cohort study

Fig.1-28 | Structure of this Ph.D. thesis

Chapter 2

Domestic and international trends and research on housing and health

2.1 Efforts to prevent health injuries due to cold

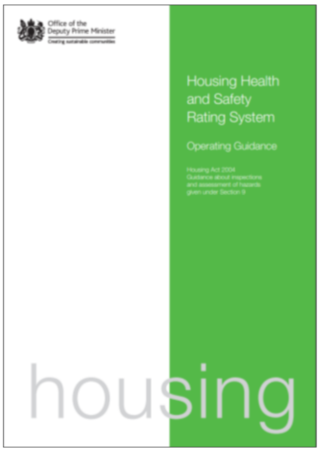
Efforts related to housing and health are known to be particularly advanced in the UK and New Zealand [74–76]. Therefore, in this chapter, I will introduce the efforts adopted in these two leading countries in the field of housing and health, as well as the efforts in Japan.

2.1.1 Efforts in the UK

(1) Housing Health and Safety Rating System

The Housing Health and Safety Rating System (HHSRS) was introduced under the UK Housing Act 2004, and is used to evaluate the health status and safety of housing in England and Wales [77]. The HHSRS was developed under the Ministry of Housing, Communities and Local Government (formerly the Department for Communities and Local Government), with the Building Research Establishment and the University of Warwick, and is currently being legislated. The HHSRS is an evaluation tool for identifying potential risks to health and safety arising from poor housing and for protecting residents. Its best feature is that houses that are found to be defective in an HHSRS evaluation will receive injunctions and penalties for repair, closure, or demolition. To evaluate defects and risks, 29 categories of hazards are classified into 4 groups: physiological requirements; psychological requirements; protection against infection; and protection against accidents (Table 2-1). These are evaluated by inspectors from local governments that specialize in public health.

Table 2-1 | Profiles of potential health and safety hazards in dwellings in HHSRS [77]



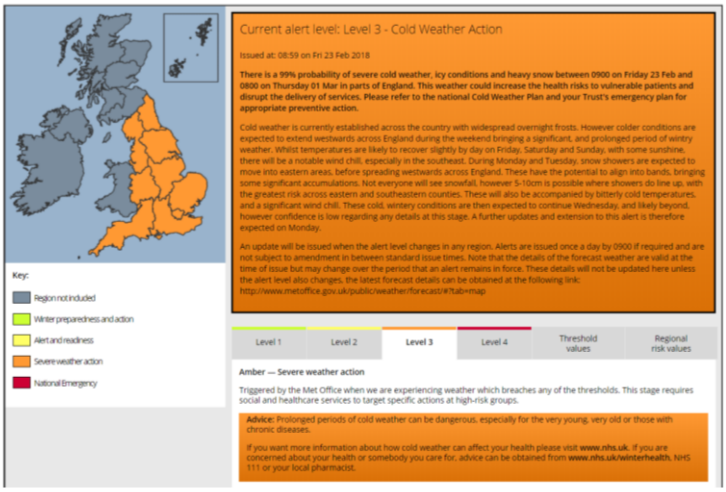
Physiological requirements	Psychological requirements	Protection against accidents
01 Damp & mould growth	11 Crowding & space	19 Falls associated with Baths, etc.
02 Excess cold	12 Entry by intruders	20 Falling on level surfaces, etc.
03 Excess heat	13 Lighting	21 Falling on stairs, etc.
04 Asbestos & MMF	14 Noise	22 Falling between levels
05 Biocides		23 Electrical hazards
06 CO & fuel combustion products	**Protection against infection**	24 Fire
07 Lead	15 Domestic hygiene, pests & refuse	25 Flames, hot surfaces, etc.
08 Radiation	16 Food safety	26 Collision & entrapment
09 Uncombusted fuel gas	17 Personal hygiene sanitation & drainage	27 Explosions
10 VOCs	18 Water supply	28 Position & operability of amenities, etc.
		29 Structural collapse & falling elements

MMF, manufactured mineral fibers; CO, carbon monoxide; VOCs, volatile organic compounds.

(2) Cold Weather Plan for England

The Cold Weather Plan (CWP) for England was established in 2011 by Public Health England (PHE) through collaboration with the National Health Service (NHS), the Local Government Association (LGA), and the UK Met Office, and aims to protect health and reduce harm from cold weather [72]. This plan provides warnings for health injuries due to the cold, a cold weather alert system (Fig.2-1), recommendations for appropriate heating (minimum room temperature threshold of 18°C), promotion of investment in insulation retrofit of houses, and distribution of coupons for heating fuel to poor residents struggling with fuel costs. The collection of evidence that supports the CWP for England, namely, "CWP for England, Making the Case: Why Long-Term Strategic Planning for Cold Weather is Essential to Protecting Health and Wellbeing" [78], and simplified versions of the CWP [79] have simultaneously been made publicly available to actively raise awareness among citizens about preventing health problems due to cold houses.

Cold weather alert



Level 0	**Year-round planning** *All year*
Level 1	**Winter preparedness and action programme** *1 November to 31 March*
Level 2	**Severe winter weather is forecast – Alert and readiness** *mean temperature of 2°C or less for a period of at least 48 hours and/or widespread ice and heavy snow are predicted, with 60% confidence*
Level 3	**Response to severe winter weather – Severe weather action** *Severe winter weather is now occurring: mean temperature of 2°C or less and/or widespread ice and heavy snow.*
Level 4	**Major incident – Emergency response** *Central Government will declare a Level 4 alert in the event of severe or prolonged cold weather affecting sectors other than health*

Fig.2-1 | The Cold Weather Plan for England and cold weather alert system [72]

2.1.2 Efforts in New Zealand

(1) Healthy Housing Index (HHI) Pilot Study

The Healthy Housing Index (HHI) measures the healthiness and safety of a house and the potential occurrence of diseases and accidents due to housing factors. The measurements were performed by He Kainga Oranga, a research organization affiliated with the University of Otago that studies housing and health, and the Building Research Association of New Zealand (BRANZ) in a pilot study with the following two objectives: (1) to develop an injury hazard index; and (2) to measure the relationship between the developed index and injury outcomes [80].

The pilot investigation consisted of three phases. The first phase was the conceptual development of HHI, which involved discussions with various stakeholders and a review of the literature on housing and health (including the UK's HHSRS). The second phase involved recruiting 259 residents in 102 households and collecting data on their housing status. The housing status data were collected using a questionnaire, which investigated the physical condition of the houses, including the (i) structural soundness; (ii) validity of medical services; (iii) warmth and dryness; (iv) safety; and (v) protection from external hazards. The third phase involved the development of the injury hazard index and measurement of the relationship between the developed index and injury outcomes. The researchers ultimately determined that an increase of 1 in the injury hazard index score increased the probability of an injury occurring by 22% (95% confidence interval: 6–41%), suggesting that measures to decrease the hazard index score may be effective for reducing injuries (Table 2-2).

Table 2-2 | Healthy Housing Index hazards and odds ratios of reported injuries over three years [80]

Parameter	Estimate	Standard error	95% Confidence limits	Odds ratio	P-value
Intercept	-4.282	0.646	(-5.547, -3.016)	0.014	<0.001
sumhazards	0.199	0.073	(0.055, 0.342)	1.220	0.007

(2) Warm Up New Zealand: Heat Smart (WUNZ:HS) Programme

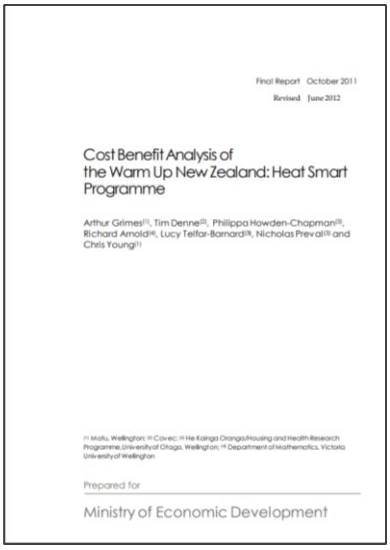
The Warm Up New Zealand: Heat Smart (WUNZ:HS) Programme was initiated in July 2009. It is New Zealand's largest-ever program to provide insulation retrofit and efficient and environmentally-friendly heating equipment, having received NZ$340 million in funding from the New Zealand government. The program was started based on more than 10 years of research findings from He Kainga Oranga, and the results generated by WUNZ:HS are affecting policy.

To evaluate the costs and benefits of the program, WUNZ:HS was managed by the Energy Efficiency and Conservation Authority (EECA), an organization that aims to improve energy consumption in New Zealand. The New Zealand Ministry of Economic Development conducted the cost-benefit analysis. Households were selected as matched pairs of control and intervention households with similar building age, scale, performance, and area. The sample size including both the intervention group and control group comprised a total of 255,672 households and 973,710 residents. The main outcomes were: (1) the ratio of benefit to cost of the entire program; (2) measurement of program costs; (3) changes to employment due to the program; (4) changes to electricity and gas consumption due to the program; (5) changes to the hospitalization rate and mortality rate due to the program; and (6) changes to hospitalization costs and costs of pharmaceutical products per household due to the program.

As a result of the WUNZ:HS intervention, the mortality rate among participants aged 65 years and older who were recently hospitalized for cardiovascular disease (CVD) decreased by 27%. Additionally, the intervention led to a decrease in hospitalization costs associated with CVD, respiratory diseases, and asthma of NZ$67.44, NZ$98.88, and NZ$107.52 per year per household, respectively. Furthermore, the introduction of insulation materials significantly decreased the amount spent on pharmaceutical products. When a final cost-benefit analysis was performed by combining the amount of energy saved, the influence on industry and changes in employment, in addition to the health impacts discussed above, the benefits of WUNZ:HS amounted to NZ$1,283 million (energy-saving: NZ$17 million, health: NZ$1,266 million). Given that the cost was NZ$332 million, the cost-benefit ratio was estimated to be 3.9:1 (Table 2-3).

This estimation has been summarized in four reports detailing the (1) overall impact [81]; (2) health impacts (e.g., use of medical institutions, amount spent on pharmaceutical products, mortality rate) [82]; (3) energy-saving impact [83]; and (4) influence on industry and changes in employment [84] due to the WUNZ:HS intervention. Please refer to these reports for details.

Table 2-3 | Cost benefit analysis of the Warm Up New Zealand: Heat Smart Programme [81]


Final Report October 2011
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Cost Benefit Analysis of the Warm Up New Zealand: Heat Smart Programme

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Prepared for

Ministry of Economic Development

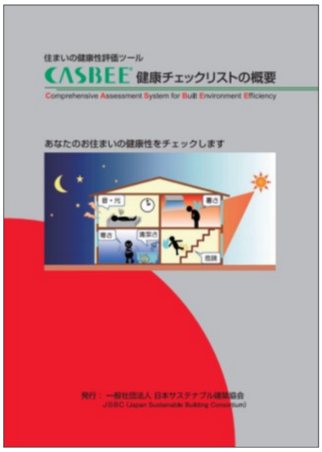
Costs	Value (NZ$ million)
Admin costs	23
Deadweight costs of tax	51
Installations - insulation	173
Installations - clean heat	85
Subtotal (A)	332
Benefits	**Value (NZ$ million)**
Energy	17
Health	1,266
Subtotal (B)	1,283
Net benefit (B – A)	951
Cost benefit ratio (B:A)	3.9:1

2.1.3 Efforts in Japan

(1) Comprehensive Assessment System for Built Environment Efficiency (CASBEE) Housing Health Checklist

Following the trends in foreign countries, Japan has also actively conducted investigative research on the relationship between the living environment and health in recent years. At the center of this movement was the "Health Maintenance Promoting Housing Research Council and its Consortium," established under the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) between 2007 and 2013. Several investigative research studies have been conducted with the aim of promoting health among citizens, and the most apparent product of these findings is the CASBEE Housing Health Checklist [85]. The CASBEE Housing Health Checklist was compiled with reference to examples, such as the UK's HHSRS. This checklist serves as a simple self-diagnosis tool for residents to identify problems in their houses that may affect their health. Points are accumulated according to the room, place, and health elements, to obtain a score out of 132 (Table 2-4). This checklist has been developed to provide residents the opportunity to check the health status of their living environment, identify abnormalities related to health, and seek improvement. Although design maps [86] and evidence collections [87] have been published as a result of this approach, from a medical and public health perspective, there is currently insufficient evidence from CASBEE Housing Health Checklist data on the impact of housing on health.

Table 2-4 | Categories of health and safety hazards in CASBEE Housing Health Checklist [85]



Rooms and places	Points
(1) Living room	21
(2) Bedroom	21
(3) Kitchen	15
(4) Bathroom, dressing room, and washroom	21
(5) Toilet	9
(6) Entrance	9
(7) Corridors, stairs, and storage	21
(8) Surroundings	15
(9) Optional	—

Health elements	Points
(1) Thermal environment	36
(2) Acoustic environment	6
(3) Light environment	12
(4) Hygiene	27
(5) Safety	45
(6) Security	6

2.2 Review of previous research on housing and health

2.2.1 Clinical trials related to housing and health

The influence of housing on health has been summarized in numerous books and in the literature, including reports from the WHO. There is a diverse variety of reports concerning the influence of cold on health in general and on mental health, and the influence of air quality and dampness on respiratory diseases [88–95]. Randomized controlled trials and observational studies related to housing and health have been systematically summarized in a report by the National Institute for Health and Care Excellence (NICE) [74] (Table 2-5).

Table 2-5 | Summary of findings on the effectiveness of clinical trials (modified from [74])

No.	Study	Country	Design	Setting	Target	Outcome
1	Experiment of room heating	JPN	Assessor blinded, simple RCT	■Baseline Participants maintained a comfortable room temperature in an accommodation facility ■Intervention Participants were randomly assigned to an intensive room-heating group and a weak room-heating group	146 healthy participants aged 18–60 years	**Ambulatory BP↓**
	HEIJO-KYO Study	JPN	RCT	■Baseline Participants measured in a real-life setting ■Intervention Participants were instructed to set the timer of the heating device in their living room to start 1 h before getting out of bed (n=186)	359 participants aged 60 or over	**Ambulatory BP↓**
2	CHARISMA study Asthma	Wales	Pragmatic RCT	■Intervention Housing modification to improve ventilation, and central heating if necessary (n=88)	177 asthmatic children	PedsQL (QOL score)↑ Absence from school↓
3	RCT of energy efficiency	ENG	Pragmatic RCT	■Intervention Households received an individually-tailored package of improved heating and insulation	Families in fuel poverty	Heating costs↓ Satisfaction with home warmth↑ Self-reported health→
4	NZ trial of healthy housing	NZ	Before-after (within-person, crossover design)	■Intervention Healthy housing programme 1) Improving tenant access to healthcare 2) Reducing the risk of housing-related health issues 3) Providing a link to the appropriate social service agencies	3,410 h'holds 9,736 people participating in The Healthy Housing Programme	Acute hospitalization↓
5	WHO Frankfurt Housing Intervention Project	GER	Controlled observational study	■Intervention Insulation retrofit of houses	131 dwellings 220 residents (intervention group) 104 dwellings 155 residents (control group)	Thermal comfort↑
6	NZ study of seven low income communities	NZ	Community-based, cluster, single blinded randomized study	■Intervention Installation of a standard retrofit insulation package	1,350 h'holds (4,407 people)	Energy consumption↓ Self-rated health↑ Wheezing↓ Colds and flu↓ A day off school or work↓

Table 2-5 | Summary of findings on the effectiveness of clinical trials (continued) (modified from [74])

No.	Study	Country	Design	Setting	Target	Outcome
7	NZ study of households with asthmatic children	NZ	RCT	■Intervention Installation of a non-polluting, more effective home heater (heating intervention)	409 children aged 6–12 years with asthma	A day off school↓ Visits to a doctor or pharmacist for asthma↓, etc.
8	Housing intervention For COPD	SCO	RCT	■Intervention Replacement and upgrades to central heating systems; installation of loft, under-floor and cavity wall insulation	178 patients with COPD	Fuel costs↓ Respiratory symptom score↑
9	Warm Front Scheme	ENG	Controlled before-after comparison	■Intervention Warm Front package (insulation, heating repair or replacement, draught proofing)	Low income households	Thermal comfort↑ Stress↓ Mental and physical health↑
10	Newham fuel poverty intervention	ENG	Ecological observational study (controlled before-after comparison)	Comparison of the yearly excess winter mortality ratio for Newham and all of London from before and throughout the duration of the Warm Zone project (a government-led fuel poverty reduction scheme in Newham)	25,000 residents aged 65 or over	No clear evidence
11	Domestic heating programme	SCO	Prospective controlled study	A prospective controlled study in Scotland comparing participants who received new central heating devices under a publicly-funded initiative, and those that did not	1,281 h'holds that received new central heating devices and 1,084 comparison h'holds	Self-reported diagnosis of heart disease↓ **Self-reported diagnosis of high blood pressure↓** General health↑ Physical health↑
12	Glasgow thermal quality study	SCO	Controlled before-after comparison	■Intervention Two blocks of flats were upgraded from being cold, damp and mouldy to being comfortably warm, dry and mould-free throughout.	75 subjects (intervention) 40 subjects (control)	Heating costs↓ **BP↓** Self-reported health↑
13	Watcombe Housing Study	ENG	Before-after intervention study (waiting list)	■Intervention Upgrading houses (including central heating, ventilation, rewiring, insulation, and re-roofing)	119 council-owned houses, about 480 residents	The combined asthma symptom score↓ General health→ Mental health→
14	New Brunswick and Nova Scotia energy efficient new homes study	CAN	Controlled comparison	Comparison of the test group and control group. The test group was R-2000™ homes built to preset and certified criteria for energy efficient ventilation and construction practices.	52 homes 128 occupants (test group) 53 homes 149 occupants (control)	Symptoms↓ (throat irritation, cough, fatigue and irritability)
15	Cornwall home heating study	ENG	Before-after study	■Intervention Installation of gas central heating in most cases	72 children with asthma living in 59 damp homes	All respiratory symptoms↓ A day off school for asthma↓
16	Longitudinal study of housing and health	SCO	Before-after study	■Intervention Improvement of heating system	997 households on an isolated housing estate	Respiratory health→ General health→

In the UK, randomized controlled trials [96−99], before-after interventional comparison studies [100−105], and prospective studies [106] related to the impact of introducing insulation materials and central heating systems on health (general health, mental health, and respiratory diseases including asthma) have been conducted, and the CWP for England, described above, was formulated based on findings from these studies. In New Zealand, an investigation on the changes to health status (e.g., cold, insomnia, rate of absenteeism) in 4,407 residents in 1,350 households before and after insulation retrofit [107] and an investigation on the influence of introducing heating devices that do not pollute the air on the health of children [108] have been conducted based on randomized controlled trial designs. However, the NICE report indicates that knowledge related to housing and health remains insufficient because the evidence is subjective, suggesting the need for objective evidence based on actual measurements [109].

2.2.2 Clinical trials related to housing and hypertension/cardiovascular disease

(1) Experiment of room heating (Japan)

A randomized controlled trial was conducted in Japan to assess the influence of room heating on blood pressure [110]. Baseline measurements were taken at accommodation facilities where the temperature could be adjusted freely by participants depending on their bedding and clothing. Measurements were retaken after randomly assigning the participants to laboratories set at either 12°C or 22°C. The results suggest that, in addition to a significant decrease in blood pressure in the morning and evening, a morning blood pressure surge at the time of waking is suppressed in the warmer condition (Fig.2-2).

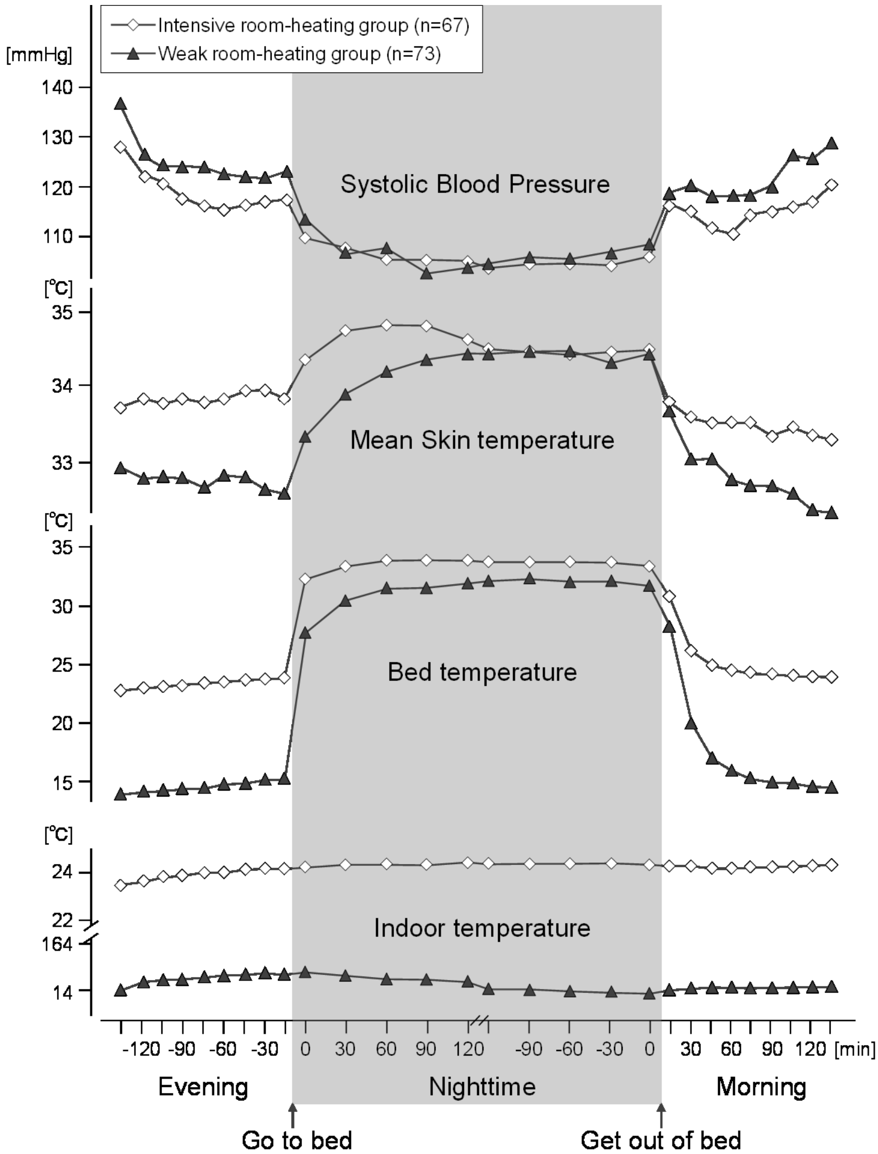


Fig.2-2 | Fluctuations in systolic blood pressure, mean skin temperature, bed temperature and indoor temperature [110]

(2) Housing Environments and Health Investigation among Japanese Older People in Nara, Kansai Region: a prospective community-based cohort (HEIJO-KYO) study (Japan)

The HEIJO-KYO study was a large-scale prospective cohort study initiated in September 2010 to investigate the influence of the living environment on health (1,127 participants). Researchers visited the homes of participants aged 60 years or older and measured health indices (e.g., ambulatory blood pressure, quality of sleep, depression, cognition, blood parameters) and living environment (e.g., temperature, light, noise) over 48 hours. The relationship between the living environment and health indices was determined using epidemiological approaches to extrapolate the relationship to a long-term prognosis. In doing so, they answered questions such as, “in what kind of living environments do people live longer?” and “in what kind of living environments do people develop stroke, ischemic heart disease or cancer?” This research focused on the biological rhythm (circadian rhythm) and the living environment by measuring melatonin secretion, body temperature rhythm, and levels of physical activity.

Among the HEIJO-KYO studies, a randomized controlled trial was conducted on the influence of heating on blood pressure [111]. Participants in the intervention group were instructed by a doctor to set their heating device to heat to 24°C one hour prior to getting out of bed. The room temperature four hours after the participants had gotten out of bed rose 2.09°C, and their SBP and DBP decreased by 4.42 and 2.33 mmHg, respectively (Fig.2-3).

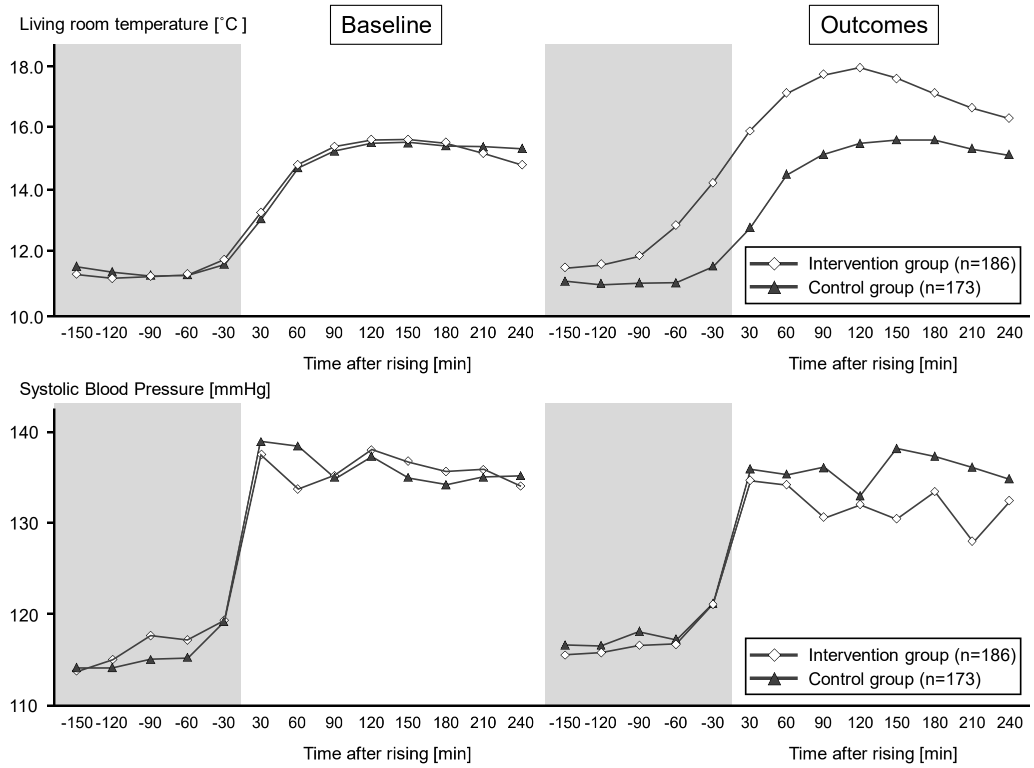


Fig.2-3 | Fluctuation of living room temperature, physical activity, and SBP [111]

(3) Central heating programme (Scotland)

In Scotland, a program has been implemented to build new central heating units in households (where the head of the household or spouse is 60 years or older) with inadequate or irreparable central heating systems. The main purpose of the program is to improve the health of elderly people, reduce the number of deaths during the winter season, decrease the incidence of cold-related diseases, and reduce the burden on the UK NHS. The program was initiated after recognizing that there was little research related to the effect of cold housing on health.

A prospective control study that compared participants with new central heating systems (1,281 households) to a control group (1,084 households) investigated the incidence of heart disease, cardiovascular disease, and hypertension using a questionnaire [106]. The study reported that a diagnosis of heart disease and hypertension was less likely (odds ratios: 0.69 (95% CI: 0.52–0.91) and 0.77 (95% CI: 0.61–0.97), respectively) among participants who lived in houses with new central heating systems (Table 2-6).

Table 2-6 | Covariate-adjusted associations between "treatment group" membership (heating recipients vs comparison group households) and health outcomes (2002–06) [106]

Measure	Type	Estimate (95%CI)	n	p
Specific symptoms and health conditions				
Whether respondent has ever been diagnosed with bronchitis, etc.	O	1.29 (0.97 to 1.72)	1,983	0.09
Whether respondent has ever been diagnosed with nasal allergy	O	1.52 (1.05 to 2.20)	2,136	0.03
Whether respondent has ever been diagnosed with heart disease	O	0.69 (0.52 to 0.91)	1,928	0.01
Whether respondent has ever been diagnosed with high blood pressure	O	0.77 (0.61 to 0.97)	1,340	0.02
Use of primary and secondary health services				
Number of overnight hospital stays in past 12 months (one or more vs zero)	P	0.74 (0.54 to 1.03)	2,309	0.08

Type: O = Odds ratio, P = Poisson regression coefficient

(4) Glasgow thermal quality study (Scotland)

In Scotland, a study examined improvements to blood pressure due to installation of a housing renovation package. In the mid-1980s, the Easthall Residents Association (ERA) and the Technical Services Agency (TSA) investigated existing residences in Easthall and found that problems of cold and condensation were caused by poor insulation materials. For this reason, the ERA and TSA developed a renovation package, termed Heatfest, that involved double-skinning outer walls, introducing insulation materials, doubling glass, and introducing a gas central heating system. They conducted interventional studies with financial aid from the European Economic Community and the Glasgow City Council [102]. Two blocks (36 houses) were selected as the intervention group and two other blocks were chosen as the control group. Blood pressure, which is a risk factor for coronary artery heart disease and stroke, was measured in these groups. The intervention group showed significant improvements in blood pressure compared to the control group (Table 2-7).

Table 2-7 | Changes in blood pressure in intervention and control group [102]

Variable	n	Mean	SD	SE mean	CI for difference	t test p value	Recorded value	
							Max	Min
Intervention								
Systolic BP								
Before	27	142.14	22.91	4.41	—		196	112
After	27	122.78	15.94	3.07	—	Paired	148	100
Difference	27	−19.36	14.51	2.79	−13.93 to −25.41	0.000		
Control								
Systolic BP								
Before	9	140.00	14.59	4.86	—		163	117
After	9	142.78	18.51	6.17	—	Paired	169	126
Difference	9	+ 2.78	9.30	3.10	+ 9.80 to −4.37	0.396		
Difference between intervention and control								
Intervention	27	−19.4	14.5	2.8				
Control	9	+2.78	9.30	3.1		Two sample		
Estimated difference		22.14			13.77 to 31.12	0.000		

(5) Warm Up New Zealand: Heat Smart (WUNZ:HS) Programme (New Zealand)

The WUNZ:HS (described in Section 2.1.2) Programme provided participants with insulation retrofit and effective and environmentally-friendly heating equipment and examined the risk of death due to CVD in these households [112]. Survival analysis using the Kaplan-Meier method (Fig.2-4) and Cox proportional hazard analysis (Table 2-8) were performed on a sub-cohort (3,287 participants out of the more than 900,000 people who participated in WUNZ:HS) comprising residents over the age of 65 years who were hospitalized in the past for CVD. The results clearly indicate that the hazard ratio for deaths due to CVD was smaller in households that underwent insulation retrofit or insulation retrofit and receipt of heating equipment than in the control group.

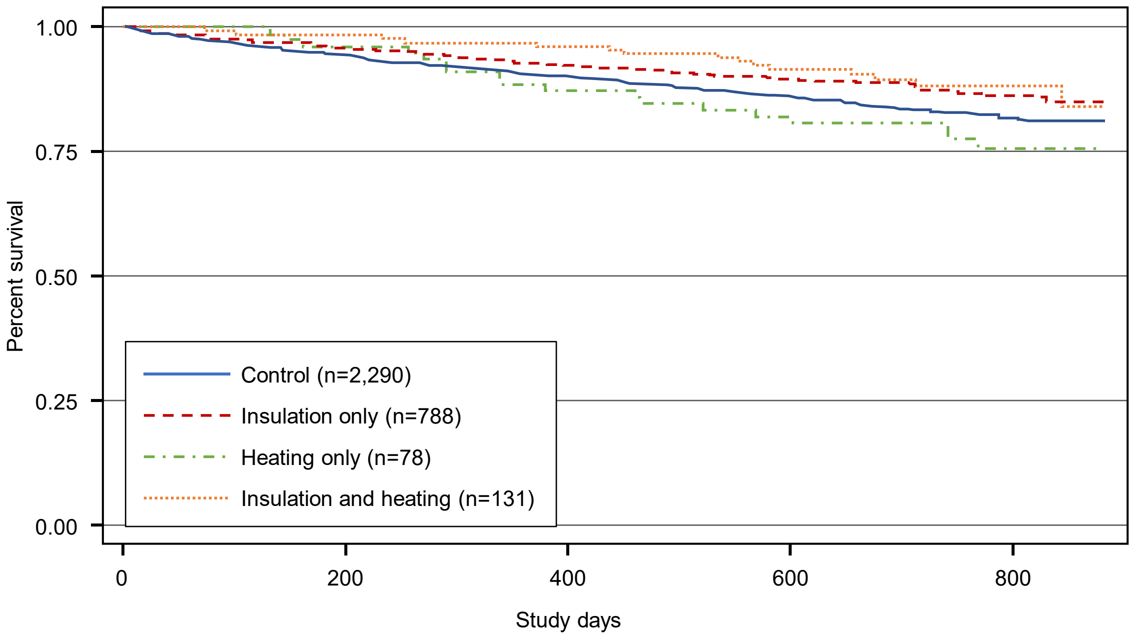


Fig.2-4 | Kaplan-Meier survival estimates for the circulatory subcohort [112]

Table 2-8 | Adjusted cox proportional hazards model results: circulatory subcohort [112]

Variable	HR (vs control)	Robust SE	Z	p < |Z|	95%CI
Insulation only	0.673	0.079	−3.37	0.001	0.535 to 0.847
Heating only	1.348	0.293	1.38	0.169	0.881 to 2.064
Insulation and heating	0.581	0.150	−2.10	0.035	0.350 to 0.964

Model controls for age, sex, ethnicity, NZDep 2006 score (Socioeconomic Deprivation Index), hospitalization-based variables, dwelling risk score and climate zone.

2.3 Review of previous research on temperature and blood pressure

A number of recent studies have systematically summarized research related to temperature and blood pressure using meta-analysis [113] (Table 2-9). The meta-analyses indicate that the rise in SBP due to decreases in indoor temperature (an increase of 3.8 mmHg when the indoor temperature decreased by 10°C) is greater than that due to decreases in outdoor temperature (an increase of 2.6 mmHg when the outdoor temperature decreased by 10°C). Studies that examined the relationship between indoor temperature and blood pressure are summarized below.

Table 2-9 | Summary of studies on ambient temperature and blood pressure in adults [113]

No.	Author	Country	Statistical method [a]	Measurements			Target (age, years)	Outcome (BP change per 10°C reduction)
				Blood pressure	Temperature[b]	Range [˚C]		
1	Wu et al.	CHN	GLMM	SBP, DBP	Min.	15.8 (0.9–25.4)	39 healthy undergraduate male students (mean: 20.1)	SBP: 3.4 (2.2–4.7) DBP: 3.6 (2.7–4.4)
2	Lanzinger et al.	GER	AMM	Ambulatory SBP, DBP, PP	Mean	10.9 ±17.3	30 type 2 diabetes patients (66.6±6.4)	SBP: 10.0 (5.0–14.0) DBP: 3.0 (1.0–6.0)
3	Saeki et al.	JPN	LR	Daytime SBP	Daytime **indoor temp.**	2.2–27.1	880 home-dwelling men and women (72.1±7.1)	2.2 (0–4.3)
4	Chen et al.	CHN	LR	Baseline and repeatedly measured SBP and DBP	Mean	1.0–30.0	1,831 hypertensive patients (Male: 55.3±10.5, Female: 55.2±9.5)	■Baseline SBP: 2.7 (1.8–3.5) DBP: 1.7 (1.3–2.2) ■Repeatedly measured SBP: 2.14 (2.06–2.22) DBP:1.44 (1.39–1.49)
5	Hong et al.	KOR	GLM	Baseline and repeatedly measured SBP and DBP	Mean, Max., Min.	–	55,567 asymptomatic subjects (49.4±12.6)	■Mean (baseline) SBP: 1.6 (1.2–1.9) DBP: 1.0 (0.8–1.2) ■Mean (repeat) SBP: 1.1 (0.7–1.6) DBP: 1.0 (0.77–1.2) ■Min(baseline) SBP: 1.9 (1.5–2.2) DBP:1.2 (1.0–1.4) ■Min (repeat) SBP: 1.3 (0.9–1.7) DBP: 1.0 (0.8–1.3)
6	Woodhouse et al.	ENG	LR	SBP, DBP	Mean, **indoor temp.**	Mean: 2–18 Indoor temp. : 17–30	96 community citizens (Median: 69)	■Mean SBP: 7.0 (4.0–9.0) DBP: 3.0 (1.0–4.0) ■Indoor temp. SBP: 9.0 (4.0–14.0) DBP: 4.0 (2.0–7.0)
7	Dashti et al.	USA	LR	SBP, DBP	Mean	9.8 (−24.4–28.9)	819 (48.3±15.9) ・610 normotensive ・209 hypertensive	SBP: 1.8 (0.8–2.8) DBP: 1.0 (0.4–1.6)

[a] GLMM: generalized linear mixed-effects model; AMM: additive mixed regression model; LR: multiple linear regression; GLM: generalized linear model; BHM: Bayesian hierarchical model. [b] Mean: daily mean outdoor temperature; Min.: daily minimum outdoor temperature; Max.: daily maximum outdoor temperature

Table 2-9 | Summary of studies on ambient temperature and blood pressure in adults (continued) [113]

No.	Author	Country	Statistical method [a]	Measurements			Target (age)	Outcome (BP change with per 10°C reduction)
				Blood pressure	Temperature[b]	Range [˚C]		
8	Dashti et al.	USA	LR	SBP, DBP	Mean	12.6 (−14.4–31.1)	1,248 (57.2±7.6) ・399 normotensive ・849 hypertensive	SBP: 2.3 (1.1–3.5) DBP: 0.4 (0.2–1.0)
9	Yang et al.	CHN	LR	SBP	Mean (≥5˚C)	Summer: 25.5 Winter: 3.8	23,000 individuals with prior-CVD (52±11)	SBP: 6.2 (5.7–6.7)
10	Kent et al.	USA	LR	SBP, DBP	Max., Min.	—	21,894 general population without previous stroke or TIA[c] (65.7±9.3)	■Max SBP: 1.3 (0.9–1.7) DBP: 0.5 (0.3–0.7) ■Min SBP: 0.6 (0.3–0.9)
11	Kunutsor and Powles	GHA	LR	SBP	**Indoor temp.**	Morning: 28–34 Afternoon: 39–43	574 general population (37.8±14.0)	SBP: 5.2 (1.0–13.0)
12	Barnett et al.	—	BHM	SBP	Mean, **indoor temp.**	Mean: 1.6–20.4 Indoor temp.: 18–24	115,434 general population (35–64)	■Mean SBP: 1.9 (1.1–2.6) ■Indoor temp. SBP: 3.1 (1.9–4.4)
13	Madsen and Nafstad et al.	NOR	GLM	SBP, DBP	Mean	6.2±7.5	16,827 general population (30–76)	SBP: 2.0 (1.0–3.0) DBP: 1.6 (1.0–2.0)
14	Jehn et al.	USA	LR	SBP	Mean	Quartiles (25th, 50th, and 75th) : 3, 10, 21	333 not hypertensive (45.1±10.4)	SBP: 0.4 (0.1–0.8)
15	Bruce et al.	ENG	LR	SBP, DBP	Mean, Max.	Mean.: 8.7±4.3 Max.: 12.3±4.86	7,735 general population (40–59)	■Mean SBP: 3.2 (1.0–5.4) DBP: 1.6 (2.0–3.0) ■Max SBP: 3.8 (2.0–5.6) DBP: 1.8 (0.6–3.0)

[a] GLMM: generalized linear mixed-effects model; AMM: additive mixed regression model; LR: multiple linear regression; GLM: generalized linear model; BHM: Bayesian hierarchical model. [b] Mean: daily mean outdoor temperature; Min.: daily minimum outdoor temperature; Max.: daily maximum outdoor temperature. [c] TIA: transient ischemic attack

(1) Saeki et al. (Japan)

In the HEIJO-KYO study, Saeki et al. measured ambulatory blood pressure over two days in 868 elderly people over the age of 60 years during the winter months between October and April, and compared the influence of indoor temperature and outdoor temperature on blood pressure [114] (Table 2-10). Multilevel linear regression analysis revealed that while the daytime outdoor temperature had no significant influence on blood pressure, the indoor temperature significantly influenced blood pressure, with the SBP rising by 2.2 mmHg when the indoor temperature decreased by 10°C. Furthermore, the nocturnal blood pressure was influenced by the bed temperature, and the rise in blood pressure at the time of waking (morning surge) was affected by the indoor temperature at the time of waking.

Table 2-10 | Multilevel linear regression analysis of the association between ambulatory blood pressure and temperature [114]

Dependent variable	Predictor	Adjusted β (95%CI) BP change per 1°C reduction	AIC	p
Daytime SBP	Daytime outdoor temp.	0.02 (−0.13 to 0.17)	13,194.3	0.812
	Daytime indoor temp.	−0.22 (−0.43 to −0.003)	13,160.9	0.047
	Daytime ambient temp.	−0.29 (−0.48 to −0.10)	13,093.0	0.003
Night-time SBP	Night-time outdoor temp.	0.12 (−0.02 to 0.26)	13,257.9	0.096
	Night-time indoor temp.	0.05 (−0.14 to 0.24)	13,212.0	0.617
	Night-time bed temp.	−0.19 (−0.36 to −0.02)	13,188.1	0.030
Sleep-trough morning BP surge	Morning outdoor temp.	−0.10 (−0.29 to 0.08)	14,355.8	0.275
	Morning indoor temp.	−0.33 (−0.55 to −0.11)	14,314.7	0.003
	Morning ambient temp.	−0.31 (−0.51 to −0.10)	14,257.4	0.003
Prewaking morning BP surge	Morning outdoor temp.	−0.17 (−0.35 to 0.01)	14,190.0	0.059
	Morning indoor temp.	−0.31 (−0.52 to −0.10)	14,154.4	0.004
	Morning ambient temp.	−0.29 (−0.49 to −0.09)	14,101.3	0.004

Adjusted for age, sex, body mass index, current smoking, habitual drinking, diabetes, calcium channel blocker, angiotensin-converting enzyme/angiotensin receptor blockers, other antihypertensives, evening administration, and physical activity at BP measurement.

(2) Woodhouse et al. (England)

Woodhouse et al. conducted home visits to measure the blood pressure of 96 subjects at two-month intervals over a one-year period [115]. The relationship between indoor temperature and blood pressure was examined using linear regression analysis, which revealed that blood pressure increased by 9.0 mmHg when the indoor temperature decreased by 10°C (Table 2-11).

Table 2-11 | Regression analyses on the relationship between indoor temperature and SBP (Woodhouse et al.) [115]

Dependent variable	Predictor	Adjusted β (95%CI) BP change per 1°C reduction	p
Systolic blood pressure	Living-room temp.	−1.3 (−1.8 to −0.8)	< 0.0001
	Living-room temp. (adjusted for mean daily outdoor temp.)	−0.9 (−1.4 to −0.4)	0.0004
	Mean daily outdoor temp.	−0.8 (−1.1 to −0.6)	< 0.0001
	Mean daily outdoor temp. (adjusted for living-room temp.)	−0.7 (−0.9 to −0.4)	< 0.0001
	Body mass index	−0.4 (−1.3 to 0.5)	0.4
	No. of walks per week	0.2 (−0.1 to 0.4)	0.3
	Gardening	−0.9 (−3.7 to 1.9)	0.5
	Physical leisure activities	3.7 (0.8 to 6.6)	0.01

(3) Kunutsor and Powles (Ghana)

In the study by Kunutsor and Powles, trained staff measured the blood pressure of 574 subjects from Ghana, aged between 18 and 65 years old [116]. When the relationship between indoor temperature and blood pressure was examined using linear regression analysis, they found that blood pressure increased by 5.2 mmHg when the indoor temperature decreased by 10°C (Table 2-12).

Table 2-12 | Regression analyses on the relationship between indoor temperature and SBP (Kunutsor and Powles) [116]

Dependent variable	Predictor	Adjusted β(SE) BP change per 1°C reduction	p
Systolic blood pressure	Constant	100.812 (13.096)	0.000
	Age (years)	0.332 (0.062)	0.000
	Waist circumference (cm)	0.411 (0.090)	0.000
	Alcohol (yes or no)	−3.003 (1.758)	0.088
	Smoking (yes or no)	−0.362 (2.832)	0.898
	Temperature (˚C)	−0.521 (0.262)	0.047

(4) Barnett et al. (16 countries)

The MONICA (Multinational MONItoring of trends and determinants in CArdiovascular disease) Project conducted by the WHO between 1979 and 1996 measured blood pressure twice in 115,434 people aged between 35 and 64 years old from 16 countries [117]. Analysis of the relationship between temperature and SBP using a Bayesian hierarchical model showed that blood pressure increased by 3.1 mmHg when the indoor temperature decreased by 10°C, whereas the blood pressure increased by 1.9 mmHg when the outdoor temperature decreased by 10°C (Table 2-13).

Table 2-13 | Models for mean SBP quantifying the effects of season and temperature [117]

No	Dependent variable	Predictor	Adjusted β (95%CI) BP change per 1°C reduction
1	Systolic blood pressure (n = 45,031)	Season (midwinter vs. midsummer)	1.93 (0.86 to 3.01)
		Indoor temperature (˚C)	−0.31 (−0.44 to −0.19)
2	Systolic blood pressure (n= 53,728)	Season (midwinter vs. midsummer)	−0.36 (−1.86 to 1.12)
		Outdoor temperature (˚C)	−0.19 (−0.26 to −0.11)
		Outdoor temperature × sex = male	0.05 (−0.02 to 0.11)
		Short-term temperature trend (˚C)	−0.96 (−3.05 to 1.22)

All models used a random intercept and random slope for body mass index.
All models also included fixed effects for age (nonlinear), sex, age×sex, body mass index×sex and type of sphygmomanometer.

Chapter 3

Field surveys on housing thermal environment and blood pressure

Chapter 3 | Field surveys on housing thermal environment and blood pressure

3.1 Outline of field surveys on housing thermal environment and blood pressure

(1) Areas, periods and ethics

The surveyed areas, periods and number of participants are shown in Fig.3-1. Surveys were administered to adult residents (men and women aged 20 years and older) in four areas in Japan: Tosa Town (Kochi Prefecture), Nagato City and surrounding areas (Yamaguchi Prefecture), Yusuhara Town (Kochi Prefecture), and Uenohara City (Yamanashi Prefecture). In addition, surveys were administered to the customers of construction companies located in Tohoku, Kanto, Chubu, Kinki, Chugoku, Shikoku and Kyushu who moved to high thermal insulation performance houses. The surveys were mainly conducted in winter, when deaths due to cardiovascular disease (CVD) are most frequent. Surveys in summer were also conducted on the same participants in Yusuhara Town and Uenohara City. The study included 228 households and 387 participants in winter, and 52 households and 63 participants in summer, with a total of 280 households and 450 participants. Briefing sessions were held for the participants of the field surveys (Fig.3-2) and informed consent was obtained. A survey protocol, which included ethical issues, was approved by the Bioethics Committee of the Faculty of Science and Technology, Keio University (approval number: 24-11, 25-13, 26-11).

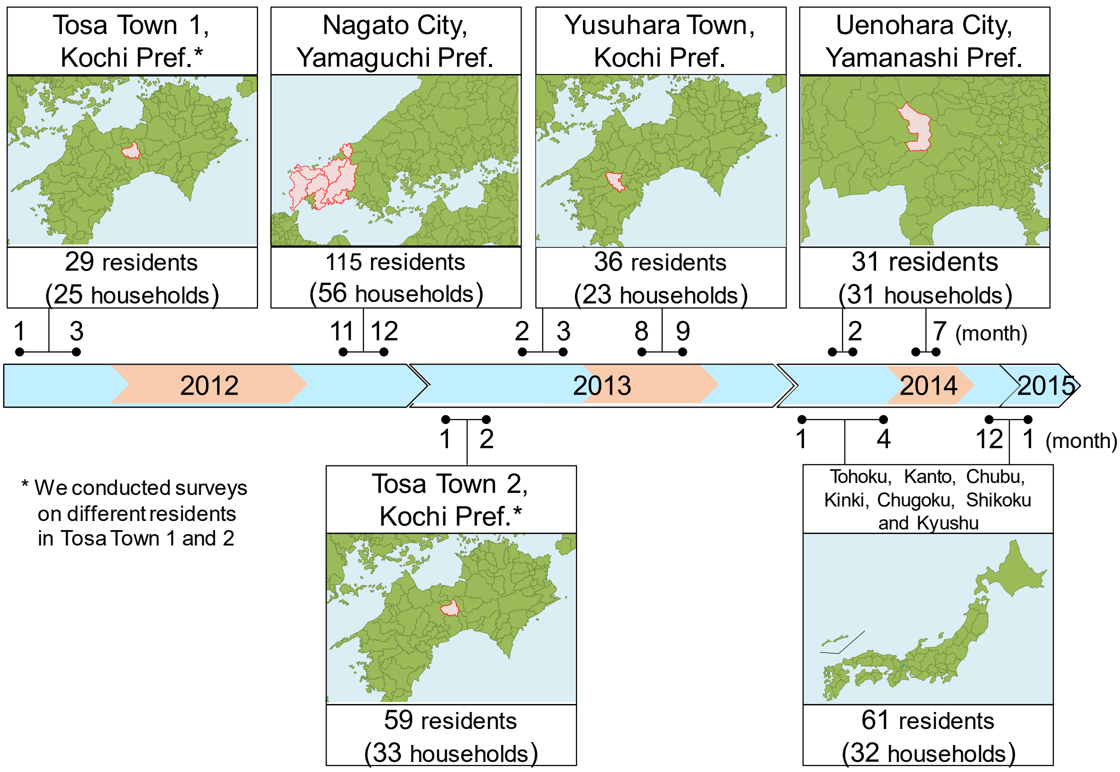


Fig.3-1 | Surveyed areas, periods and number of participants of field surveys in 2012–15

i) Tosa Town 1, Kochi Prefecture

ii) Nagato City, Yamaguchi Prefecture

iii) Yusuhara Town, Kochi Prefecture (in winter)

iv) Yusuhara Town, Kochi Prefecture (in summer)

v) Tosa Town 2, Kochi Prefecture

vi) Uenohara City, Yamanashi Prefecture

Fig.3-2 | Series of briefing sessions for field surveys

(2) Measurement items

(i) Actual measurements (Table 3-1)

■ Temperature/humidity

Indoor temperature and humidity at 1.1 m above the floor were measured in the living room and bedroom at 10-min intervals. Indoor temperature only at 1.1 m above the floor was measured in the toilet and changing room (indoor temperature in the changing room was not measured in survey case A).

■ Ambulatory blood pressure

According to the "Guidelines for the clinical use of 24 hour ambulatory blood pressure monitoring (ABPM)" (JCS 2010) [118], daytime (07:00‑22:00) BP was automatically measured every 30 minutes, and nighttime (22:00‑07:00) BP was measured at 1-hour intervals, with consideration for sleep quality. Continuous measurement was performed for a total of 7 days, excluding during bathing.

■ Home blood pressure

Blood pressure was measured by participants twice daily: before getting into bed in the evening and after getting out of bed in the morning, in accordance with the guidelines of the Japanese Society of Hypertension [119]. The conditions for measurement after getting out of bed in the morning were (i) within 1 hour after getting up, (ii) after urination, before breakfast and taking medication, and (iii) after sitting for 1–2 minutes. The condition for measurement before getting into bed in the evening was after sitting for 1–2 minutes. Home BP was measured in the living room. The specifications of each measuring instrument are shown in Table 3-2.

Table 3-1 | Outline of actual measurements in 2012–15

Survey case	Area	Number (households)	Number analyzed	Temperature and relative humidity	Ambulatory BP	Home BP
				Period	Period	Period
A	Tosa Town	14 (13)	14 (13)	2012.1.13–2.17	2012.1.13–1.19	2012.1.20–2.17
		15 (12)	15 (12)	2012.1.27–3.2	2012.1.27–2.2	2012.2.3–3.2
B	Nagato City, etc.	115 (56)	82 (44)	2012.11.14–12.15	―	2012.11.30–12.14
C *	Tosa Town	24 (15)	20 (13)	2013.1.17–1.30	―	2013.1.18–1.30
		35 (18)	33 (18)	2013.2.2–2.14	―	2013.2.3–2.13
D-1	Yusuhara Town	36 (23)	33 (22)	2013.2.15–3.8	―	2013.2.17–3.7
D-2		33 (22)	33 (22)	2013.8.7–9.7	―	2013.8.9–9.7
E-1	Uenohara City	31 (31)	29 (29)	2014.2.2–2.16	―	2014.2.2–2.16
E-2		30 (30)	29 (29)	2014.6.29–7.15	―	2014.7.1–7.15
F-1	Tohoku, Kanto, Chubu, Kinki, Chugoku, Shikoku and Kyushu	61 (32)	57 (30)	2014.1.25–4.2	―	2014.1.25–4.2
F-2		56 (28)	52 (26)	2014.11.28–2015. 1.19	―	2014.11.28–2015. 1.19

* We also conducted temperature and humidity measurements for 334 participants (145 households) in case C.

Table 3-2 | Specifications of instruments used for actual measurements in 2012–15

Item	Temperature and relative humidity *	Temperature	Ambulatory BP	Home BP
Image				
Instrument (Company)	RTR-53A (T&D Corp.)	TR-51i (T&D Corp.)	TM-2431 (A&D Co., LTD)	HEM-7420 (Omron Healthcare Co., LTD)
Range	Temperature: 0–55˚C Humidity: 10–95%RH	Temperature:－40–80˚C	BP: 0–300mmHg PUL: 30–200 bpm	BP: 0–299mmHg PUL: 40–180 bpm
Accuracy	Temperature: Ave.±0.3˚C Humidity: ±5%RH	Temperature: Ave.±0.5˚C	BP: ≤ ±3mmHg PUL: ≤ ±5%	BP: ≤ ±3mmHg PUL: ≤ ±5%
Resolution	Temperature: 0.1˚C Humidity: 1%RH	Temperature: 0.1˚C	BP: 1 mmHg PUL: 1 bpm	BP: 1 mmHg PUL: 1 bpm
Method	–	–	Oscillometric	Oscillometric

* Other instruments: RTR-503, TR-72U

(ii) Questionnaire

A questionnaire survey was conducted on the same participants who performed the actual measurements (Table 3-3). The main purpose was to extract information such as the attributes and health condition of residents, and the performance and environment of houses. The survey forms consisted of "Personal factors" and "Housing" sections (Table 3-4). The details are as follows:

■ Section 1: Personal factors

The survey items in this section were focused on "personal attributes" such as age, sex, and body weight, and "lifestyle habits" such as diet, smoking, and alcohol consumption, which are considered factors that affect blood pressure. The health status of residents was determined by focusing on heart diseases and cerebrovascular diseases caused by hypertension; and diabetes, hyperlipidemia, and kidney disease, which are related to hypertension. For each disease, participants chose from responses of "healthy," "under treatment," or "cured". Survey case A to D also inquired about the age at onset of hypertension.

■ Section 2: Housing

Participants provided answers to "basic information" on housing (e.g. structure, total floor area, building age) and "performance" of housing (e.g. presence or absence of insulation, window glazing, window frame). In addition, participants answered questions on the frequency of health problems occurring in each room in the house, according to the Comprehensive Assessment System for Built Environment Efficiency (CASBEE) health checklist, by choosing from four answers on a scale from "often" to "none."

Table 3-3 | Outline of questionnaire surveys for field measurements in 2012–15

Survey case	Area	Number (households)	Number analyzed	Period	Distribution	Collection
A	Tosa Town	29 (25)	27 (25)	2012.1.20–3.2	Direct	Direct
B	Nagato City, etc.	161 (67)	143 (65)	2012.11.15–12.11	Indirect (via survey cooperators)	Indirect (via survey cooperators)
C	Tosa Town	483 (181)	387 (173)	2013.1.18–2.13	Indirect (via survey cooperators)	Indirect (via survey cooperators)
D-1	Yusuhara Town	38 (23)	38 (23)	2013.2.17–3.7	Direct	Direct
D-2		32 (22)	32 (22)	2013.8.7–9.7	Direct	Direct
E-1	Uenohara City	31 (31)	31 (31)	2014.2.2–2.16	Direct	Direct
E-2		29 (29)	28 (28)	2014.6.29–7.15	Direct	Direct
F-1	Tohoku, Kanto, Chubu, Kinki, Chugoku, Shikoku and Kyushu	61 (32)	56 (30)	2014.1.25–4.2	Direct	Indirect (via survey cooperators)
F-2		56 (28)	52 (26)	2014.1.28–2015.1.22	Indirect (via survey cooperators)	Indirect (via survey cooperators)

Table 3-4 | Part of the questionnaire contents for field measurements in 2012–15

Section 1: Personal factors				
Age	(______) years old			
Sex	1) Male	2) Female		
Height/Weight	(______) cm	(______) kg		
Antihypertensive drug	1) None	2) Previously taken	3) Currently taking	
Smoking	1) None	2) Quit smoking	3) Smoking	
Alcohol consumption	1) None	2) 1–2 times weekly	3) 3–5 times weekly	4) 6+ times weekly
Taste preferences	1) Weak	2) Normal	3) Strong	4) On a bland diet
Feeling stress Difficulty sleeping Cold limbs	1) Never	2) Not often	3) Sometimes	4) Frequently
Diseases	1) Healthy	2) Under treatment	3) Cured	
	[Cardiac disease/Cerebrovascular disease/Cancer/Osteoporosis/Diabetes/Hyperlipemia/Kidney disease/Psychiatric disorders/Bronchial asthma/Allergic rhinitis/Dementia/Hypertension/Other]			
Section 2: Housing				
Structure	1) Detached house	2) Multi-unit housing		
Total floor area	(______) m^2			
Building age /Duration of residence	(______) years old	(______) years		
Building frame	1) Wooden	2) Reinforced concrete	3) Steel	4) Other (______)
Insulation	1) Present	2) Absent		
Window glazing	1) Single	2) Double	3) Triple	
Window frame	1) Aluminum	2) Aluminum (double)	3) Insulation	4) Old wooden
	5) New wooden	6) Plastic		

(3) Blood pressure indices used for analysis

The average values from 24-hour blood pressure measurements conducted in Tosa Town (survey case A) are shown in Fig.3-3 (n = 27). As indicated in the figure, blood pressure exhibits a circadian rhythm such that it decreases during sleep, rises when a person wakes up, remains high during the day, and decreases towards the night. The results of a previous study [120] on the number CVD cases in 2-hour intervals across 24 hours are shown in Fig.3-4. Comparison of Fig.3-3 and Fig.3-4 reveals similar trends in the change in blood pressure and the number CVD cases, and suggests that onset of CVDs is concentrated at the time of waking, when blood pressure rises sharply. These results demonstrate a phenomenon known as "morning hypertension", which underlies the widely accepted importance of blood pressure management at the time of waking [121]. This chapter therefore focused on home blood pressure after waking and ambulatory blood pressure from bedtime to after waking.

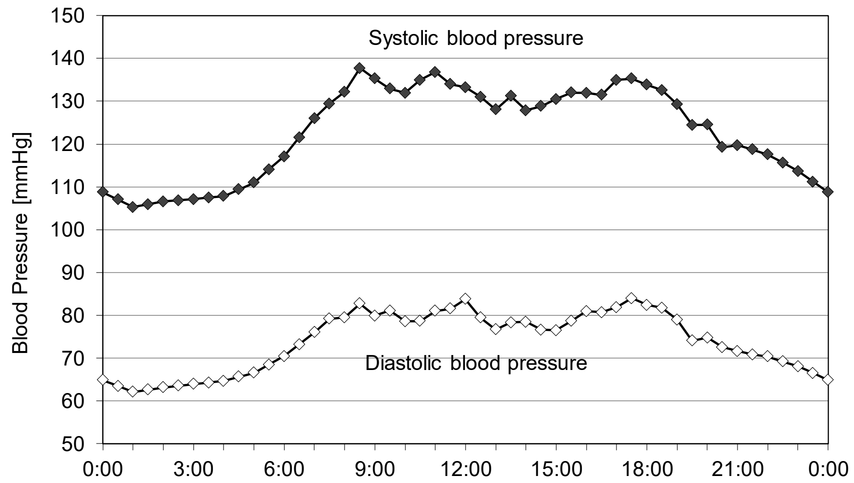


Fig.3-3 | Circadian rhythm of blood pressure in survey case A

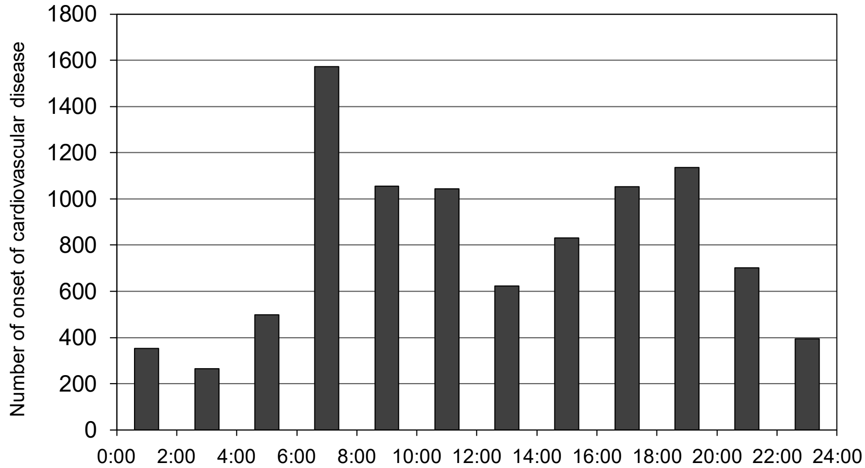


Fig.3-4 | Time-specific onset number of cardiovascular diseases for 2-h intervals [120]

3.2 Influence of indoor temperature on morning surge in blood pressure

3.2.1 Objective

In this section, I compared the morning surge in blood pressure of subjects on the day with the highest indoor temperature and the day with the lowest indoor temperature, based on ambulatory blood pressure monitoring over 24 hours for 7 consecutive days during winter. I aimed to show that the indoor temperature, and not the outdoor temperature, affected the fluctuations in blood pressure before and after waking [122].

3.2.2 Data analysis

Data was collected from 29 residents in Tosa Town 1 (Fig.3-5). The indoor temperature/humidity and the participants' ambulatory blood pressure over 24 hours were measured during winter and these variables were analyzed. The mean age of participants was 63 years old, and women accounted for approximately two-thirds of the participants. The mean body mass index (BMI) was 23 kg/m^2, and the participants generally had standard body types. Approximately 70% of the participants were non-smokers and approximately 50% of the participants drank alcohol less than once a week. Six participants had been taking antihypertensive drugs. For the following analysis, we included 21 participants who were elderly, had a high risk of developing CVD, and had a standard body type, accounting for a large part of the population as an effective sample.

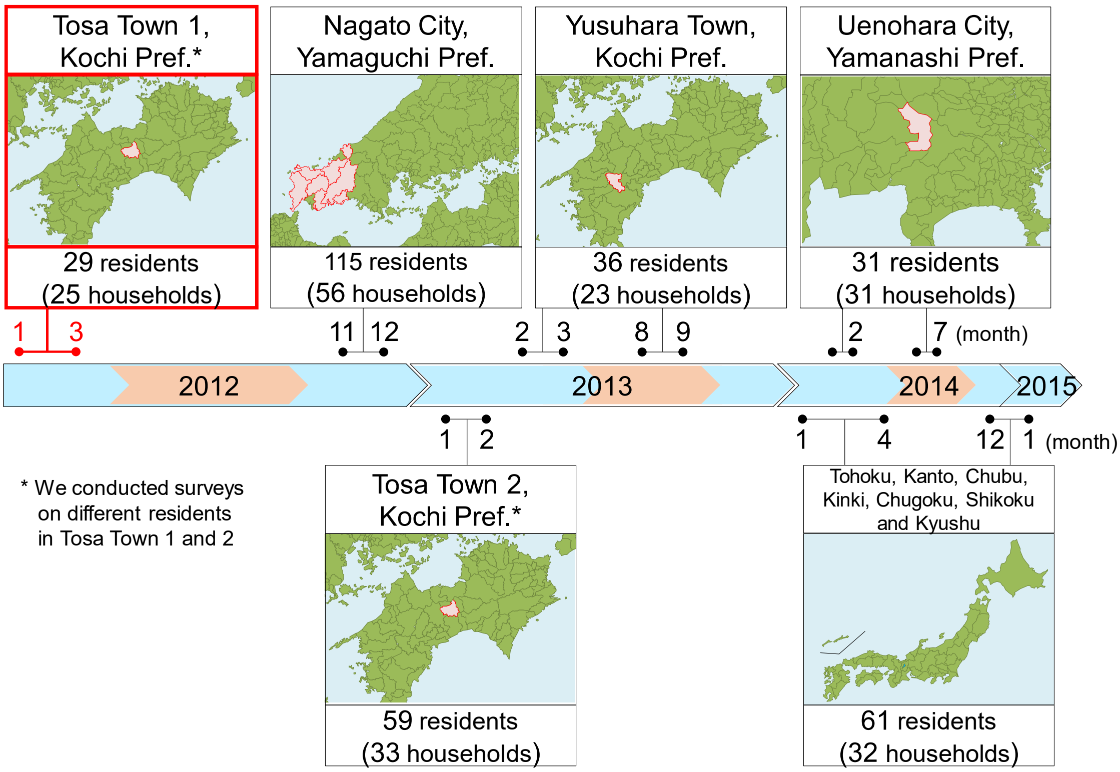


Fig.3-5 | Location, period and number of participants of the field survey in 2012

3.2.3 Influence of indoor temperature on morning surge

(1) Comparison of morning surge by room

Analysis was conducted with a focus on the morning surge in blood pressure, which previous research has suggested is involved in multiple CVDs [123, 124]. From of the seven-day measurement period, the days with the highest and lowest bedroom temperatures at the time of waking were extracted. The influence of indoor temperature on morning surge (defined as the maximum SBP two hours after waking minus the minimum SBP during sleep), which is an indicator of blood pressure fluctuations at the time of waking, was examined. Fig.3-6 shows the comparison of the morning surge on the day with the highest indoor temperature to that on the day with the lowest indoor temperature in each room, at the time of waking. The results clearly indicate that the morning surge was significantly greater on the day with lowest temperature in the bedroom than on the day with highest temperature. In contrast, there were no significant differences between the days with the highest and lowest temperature in the living room or the days with the highest and lowest outdoor temperature. The above results suggest that controlling the temperature in the room in which one sleeps is important for reducing the morning surge. The subsequent analyses focused on the room temperature in the bedroom.

(2) Comparison of morning surge according to time period

To examine the question, "what time period affects the morning surge in the bedroom?", we compared the morning surge in subjects on the day with the highest room temperature and the day with the lowest room temperature in the bedroom (1) during sleep; (2) two hours before waking; (3) at waking; and (4) two hours after waking (Fig.3-6). A significant difference in the morning surge was observed between the day with the highest room temperature and the day with the lowest room temperature at waking (condition (3)). Therefore, maintaining a high indoor temperature around the time of waking may enable better control of the morning surge in blood pressure. An explanation for why significant differences were not observed during sleep or two hours before waking (conditions (1) and (2), respectively) is that the effect of the temperature in the bed may be more important than that of the indoor temperature on the morning surge. Furthermore, an explanation as to why a significant difference in morning surge was not observed two hours after waking (condition (4)) is that subjects may not remain in the bedroom and may, therefore, be affected by the indoor temperature in other rooms and temperature disparities between rooms as he or she moves among rooms.

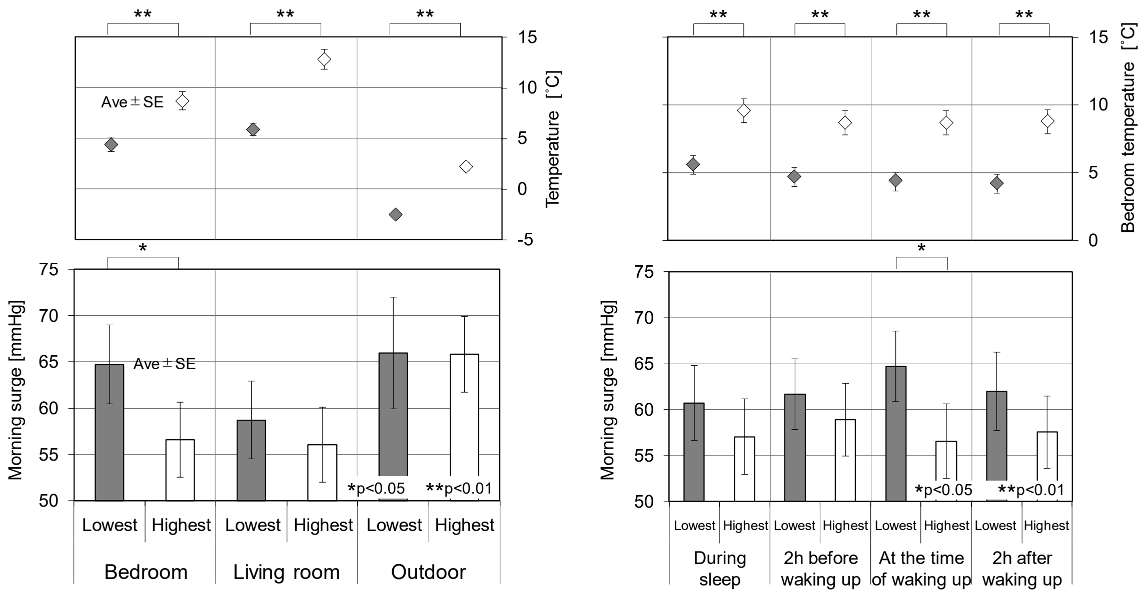


Fig.3-6 | Morning surge on days with the highest/lowest temperature in each room (left). Morning surge on days with the highest/lowest bedroom temperature according to time period (right)

(3) Fluctuations in blood pressure before and after getting out of bed

The relationship between the bedroom temperature and morning surge was examined by averaging the blood pressure of all participants, before and after waking, on the day with the lowest room temperature and the day with the highest room temperature. Fluctuations in bedroom temperature at the time of waking on the day with the highest room temperature and the day with the lowest room temperature are shown in Fig.3-7. The average room temperature on the day with the lowest room temperature was 3.6°C (range: 2.9–4.1°C) lower than that on the day with the highest room temperature. Fluctuations in blood pressure are shown in Fig.3-8. Average blood pressure on the day with the lowest room temperature was elevated relative to that on the day with the highest room temperature, and the average difference was 6.3 mmHg (range: 1.1–15.5 mmHg). In addition, there was a large difference in blood pressure after waking (average: 8.2 mmHg). One cause of these differences, according to our analysis, is likely the indoor temperature.

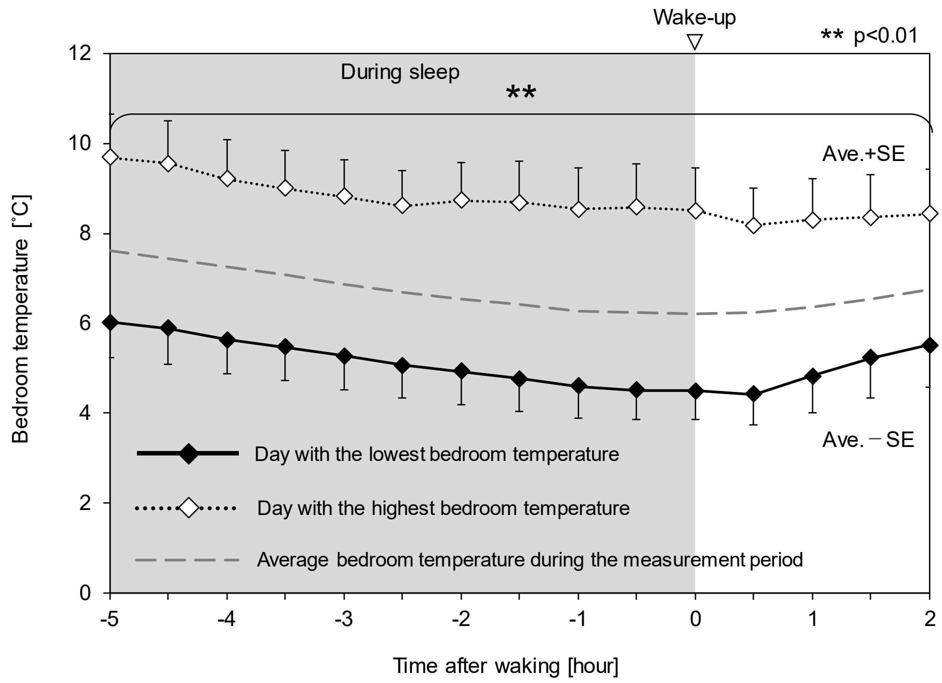


Fig.3-7 | Fluctuations in bedroom temperature before and after getting out of bed

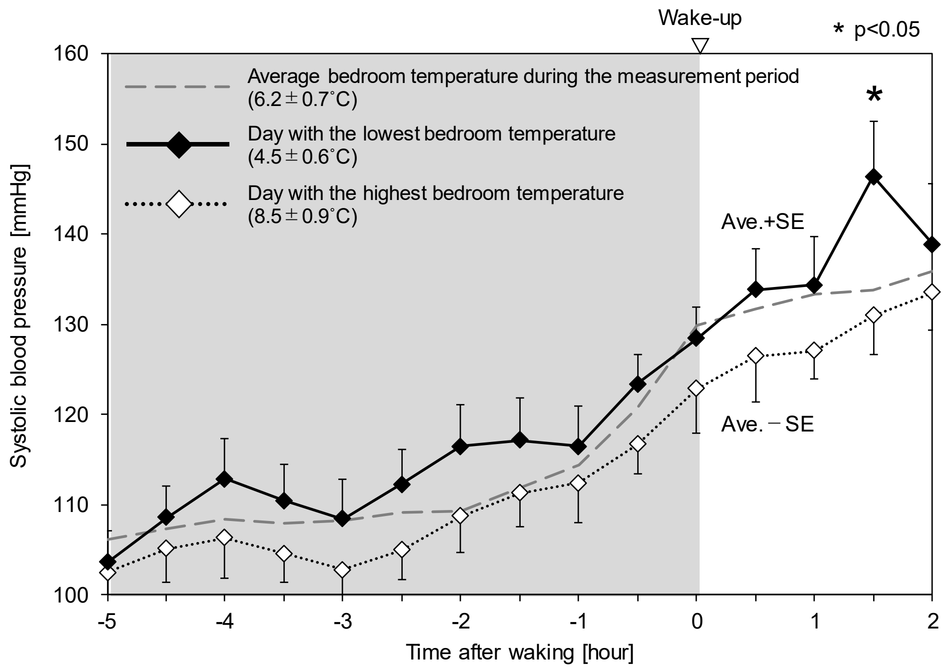


Fig.3-8 | Fluctuations in systolic blood pressure before and after getting out of bed

3.3 Causal relationship between rise in room temperature and decrease in blood pressure

3.3.1 Objective

This section aims to demonstrate the causal relationship between temperature in the home and blood pressure, by considering temporal precedence, by comparing the blood pressure before and after relocation of residents from a house with low insulation capacity to one with high insulation capacity [125].

3.3.2 Data analysis

Sixty-one clients of construction companies across the country who relocated had temperature and humidity measurements taken before and after relocation, and had blood pressure measurements taken at home, and this data were analyzed (Fig.3-9). The number of participants according to the areas described in "Standards of Judgment for Business Operators" was: Area 4: 6 people; Area 5: 26 people; Area 6: 27 people; and Area 7: 2 people. Areas 5 and 6, therefore, accounted for the majority of participants.

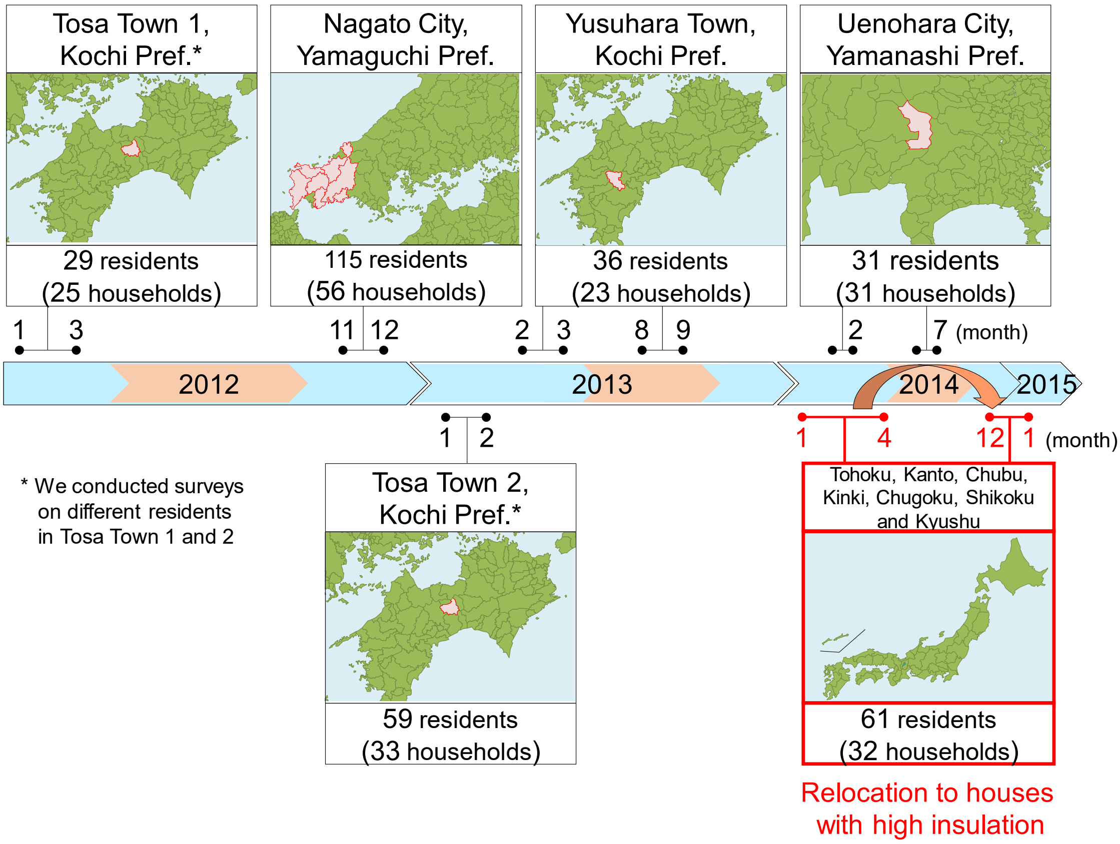


Fig.3-9 | Location, period and number of participants of field surveys in 2014–15

3.3.3 Comparison of attributes before and after relocation

Table 3-5 shows the cumulative results of the questionnaire related to individual factors before and after relocation. The mean age of participants before relocation was 37 years old. The mean BMI before and after relocation was consistently 23 kg/m^2, and, on average, the participants had a normal body type. There were slightly more women than men. Almost no participants were affected by diseases or taking antihypertensive drugs. Evaluation of lifestyle habits indicated that there were many participants who were eating salt cured products one to two times weekly, greasy food three to four times weekly, and vegetables and fruit every day of the week. Furthermore, approximately two thirds of the participants had normal taste preferences. Approximately 60% of participants were non-smokers and non-drinkers. Both before and after relocation, approximately 80% of participants lacked physical exercise.

Table 3-5 | Characteristics of participants before and after relocation

Item	Answer	Before relocation	After relocation	p-value
Personal attributes				
Age	20s	9	5	n.s.
	30s	27	30	
	40s	14	15	
	50s	3	3	
	60s	1	1	
Sex	Men	25	25	n.s.
	Women	29	29	
BMI	Leptosome (<18.5)	5	6	n.s.
	Normal (18.5–25.0)	36	37	
	Obesity (>25.0)	13	9	
	NA	0	2	
Cardiac disease	None	52	52	n.s.
	Under treatment	2	1	
	Cured	0	1	
Cerebrovascular disease	None	54	53	n.s.
	Under treatment	0	0	
	Cured	0	1	
Diabetes	None	53	53	n.s.
	Under treatment	0	0	
	Cured	0	1	
	NA	1	0	
Hyperlipemia	None	52	49	n.s.
	Under treatment	2	5	
	Cured	0	0	
Kidney disease	None	54	54	n.s.
	Under treatment	0	0	
	Cured	0	0	
Psychiatric disorders	None	53	51	n.s.
	Under treatment	0	0	
	Cured	1	3	
Hypertension	None	49	50	n.s.
	Under treatment	4	4	
	Cured	1	0	
Antihypertensive drug	None	50	51	n.s.
	Currently taking	4	3	
Lifestyle				
Taste preference	Weak	7	5	n.s.
	Normal	36	38	
	Strong	11	11	
	On a bland diet	0	0	
Salt-cured products	None	9	13	†
	1–2 times weekly	35	29	
	3–4 times weekly	4	11	
	5–6 times weekly	3	0	
	Everyday	3	1	
Greasy food	None	0	0	n.s.
	1–2 times weekly	17	18	
	3–4 times weekly	25	23	
	5–6 times weekly	9	12	
	Everyday	3	1	
Vegetables and fruit	None	0	0	n.s.
	1–2 times weekly	3	4	
	3–4 times weekly	11	7	
	5–6 times weekly	13	13	
	Everyday	26	30	
	NA	1	0	
Alcohol consumption	None	29	26	n.s.
	1–2 times weekly	8	9	
	3–4 times weekly	8	5	
	5–6 times weekly	4	8	
	Everyday	5	6	
Smoking	None	31	31	n.s.
	Quit smoking	10	10	
	Smoking	12	13	
	NA	1	0	
Exercise	Insufficient	28	26	n.s.
	Slightly insufficient	15	21	
	Almost enough	7	5	
	Enough	4	2	

† $p<0.10$

Table 3-6 shows the cumulative results related to housing before and after relocation. Prior to relocation, the majority of participants lived in apartments, and the majority of houses had wooden or steel-frame structure. The average total floor area was 67 m^2 before relocation and 110 m^2 after relocation, indicating that houses were significantly more spacious after relocation. While a large number of houses prior to relocation had insulation material, the majority had single-layer glass windows and aluminum sashes. We estimated the insulation performance of houses before relocation in accordance with previous research [126], and found that there were only houses that complied with pre-1980 standards or the 1980 standards. In contrast, the heat loss coefficient (Q-value) of houses after relocation, as determined from data obtained from the questionnaire for construction companies, was on average 1.9 W/m^2K, and the Q-values of all houses complied with the 1999 standards. Furthermore, the average equivalent clearance area (C-value) was 0.4 cm^2/m^2, and the C-value also complied with the 1999 criteria. Therefore, houses after relocation had very high insulation performance.

Table 3-7 shows the cumulative results related to the heating devices used before and after relocation. Prior to relocation, approximately 30% of households used petroleum fan heaters and approximately 40% used kotatsu tables. After relocation, the proportion of households using fan heaters or stoves decreased, while, conversely, the proportion of households using room air conditioners increased. While many participants used heating continuously while at home prior to relocation, after relocation, there was an increase in heating used “only in the morning and evening in the living room” and “only in the evening in the bedroom”, according to questionnaire responses, indicating that there was an increase in intermittent use of heating. Furthermore, there was no significant change, before and after relocation, in the proportion of participants using heating in non-living rooms like toilets and changing rooms.

Table 3-6 | Characteristics of housing before and after relocation

Item	Answer	Before relocation	After relocation	p-value
Specifications				
Structure	Detached house	6	27	**
	Apartment	17	0	
	Mansion	5	0	
	NA	1	0	
Building frame	Wooden	11	27	**
	Reinforced concrete	7	0	
	Steel	10	0	
	NA	1	0	
Total floor area	<50 m^2	9	0	**
	50–100 m^2	12	9	
	100–150 m^2	3	16	
	≥150m^2	1	1	
	NA	4	1	

** p<0.01

Item	Answer	Before relocation	After relocation	p-value
Performance				
Insulating material	Absent	5	0	**
	Present	10	27	
	Unknown	13	0	
	NA	1	0	
Window glazing	Single	19	0	**
	Double	7	27	
	Unknown	2	0	
	NA	1	0	
Window frame	Aluminum	22	0	**
	Insulation	1	27	
	Unknown	2	0	
	NA	4	0	
Building age	<10 years	9	27	**
	10–19 years	9	0	
	20–29 years	3	0	
	≥30 years	4	0	
	NA	4	0	
Thermal insulation performance	Pre-1980 standards	5	0	**
	1980 standards	16	0	
	1992 standards	0	0	
	1999 standards	0	27	
	NA	8	0	

Table 3-7 | Characteristics of heating devices before and after relocation

Item	Answer	Before relocation	After relocation	p-value
Heating device				
Petroleum fan heaters	Absent	21	26	†
	Present	8	1	
Gas fan heaters	Absent	27	25	n.s.
	Present	2	2	
Petroleum/gas stove	Absent	25	27	n.s.
	Present	4	0	
Electric stove	Absent	26	27	n.s.
	Present	3	0	
Kotatsu	Absent	18	20	n.s.
	Present	11	7	
Room-air conditioner	Absent	8	3	n.s.
	Present	21	24	

Item	Answer	Before relocation	After relocation	p-value
Use of Heating				
Heating time in the living room	All day	7	8	n.s.
	While at home	30	15	
	Morning and evening	14	22	
	Morning	0	2	
	Evening	2	3	
	No use	0	2	
	NA	1	2	
Heating time in the bedroom	All day	2	3	n.s.
	While at home	11	0	
	Morning and evening	4	1	
	Morning	0	2	
	Evening	6	13	
	No use	31	33	
	NA	0	2	
Heating device in the restroom	No installation	18	11	n.s.
	No use	1	1	
	Use	10	14	
	NA	0	1	
Heating device in the changing room	No installation	26	24	n.s.
	No use	0	0	
	Use	3	2	
	NA	0	1	

† p<0.10

The results of subjective evaluations concerning the living environment before and after relocation indicate that there was a significant decline in the frequency of participants experiencing coldness in each room, with a particularly marked improvement in the corridor, changing room, and bathroom, which are generally considered non-living rooms (Fig.3-10). In addition, there were also significant improvements in conditions related to humidity in the bedroom (dry nose and dry throat when waking up in winter), acoustic environment of the bedroom (sound and vibrations inside and outside the bedroom are disrupting even when windows and doors are closed), and in the light environment of the bedroom (inability to sleep at night due to the surroundings being too bright).

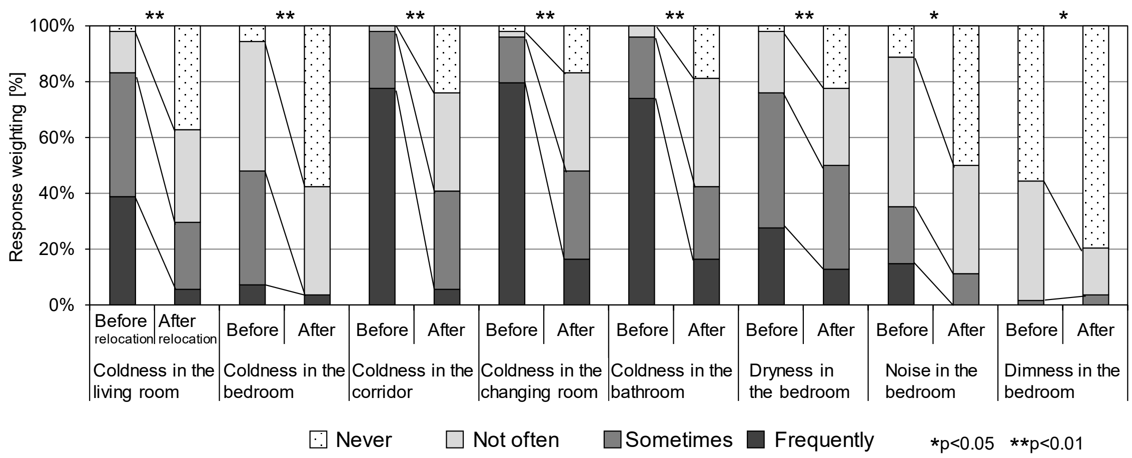


Fig.3-10 | Conditions of each room before and after relocation

3.3.4 Comparison of indoor temperature before and after relocation

The fluctuations in indoor and outdoor temperature across 24 hours before and after relocation are shown in Fig.3-11. The mean daily temperature before relocation was 5.7°C and that after relocation was 5.1°C, indicating that the temperature was similar although slightly lower after relocation. The indoor temperature across 24 hours in each room was higher after relocation than before relocation, and the indoor temperature in the toilet and changing room, which were regarded as non-living rooms, was maintained at 15°C or higher after relocation. The disparity between temperatures in the living room and non-living room (toilet) before and after relocation was 3.3°C and 2.5°C, respectively, indicating that the disparity in indoor temperature decreased following relocation. In addition, the difference between the living room temperature before and after relocation was large in the morning. The difference in mean daily living room temperature before and after relocation was 1.0°C, while the difference in living room temperature at 6 a.m. was 2.0°C. The difference in thermal insulation performance before and after relocation was assumed to have affected the magnitude of the decrease in room temperature at night. The average, standard deviation (SD), and maximum and minimum indoor temperature before and after relocation are shown in Fig.3-12. The maximum temperature in each room decreased, while the minimum temperature increased after relocation, indicating that the room temperature tended stabilize after relocation. These findings indicate that relocation to a house with high thermal insulation had two main effects: (1) increasing the room temperature and (2) stabilization of the room temperature.

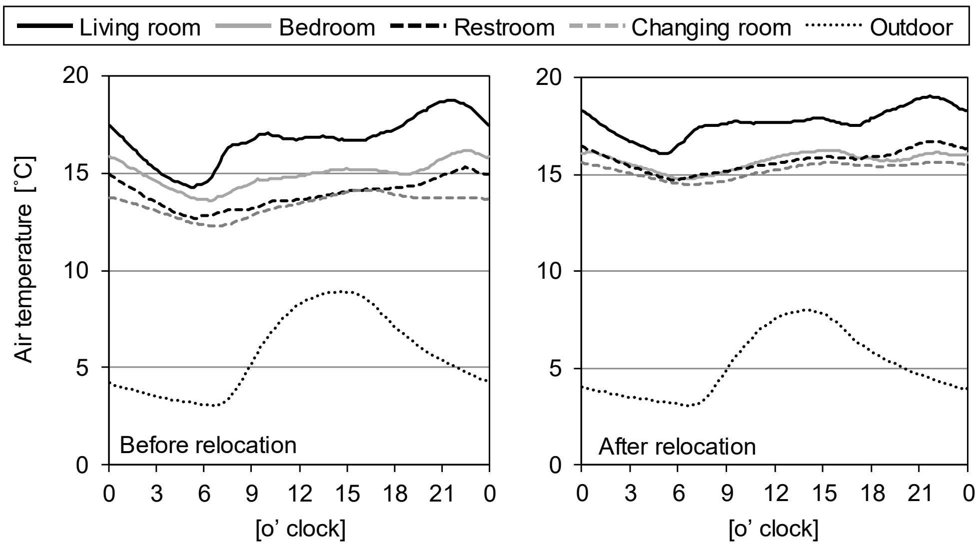


Fig.3-11 | Fluctuations in indoor and outdoor temperature before and after relocation

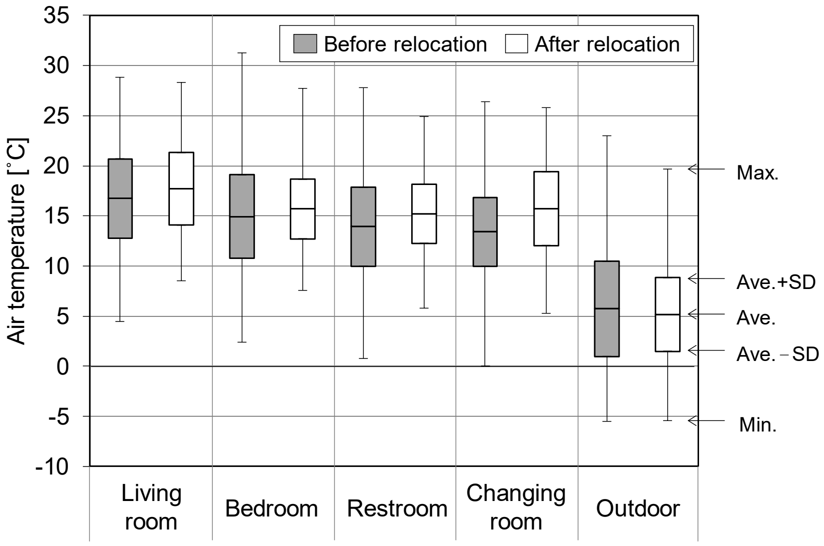


Fig.3-12 | Comparison of temperatures before and after relocation

3.3.5 Comparison of blood pressure before and after relocation

Having identified significant differences in lifestyle habits or outdoor temperatures before and after relocation in 8 participants, we assessed the average indoor temperature in the living room and blood pressure (BP) in the morning, before and after relocation, in 46 participants (the initial 8 participants were excluded from the analysis). The average number of measurements conducted by the participants was 14 both before and after relocation (range: 9–15 times), and measurements were taken for approximately 2 weeks.

In Fig.3-13, identity (ID) codes were assigned to the participants: IDs 1 to 16 denote participants who experienced decreased living room temperatures after relocation (room temperature decreased group), while IDs 17 to 46 denote participants who experienced increased room temperatures after relocation (room temperature increased group). Average systolic blood pressure (SBP) of participants in the room temperature decreased group increased after relocation, while average SBP of participants in the room temperature increased group decreased after relocation (Fig.3-14).

A valid sample (n = 46) was used to examine the influence of changes in room temperature on BP due to relocation. Fig.3-15 shows the relationship between changes in living room temperature and BP in the morning by relocation. The horizontal axis shows five groups divided based on the change in living room temperature due to relocation (room temperature after relocation – room temperature before relocation) and the vertical axis shows the change in BP in the morning (BP after relocation – BP before relocation). There was a significant dose-response relationship between room temperature and SBP (Jonckheere-Terpstra test, $p<0.05$).

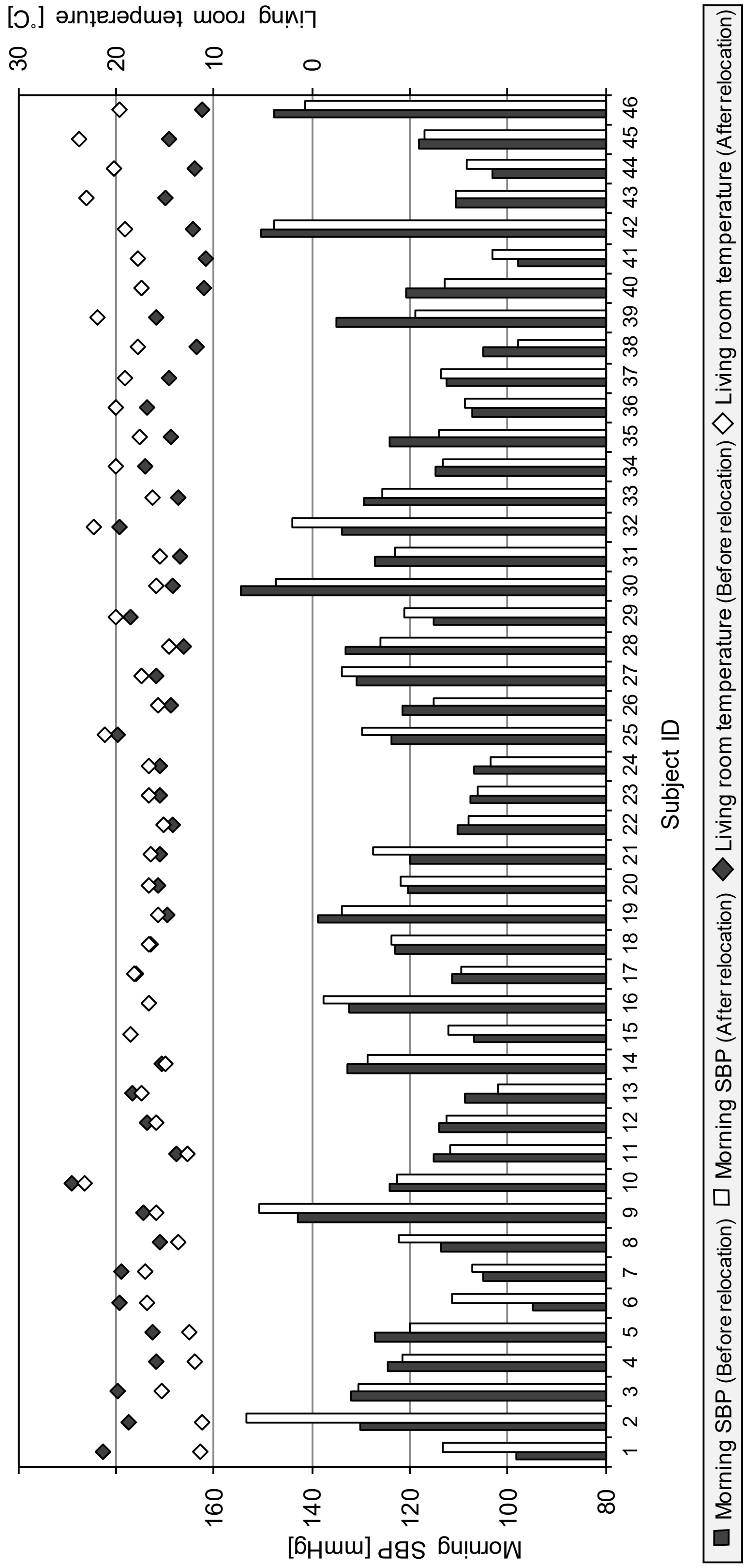
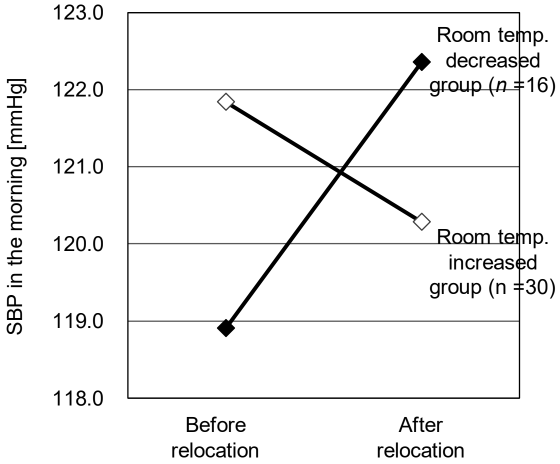


Fig.3-13 | Living room temperature and morning SBP of each subject before and after relocation



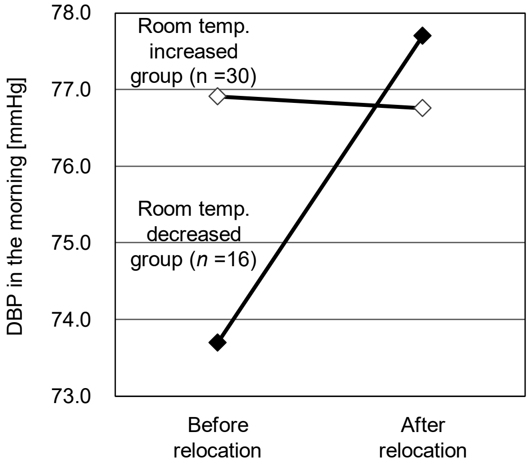
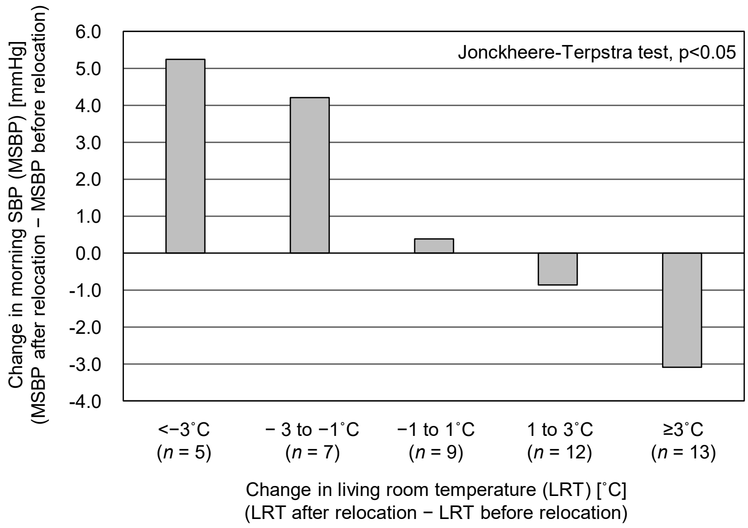


Fig.3-14 | Average blood pressure in the room temperature increased/decreased groups before and after relocation



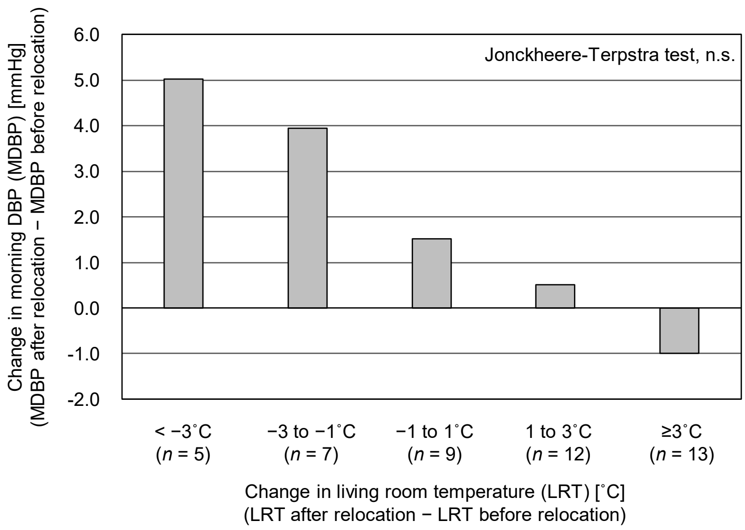


Fig.3-15 | Relationship between changes in living room temperature and BP following relocation

3.4 Summary of chapter 3

This chapter introduced the results of field surveys (pilot study), which formed the basis of the nationwide survey. To strengthen the evidence for the prevention of hypertension through improvement of the indoor thermal environment of houses such that it is recognized even in the fields of medicine and public health, the field surveys must address three main challenges:

(1) Relocation significantly changed factors other than the thermal environment.

Because relocation to a high-insulation home involved changing sites, it is highly likely that factors other than the thermal environment also significantly changed. As such, it may be more effective to use insulation retrofit as an intervention, which changes the thermal environment while participants continue to live in the same house.

(2) There was no control group, and the study consisted of a single group compared before and after the intervention.

Because a non-intervention group (control group) was not established, it is impossible to rule out the possibility that the decrease in blood pressure was due to a factor other than relocation to high-insulation housing. Therefore, it is necessary to establish both an “insulation retrofit group” and a “control group” in the study design and to conduct comparisons between the two groups.

(3) The sample size was small.

In medicine and public health studies, sample sizes of 1,000 or more participants are accepted globally, and such studies are cited as rationale for various guidelines and standard values, such as those for blood pressure. For this reason, the scale of this investigation was too small to propose “a recommended room temperature to prevent hypertension”. Therefore, the sample size needs to be increased.

The next chapter will provide a summary of the survey entitled “Nationwide survey on changes in residents' health by energy-saving retrofit of living space in Japan: Smart Wellness Housing survey (SWH survey),” which takes into consideration the aforementioned challenges.

Chapter 4

Outline of the before and after insulation retrofit survey in Japan (SWH survey)

Chapter 4 | Outline of the before and after insulation retrofit survey in Japan (SWH survey)

4.1 Introduction

"Excess winter mortality" (EWM) is a global problem [45−49]. EWM is a phenomenon in which the mortality rate increases sharply in winter, and is predominantly caused by cardiovascular and respiratory diseases [50−52]. A paradoxical relationship in which EWM is higher in areas with milder winter climates has been observed in Europe [53, 54], the USA [55] and Asia [56, 57]. This is attributed to houses in these areas being less prepared for the winter season, resulting in lower than recommended indoor temperatures. In fact, lower indoor temperatures have been reported in areas with higher outdoor temperatures [45], and EWM is higher in colder houses than warmer houses [49]. As a consequence of these observations, research on housing and health has increased in recent years.

The influence of housing on health is summarized in many papers, including a World Health Organization (WHO) report which covers issues such as the influence of cold temperatures on overall and mental health, and respiratory illness due to air quality or dampness [88−95]. Meta-analyses and systematic reviews have noted that the UK and New Zealand are leading the research on housing and health [74−76].

In the UK, randomized controlled trials (RCTs) [96−99], before and after surveys [100−105], and prospective surveys [106] have been used to evaluate the effects of the installation of insulation materials and central heating systems on health. The "Cold Weather Plan for England", developed in 2011, was based on the results of these studies. This policy has led to several initiatives, including a recommendation for heating (room temperature of 18°C), promotion of investment in housing insulation retrofit, and a "cutting the cost of keeping warm" strategy for households in fuel poverty. In New Zealand, RCTs have been conducted by surveying 1,350 households and 4,407 participants on changes in residential environment and health conditions before and after insulation retrofit [107] and surveying the effects of introducing environmentally-friendly heating equipment on children's health [108].

Despite such research, knowledge of the effects of housing on health remains limited. Many evaluations to date have used a subjective indicator, suggesting that objective evidence based on actual measurements is needed [109].

The purpose of this study was to clarify the effect of insulation retrofit on residents' health in Japan based on an objective indicator. In this chapter, we describe the study profiles.

4.2 Method

4.2.1 Ethics

The study protocol which included ethical issues and informed consent procedure were approved by the ethics committee of the Hattori Clinic Institutional Review Board. This study was registered at http://www.umin.ac.jp/ctr/ (trial registration reference number: UMIN000030601).

4.2.2 Study design

This survey was administered to households receiving subsidies for insulation retrofit as part of the Model Project for Smart Wellness Housing (SWH) Promotion by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT). We collected data on the indoor environment and health of participants before and after insulation retrofit. A control group comprising participants who initially intended to conduct the renovation but, in the end, did not do so was used for comparison. This non-RCT was designed to primarily verify the health effects due to insulation retrofit. The study design is shown in Fig.4-1. The author took part in the discussion on the study design, during which he took into consideration the challenges of the field surveys in Chapter 3. In addition, the author played a major role in planning methods of statistical analysis and formulating survey procedures (e.g. periods, questionnaire items for residents and experts on housing, diary items, and instruments for actual measurements).

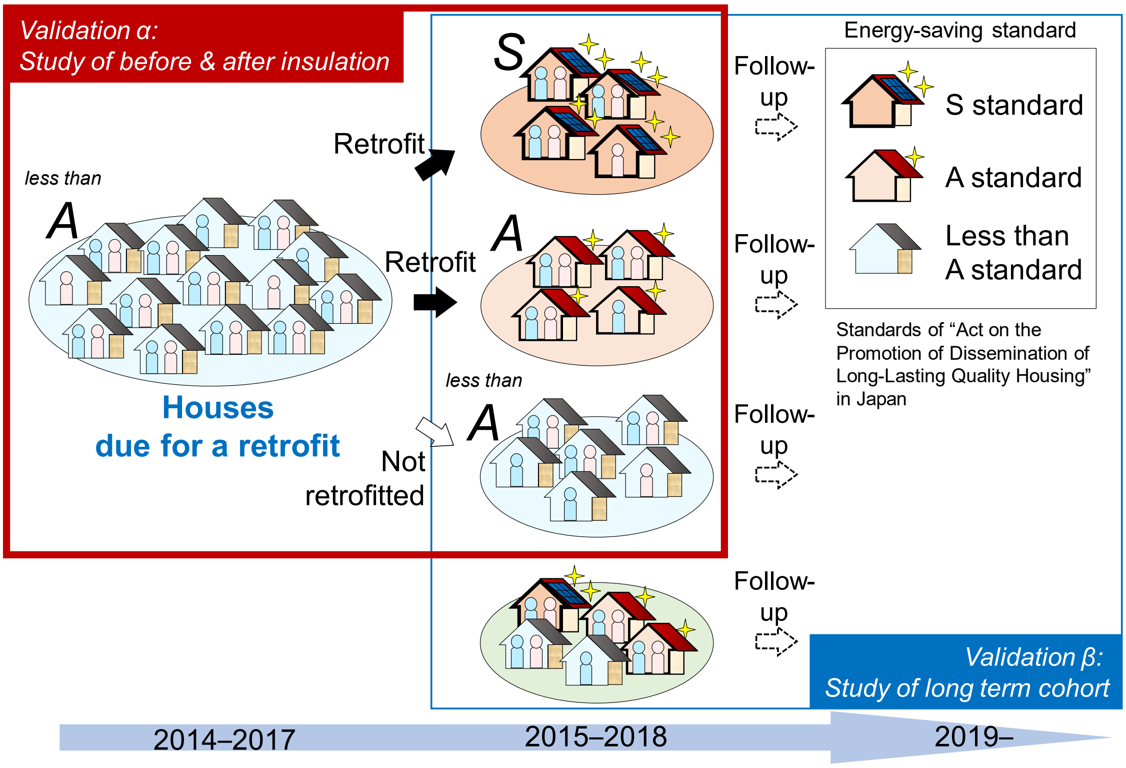


Fig.4-1 | Overview of the before and after insulation retrofit survey in Japan (SWH survey)

4.2.3 Recruitment

Participants were recruited by construction companies comprising 68 Model Project teams throughout all 47 prefectures in Japan. Inclusion criteria were (1) participants over 20 years old, and (2) participants whose houses before the renovation did not meet S (Supreme) standards of the "Act on the Promotion of Dissemination of Long-Lasting Quality Housing" in Japan. We primarily recruited participants eligible for subsidies for insulation retrofit as part of the Model Project. Two participants per household (generally a husband and wife pair) were asked to conduct actual measurements, and other family members who did not conduct measurements answered a questionnaire. Each participant received a monetary incentive.

4.2.4 Sample size determination

Based on previous meta-analysis [113], systolic blood pressure decreases by 0.38 mmHg per 1°C increase in indoor temperatures. An interim analysis showed that living room temperatures increased by 2.7°C following insulation retrofit. We therefore assumed that insulation retrofit would decrease systolic blood pressure by 1.0 mmHg (0.38 mmHg/°C × 2.7°C). Assuming a standard deviation of 20 mmHg according to the National Health and Nutrition Survey [127], we calculated that a sample size of 3,142 participants was required to obtain power >80% with $\alpha<0.05$ (two-sided) in a paired t-test. Assuming that about half of households would not participate in the retrofit, we set a target sample size of 6,000 participants.

4.2.5 Intervention

The intervention was the thermal insulation retrofit of participants' homes. Subsidies of up to 1.2 million yen were provided for insulation retrofit by the Project for Promotion of SWH, and households using the subsidies were recruited to participate in this study. The adiabatic level after insulation retrofit was required to satisfy the S standards (approximately equivalent to a long life high-quality newly built house) or A standards (lower than S standards but constant performance improvement is expected) of the "Act on the Promotion of Dissemination of Long-Lasting Quality Housing" in Japan.

4.2.6 Measurements

The SWH survey items are shown in Table 4-1 and Table 4-2. Data on the indoor thermal environment and energy consumption of houses, and health conditions of residents were collected from actual measurements using a questionnaire, diary and health exam, conducted in their place/community of residence. Data collection was performed continuously, before and after insulation retrofit. To investigate the design specifications of participants' homes from the viewpoint of experts, we administered questionnaires to not only residents but also the construction companies that conducted the insulation retrofit. To determine preventive measures against heat stroke and cardiovascular disease due to the indoor heat environment, we also administered optional summer surveys. The specifications of instruments used for actual measurements are shown in Table 4-3. Additionally, items of the questionnaire for residents, diary for residents, and questionnaire for experts on housing are shown in Appendix 1 to 3 at the end of this thesis.

Table 4-1 | Summary of subjective data collected in the Smart Wellness Housing survey

Questionnaire for residents
1) Health condition
SF-8 (MOS Short Form 8 Health Survey) [128−131]
GHQ (General Health Questionnaire)-12 [132]
2) Lifestyle
PSQI (Pittsburgh Sleep Quality Index) * [133, 134]
OABSS (OverActive Bladder Symptom Score) * [135]
WFun (Work Functioning impairment scale) * [136]
Salt Check Sheet [137], smoking, alcohol consumption *
3) Physical condition/Activity
Body aches, fitness habits, social capital
4) Symptoms/Disease
JRQLQ (Japan Rhinitis Quality of Life Questionnaire) * [138, 139]
Subjective symptoms *
Current hospital visits (e.g., ICD10)
Antihypertensive drugs *
5) Housing
CASBEE (Comprehensive Assessment System for Built Environment Efficiency)
Housing Health Checklist [85]
Lifestyle at home
Heating, bathing, clothing *, time at home *
6) Individual attributes
Age *, sex *, height and weight *, duration of residence, educational status, household income, reason for renovation
7) Health condition of children
Age *, sex *, allergies *, asthma *
(head of household answered the questionnaire on their children's behalf)
Diary for residents
1) Sleep
Wake time *, bedtime *, quality of sleep *, sleep medication *
2) Wake
Time leaving and arriving home *, alcohol consumption *
Questionnaire for experts in housing
1) Housing attributes
Building age, total floor area, building type, structure, conditions of renovation, central heating, adiabatic level
2) Insulation/design specification
Specifications of insulation in the walls, floor and ceiling
Specifications of window glass and window frame
CASBEE [140]
3) Interior
Wooden interior
4) Energy consumption
Electricity, gas, kerosene

*data collected in winter and summer

Table 4-2 | Summary of objective data collected in the Smart Wellness Housing survey

Actual measurements (Winter: 2 weeks, Summer: 1 week)
1) Room air temperature and relative humidity * (TR-72wf (T&D Corp.))
Living room, bedroom, changing room ***
at 1 m above the floor at 10-min intervals
2) Room air temperature ** (RTR-501 (T&D Corp.))
Living room, bedroom, changing room ***
at 0 m above the floor at 10-min intervals
3) Home blood pressure (HBP) * (HEM-7251G (Omron Healthcare Co.))
SBP (systolic blood pressure), DBP (diastolic blood pressure), pulse
in the morning and evening
4) Physical activity (PA) * (HJA-750C Active style Pro (Omron Healthcare Co.))
Steps, intensity of PA, time spent in PA, calorie consumption
Health exam (optional survey)
1) Physical parameters
Height and weight, BMI (body mass index), abdominal girth
2) Blood pressure
SBP (systolic blood pressure), DBP (diastolic blood pressure)
3) Blood
White blood cell count, red blood cell count, hemoglobin content,
hematocrit, platelet count
4) Blood lipids
TC (total cholesterol), HDL (high-density lipoprotein) cholesterol,
LDL (low-density lipoprotein) cholesterol, neutral fat
5) Blood glucose
Blood glucose level, HbA1c (hemoglobin A1c), urinary sugar
6) Liver function
AST (GOT), ALT (GPT), ALP, γ-GTP
7) Kidney function
Cr (creatinine), UP (uric protein), UB (uric blood)
8) Uric acid
Uric acid
9) Heart
ECG (electrocardiogram)
10) Lung
Chest X-ray

*Data collected in winter and summer, **data collected in winter since November 2015
***Bathroom in a typical Japanese home consists of two rooms: a changing room where you take off your clothes, and the actual bathroom with a shower space and a deep bathtub.
AST, aspartate aminotransferase; GOT, glutamate oxaloacetate transaminase; ALT, alanine aminotransferase; GPT, glutamate pyruvate transaminase; ALP, alkaline phosphatase; γ-GTP, gamma-glutamyl transpeptidase

Table 4-3 | Specifications of instruments for actual measurements in the SWH survey

Item	Temperature and relative humidity	Temperature	Home BP	Physical activity (PA)
Image				
Instrument (Company)	TR-72wf (T&D Corp.)	RTR-501 (T&D Corp.)	HEM-7251G (Omron Healthcare Co.)	HJA-750C Active style Pro (Omron Healthcare Co.)
Range	Temperature: 0–55˚C Humidity: 10–95%RH	Temperature:－40–80˚C	BP: 0–299mmHg PUL: 40–180 bpm	–
Accuracy	Temperature: Ave.±0.5˚C Humidity: ±5%RH	Temperature: Ave.±0.5˚C	BP: ≤ ±3mmHg PUL: ≤ ±5%	–
Resolution	Temperature: 0.1˚C Humidity: 1%RH	Temperature: 0.1˚C	BP: 1 mmHg PUL: 1 bpm	Steps: 1 step Intensity of PA: 0.1 METs
Method	–	–	Oscillometric	3D accelerometer

4.2.7 Statistical analysis

Data obtained from the SWH survey were statistically analyzed for the following: the relationship between indoor temperature and home blood pressure (HBP), physical activity, symptoms (such as shoulder stiffness, back pain, cold symptoms, headache), disease, and the results of the health exam at baseline. Multivariate analyses including a multilevel model will be used to account for confounders such as age, sex, and body mass index (BMI). HBP and physical activity after insulation retrofit will be compared with baseline values using multivariate analysis to adjust for differences in baseline characteristics due to the non-randomized controlled design. All statistical tests will be two-sided with a significance level of 0.05.

4.3 Results

4.3.1 Participant numbers and characteristics

Fig.4-2 and Fig.4-3 show the number of households and participants in winter and summer. Results from the baseline questionnaire survey in winter were obtained from 2,137 households and 4,396 participants as of July 2018. Actual measurements of HBP and physical activity at baseline in winter were conducted by 2,095 households and 3,775 participants, and 2,113 households and 3,793 participants, respectively.

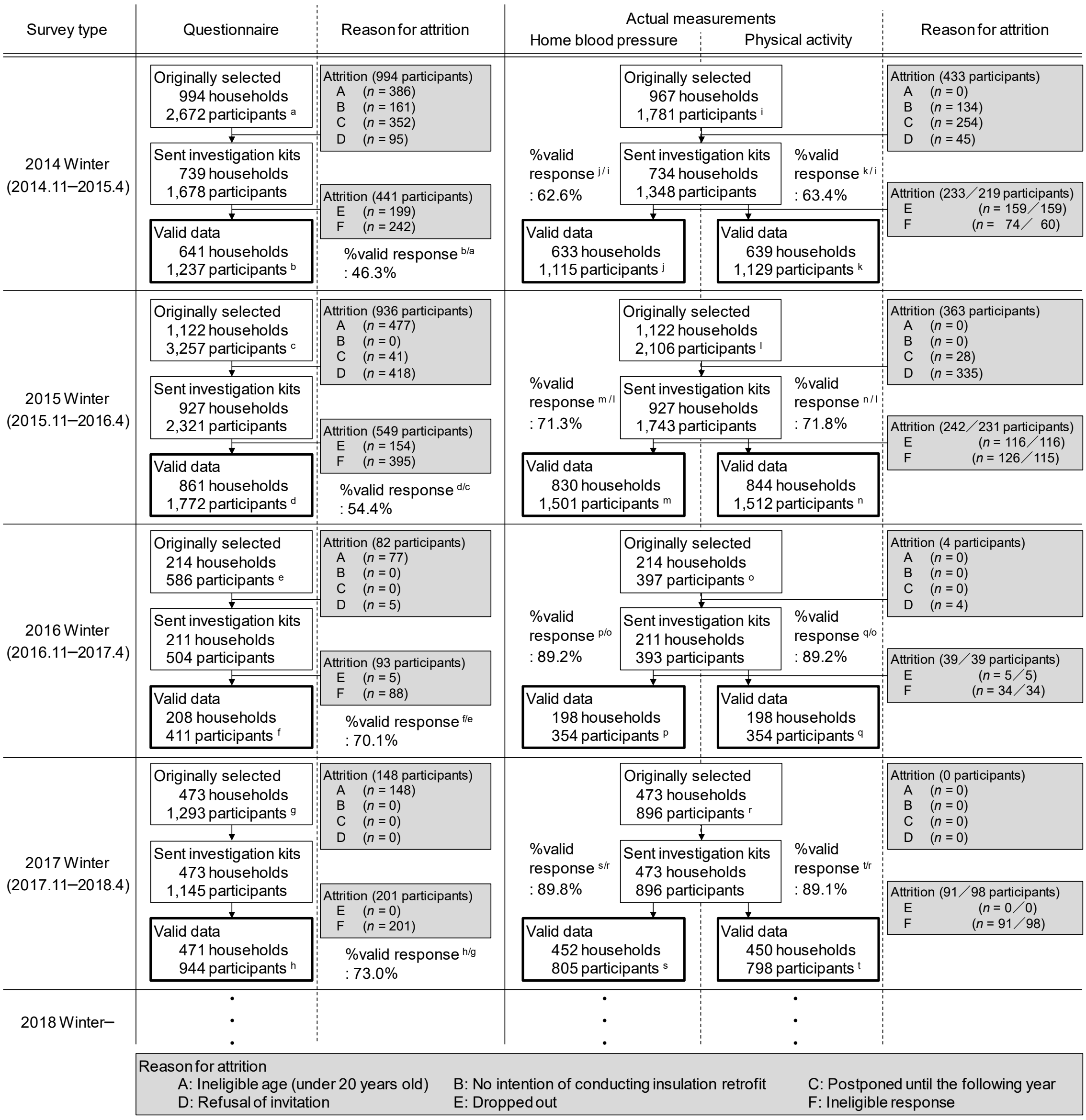


Fig.4-2 | Flowchart of recruitment of participants for the Smart Wellness Health survey in winter

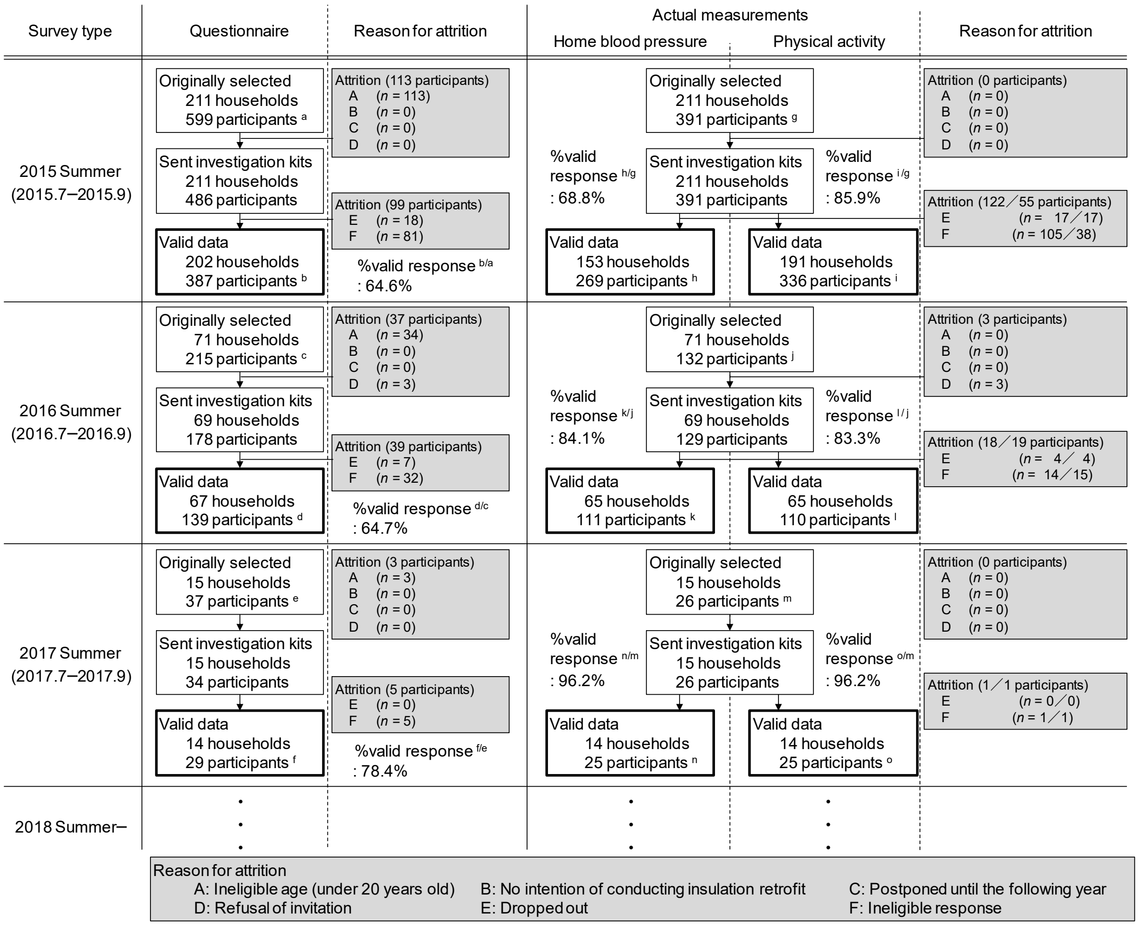


Fig.4-3 | Flowchart of recruitment of participants for the Smart Wellness Health survey in summer

4.3.2 Baseline characteristics of participants

Table 4-4 shows the characteristics of participants in the baseline survey in winter. The mean age of the participants was 56 years, and 53.8% were women. The mean BMI was 22.7 kg/m^2, which is considered "normal weight" (18.5–24.9 kg/m^2) according to WHO. More than 10% of participants suffered from hyperlipidemia, hypertension, allergic rhinitis or back pain. About 70% of the participants were non-smokers, and half of the participants did not drink.

Table 4-5 shows the results of actual measurements in the baseline survey in winter. The mean home systolic blood pressure in the morning and evening was 130 mmHg and 123 mmHg, respectively. These data show a general trend that BP is higher in the morning than in the evening. The mean number of steps taken was 6,154 steps/day, which is lower than the recommended 8,000–10,000 steps/day by the Physical Activity Reference 2013 for Health Promotion [141].

Table 4-4 | Characteristics of the participants in the baseline survey

Category	Response	Number of participants (%)									
		2014 Winter		2015 Winter		2016 Winter		2017 Winter		Total	
Age	20–29	62	(5.0)	116	(6.5)	23	(5.6)	45	(4.8)	246	(5.9)
	30–39	123	(9.9)	192	(10.8)	42	(10.2)	92	(9.7)	449	(10.5)
	40–49	210	(17.0)	285	(16.1)	70	(17.0)	118	(12.5)	683	(16.6)
	50–59	305	(24.7)	428	(24.2)	95	(23.1)	203	(21.5)	1,031	(24.1)
	60–69	288	(23.3)	463	(26.1)	99	(24.1)	296	(31.4)	1,146	(24.7)
	70–79	180	(14.6)	188	(10.6)	56	(13.6)	128	(13.6)	552	(12.4)
	80–89	61	(4.9)	81	(4.6)	18	(4.4)	52	(5.5)	212	(4.7)
	90–99	4	(0.3)	12	(0.7)	4	(1.0)	8	(0.8)	28	(0.6)
	100–109	0	(0.0)	1	(0.1)	0	(0.0)	0	(0.0)	1	(0.0)
	Missing	4	(0.3)	6	(0.3)	4	(1.0)	2	(0.2)	16	(0.6)
	Ave. (S.D.)	56.1	(14.9)	55.1	(15.6)	56.0	(15.4)	57.8	(15.0)	56.1	(15.3)
Sex	Men	572	(46.2)	819	(46.2)	189	(46.0)	431	(45.7)	2,011	(46.1)
	Women	661	(53.4)	949	(53.6)	219	(53.3)	512	(54.2)	2,341	(53.6)
	Missing	4	(0.3)	4	(0.2)	3	(0.7)	1	(0.1)	12	(0.3)
Body mass index	<18.5	96	(7.8)	131	(7.4)	30	(7.3)	61	(6.5)	318	(7.3)
	18.5–25.0	856	(69.2)	1,247	(70.4)	294	(71.5)	684	(72.5)	3,081	(70.6)
	>25.0	269	(21.7)	376	(21.2)	80	(19.5)	195	(20.7)	920	(21.1)
	Missing	16	(1.3)	18	(1.0)	7	(1.7)	4	(0.4)	45	(1.0)
	Ave. (S.D.)	22.7	(3.5)	22.8	(3.5)	22.5	(3.2)	22.7	(4.1)	22.7	(3.6)
Smoking	None	828	(66.9)	1,243	(70.1)	279	(67.9)	708	(75.0)	3,058	(70.1)
	Quit smoking	101	(8.2)	140	(7.9)	27	(6.6)	68	(7.2)	336	(7.7)
	Smoking	188	(15.2)	259	(14.6)	70	(17.0)	101	(10.7)	618	(14.2)
	Missing	120	(9.7)	130	(7.3)	35	(8.5)	67	(7.1)	352	(8.1)
Alcohol	None	591	(47.8)	799	(45.1)	197	(47.9)	471	(49.9)	2,058	(47.2)
	Sometimes	311	(25.1)	509	(28.7)	97	(23.6)	245	(26.0)	1,162	(26.6)
	Everyday	302	(24.4)	439	(24.8)	111	(27.0)	213	(22.6)	1,065	(24.4)
	Missing	33	(2.7)	25	(1.4)	6	(1.5)	15	(1.6)	79	(1.8)
Anti hypertensive drug use	None	904	(73.1)	1,311	(74.0)	311	(75.7)	659	(69.8)	3,185	(73.0)
	Currently	280	(22.6)	406	(22.9)	81	(19.7)	247	(26.2)	1,014	(23.2)
	Missing	53	(4.3)	55	(3.1)	19	(4.6)	38	(4.0)	165	(3.8)
Hospital visits	Diabetes	63	(5.1)	116	(6.5)	28	(6.8)	70	(7.4)	277	(6.3)
	Obesity	73	(5.9)	122	(6.9)	23	(5.6)	57	(6.0)	275	(6.3)
	Hyperlipidemia	195	(15.8)	281	(15.9)	66	(16.1)	172	(18.2)	714	(16.4)
	Mental illness	37	(3.0)	45	(2.5)	7	(1.7)	29	(3.1)	118	(2.7)
	Nervous system disorder	50	(4.0)	81	(4.6)	17	(4.1)	30	(3.2)	178	(4.1)
	Hypertension	270	(21.8)	369	(20.8)	81	(19.7)	248	(26.3)	968	(22.2)
	Stroke	23	(1.9)	29	(1.6)	9	(2.2)	19	(2.0)	80	(1.8)
	Angina/MI	43	(3.5)	65	(3.7)	13	(3.2)	25	(2.6)	146	(3.3)
	Allergic rhinitis	120	(9.7)	209	(11.8)	44	(10.7)	120	(12.7)	493	(11.3)
	COPD	8	(0.6)	12	(0.7)	4	(1.0)	3	(0.3)	27	(0.6)
	Asthma	34	(2.7)	47	(2.7)	11	(2.7)	24	(2.5)	116	(2.7)
	Skin disease	67	(5.4)	113	(6.4)	22	(5.4)	80	(8.5)	282	(6.5)
	Arthropathy	95	(7.7)	162	(9.1)	33	(8.0)	72	(7.6)	362	(8.3)
	Back pain	197	(15.9)	278	(15.7)	56	(13.6)	142	(15.0)	673	(15.4)
	Osteoporosis	41	(3.3)	60	(3.4)	14	(3.4)	46	(4.9)	161	(3.7)
	Kidney disease	12	(1.0)	24	(1.4)	7	(1.7)	12	(1.3)	55	(1.3)
	Fracture	9	(0.7)	22	(1.2)	6	(1.5)	17	(1.8)	54	(1.2)
	Injury/ burn injury	18	(1.5)	36	(2.0)	5	(1.2)	21	(2.2)	80	(1.8)
	Malignant neoplasm	30	(2.4)	36	(2.0)	8	(1.9)	25	(2.6)	99	(2.3)

MI, myocardial infarction; COPD, chronic obstructive pulmonary disease.

Table 4-5 | Results of actual measurements in the baseline survey

Category	Item	Mean (SD)									
		2014 Winter		2015 Winter		2016 Winter		2017 Winter		Total	
HBP (morning)	Systolic BP (mmHg)	131	(18)	129	(18)	129	(19)	131	(17)	130	(18)
	Diastolic BP (mmHg)	81	(11)	81	(11)	80	(11)	81	(10)	81	(11)
	Pulse (bpm)	69	(9)	69	(9)	70	(9)	68	(9)	69	(9)
HBP (evening)	Systolic BP (mmHg)	124	(16)	123	(16)	123	(18)	124	(16)	123	(16)
	Diastolic BP (mmHg)	75	(10)	75	(10)	74	(11)	75	(10)	75	(10)
	Pulse (bpm)	72	(10)	72	(9)	73	(10)	72	(9)	72	(9)
Physical activity	Pedometer wear time (minutes/day)	779.7	(81.8)	774.4	(80.8)	769.5	(76.9)	779.1	(77.4)	776.5	(80.1)
	Steps (steps/day)	5,962	(3,020)	6,221	(2,908)	6,353	(2,876)	6,214	(2,990)	6,154	(2,958)
	Time in MVPA (minutes/day)	89.2	(38.4)	94.1	(39.3)	93.1	(38.7)	91.3	(36.7)	91.9	(38.5)
	Amount of MVPA (MET-h/day)	5.67	(2.67)	6.03	(2.76)	6.01	(2.79)	5.79	(2.54)	5.87	(2.69)

HBP, home blood pressure; MVPA, moderate to vigorous physical activity; MET, metabolic equivalent of task

4.3.3 Baseline characteristics of homes

Fig.4-4 to Fig.4-6 show the average and minimum temperatures in the living room, bedroom, and changing room when participants were at home. The average temperature in the living room, bedroom and changing room was 16.7°C, 12.6°C and 12.8°C, respectively. The minimum temperature in the living room was below 18°C (the recommended minimum temperature by the WHO and UK guidelines) in 91.6% of households.

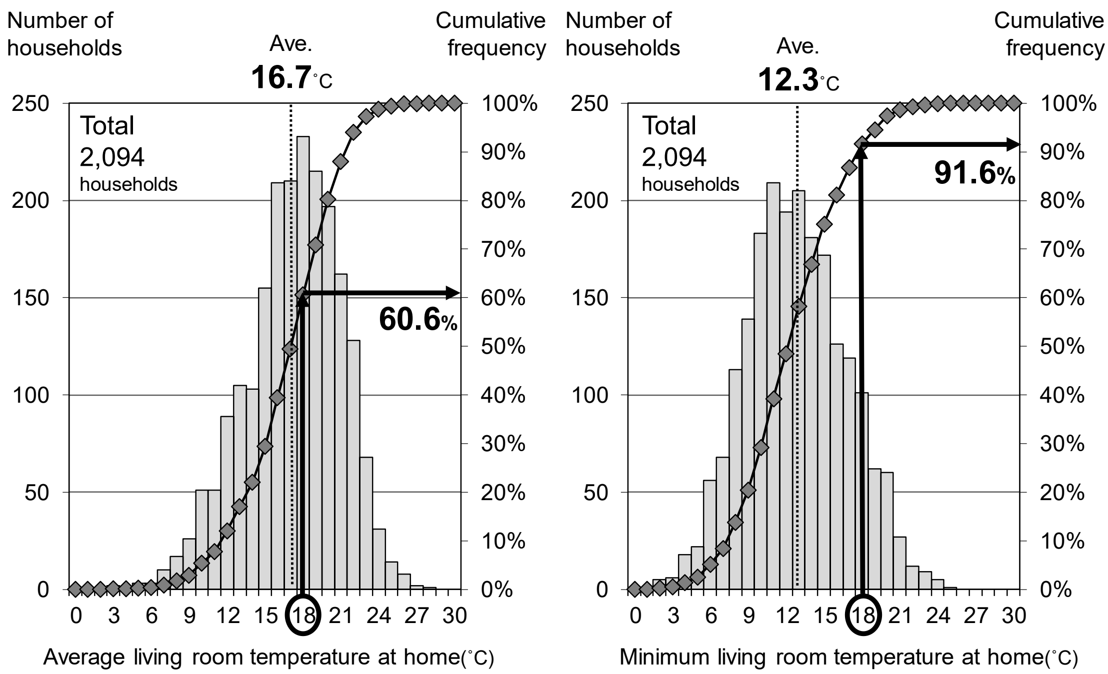


Fig.4-4 | Average (left) and minimum (right) living room temperature at home

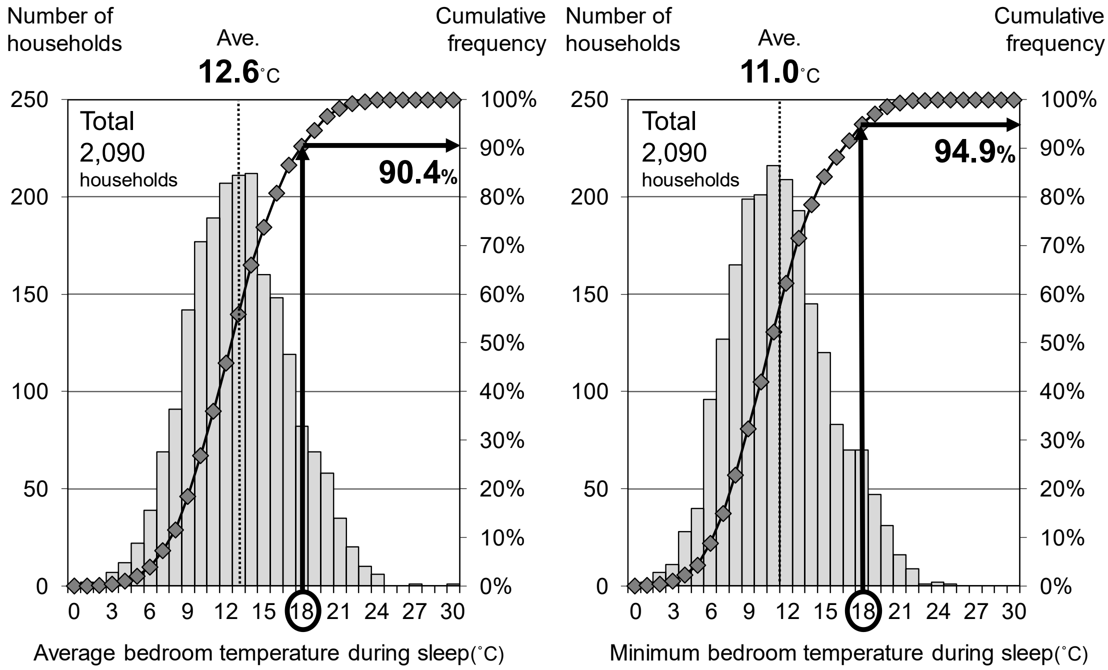


Fig.4-5 | Average (left) and minimum (right) bedroom temperature during sleep

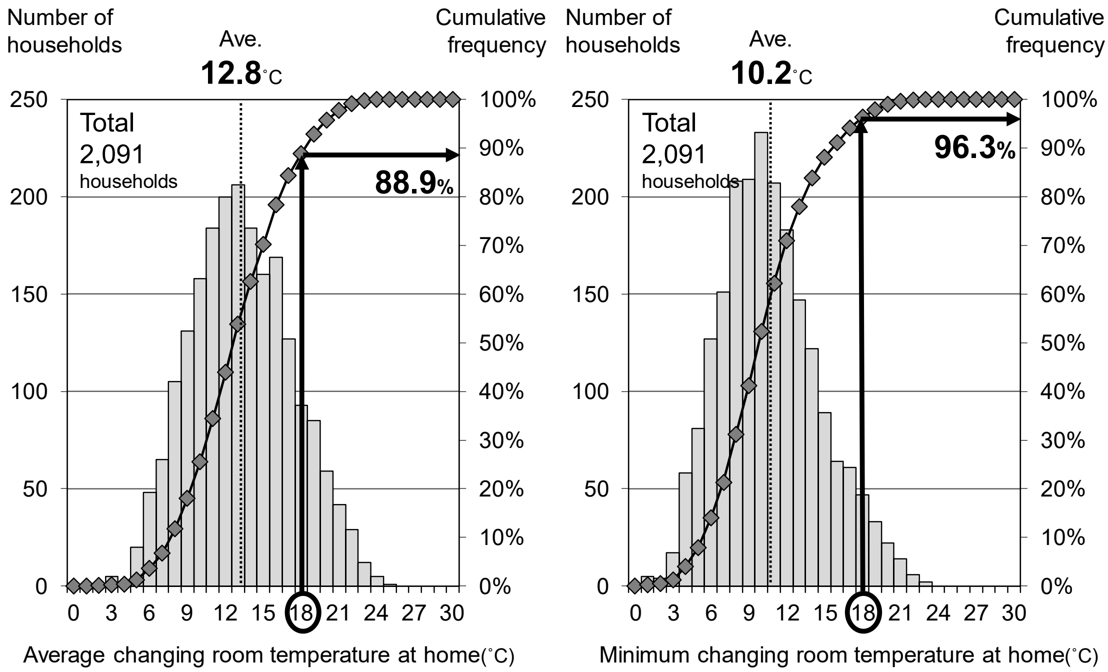


Fig.4-6 | Average (left) and minimum (right) changing room temperature at home

4.4 Discussion

4.4.1 Present status of housing in Japan

The results of actual measurements of indoor temperature from approximately 2,000 houses across Japan indicate that the average living room temperature in winter was 16.7°C. Similarly, an investigation of the indoor environment of 602 houses across Japan reported the average living room temperature during winter to be 17°C [69]. In contrast, according to the UK's large-scale room temperature survey, "The comprehensive English House Condition Survey (EHCS) 1996," the average living room temperature in winter in the UK was 18.1°C [142]. In addition, the Energy Follow-Up Survey 2011 involving 823 dwellings in the UK revealed that the mean monthly temperature for the whole house/apartment was 18.1°C in December [143]. Furthermore, an investigation that targeted apartments in New York, USA, reported an average living room temperature in winter of 23.3°C [144].

Currently, 39% of existing houses in Japan are not insulated, which means that a larger proportion of houses have low insulation performance [66]. The heat transmission coefficient for the window (U_W value; the lower the U_W value, the better insulated the structure), which is an indicator of the standard of insulation, is 1.0–2.0 W/m^{2}K in European and American countries, compared to 2.33 W/m^{2}K in Hokkaido and 4.65 W/m^{2}K in Tokyo, indicating a significant lag in insulation standards in Japan [67]. In addition, the energy consumption in houses in Japan is minimal compared to that of other countries, with the energy used for heating being one-quarter of that used in European and American countries [68]. This is because, while continuous heating of the entire building is the norm in Europe and the USA, in Japan, partial intermittent heating is used in the living room only. Due to the two factors mentioned above (low insulation performance and the difference in heating use), the room temperature in Japan is considered to be of lower standard than that in European and American countries. There is therefore a concern that the indoor temperature in Japan is declining and that such housing effects may greatly impact health.

4.4.2 Strengths and limitations

To our knowledge, the SWH survey is one of the largest in the world to evaluate the health impacts of insulation retrofit, based on objective indicators.

The strengths of the SWH survey are:

(1) Clarifying the influence of energy saving strategies, such as insulation retrofit, on health based on an objective indicator

Hypertension, a major cause of cardiovascular disease, is known as the "silent killer [15]" because it does not produce subjective symptoms. This highlights the importance of evaluating health based on an objective indicator rather than a subjective indicator.

(2) Studying the relationship between housing and health in Japan

The length of the Japanese archipelago stretches in a north to south direction, resulting in large regional differences in climate and four distinct seasons. This study was designed to investigate the effects in both winter and summer to comprehensively evaluate the health impact of living environments. Moreover, conducting a survey in Japan, where the adiabatic criteria is far behind that in European and American countries, is expected to improve institutional and regulatory developments.

(3) Cross-cutting framework of architecture, medicine and public health, industry, government and academia

The research team, composed of mainly experts in architecture, medicine and public health from across the nation, aims to establish solid evidence of the relationship between housing and health. This survey is the first of its kind in that it involves the Model Project team of construction companies across all 47 prefectures in Japan, and government agencies.

(4) Dissemination of survey results

We have established a public awareness team and will actively disseminate and report the study results to residents through approaches such as symposiums and newspapers. These findings will be instrumental for determining the future of housing and will contribute to improving public health.

In contrast, the study has the following three unavoidable limitations:

(1) Comparison of before and after renovation was conducted only for households subsidized by the Model Project for Promotion of SWH

Because this survey was conducted on households receiving subsidies for insulation retrofit, we could not define the parent population. Therefore, our findings may not be applicable to the entire Japanese population.

(2) Random allocation of intervention is impossible

Because it is unethical to randomly divide houses into renovation and non-renovation groups, this survey was conducted as a non-RCT with groups defined according to participants' choice to conduct/not conduct insulation retrofit. Therefore, there may be differences in baseline characteristics between the intervention and control groups. Consequently, we measured various indicators that affect health outcomes, and adjusted these based on multivariate analysis to minimize confounding.

(3) Health effects of insulation retrofit will be evaluated in a relatively short period of time

Determining morbidity rate as a health outcome is unrealistic in a relatively short period of several years. Instead, this study was designed to verify changes in intermediate indicators relevant to the outcomes such as home blood pressure and physical activity. Outcomes that need to be evaluated long-term will be examined in a future cohort study.

The National Health Promotion Movement in the 21st century “Health Japan 21 (the second term)” was established in Japan in 2012, and countermeasures have put emphasis on primary prevention such as improving lifestyle habits for public health promotion [145]. While diet, physical activity, rest, alcohol consumption, and smoking are included in the policy, living environment is not. A clear demonstration of the effect of living environment on health will aid policy development to improve living environments for health and prevention of disease prior to the need for lifestyle improvement or primary prevention. Additionally, because “housing is one of the social determinants of health and plays an important role in reducing health inequalities” [146−148], improvement of home living environments will contribute to reducing health inequalities promoted by WHO [149].

Chapter 5

Relationship between indoor temperature and home blood pressure

Chapter 5 | Relationship between indoor temperature and home blood pressure

5.1 Introduction

Cardiovascular disease (CVD), the world's leading cause of death, causes 17.9 million deaths each year (as of 2016), which accounts for 31% of deaths worldwide [2]. Studies estimate that deaths due to CVD will increase to 23.6 million people per year in 2030 [3]. Prevention of CVD is therefore an urgent issue.

The number of deaths due to CVD rises in winter, a phenomenon known as "excess winter mortality (EWM)" [45−47]. The rise is especially sharp in cold homes [49]. The mechanism underlying EWM suggests that it is partially explained by cold-induced high blood pressure (BP). To maintain a constant core body temperature in low temperatures, blood vessels constrict to suppress heat dissipation, leading to a rise in BP and CVD. In fact, many studies have shown that seasonal fluctuations in blood pressure peak in winter [150−153]. Of note, people in modern society spend between 60% and 70% of their time at home [60−62]. This ratio is higher in elderly people, who have declining physiological function, and in children, whose physiological function is underdeveloped [63]. These findings highlight the need to examine the effect of the indoor thermal environment of houses on blood pressure.

This prospective intervention trial aimed to quantitatively evaluate the relationship between home blood pressure (HBP) and indoor temperature. The study used multilevel linear regression analysis and sensitivity analysis to analyze data from a baseline survey of participants who intended to conduct insulation retrofit in their homes, defined as heat-insulation work such as those on the outer walls, floor and/or roof, replacement of single-glazed windows with double-glazed windows, and replacement of window frames.

5.2 Method

5.2.1 Study design

The purpose and protocol of the Smart Wellness Housing (SWH) survey were described in Chapter 4. The SWH survey was administered to households that received subsidies for insulation retrofit as part of the Model Project for Promotion of SWH by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT). We collected data on the indoor environment and health of participants before and after insulation retrofit. This survey was conducted as a non-randomized controlled trial with groups defined according to participants' choice to conduct or not conduct insulation retrofit, and is registered in the UMIN Clinical Trials Registry (http://www.umin.ac.jp/ctr/index.htm; trial number: UMIN000030601). The study protocol and informed consent procedure were approved by the ethics committee of the Hattori Clinic Institutional Review Board.

5.2.2 Area classification in Japan

In Japan, a total of eight areas are defined based on the heating degree-day (HDD) value (difference between a room temperature of 18°C and the average outside temperature on days where the average outside temperature is less than 18°C) (Table 5-1). These area classifications are defined according to the Standards of Judgment for Business Operators, and are commonly known as energy-saving areas. In Japan, the required insulation performance standards have been defined for each area [154]. The analysis in this paper examined these area classifications under the variable "area".

Table 5-1 | Area classification based on heating degree-day values [154]

Area	HDD [°C day]	Prefecture in area classification
1	4,500 ≤ HDD	Hokkaido
2	3,500 ≤ HDD < 4,500	
3	3,000 ≤ HDD < 3,500	Aomori, Iwate, Akita
4	2,500 ≤ HDD < 3,000	Miyagi, Yamagata, Fukushima, Tochigi, Niigata, Nagano
5	2,000 ≤ HDD < 2,500	Ibaraki, Gunma, Saitama, Chiba, Tokyo, Kanagawa, Toyama, Ishikawa, Fukui, Yamanashi, Gifu, Shizuoka, Aichi, Mie, Shiga, Kyoto, Osaka, Hyogo, Nara, Wakayama, Tottori, Shimane, Okayama, Hiroshima, Yamaguchi, Tokushima, Kagawa, Ehime, Kochi, Fukuoka, Saga, Nagasaki, Kumamoto, Oita
6	1,500 ≤ HDD < 2,000	
7	500 ≤ HDD < 1,500	Miyazaki, Kagoshima
8	HDD < 500	Okinawa

HDD, Heating degree-day

5.2.3 Home blood pressure and other measurements

Participants were asked to measure their HBP twice after getting out of bed in the morning and twice before getting into bed in the evening while seated, in accordance with the guidelines of the Japanese Society of Hypertension (JSH 2009) [119]. HBP was measured in the living room for two weeks using an automatic oscillometric device (HEM-7251G; Omron Healthcare Co., Ltd.). To avoid reporting bias, BP data were automatically stored and uploaded to the internet via 3G mobile networks.

Indoor temperature and relative humidity at 1.0 m above the floor were measured in the living room, bedroom, and changing room at 10-min intervals (TR-72wf; T&D Corp., measurement accuracy: ±0.5°C, ±5%). There were two conditions for the installation site, namely (1) that the instrument was not placed in direct sunlight and (2) that the instrument was far away from heating equipment or heat-generating devices like refrigerators and televisions. Outdoor temperature (variable name: $Temp_{Out}$) was obtained from the closest local meteorological observatory to each participant's house.

A questionnaire on individual attributes, lifestyle and housing was also conducted. The questionnaire covered individual attributes, such as age, sex, and weight; and lifestyle indicators, such as eating habits, smoking, alcohol consumption, and health conditions, focusing on diseases associated with hypertension. As an indication of socio-economic status, questions about household income and educational status were included in the questionnaire, as well as questions about the presence or absence of co-habitants and the amount of clothing worn. With regards to heating in the house, questions about floor heating, use of kotatsu tables, and use of heating prior to waking up (timer-operated) were also included. A diary survey was also conducted, in which participants provided details of their daily wake time, bedtime, quality of sleep and whether or not they consumed alcohol.

5.2.4 Statistical analysis

For continuous variables that formed a normal distribution, the results were presented as mean and standard deviation. For continuous variables that formed a non-normal distribution, the results were presented as median and interquartile range. For the former and latter distributions, differences between groups were tested using the student's t-test and the Mann-Whitney's U-test, respectively. Inter-group comparisons of the proportions were performed using the χ^2-test.

To quantify the effect of indoor temperature on HBP, multilevel linear regression analysis was conducted with random intercepts for each individual, consisting of individual-level parameters (age, sex, body mass index (BMI), salt check sheet [137], vegetable consumption, exercise, smoking, alcohol consumption, use of antihypertensive drugs, outdoor temperature) and repeatedly measured parameters (HBP, living room temperature (variable name: $Temp_{Lr}$), temperature disparity between the living room and bedroom (variable name: ΔTemp), quality of sleep, sleep duration, and alcohol consumption the previous night). $Temp_{Lr}$ and ΔTemp values determined at the time of HBP measurements were used in the multilevel linear regression models. $Temp_{Lr}$ and ΔTemp were added to each sequential model beginning with the lowest degree, and the models were compared using a goodness of fit index (Akaike's information criteria) to select the best-fitted model. The multilevel linear regression models were as follows:

Day level:

$HBP_{ij} = b_{0j} + b_{1j}\times Temp_{Lr\ ij} + b_{2j}\times Temp_{Lr\ ij}{}^{2} + b_{3j}\times Temp_{Lr\ ij}{}^{3} + b_{4j}\times \Delta Temp_{ij} + b_{5j}\times \Delta Temp_{ij}{}^{2} + b_{6j}\times$ Quality of sleep $_{ij} + b_{7j}\times$ Sleep duration $_{ij} + b_{8j}\times$ Alcohol consumption the previous night $_{ij} + r_{ij}$.

Individual level:

$b_{0j} = \gamma_{00} + \gamma_{01}\times Age_j + \gamma_{02}\times Sex_j + \gamma_{03}\times BMI_j + \gamma_{04}\times$ Salt check sheet$_j$ $+ \gamma_{05}\times$ Vegetable consumption$_j$ $+ \gamma_{06}\times$ Exercise$_j$ $+ \gamma_{07}\times$ Smoking$_j$ $+ \gamma_{08}\times$ Alcohol consumption$_j$ $+ \gamma_{09}\times$ Antihypertensive drug use$_j$ $+ \gamma_{010}\times Temp_{Out\ j} + u_{0j}$

$b_{1j} = \gamma_{10} + \gamma_{11}\times Age_j + \gamma_{12}\times Sex_j$

$b_{2j} = \gamma_{20}, \ldots, b_{8j} = \gamma_{80}$

where HBP_{ij} is the observed BP measurement for participant j on day i, b_{0j} is the random intercept, b_{1j}-b_{8j} are regression coefficients for each explanatory variable, γ_{00}-γ_{80} are fixed effects, u_{0j} is a random effect, and r_{ij} is the error for participant j on day i.

In addition, to analyze the relationship between indoor temperature, the residing area, and resident attributes, a multi-level model was also applied, in which the objective variable was the living room temperature at the time of the blood pressure measurement in the morning. The model was constructed as a random intercept model. Individual-level variables, namely, energy-saving areas and resident attributes (age, sex, BMI, household income, duration of residence, presence or absence of co-habitants, amount of clothing worn, use of kotatsu tables, and use of a timed-heating device when waking up) were the input variables, and the day level variable (outdoor temperature) was nested within the individual level variables. As the objective variable was continuous, multilevel linear regression analysis was performed to calculate the fixed effect of resident area and attributes. Furthermore, multilevel logistic regression analysis was performed by inputting room temperature as a categorical variable (above or below 18°C, which is the minimum room temperature recommended by the WHO [70] and the UK guidelines [71, 72]), and the odds ratio was determined.

Regression coefficients were estimated using the maximum likelihood method. All P values were two sided, and a two-sided P value less than 0.05 was considered statistically significant. All analyses were performed using SPSS Ver. 24 (SPSS Inc., Chicago, Illinois, USA).

5.3 Results

5.3.1 Blood pressure indices used for analysis

As a preliminary step to verify the relationship between BP and indoor temperature, BP values were compared with the presence or absence of current hospital visits due to cerebrovascular disease and heart disease for each BP index to confirm the reliability of HBP as a predictor of CVD. In addition to HBP in the morning and evening, clinic blood pressure (CBP), which was measured in the health exam, was also used for the verification. Because the number of samples differed for HBP and CBP, only the 1,866 participants with both HBP and CBP data were analyzed. The relationship between HBP/CBP and cerebrovascular disease is shown in Table 5-2A. Although only a few participants had cerebrovascular disease and there was no significant difference in incidence ($p > 0.05$), there was a relatively large difference in morning SBP ($p = 0.072$) and evening SBP ($p = 0.071$). The relationship between HBP/CBP and heart disease is shown in Table 5-2B. Compared to participants without hospital visits due to heart disease, participants with hospital visits had significantly higher morning SBP ($p = 0.001$). In contrast, there was no significant difference in CBP between participants with and without hospital visits due to CVD. According to previous studies [155, 156], HBP is a better prognostic factor for CVD than CBP. In addition, guidelines for the management of hypertension published in 2014 (JSH2014) [44] states that diagnosis by HBP is given priority when the values of HBP and CBP differ. Subsequent analyses therefore focused on HBP.

Table 5-2 | Relationship between home/clinic blood pressure and cardiovascular disease

A. Cerebrovascular disease

Classification	BP index	Hospital visit due to cerebrovascular disease		Difference	*p* value
		Yes (*n* = 24)	No (*n* = 1,842)		
		Mean ± SD	Mean ± SD		
Blood pressure	SBP at clinic, mmHg	128 ± 18	123 ± 17	5	0.151
	DBP at clinic, mmHg	76 ± 11	75 ± 11	2	0.434
	MSBP at home, mmHg	135 ± 20	129 ± 16	6	**0.071**
	MDBP at home, mmHg	81 ± 12	81 ± 10	0	0.927
	ESBP at home, mmHg	128 ± 17	122 ± 15	6	**0.072**
	EDBP at home, mmHg	74 ± 9	74 ± 10	0	0.818

B. Heart disease (angina/myocardial infarction)

Classification	BP index	Hospital visit due to heart disease		Difference	*p* value
		Yes (*n* = 47)	No (*n* = 1,818)		
		Mean ± SD	Mean ± SD		
Blood pressure	SBP at clinic, mmHg	125 ± 16	123 ± 17	1	0.640
	DBP at clinic, mmHg	74 ± 9	75 ± 11	0	0.903
	MSBP at home, mmHg	136 ± 16	129 ± 16	8	**0.001**
	MDBP at home, mmHg	82 ± 9	81 ± 11	1	0.655
	ESBP at home, mmHg	126 ± 16	122 ± 15	4	**0.066**
	EDBP at home, mmHg	74 ± 9	75 ± 11	0	0.754

MSBP, systolic blood pressure in the morning; MDBP, diastolic blood pressure in the morning; ESBP, systolic blood pressure in the evening; EDBP, diastolic blood pressure in the evening.

5.3.2 Patterns of participation in home blood pressure measurement

The SWH survey, which started in the winter of 2014, obtained data from a total of seven periods as of October 2018: four winter periods (2014–2017) and three summer periods (2015–2017). A summary of the number of participants who conducted HBP measurements is shown in Table 5-3, and the participation pattern in the survey is shown in Table 5-4. There were a total of 3,811 participants (2,111 households), some of whom participated in the survey for six periods. A total of 3,809 participants (2,110 households) participated for more than one winter period, and 417 participants (238 households) participated for more than one period in both summer and winter.

Table 5-3 | Summary of the number of participants in home blood pressure measurements

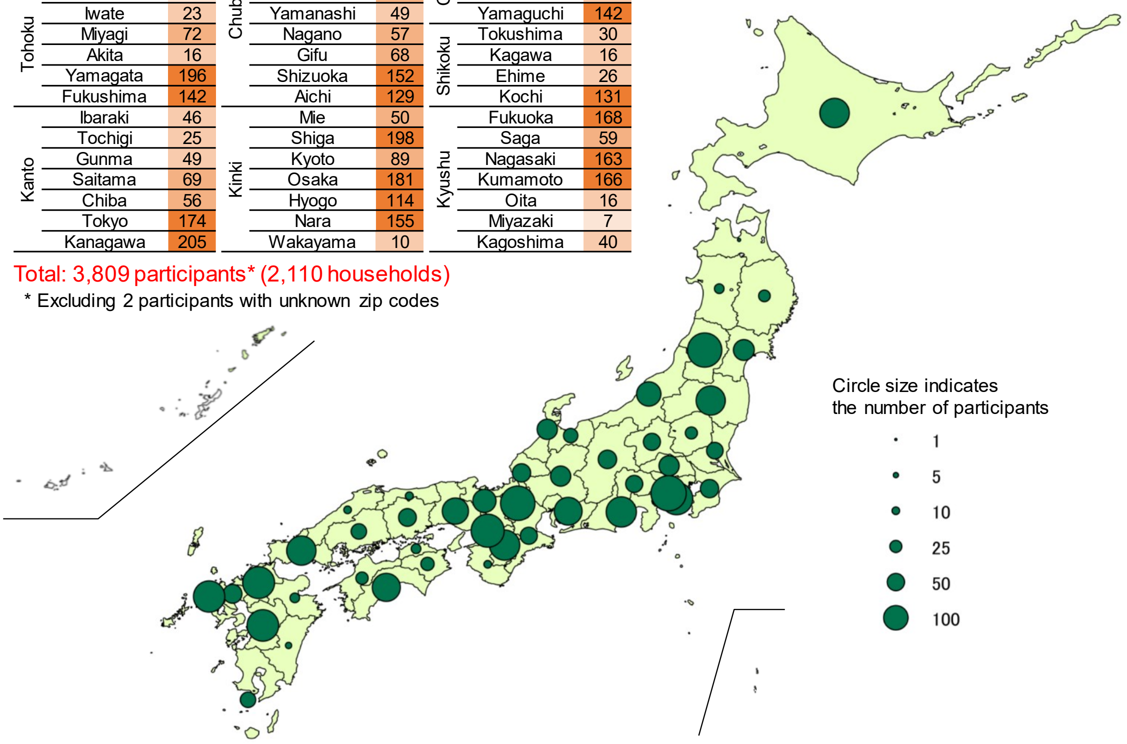
Number of participations	Number of participants	Number of households
1	2,414	1,361
2	1,059	608
3	201	121
4	65	39
5	68	43
6	4	3
Total	3,811	2,111

Table 5-4 | Patterns of participation in home blood pressure measurements

Number of participations	2014	2015		2016		2017		Total
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	
6 periods (*n* = 4)	○	○	○	○	—	○	○	4
5 periods (*n* = 68)	○	○	○	○	○	—	—	57
	○	○	○	○	—	○	—	7
	○	○	○	○	—	—	○	1
	○	—	○	○	—	○	○	1
	—	○	○	○	—	○	○	2
4 periods (*n* = 65)	○	○	○	○	—	—	—	33
	○	○	○	—	○	—	—	5
	○	○	○	—	—	○	—	3
	○	○	○	—	—	—	○	1
	○	○	—	○	○	—	—	8
	○	—	○	○	○	—	—	6
	—	○	○	○	○	—	—	2
	—	○	○	○	—	○	—	3
	—	—	○	○	○	○	—	4
3 periods (*n* = 201)	○	○	○	—	—	—	—	85
	○	○	—	—	○	—	—	9
	○	—	○	○	—	—	—	17
	○	—	○	—	○	—	—	23
	○	—	—	○	○	—	—	2
	—	○	○	○	—	—	—	5
	—	○	—	○	○	—	—	1
	—	—	○	○	○	—	—	35
	—	—	○	○	—	○	—	4
	—	—	○	○	—	—	○	4
	—	—	○	—	○	○	—	5
	—	—	○	—	—	○	○	2
	—	—	—	—	○	○	○	9
2 periods (*n* = 1,059)	○	○	—	—	—	—	—	36
	○	—	○	—	—	—	—	253
	○	—	—	—	○	—	—	48
	○	—	—	—	—	—	○	8
	—	○	○	—	—	—	—	4
	—	○	—	—	○	—	—	2
	—	—	○	○	—	—	—	49
	—	—	○	—	○	—	—	310
	—	—	○	—	—	○	—	6
	—	—	○	—	—	—	○	130
	—	—	—	○	○	—	—	2
	—	—	—	—	○	—	○	208
	—	—	—	—	—	○	○	3
1 period (*n* = 2,414)	○	—	—	—	—	—	—	509
	—	○	—	—	—	—	—	2
	—	—	○	—	—	—	—	955
	—	—	—	—	○	—	—	143
	—	—	—	—	—	—	○	805
Total				—				3,811

○, participated in the survey; —, did not participate in the survey

The residential areas of the 3,811 participants in the HBP measurement are shown in Fig.5-1 (excluding 2 participants with unknown zip codes). The participants resided in 46 prefectures, excluding Okinawa, and obtained samples were relatively evenly distributed throughout Japan, from Hokkaido to Kyushu.



	Prefecture	*n*		Prefecture	*n*		Prefecture	*n*
	Hokkaido	145	Chubu	Niigata	98	Chugoku	Tottori	11
				Toyama	35		Shimane	10
				Ishikawa	69		Okayama	53
Tohoku	Aomori	2		Fukui	57		Hiroshima	40
	Iwate	23		Yamanashi	49		Yamaguchi	142
	Miyagi	72		Nagano	57	Shikoku	Tokushima	30
	Akita	16		Gifu	68		Kagawa	16
	Yamagata	196		Shizuoka	152		Ehime	26
	Fukushima	142		Aichi	129		Kochi	131
Kanto	Ibaraki	46	Kinki	Mie	50	Kyushu	Fukuoka	168
	Tochigi	25		Shiga	198		Saga	59
	Gunma	49		Kyoto	89		Nagasaki	163
	Saitama	69		Osaka	181		Kumamoto	166
	Chiba	56		Hyogo	114		Oita	16
	Tokyo	174		Nara	155		Miyazaki	7
	Kanagawa	205		Wakayama	10		Kagoshima	40

Total: 3,809 participants* (2,110 households)

* Excluding 2 participants with unknown zip codes

Fig.5-1 | Residential area of participants conducting home blood pressure measurements

5.3.3 Comparison of home blood pressure between summer and winter

To determine the seasonal fluctuation in BP, the average HBP of all participants in each survey period was determined and is shown in Fig.5-2. There was a clear seasonal difference in BP between summer and winter. This seasonal difference was identified in both morning and evening HBP.

Comparison of the average HBP and coefficient of variation (CV) (standard deviation (SD)/average) between summer and winter was conducted for data obtained from 320 of 417 participants. The average HBP was higher, and the CV during measurement was larger in winter than in summer (Table 5-5). Therefore, subsequent analyzes focused on BP in winter, when BP is high and the variation in BP is large and unstable.

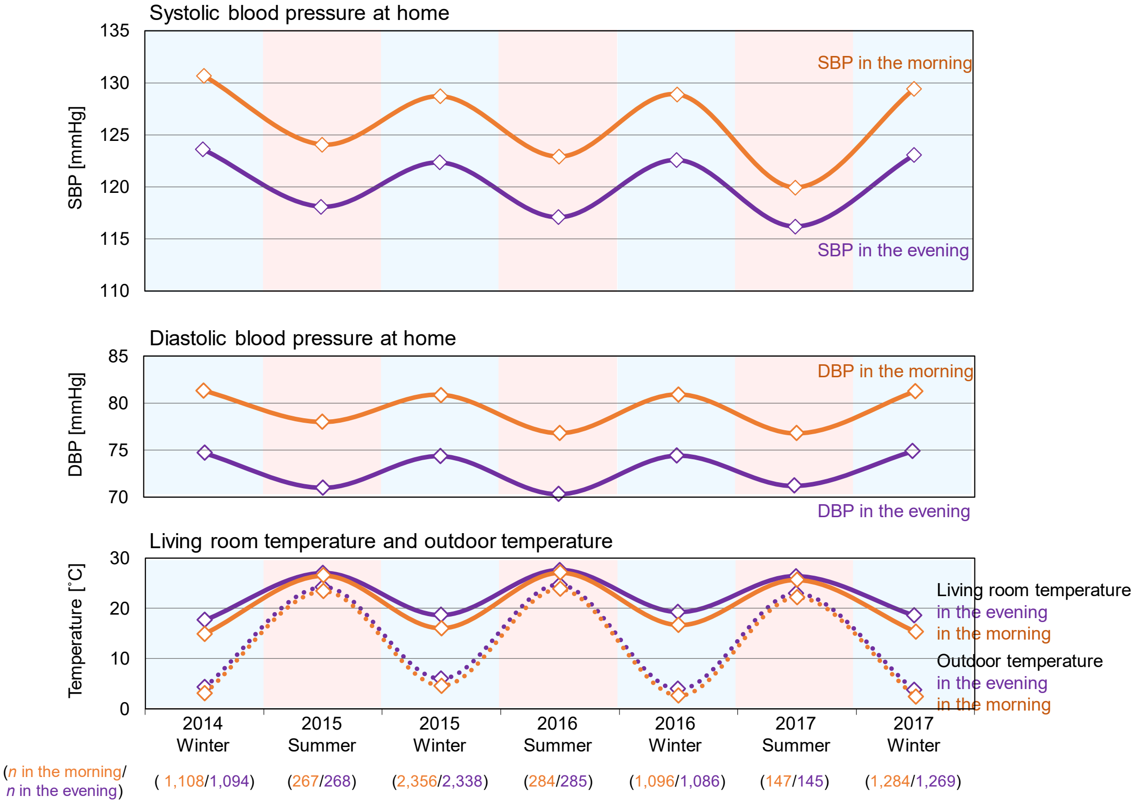


Fig.5-2 | Seasonal variation in home blood pressure and temperature

Table 5-5 | Comparison of BP and CV of BP between summer and winter

Variable		Summer (*n*=320)	Winter (*n*=320)	Difference	*p* value*
Morning SBP					
Average	[mmHg]	123.5	130.1	6.5	0.00
CV†	[-]	0.062	0.072	0.010	0.00
Morning DBP					
Average	[mmHg]	77.3	80.6	3.2	0.00
CV†	[-]	0.067	0.073	0.005	0.01
Evening SBP					
Average	[mmHg]	116.8	123.7	6.9	0.00
CV†	[-]	0.067	0.082	0.015	0.00
Evening DBP					
Average	[mmHg]	70.0	73.7	3.8	0.00
CV†	[-]	0.080	0.090	0.010	0.00

*Paired t test

SBP, systolic blood pressure; DBP, diastolic blood pressure; CV, coefficient of variation.

Participants were grouped into the stable living room temperature group (living room temperature in the morning ≥18˚C in winter, <26˚C in summer) and the unstable living room temperature group (living room temperature in the morning <18˚C in winter, ≥26˚C in summer) for each period, and average BP values were compared (Fig.5-3). The range of the seasonal fluctuation in BP was smaller in the stable room temperature group than in the unstable room temperature group, suggesting that a stable room temperature may stabilize BP.

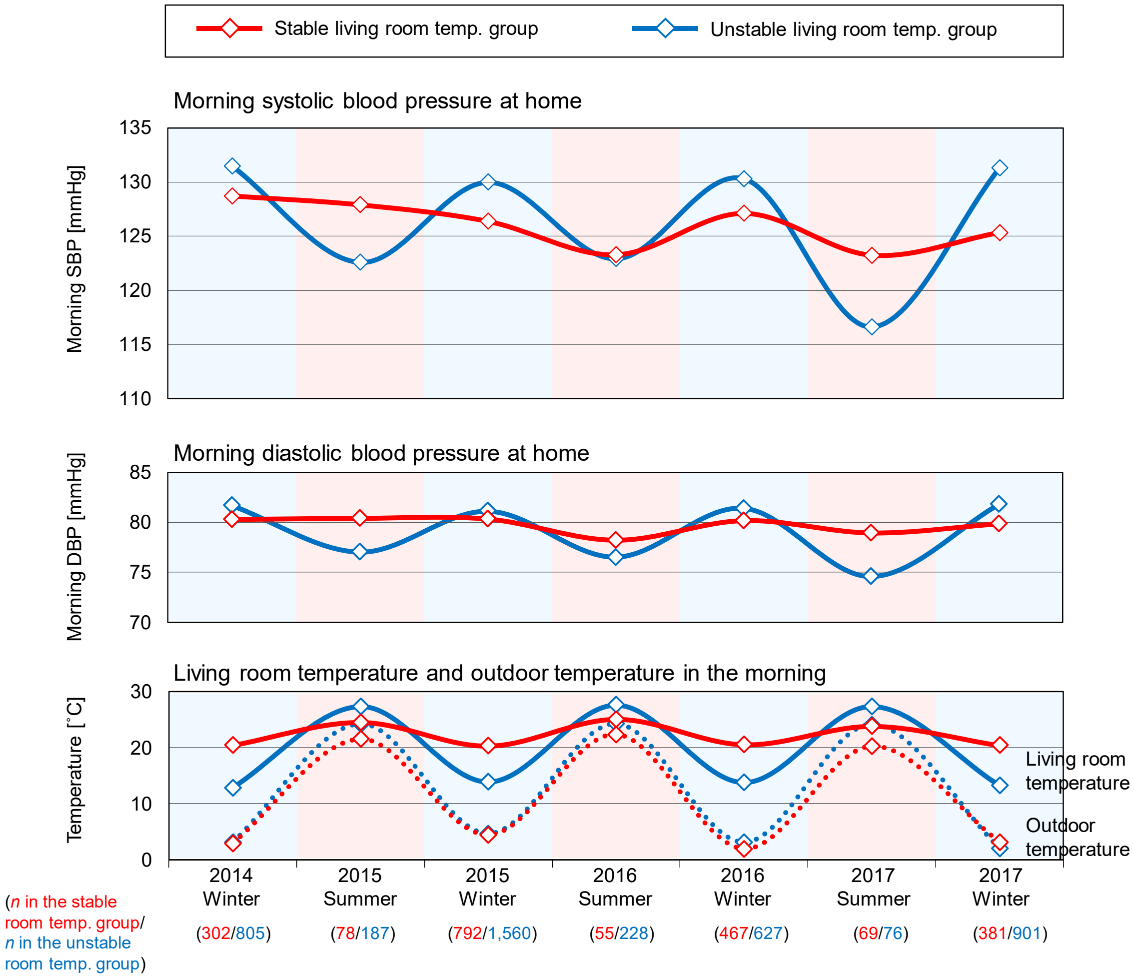


Fig.5-3 | Seasonal variation in home blood pressure and temperature in the stable/unstable living room temperature groups

Stable room temp. group: living room temperature in the morning ≥18˚C in winter, <26˚C in summer. Unstable room temp. group: living room temperature in the morning <18˚C in winter, ≥26˚C in summer.

5.3.4 Attributes of participants in the winter survey

Fig.5-4 shows the flow for the selection of valid samples in the winter survey. A total of 2,095 households and 3,775 participants responded to the survey, and valid data were obtained from 2,007 households and 3,514 participants. Personal attributes are aggregated in Table 5-6. The average systolic blood pressure (SBP) in the morning (130 mmHg) was significantly higher than that in the evening (123 mmHg; $p<0.001$). The average age was 57 years for both men and women, and the age range was 20 to 99 years. The ratio of men to women was approximately 1:1, although there were slightly more women than men. The average BMI was 22.8 kg/m^2, which is within the range for "normal weight" (18.5–24.9 kg/m^2). About 70% of participants had no exercise habit, and about 75% of the participants ate vegetables frequently. About 70% of participants were non-smokers, and about 50% did not consume any alcohol. About 25% of participants took antihypertensive drugs.

The average living room temperature at the time of the morning and evening HBP measurements was 15.1°C (range: 1.0–27.6°C) and 18.1°C (range: 2.7°C–29.0°C), respectively. The living room temperature in the morning was significantly lower than that in the evening. Additionally, the temperature in the bedroom and the changing room were lower than that in the living room, indicating the presence of a temperature disparity between the living room and bedroom (3.0°C), and living room and changing room (4.2°C).

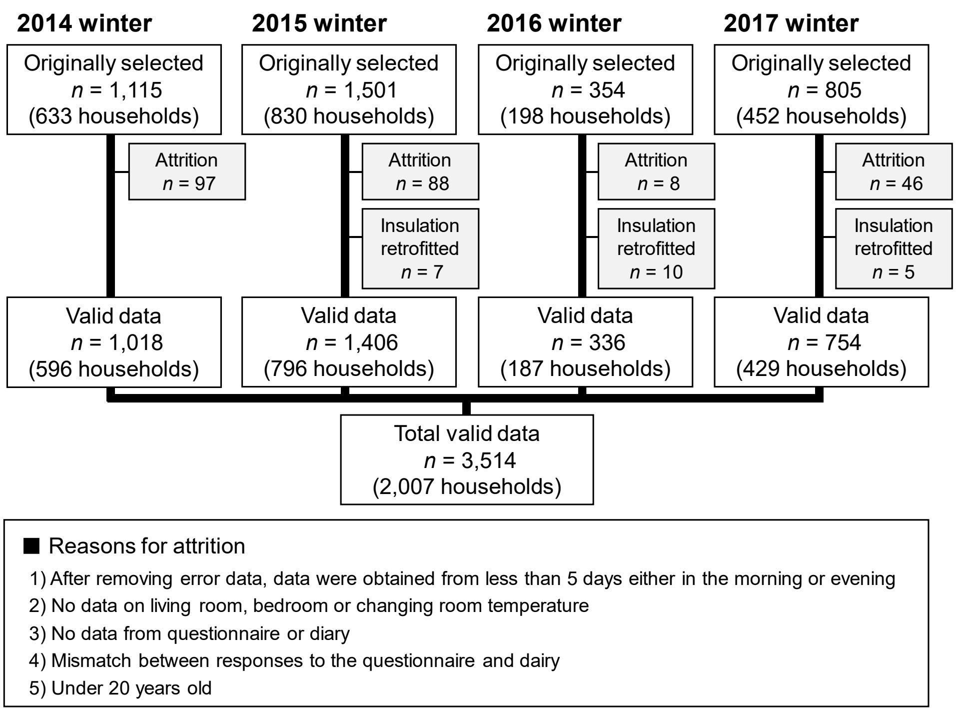


Fig.5-4 | Subject flow of valid samples

"Insulation retrofitted" indicates participants who completed insulation retrofit at the baseline survey.

Table 5-6 | Characteristics of participants in the baseline survey in winter

Variable	Mean	± S.D.
HSBP, mmHg		
In the morning	130	± 18
In the evening	123	± 16
HDBP, mmHg		
In the morning	81	± 11
In the evening	74	± 10
Temp_{Lr}, °C		
In the morning	15.1	± 4.3
In the evening	18.1	± 3.9
Temp_{Br}, °C		
In the morning	12.1	± 4.3
In the evening	14.0	± 4.3
Temp_{Cr}, °C		
In the morning	10.8	± 4.1
In the evening	13.2	± 4.0
Temp_{Out}, °C		
In the morning	3.6	± 3.3
In the evening	5.0	± 3.5
Age, years	57	± 13
BMI, kg/m^2	22.8	± 3.6
Salt check sheet, points	13.1	± 4.3

Variable	Number	(%)
Sex		
Men	1,658	(47.2)
Women	1,856	(52.8)
Missing	0	(0.0)
Exercise		
Rarely	2,478	(70.5)
Regularly	1,003	(28.5)
Missing	33	(0.9)
Vegetable consumption		
Rarely	96	(2.7)
2–3 times/week	731	(20.8)
Regularly	2,658	(75.6)
Missing	29	(0.8)
Smoking		
None	2,468	(70.2)
Quit smoking	281	(8.0)
Smoking	483	(13.7)
Missing	282	(8.0)
Alcohol consumption		
None	1,618	(46.0)
Sometimes	904	(25.7)
Everyday	933	(26.6)
Missing	59	(1.7)
Antihypertensive drug use		
None	2,543	(72.4)
Currently	851	(24.2)
Missing	120	(3.4)

HSBP, home systolic blood pressure; HDBP, home diastolic blood pressure; Temp_{Lr}, living room temperature; Temp_{Br}, bedroom temperature; Temp_{Cr}, changing room temperature; Temp_{Out}, outdoor temperature; BMI, body mass index.

5.3.5 Relationship between indoor temperature and home blood pressure in winter

Multilevel linear regression analysis was performed using BP as an objective variable to verify the relationship between indoor temperature and HBP. First, the model expressed as a linear function of the living room temperature was used to compare the effect of indoor temperature on SBP and diastolic blood pressure (DBP) in the morning and evening (Table 5-7). The model was developed by adjusting for factors related to hypertension indicated in the JSH2014 [44] (detailed models in Table 5-8). While there was little difference in the effect of living room temperature on DBP between the morning and evening, the effect of living room temperature on SBP in the morning was greater than that in the evening. Participants aged 57 years (mean age in this survey) had an average increase in morning/evening SBP of 6.4/5.0 mmHg per 10°C decrease in living room temperature.

Table 5-7 | Multilevel model of the relationship between living room temperature and BP in the morning and evening

Objective variable	Explanatory variable	Univariate model		Multivariate model*	
		β (95%CI)	p value	Adjusted β (95%CI)	p value
Morning SBP	$Temp_{Lr}$ [°C]	−0.643 (−0.706, −0.579)	0.000	−0.636 (−0.668, −0.605)	0.000
Morning DBP	$Temp_{Lr}$ [°C]	−0.363 (−0.403, −0.323)	0.000	−0.355 (−0.376, −0.334)	0.000
Evening SBP	$Temp_{Lr}$ [°C]	−0.484 (−0.555, −0.413)	0.000	−0.501 (−0.541, −0.461)	0.000
Evening DBP	$Temp_{Lr}$ [°C]	−0.336 (−0.382, −0.289)	0.000	−0.348 (−0.375, −0.321)	0.000

*Adjusted for age, sex, BMI, salt check sheet, vegetable consumption, exercise, smoking, alcohol consumption, antihypertensive drug use, outdoor temperature, quality of sleep, sleep duration, alcohol consumption the previous night or tonight

CI, confidence interval; SBP, systolic blood pressure; DBP, diastolic blood pressure

Table 5-8 | Multilevel model of the relationship between living room temperature and BP in the morning and evening (detailed models of Table 5-7)

Explanatory variable		Morning SBP Adjusted β	Morning SBP p value	Morning DBP Adjusted β	Morning DBP p value	Evening SBP Adjusted β	Evening SBP p value	Evening DBP Adjusted β	Evening DBP p value
		Objective variable*							
Level 1: Day level									
$Temp_{Lr}$	[°C]	−0.636	0.000	−0.355	0.000	−0.501	0.000	−0.348	0.000
Sleep duration	[hours]	−0.204	0.000	−0.098	0.000	0.166	0.000	0.085	0.003
Quality of sleep	0) Bad (ref.)	0	–	0	–	0	–	0	–
	1) Good	−0.860	0.000	−0.659	0.000	−0.086	0.497	−0.203	0.018
Alcohol consumption**	0) None (ref.)	0	–	0	–	0	–	0	–
	1) Drinking	−0.539	0.000	−0.305	0.001	−3.468	0.000	−3.505	0.000
Level 2: Individual level									
Age	[years]	0.543	0.000	0.117	0.000	0.357	0.000	0.058	0.000
Sex	0) Men (ref.)	0	–	0	–	0	–	0	–
	1) Women	−2.637	0.000	−2.178	0.000	−2.108	0.000	−0.493	0.231
BMI	[kg/m^2]	1.295	0.000	1.045	0.000	1.586	0.000	1.155	0.000
Exercise	0) Regularly (ref.)	0	–	0	–	0	–	0	–
	1) Rarely	0.535	0.352	0.426	0.287	0.005	0.993	0.062	0.875
Salt check sheet	[points]	0.357	0.000	0.210	0.000	0.255	0.000	0.112	0.008
Vegetable consumption	0) Regularly (ref.)	0	–	0	–	0	–	0	–
	1) 2–3 times/week	2.405	0.000	1.520	0.001	2.380	0.000	1.404	0.001
	2) Rarely	2.876	0.068	2.167	0.048	3.809	0.015	2.651	0.014
Smoking	0) None/Quit smoking (ref.)	0	–	0	–	0	–	0	–
	1) Smoking	3.074	0.000	1.195	0.022	5.218	0.000	2.384	0.000
Alcohol consumption	0) None (ref.)	0	–	0	–	0	–	0	–
	1) Sometimes	0.073	0.907	0.774	0.073	−1.193	0.053	−0.382	0.370
	2) Everyday	3.580	0.000	3.324	0.000	−1.488	0.024	−1.668	0.000
Antihypertensive drug use	0) None (ref.)	0	–	0	–	0	–	0	–
	1) Currently	5.040	0.000	1.604	0.000	2.900	0.000	0.520	0.247
$Temp_{Out}$	[°C]	−0.007	0.924	−0.041	0.440	0.095	0.192	0.039	0.436

* *n* = 64,109 observations (2,902 participants × Ave. 22 observations/participant) in the morning
n = 66,443 observations (2,901 participants × Ave. 23 observations/participant) in the evening

** Alcohol consumption the previous night for morning SBP and DBP. Alcohol consumption tonight for evening SBP and DBP.

SBP, systolic blood pressure; DBP, diastolic blood pressure; $Temp_{Lr}$, living room temperature; $Temp_{Out}$, outdoor temperature.

Given evidence indicating that CVD occurs frequently in the morning [120, 157−159] and that SBP provides important prognostic information about CVD [14, 160, 161], the final model of SBP in the morning was developed by adjusting for factors related to hypertension (JSH2014) [44] (Table 5-9). Focusing on the fixed effects of personal attributes, the analysis showed that 1) SBP increased by 5.4 mmHg per 10 years of age, 2) SBP of women was 2.6 mmHg lower than that of men, 3) obese residents with higher BMI had higher SBP, 4) residents who consumed excess salt or did not eat vegetables had high BP, and 5) drinkers and smokers had high BP. These findings are similar to relationships identified in previous studies [44]. Therefore, these results confirmed that the subjects of this survey were not outliers. Focusing on the indoor temperature, the analysis showed that SBP increased as the living room temperature decreased. Further, it became clear that the relationship between living room temperature and SBP was not linear but was instead a cubic relationship. The same relationship was found for other BP indices (SBP in the evening, DBP in the morning and evening). The temperature disparity between the living room and bedroom also affected SBP independently of the living room temperature.

Fig.5-5A shows the relationship between SBP and living room temperature for each 10-year age group in men, calculated by inputting the average values for men into the final model (Table 5-9). The data showed that, for example, when the living room temperature dropped from 20°C to 10°C, morning SBP increased by 4.1 mmHg in 30-year-old men, 7.8 mmHg in 60-year-old men and 10.3 mmHg in 80-year-old men. This indicates that the indoor temperature had a stronger effect on SBP in older residents. Fig.5-5B shows the results in women. Women showed low SBP but high sensitivity to changes in indoor temperatures. When the living room temperature dropped from 20°C to 10°C, morning SBP increased by 5.4 mmHg in 30-year-old women, 9.1 mmHg in 60-year-old women, and 11.5 mmHg in 80-year-old women.

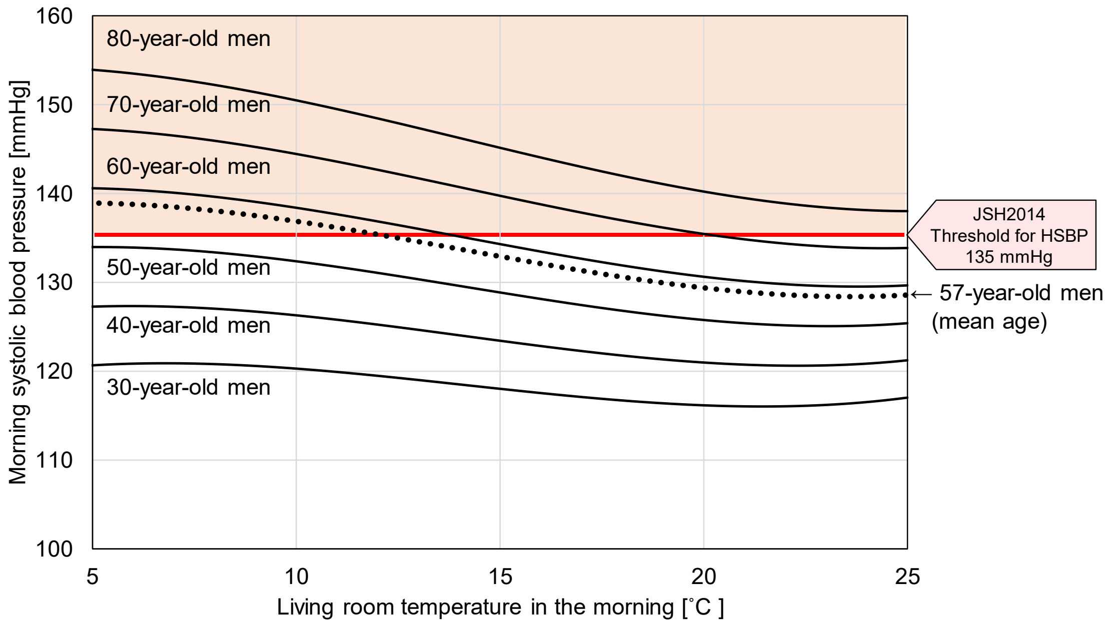
Table 5-9 | Multilevel model of morning SBP

Explanatory variable		Univariate model		Multilevel model	
		β	*p* value	Adjusted β	*p* value
Level 1: Day level					
$Temp_{Lr}$	[°C]	−0.643	0.000	−0.829	0.000
$Temp_{Lr}^2$	$[°C]^2$	0.046	0.000	0.009	0.050
$Temp_{Lr}^3$	$[°C]^3$	−0.004	0.000	0.003	0.000
ΔTemp	[°C]	−0.197	0.000	0.250	0.000
$\Delta Temp^2$	$[°C]^2$	0.036	0.000	0.006	0.071
Sleep duration	[hours]	−0.216	0.008	−0.218	0.000
Quality of sleep	0) Bad (ref.)	0	−	0	−
	1) Good	−0.864	0.000	−0.817	0.000
Alcohol consumption the previous night	0) None (ref.)	0	−	0	−
	1) Drinking	−0.621	0.036	−0.555	0.000
Age × $Temp_{Lr}$	[years]×[°C]	−	−	−0.012	0.000
Sex (Women) × $Temp_{Lr}$	[-]×[°C]	−	−	−0.127	0.000
Level 2: Individual level					
Age	[years]	0.595	0.000	0.542	0.000
Sex	0) Men (ref.)	0	−	0	−
	1) Women	−8.652	0.000	−2.642	0.000
BMI	$[kg/m^2]$	1.792	0.000	1.296	0.000
Exercise	0) Regularly (ref.)	0	−	0	−
	1) Rarely	−2.318	0.000	0.530	0.357
Salt check sheet	[points]	0.622	0.000	0.355	0.000
Vegetable consumption	0) Regularly (ref.)	0	−	0	−
	1) 2–3 times/week	2.023	0.000	2.397	0.000
	2) Rarely	3.661	0.000	2.888	0.067
Smoking	0) None/Quit smoking (ref.)	0	−	0	−
	1) Smoking	4.375	0.000	3.090	0.000
Alcohol consumption	0) None (ref.)	0	−	0	−
	1) Sometimes	−1.266	0.000	0.083	0.894
	2) Everyday	6.580	0.000	3.579	0.000
Antihypertensive drug use	0) None (ref.)	0	−	0	−
	1) Currently	14.025	0.000	5.046	0.000
$Temp_{Out}$	[°C]	−0.205	0.000	−0.004	0.961

* n = 64,025 observations (2,902 participants × Ave. 22 observations/participant)

$Temp_{Lr}$, living room temperature; ΔTemp, temperature disparity between the living room and bedroom; $Temp_{Out}$, outdoor temperature.

A: Average model for men in each age group in the SWH survey



B: Average model for women in each age group in the SWH survey

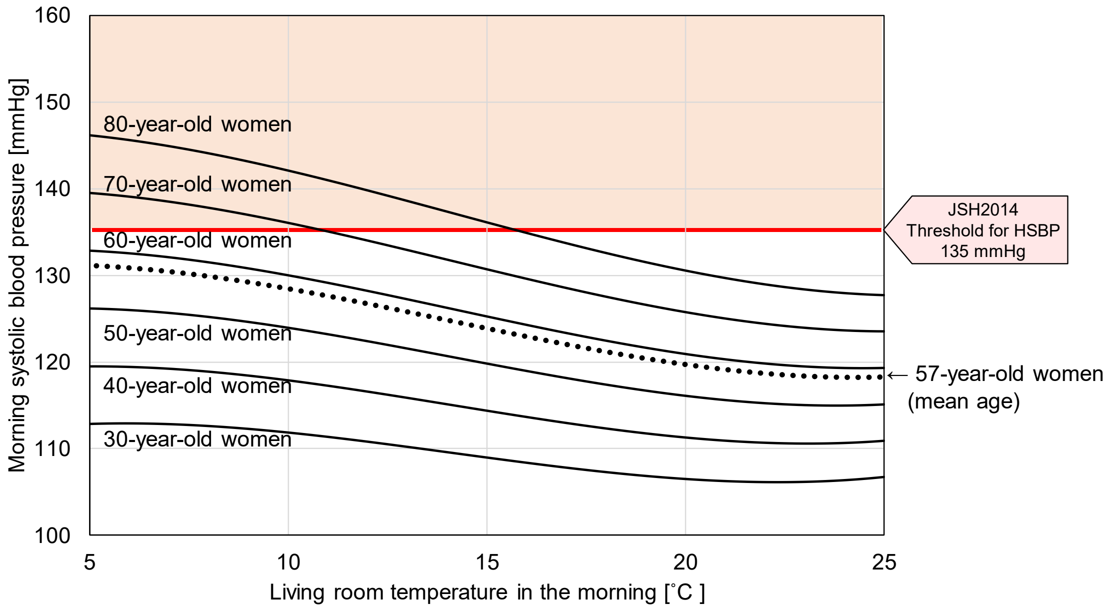


Fig.5-5 | Relationship between living room temperature and morning SBP

A: Average values for male participants were inputted into the final model: vegetable consumption=regularly, exercise=rarely, current smoking status=non-smoker, alcohol consumption=every day, antihypertensive drug use=none.

B: Average values for female participants were inputted into the final model: vegetable consumption=regularly, exercise=rarely, current smoking status=non-smoker, alcohol consumption=none, antihypertensive drug use=none.

The relationship between the living room and bedroom room temperatures and SBP (average models for men and women in this survey) is shown in Fig.5-6A and Fig.5-6B. This analysis found that, for example, when the indoor temperature in the living room and bedroom were both 18°C (the minimum temperature recommended by the WHO [70] and UK guidelines [71, 72]), the average morning SBP in men was 130 mmHg. When only the bedroom temperature dropped to 10°C, the average morning SBP in men was 132 mmHg. This relationship was similarly observed for the changing room (Fig.5-6C, D), indicating the importance of warming the entire house, not just the living room.

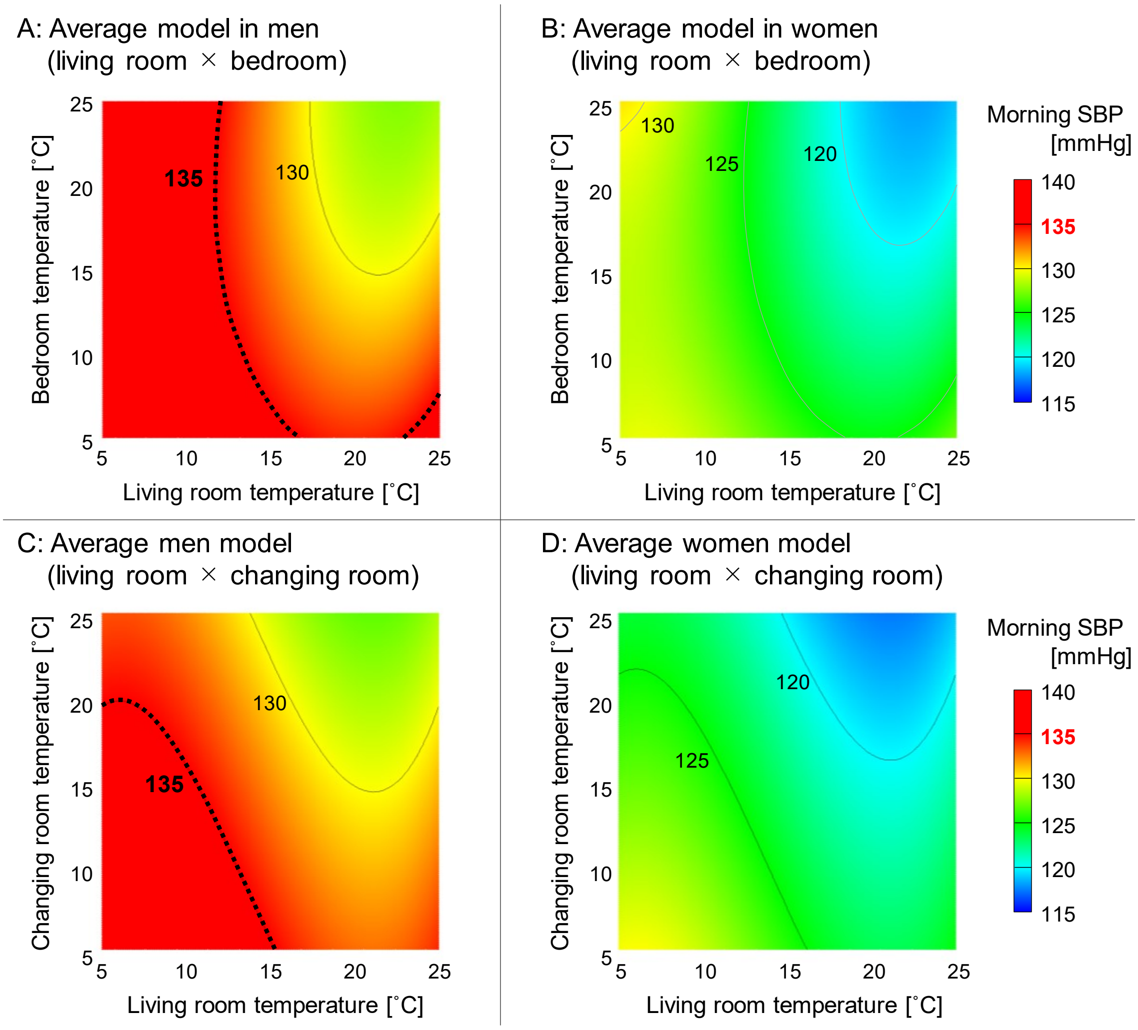


Fig.5-6 | Relationship between living room/bedroom/changing room temperature and morning SBP

5.3.6 Sensitivity analysis of the effect of indoor temperature on home blood pressure

To collate data that would be useful for determining optimum room temperature recommendations for the prevention of hypertension, sensitivity analysis was conducted to verify the effect of changes in indoor temperature on HBP according to the odds associated with morning SBP increasing to ≥135 mmHg (diagnostic threshold for hypertension or normotension [44]). First, sensitivity analysis was conducted using unadjusted raw data, the results of which are shown in Fig.5-7A. In both men and women, the proportion of SBP data points with SBP ≥135 mmHg tended to be higher at low room temperatures. Based on multilevel logistic regression analysis, sensitivity analysis was conducted after adjusting for personal attributes and lifestyle habits. For the objective variable in this analysis, SBP ≥135 mmHg and <135 mmHg were two-valued variables, and explanatory variables were the same as those used in multilevel linear regression analysis in the previous section. After confirming fitness, the model was developed as a linear function model of the living room temperature and the temperature disparity between the living room and bedroom.

The results of this model are shown in Fig.5-7B. The living room temperature at which there was <50% odds of the SBP increasing to ≥135 mmHg was >14°C for 60-year-old men, >20°C for 70-year-old men, and >24°C for 80-year-old men; and >11°C for 70-year-old women, and >17°C for 80-year-old women.

A: Summary of raw data

Sex	Age	Number of measurements	Percentage of SBP data above 135mmHg [%]																
			All	Living room temperature in the morning															
				10 °C	11 °C	12 °C	13 °C	14 °C	15 °C	16 °C	17 °C	18 °C	19 °C	20 °C	21 °C	22 °C	23 °C	24 °C	25 °C
Men	30s	3,362	23	28	27	28	27	26	26	25	25	25	24	23	23	22	23	23	23
	40s	6,469	31	43	42	43	41	40	40	39	36	35	34	33	32	32	32	32	32
	50s	10,000	44	50	49	49	48	48	47	46	46	46	45	45	45	44	44	44	44
	60s	12,976	50	55	54	54	53	53	53	53	52	52	52	51	51	50	50	50	50
	70s	5,836	60	71	70	68	67	66	65	64	63	62	62	61	60	60	60	60	60
	80s	1,353	65	71	70	70	71	70	69	69	69	68	67	68	66	66	65	65	66
Women	30s	3,742	3	5	5	4	4	4	3	3	3	2	2	2	3	2	2	3	3
	40s	7,447	11	14	14	14	13	13	13	13	13	12	12	11	11	11	11	11	11
	50s	12,975	26	33	33	34	32	31	30	30	29	28	28	27	27	26	26	26	26
	60s	12,665	40	44	45	44	44	44	44	44	43	42	42	41	40	40	40	40	40
	70s	5,684	57	59	59	60	60	61	61	60	60	59	58	57	57	57	57	57	57
	80s	1,992	69	80	79	79	78	77	76	74	74	72	71	70	70	69	69	69	69
Total		86,302	37	45	45	44	44	43	43	42	41	40	39	39	38	38	38	38	38

B: Results of multilevel logistic regression analysis

Sex	Age	Odds ratio of SBP data above 135mmHg [-]															
		Living room temperature in the morning															
		10 °C	11 °C	12 °C	13 °C	14 °C	15 °C	16 °C	17 °C	18 °C	19 °C	20 °C	21 °C	22 °C	23 °C	24 °C	25 °C
Men	30	8	7	7	6	6	5	5	4	4	3	3	3	3	2	2	2
	40	18	16	15	13	12	11	10	9	8	7	7	6	6	5	4	4
	50	35	32	30	27	25	23	21	19	17	15	14	13	11	10	9	8
	60	**57**	**54**	**51**	47	44	41	38	35	32	29	27	24	22	20	18	16
	70	**77**	**74**	**71**	**69**	**65**	**62**	**59**	**56**	**52**	49	45	42	38	35	32	29
	80	**89**	**88**	**86**	**84**	**82**	**80**	**77**	**74**	**71**	**68**	**65**	**61**	**58**	**54**	**50**	47
Women	30	3	2	2	2	2	1	1	1	1	1	1	1	1	1	0	0
	40	6	5	5	4	4	3	3	3	2	2	2	2	1	1	1	1
	50	14	12	11	10	9	7	7	6	5	4	4	3	3	3	2	2
	60	29	26	23	20	18	16	14	12	11	10	8	7	6	6	5	4
	70	**50**	46	42	38	35	31	28	25	22	19	17	15	13	11	10	9
	80	**71**	**68**	**64**	**60**	**56**	**52**	47	43	39	35	32	28	25	22	19	17

Fig.5-7 | Sensitivity analysis of changes to morning SBP due to changes in living room temperature

A: The chart indicates that 55% of SBP data points from men in their 60s was ≥135 mmHg when the living room temperature was below 10°C. Meanwhile, 44% of SBP data points from women in their 60s was ≥135 mmHg when the living room temperature was below 10°C.

B: The participants' average values were inputted into the multilevel logistic regression model. The chart indicates that, after controlling for other variables (ΔTemp, quality of sleep, sleep duration, alcohol consumption the previous night, BMI, salt check sheet, vegetable consumption, exercise, smoking, alcohol consumption, antihypertensive drug use, TempOut), at a living room temperature of 10°C, the odds of the SBP of 60-year-old men increasing to ≥135 mmHg was 57%.

5.3.7 Identification of residents living in low room temperatures

The results of the previous section suggest that the indoor temperature affects BP. In this section, to capitalize on the strengths of the nationwide survey, we analyzed the residential area and the attributes of residents living in low-temperature environments. First, the average living room temperature at the time of HBP measurements in the morning in each prefecture was determined (Fig.5-8). Only the morning living room temperature in Hokkaido, which has a higher adiabatic level than other areas, exceeded 18˚C (the minimum temperature recommended by the WHO [70] and UK guidelines [71, 72]), while that in all other prefectures was below 18˚C. In addition, prefectures in the southwestern area of Japan, which is considered to have a mild climate, had low-room-temperature environments. Mountainous areas with high altitudes had low room temperatures, while flat areas at sea level tended to have higher room temperatures.

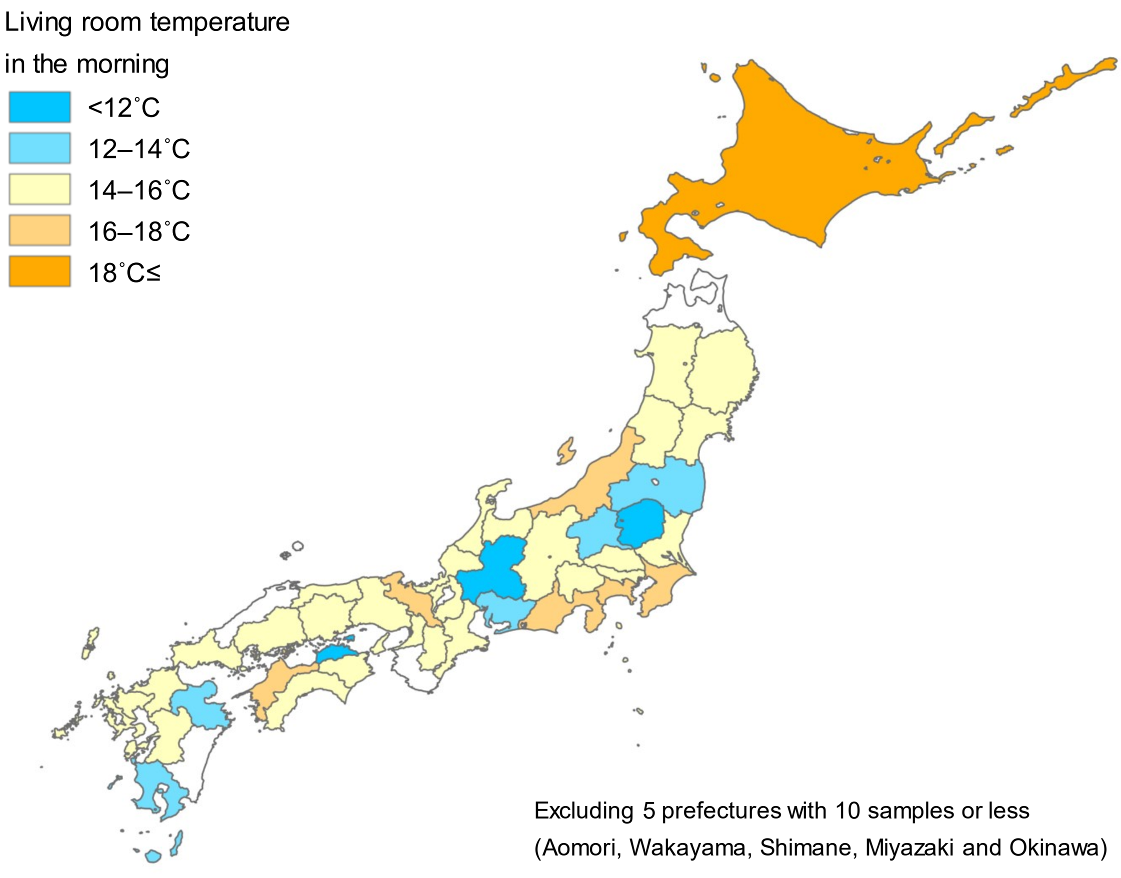


Fig.5-8 | Average living room temperature in the morning in each prefecture

Subsequently, living room temperature in the morning was compared among the residents' personal attributes (Table 5-10). The findings suggest that elderly residents and those with low household incomes or low educational status may be more likely to live in low-room-temperature environments. The living room temperature differed depending on the presence or absence of housemates and the duration of residence. Additionally, the living room temperature differed depending on the heating method used. The room temperature was high in the houses of residents who set the timer on a heater before getting up in the morning, but was low in the houses of those who used kotatsu tables. Furthermore, although room temperature did not differ depending on the amount of clothing worn during sleep, it did differ depending on the amount of clothing worn while awake.

Table 5-10 | Average living room temperature in the morning for each personal attribute

Variable	*n*	Mean	Difference from ref.	*p* value
Age				
<40 years (ref.)	381	15.9	–	–
40–49 years	572	16.0	0.1	0.999
50–59 years	917	14.9	–1.0	**0.001**
60–69 years	1,021	14.7	–1.2	**0.000**
70–79 years	466	14.6	–1.3	**0.000**
≥80 years	157	14.9	–1.0	0.147
Sex				
Men (ref.)	1,658	15.2	–	–
Women	1,856	14.9	–0.3	0.068
BMI				
Leptosome (<18.5) (ref.)	244	15.6	–	–
Normal (18.5–25.0)	2,519	15.0	–0.6	0.080
Obesity (>25.0)	751	15.0	–0.6	0.150
Household income				
Low (<2 million JPY) (ref.)	373	14.3	–	–
Middle (2–6 million JPY)	1,636	14.9	0.7	**0.015**
High (≥6 million JPY)	1,224	15.6	1.3	**0.000**
Educational status				
Junior high school (ref.)	251	14.2	–	–
High school	1,324	14.8	0.6	0.228
Technical/vocational/junior college	805	15.2	1.0	**0.006**
College/graduate college	962	15.5	1.3	**0.000**
Other	19	14.7	0.5	0.990
Housemate				
Living together (ref.)	3,237	15.1	–	–
Living alone	183	13.9	–1.2	**0.001**
Duration of residence in house *				
<25 years (ref.)	1,788	15.9	–	–
≥25 years	1,656	14.1	–1.8	**0.000**
Set the timer of heating device before getting up				
None (ref.)	2,318	14.9	–	–
Currently	1,102	15.4	0.6	**0.001**
Kotatsu table use**				
None (ref.)	2,057	15.9	–	–
Currently	1,427	13.8	–2.1	**0.000**
Amount of clothing during sleep *				
<0.75 clo (ref.)	2,948	15.1	–	–
≥0.75 clo	459	15.1	0.0	0.944
Amount of clothing while awake *				
<1.00 clo (ref.)	1,050	15.9	–	–
≥1.00 clo	2,354	14.7	–1.2	**0.000**

* Divided into two groups based on the average value
** Small table with an electric heater underneath and covered by a quilt

Given that these findings suggest that the residential area and various personal attributes may influence room temperature, multilevel analyses were performed (Table 5-11). The objective variable was the living room temperature at the time of HBP measurements in the morning, and the explanatory variables were sex and BMI, as basic attributes, and variables that showed significant differences in Table 5-10. Multilevel logistic regression analysis was also conducted. The objective variable in this analysis was living room temperature in the morning ≥18˚C (the minimum temperature recommended by the WHO [70] and UK guidelines [71, 72]). Compared with energy-saving area 6, which accounts for the majority of Japan, the room temperature in area 2 was significantly higher by 3.5˚C. In contrast, the room temperature was significantly lower in area 4 and 5 than in area 6. Regarding personal attributes, high household income was significantly correlated with higher room temperatures. In addition, use of heating from before getting up in the morning was correlated high room temperatures, indicating the importance of heating methods. In contrast, longer periods of residence in the same house and having no housemates were correlated with low room temperatures. Moreover, use of kotatsu tables and wearing large amounts of clothes while awake were correlated with lower room temperatures.

Table 5-11 | Multilevel model of living room temperature in the morning

Explanatory variable		Univariate model		Multilevel model			
		β	*p* value	Adjusted *β*	*p* value	Odds ratio *	*p* value
Level 1: Day level							
$Temp_{Out}$	[°C]	0.329	**0.000**	0.335	**0.000**	1.253	**0.000**
Level 2: Individual level							
Age	[years]	−0.033	**0.000**	0.008	0.257	1.003	0.640
Sex	0) Men (ref.)	0	−	0	−	1	−
	1) Women	−0.263	0.068	−0.309	**0.047**	0.820	0.097
BMI	[kg/m^2]	−0.023	0.250	−0.021	0.312	0.984	0.320
Energy-saving area	0) Area 6 (ref.)	0	−	0	−	1	−
	1) Area 2	3.974	**0.000**	3.529	**0.000**	17.966	**0.000**
	2) Area 3	−0.792	0.051	−0.717	0.114	0.744	0.405
	3) Area 4	−1.751	**0.000**	−1.437	**0.000**	0.698	0.053
	4) Area 5	−0.884	**0.000**	−0.724	**0.000**	0.696	**0.008**
	5) Area 7	−0.302	0.323	−0.174	0.592	0.808	0.388
Household income	0) <2 million JPY (ref.)	0	−	0	−	1	−
	1) 2–6 million JPY	0.681	**0.005**	0.339	0.182	1.246	0.268
	2) ≥6 million JPY	1.312	**0.000**	0.735	**0.006**	1.686	**0.012**
Duration of residence	[years]	−0.062	**0.000**	−0.046	**0.000**	0.971	**0.000**
Housemate	0) Living together (ref.)	0	−	0	−	1	−
	1) Living alone	−1.210	**0.000**	−1.591	**0.000**	0.394	**0.001**
Heating timer use	0) None (ref.)	0	−	0	−	1	−
	1) Currently	0.555	**0.000**	0.704	**0.000**	1.727	**0.000**
Kotatsu use	0) None (ref.)	0	−	0	−	1	−
	1) Currently	−2.103	**0.000**	−1.453	**0.000**	0.339	**0.000**
Clothing	[clo]	−2.968	**0.000**	−2.003	**0.000**	0.176	**0.000**

* Objective variable: living room temperature in the morning ≥18°C
n = 72,899 observations (2,952 participants × Ave. 25 observations/participant)
$Temp_{Out}$, outdoor temperature.

5.4 Discussion

5.4.1 Nonlinear relationship between indoor temperature and blood pressure

Although many studies have reported on the relationship between the thermal environment and BP, the majority of these studies examined the relationship between the outdoor air temperature and BP, while research focusing on the relationship between indoor room temperature and BP is limited. Woodhouse et al. [115] surveyed 96 individuals aged 65 to 74 years, and determined that SBP increased by 9.0 mmHg per 10°C decrease in indoor air temperature. However, the small sample size and inclusion of elderly patients only in this study make it difficult to determine whether or not the findings are generalizable.

The MONICA Project established by the World Health Organization (WHO) is a global survey that aims to monitor trends in cardiovascular diseases. As part of the MONICA Project, Barnett et al. [117] analyzed BP measurement data from 115,434 men and women aged 35 to 64 years, and revealed that SBP increased by 3.1 mmHg per 10°C decrease in indoor air temperature. However, this survey did not examine BP measured inside participants' homes, but rather, participants generally measured BP at a comfortable indoor temperature ranging from 18 to 24°C. Therefore, a survey of BP measurements in a cold environment has not been conducted. The present study obtained data from indoor temperatures ranging from 1.0 to 29.0°C, and showed that SBP increased by 5.0 (evening) or 6.4 mmHg (morning) per 10°C decrease in indoor air temperature. Therefore, the increase in SBP in this survey was larger than that reported by Barnett et al. This is presumably because the effect of indoor temperature on SBP is reduced at high room temperatures, given that the present findings suggest that SBP is a function of the cube of the living room temperature.

Saeki et al. [114] conducted a survey of SBP measured inside participants' homes. Among 880 elderly people with an average age of 72 years, daytime SBP increased by 2.2 mmHg per 10°C decrease in daytime indoor air temperature. This smaller effect of indoor temperature on SBP compared to the present findings may be due to differences in the compared parameters: Saeki et al. analyzed the relationship between average indoor temperature and average SBP values during daytime hours while the present study examined the relationship between raw measured values.

The above research and others on the relationship between indoor temperature and BP have been systematically summarized in recent meta-analyses [113]. These meta-analyses highlight the need to use a suitable sample size and nonlinear model to overcome problems encountered by previous research. In the present study, analysis based on about 64,000 data points from 2,900 residents showed that there was a cubic relationship between indoor room temperature and BP. That is, the effect of room temperature on SBP was reduced at low and high room temperatures. This relationship may be the result of behavioral thermoregulation such as wearing or removing clothes at low or high room temperatures, and a limitation of thermo-physiological reactions such as vasoconstriction or vasodilatation. That is, BP fluctuates greatly when an individual is in a room temperature zone in which it is difficult to feel cold. Studies on EWM [46] indicate that the number of deaths in 13 countries including Japan is much greater when the outside temperature is moderately cold than when it is extremely cold. This may be related to the increase in BP fluctuations in a room temperature zone in which it is difficult to feel cold. This evidence suggests that room temperature should be maintained even when the room temperature is not extremely low.

5.4.2 Impact of the living room and bedroom temperature disparity

While previous studies [162] that examined the variability in BP due to room temperature disparities were conducted based on subject experiments, the present study showed that SBP in the morning increased when the actual measured temperature disparity between the living room and bedroom increased in the participants' houses. The Japanese traditionally use partial heating (e.g., heating only in the living room) while Europeans and Americans use central heating, increasing the possibility of a larger temperature disparity between rooms in Japan compared to European and American countries. The results of this survey therefore suggest that traditional Japanese heating methods are unfavorable for preventing hypertension.

5.4.3 Recommendations for home temperature

WHO [70] and Public Health England (PHE) in the UK [71, 72] recommend a minimum indoor temperature of 18°C. However, this recommendation from WHO is based on the effect of low room temperature on respiratory diseases, without focus on CVDs, another key factor for EWM. Additionally, a report on minimum room temperature thresholds issued by PHE is based on data presented in 20 papers. However, these 20 papers are very heterogeneous and provide weak evidence to support the threshold. Therefore, there is still insufficient evidence for determining optimum home temperature recommendations. The present study revealed that the effect of living room temperature on SBP in the morning was greater than that in the evening, and indoor temperature had a stronger effect on SBP in older residents and women. Accordingly, optimum home temperature recommendations should be decided with reference to time zone and the characteristics of the residents themselves. Therefore, sensitivity analysis was performed to show the probability of morning SBP increasing to ≥135 mmHg (diagnostic threshold for hypertension or normotension [44]) at various living room temperatures according to age and sex. We expect that these results will send the clear message that it is important to manage indoor temperature in the morning, and that indoor room temperature management is particularly important for the health of elderly individuals. Furthermore, we also expect that they will be useful for determining optimum home temperature recommendations to prevent morning hypertension and CVD.

5.4.4 Residents at high risk of hypertension and cardiovascular disease

Our analyses in this chapter indicate that the indoor temperature is strongly related to blood pressure, and that hypertension occurs in low room temperature environments. Furthermore, hypertension during the winter season can lead to the development of CVD and has been known to cause EWM. In other words, residents living in low room temperature environments have a high risk of hypertension and CVD.

Studies related to the determinants of room temperature have been conducted in the UK [163, 164]. These studies suggest that, in addition to housing properties like the age of the building and house type, resident attributes like house composition and employment status also significantly affect the room temperature. Our analysis similarly showed that, in addition to low household income, the duration of residence in the house, single-person households, and way of living, such as the use of heating and amount of clothing worn, also affect the room temperature. Low household income may force residents to limit the use of heating or to live in housing with low performance insulation. The correlation between the duration of residence and lower room temperature may be due to familiarity discouraging residents from heating their rooms. Our data confirmed that the indoor temperature is lower in single-person households. A previous study [165] suggested that people living alone have a higher risk of hypertension, and low room temperature is hypothesized to be a contributing factor. Households using kotatsu tables, which are unique to Japan, had lower indoor temperatures. Kotatsu is a form of local heating and therefore does not allow heating of the entire space. Similarly, wearing more clothes was correlated with lower room temperatures, which suggests that some residents attempt to brave the cold by wearing more clothes.

This analysis also revealed that there is a major disparity in indoor temperatures within Japan. Comparison between prefectures revealed a maximum difference of 7.9°C, with only houses in Hokkaido exceeding the minimum recommended room temperature of 18°C provided by the WHO and the UK. Furthermore, the results of multilevel analysis showed that houses in energy-saving areas 4 and 5 had lower room temperatures than those in the majority of Japan. This suggests that the insulation standards in these areas are inadequate.

This method allowed the identification of high-risk residents that require active intervention to prevent hypertension and CVD. This result is expected to lead to the adoption of a high-risk approach used in public health interventions for the implicated area and residents.

Chapter 6

Effect of insulation retrofit on home blood pressure

Chapter 6 | Effect of insulation retrofit on home blood pressure

6.1 Introduction

Hypertension is the main cause of cardiovascular disease (CVD) [14, 166], the leading cause of death worldwide [1]. It is also known to be related to kidney diseases [167, 168] and dementia [169−172]. According to the Global Burden of Diseases, Injuries, and Risk Factors Study 2015 [173], hypertension is the risk factor that most affects a person's disability-adjusted life years. Because the number of people affected by hypertension increases with age, the number of cases of hypertension is expected to continue to increase as our society ages [43, 44]. Therefore, prevention of hypertension is an imminent challenge.

Because hypertension has almost no subjective symptoms, it is often referred to as the "silent killer" [15]. A systematic analysis [174] of 968,419 adults from 90 countries showed that 31.1% (one in three people) had hypertension as of 2010, of whom, approximately less than half (46.5%) were aware of their hypertension. Among those with hypertension, 36.9% received treatment in the form of antihypertensive agents, but only 13.8% were able to control their blood pressure within the normal range (SBP <140 mmHg, DBP <90 mmHg) [44]. The current situation wherein a large number of hypertensive patients are not receiving antihypertensive treatment and blood pressure is not well controlled indicates the inadequacy of the high-risk approach of using antihypertensive agents alone. There is therefore a need for a population approach that shifts the blood pressure of the entire population in the appropriate direction.

A population approach, rather than improvements to individuals' lifestyle habits, is necessary to improve the living environment in a way that is independent of individual efforts. The focus of such improvements to living environments is on improving housing, which is where people spend most of their time. In recent years, there has been an abundance of research on the relationship between the thermal environment inside houses and the blood pressure of residents [113−117]. However, much of this research has used cross-sectional methods, while evidence based on longitudinal studies remains limited. Therefore, this study used insulation retrofit of housing as an intervention and aimed to elucidate the cause-and-effect relationship between insulation retrofit and the blood pressure of residents by comparing residents' blood pressure before and after the intervention.

6.2 Method

6.2.1 Procedures

Participants were recruited by construction companies that constitute 68 Model Project teams across all 47 prefectures of Japan. The recruitment criteria were: (1) participants aged 20 years or older and (2) houses prior to renovation not meeting Criteria S of the "Act on the Promotion of Dissemination of Long-Lasting Quality Housing." Recruitment was performed mainly among households that were scheduled to receive subsidies for insulation retrofit as part of the Model Project. For the recruitment of households by construction companies, the Japan Sustainable Building Consortium (JSBC), the main body governing the research project, put in a request to conduct the investigation. The households that gave consent were sent an investigation kit that included questionnaires, a thermos-hygrometer, a home blood pressure meter, and an activity meter. The participants started the 14-day baseline survey (investigation prior to insulation retrofit) within 5 days of receiving the investigation kit.

After completing the baseline survey, the participants' houses were retrofitted by the construction companies. After completing the insulation retrofit, the construction companies submitted a Certificate of Conformance with Energy-Saving Standards to the MLIT to indicate that the performance of the house met the pre-determined standards. After the insulation retrofit, the participants completed the post-retrofit survey in the same manner as the baseline survey. Participants who completed both surveys without receiving the insulation retrofit, despite being scheduled to do so, were included in the analysis as control group participants.

Table 6-1 shows the patterns of participation in home blood pressure measurement and Fig.6-1 shows the recruitment process. Out of the 3,775 participants (2,095 households) who completed the baseline survey, 1,253 participants (714 households) completed 2 or more measurements, and 1,083 participants (652 households) were selected as valid samples. Of these, 975 participants (588 households) comprised the intervention group, while 108 participants (68 households) comprised the control group.

Table 6-1 | Patterns of participation in home blood pressure measurements

Group	Number of participations	2014 Winter	2015 Winter		2016 Winter	2017 Winter	Total
Intervention (insulation retrofit) (n = 1,123)	3 periods (n = 93)	Before 1^{st}	Before 2^{nd}	After 1^{st}	—	—	2
		Before 1^{st}	Before 2^{nd}	—	After 1^{st}		90
		Before 1^{st}	Before 2^{nd}	—	—	After 1^{st}	1
	2 periods (n = 1,030)	Before 1^{st}	After 1^{st}	—	—	—	248
		Before 1^{st}	—	—	After 1^{st}	—	66
		Before 1^{st}	—	—	—	After 1^{st}	8
		—	Before 1^{st}	After 1^{st}	—	—	2
		—	Before 2^{nd}	—	After 1^{st}	—	1
		—	Before 1^{st}	—	After 1^{st}	—	355
		—	Before 1^{st}	—	—	After 1^{st}	135
		—	—	—	Before 1^{st}	After 1^{st}	215
Control (n = 130)	3 periods (n = 6)	Before 1^{st}	Before 2^{nd}	—	—	—	6
	2 periods (n = 124)	Before 1^{st}	Before 2^{nd}	—	—	—	118
		—	Before 1^{st}	—	—	Before 2^{nd}	4
		—	—	—	Before 1^{st}	Before 2^{nd}	2

* "Before" indicates that the survey was completed before insulation retrofit. "After" indicates that the survey was completed after insulation retrofit. "1^{st}" and "2^{nd}" indicate residents' n^{th} participation in home blood pressure measurements before and after insulation retrofit.

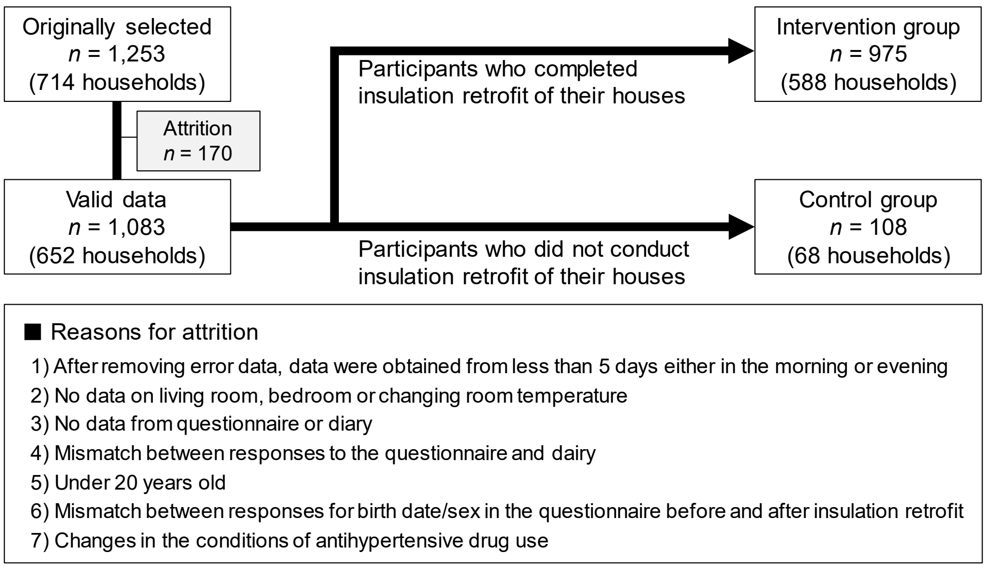


Fig.6-1 | Flow of participants through the before and after insulation retrofit study

6.2.2 Statistical analysis

To examine the influence of insulation retrofit on home blood pressure (HBP), analysis of covariance (ANCOVA) was used to compare blood pressure after the intervention (the objective variable). Because this investigation was conducted as a non-randomized controlled trial, there were potential differences in the baseline characteristics. Therefore, in addition to the baseline blood pressure, we adjusted for factors that affect blood pressure such as age, sex, body mass index (BMI), use of antihypertensive agents, salt intake, vegetable intake, exercise, smoking, drinking, sleep, living room temperature ($Temp_{Lr}$), outdoor temperature ($Temp_{Out}$), and household income to minimize any potential differences in baseline characteristics. Participants' salt check sheet score [137] was used as a measure of salt intake, while the Pittsburgh Sleep Quality Index questionnaire score [133, 134] was used as a measure of sleep. Furthermore, to account for changes in weather conditions before and after the intervention in the intervention and control groups, changes in the outdoor temperature before and after the intervention were adjusted for in the analysis.

6.3 Results

6.3.1 Attributes of participants in the intervention group and control group

The attributes of participants in the intervention group and control group at baseline are shown in Table 6-2 and Table 6-3. The average SBP in the morning was 128 mmHg in both groups. The average SBP in the evening was 121 mmHg in the intervention group and 122 mmHg in the control group. DBP was 80 mmHg in the morning and 74 mmHg in the evening in both groups. There was no significant difference in SBP or DBP between the intervention group and the control group in the morning or evening. There was no significant difference in room temperature for any indices, although the outdoor temperature was significantly lower in the control group than in the intervention group. The average age of participants in the intervention group was significantly higher, at 58 years, compared to 54 years in the control group. The average BMI was within the "normal weight" (18.5–24.9 kg/m^2) range according to WHO. The salt check sheet score was significantly higher in the control group. The ratio of men to women was about 1:1 in both groups, although there were slightly more women. There was no significant difference in exercise, vegetable consumption, smoking or alcohol consumption. Although not significant, participants in the intervention group had a higher tendency to use antihypertensive drugs.

Table 6-2 | Characteristics of participants in the intervention and control groups (mean ±SD)

Variable	Intervention Mean ± SD		Control Mean ± SD		Difference	*p* value *
HSBP, mmHg						
In the morning	128	± 17	128	± 17	0	0.782
In the evening	121	± 16	122	± 13	0	0.888
HDBP, mmHg						
In the morning	80	± 11	80	± 10	0	0.878
In the evening	74	± 10	74	± 9	0	0.973
$Temp_{Lr}$, °C						
In the morning	15.2	± 4.3	15.9	± 4.5	−0.7	0.103
In the evening	18.1	± 3.9	18.4	± 4.0	−0.3	0.451
$Temp_{Br}$, °C						
In the morning	12.5	± 4.1	12.9	± 4.8	−0.4	0.457
In the evening	14.4	± 4.1	14.4	± 4.1	0.1	0.837
$Temp_{Cr}$, °C						
In the morning	11.3	± 4.1	11.8	± 4.8	−0.5	0.266
In the evening	13.5	± 3.9	13.6	± 4.6	−0.2	0.734
$Temp_{Out}$, °C						
In the morning	3.8	± 3.5	2.8	± 3.3	1.0	**0.007**
In the evening	5.2	± 3.7	3.8	± 3.3	1.4	**0.000**
Age, years	58	± 13	54	± 14	3	**0.009**
BMI, kg/m^2	22.8	± 3.6	23.1	± 3.2	−0.4	0.324
Salt check sheet, points	13.1	± 4.3	14.2	± 4.2	−1.0	**0.022**

* t test

HSBP, home systolic blood pressure; HDBP, home diastolic blood pressure; $Temp_{Lr}$, living room temperature; $Temp_{Br}$, bedroom temperature; $Temp_{Cr}$, changing room temperature; $Temp_{Out}$, outdoor temperature; BMI, body mass index.

Table 6-3 | Characteristics of participants in the intervention and control groups (number, %)

Variable	Intervention		Control		%Difference	*p* value *
	Number (%)		Number (%)			
Sex						
Men	454	(46.6)	52	(48.1)	−1.5	0.833
Women	521	(53.4)	56	(51.9)	1.5	
Exercise						
Rarely	695	(71.9)	70	(65.4)	6.5	0.193
Regularly	271	(28.1)	37	(34.6)	−6.5	
Vegetable consumption						
Rarely	17	(1.8)	2	(1.9)	−0.1	0.632
2–3 times/week	204	(21.1)	27	(25.0)	−3.9	
Regularly	748	(77.2)	79	(73.1)	4.0	
Smoking						
None	694	(78.1)	74	(71.2)	6.9	0.193
Quit smoking	66	(7.4)	8	(7.7)	−0.3	
Smoking	129	(14.5)	22	(21.2)	−6.6	
Alcohol consumption						
None	441	(45.9)	54	(50.0)	−4.1	0.643
Sometimes	259	(27.0)	25	(23.1)	3.8	
Everyday	260	(27.1)	29	(26.9)	0.2	
Antihypertensive drug use						
None	711	(75.1)	83	(83.0)	−7.9	0.102
Currently	236	(24.9)	17	(17.0)	7.9	

* Chi-squared test

6.3.2 Changes in indoor temperature due to insulation retrofit

We examined the influence of insulation retrofit intervention on room temperature. The change in room temperature in the living room, bedroom and changing room before and after the intervention is shown for the intervention group and the control group in Fig.6-2. In the control group, the outdoor temperature was higher after the intervention, and the room temperature rose in all rooms. In contrast, in the intervention group, although the outdoor temperature decreased, the room temperature rose in all rooms after the intervention.

The room temperature the day before and after the intervention is shown for each room in Fig.6-3. In the control group, the outdoor temperature was 1.8°C higher, and the room temperature was 1.0°C higher in the living room, 1.4°C higher in the bedroom, and 1.3°C higher in the changing room after the intervention. In the intervention group, despite a drop in the outdoor temperature by 0.9°C, the room temperature was 1.4°C higher in the living room and 1.0°C higher in the bedroom and the changing room after the intervention. The rise in room temperatures against the decline in outdoor temperature is likely a direct effect of the insulation retrofit intervention.

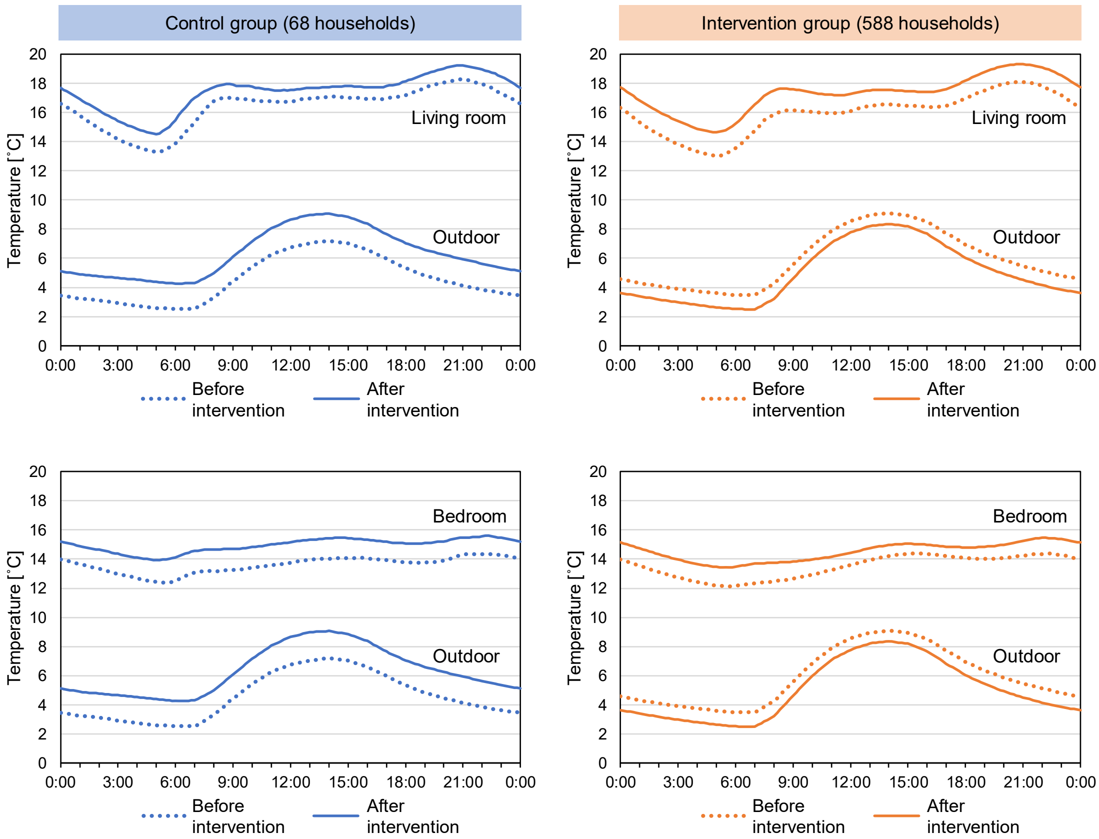


Fig.6-2 | Changes in indoor/outdoor temperature throughout one day

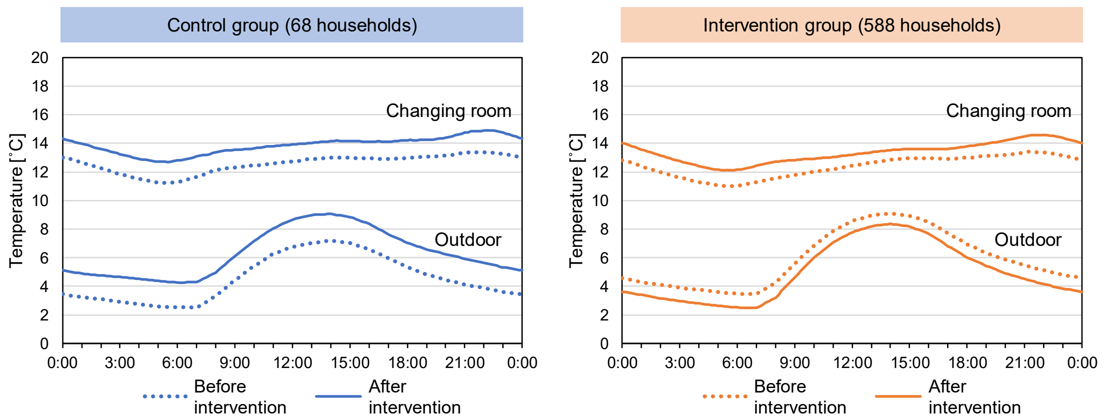


Fig.6-2 | Changes in indoor/outdoor temperature throughout one day (continued)

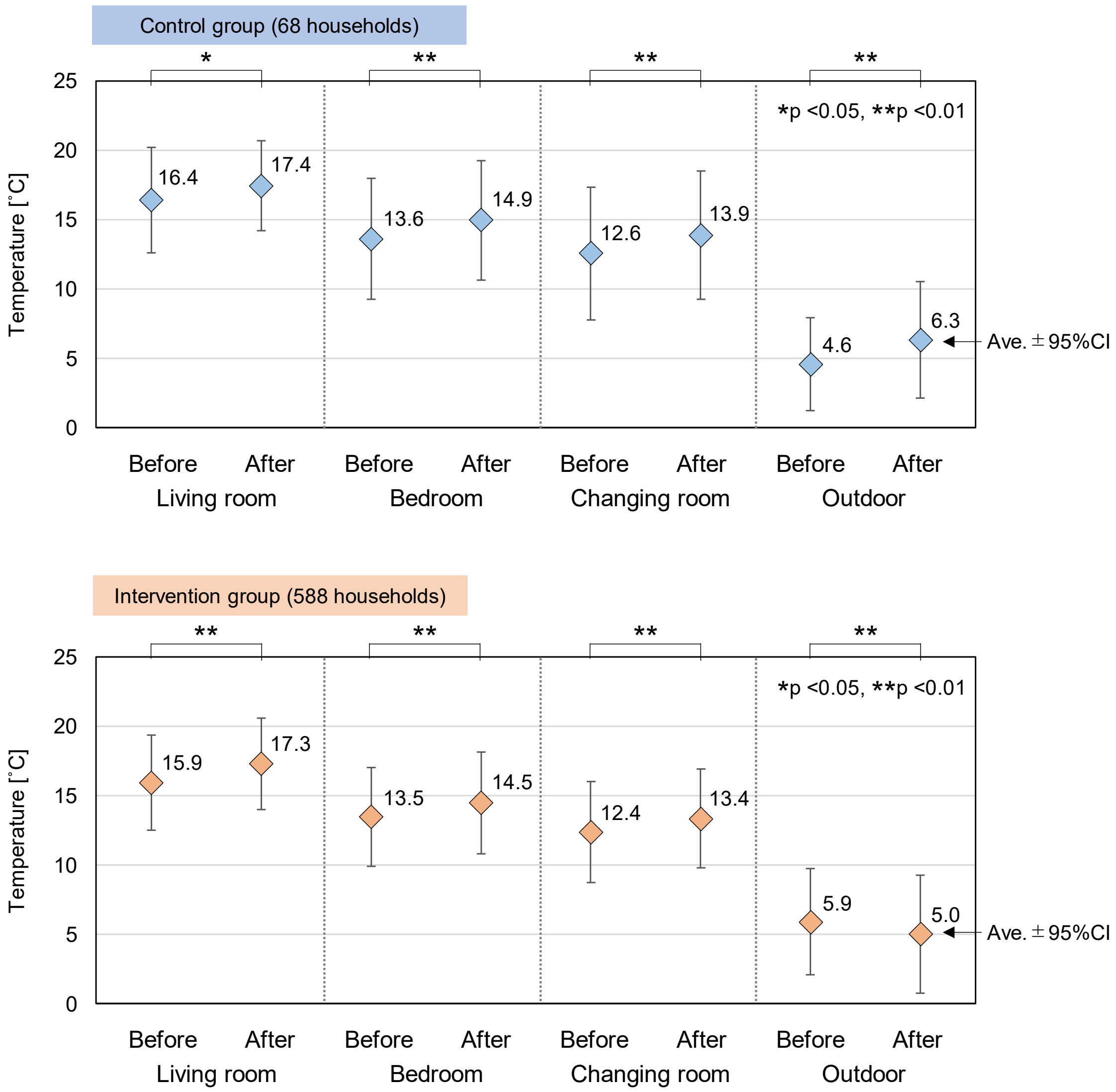


Fig.6-3 | Indoor/outdoor temperature before and after intervention

6.3.3 Causal relationship between insulation retrofit and home blood pressure

The average blood pressure in the intervention and control group before and after the intervention is shown in Fig.6-4. In the control group, all blood pressure indices increased after the intervention. In contrast, in the intervention group, SBP in the morning and evening decreased after the intervention. The increase in BP in the control group after the intervention may be a result of aging because there was a period of one or two years between the surveys before and after intervention.

In Section 6.3.1, there was a difference in baseline characteristics between the intervention group and the control group. Therefore, to adjust for the baseline characteristics, multivariate analysis was conducted to verify the effect of the insulation retrofit intervention (Table 6-4). The objective variable was the blood pressure in the follow-up survey, and the explanatory variables were factors related to hypertension (JSH2014) [44] at baseline and changes in outdoor temperature before and after the intervention and the blood pressure in the baseline survey. The analysis showed that insulation retrofit significant reduced SBP (−3.53 mmHg (95%CI: −5.26, −1.80)) and DBP (−1.49 mmHg (95%CI: −2.75, −0.23)) in the morning.

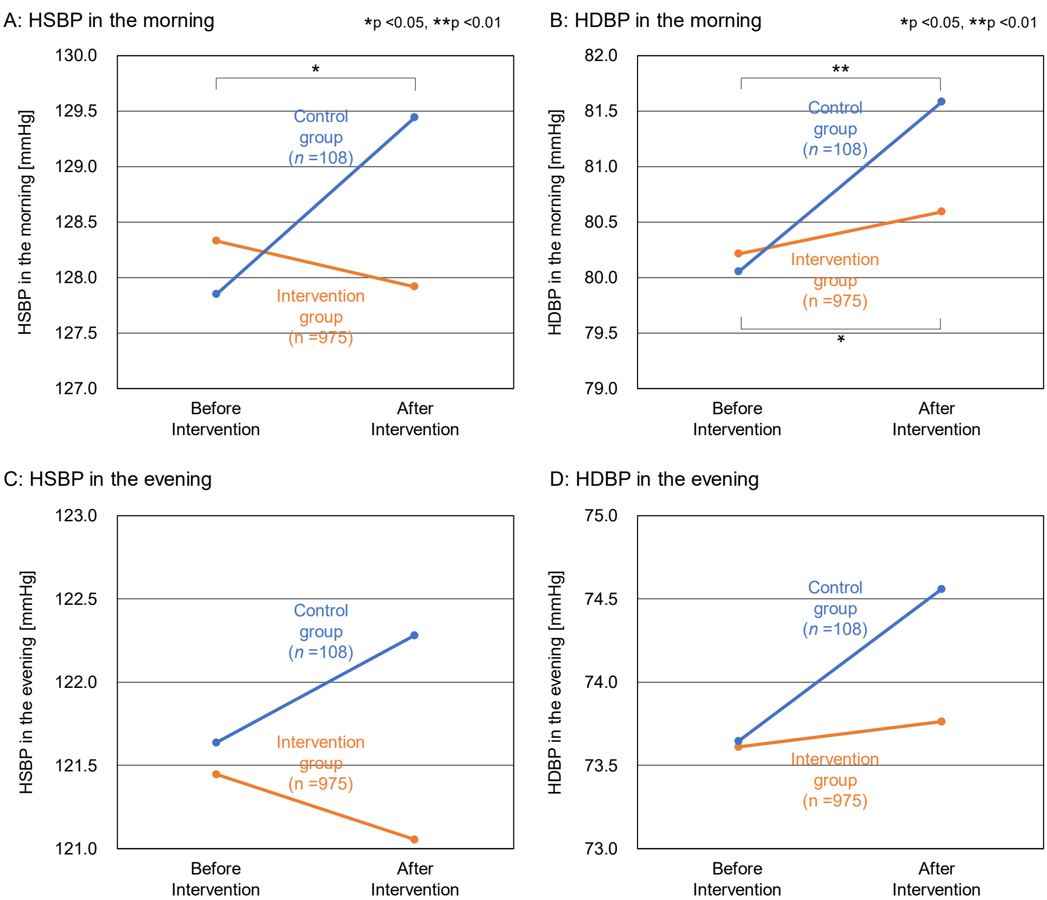


Fig.6-4 | Average blood pressure of intervention and control groups before and after intervention

Table 6-4 | Effect of insulation retrofit on home blood pressure in the morning and evening

Objective variable	Univariate model			Multivariate model *		
	β	(95%CI)	*p* value	Adjusted *β*	(95%CI)	*p* value
HSBP, mmHg						
In the morning	−1.95	(−3.46, −0.44)	**0.012**	−3.53	(−5.26, −1.80)	**0.000**
In the evening	−1.06	(−2.58, 0.47)	0.173	−1.49	(−3.31, 0.33)	0.109
HDBP, mmHg						
In the morning	−1.13	(−2.17, −0.10)	**0.032**	−1.49	(−2.75, −0.23)	**0.020**
In the evening	−0.77	(−1.83, 0.29)	0.153	−0.85	(−2.16, 0.46)	0.204

*Adjusted for BP, age, sex, body mass index, salt check sheet score, vegetable consumption, exercise, smoking, alcohol consumption, Pittsburgh Sleep Quality Index, antihypertensive drug use, household income, living room temperature, outdoor temperature at baseline, and change in outdoor temperature between before and after intervention.

CI, confidence interval; HSBP, systolic blood pressure at home; HDBP, diastolic blood pressure at home.

6.4 Discussion

6.4.1 Previous intervention studies on housing and blood pressure

Clinical trials examining the relationship between housing and blood pressure have started in Japan and other countries.

In Scotland, Walker et al. [106] examined this relationship in a program that built new central heating systems in the households of elderly individuals with inadequate or irreparable central heating facilities. They conducted a prospective control study that compared the diagnosis of heart diseases and hypertension in a central heating-introduced group (1,281 households) and control group (1,084 households). They found that the odds ratio for receiving a diagnosis of hypertension was 0.77 (95% CI: 0.61–0.97) for the central heating-introduced group, thereby confirming the positive effect of using central heating. However, given that the diagnosis of hypertension was based on self-reports using a questionnaire, this result was based on subjective data.

The two randomized controlled trials by Saeki et al. [110, 111] are examples of studies based on objective data. One was an interventional study in which participants were randomly assigned to conduct measurements in either a laboratory set to 12°C or one set to 22°C. The other was an interventional study conducted in participants' actual living environments, where a doctor instructed the participants to turn on their heating to a set room temperature of 24°C one hour before getting out of bed. Both studies reported a significant decrease in SBP in the group with the higher temperature setting at the time of waking. The interventions examined in these studies were related to the way heating is used, while the long-term effects of these interventions remain unclear. These studies recommended that insulation retrofit may be necessary in the future.

An example of a study that used insulation retrofit as an intervention was that by Lloyd et al. [102], which examined the improvement in blood pressure through provision of home renovation packages in Scotland. A housing renovation package was developed and included double-skinning the outer walls, introduction of insulation material, doubling glass on windows, and introduction of gas central heating systems, which were conducted in the interventional study. Two blocks (36 houses) were chosen as the intervention group, while two other blocks were chosen as the control group. The participants' blood pressure, a risk factor for coronary artery heart diseases and stroke, was measured. The intervention group alone showed significant improvements in blood pressure. However, because the size of the final analysis sample was very small, with only 27 participants in the intervention group and 9 participants in the control group, it is difficult to conclude that the results are universally applicable.

Building on the results of these studies, our study examined the effect of insulation retrofit on HBP in 1,083 participants living in 652 households across Japan. Given that the occurrence of cardiovascular disease events concentrates around the time of waking, numerous sources have emphasized the importance of blood pressure control at this time. Based on the above, the decrease in HBP in the morning due to home insulation retrofit in this study is likely clinically meaningful.

6.4.2 Estimated preventive effect of housing improvement on cardiovascular disease

Health Japan 21 (the second term) is a policy established to prevent CVD in Japan [41]. This policy estimates that a decrease in average SBP of Japanese aged 40 to 89 years by 4 mmHg (men: 138→134 mmHg, women: 133→129 mmHg) will lead to a corresponding decrease of approximately 9,300 deaths a year due to cerebrovascular disease, approximately 4,700 deaths a year due to ischemic heart disease, and approximately 14,000 deaths a year due to CVD as a whole in Japan (Table 6-5). This investigation showed that insulation retrofit led to a 3.5 mmHg decrease in SBP at the time of waking. Using these results and the formula below, insulation retrofit is estimated to lead to a decrease of approximately 4,800 deaths a year due to CVD in Japan (Fig.6-5).

$$\text{Decrease in the number of deaths due to CVD} = \Delta P \times \Delta x \times 1/3 \times 1.175$$

where ΔP denotes the decrease in the number of deaths due to CVD for every 1 mmHg decrease in systolic blood pressure (14,000 people/4 mmHg), Δx denotes the decrease in blood pressure due to insulation retrofit (3.5 mmHg), 1/3 is a coefficient that represents the winter period within one year (December–March) [47, 175], and 1.175 is a coefficient that represents the proportion of excess winter deaths in Japan (17.5%) [58] (Fig.1-18).

The heating intervention study by Saeki et al. in participants' actual living environments [111] showed that SBP at the time of waking decreased by 4.4 mmHg. Therefore, an intervention that combines insulation and heating is expected to further reduce blood pressure and prevent CVD. As such, while the accuracy of the value from a simple estimation is unclear, it is likely that the effect of improving the living environment will be considerable.

Table 6-5 | Estimation of decreases in CVDs due to decreases in average SBP (translated from [41])

		Cerebrovascular disease				Ischemic heart disease			
Age [years]		40–59	60–69	70–89	Total	40–59	60–69	70–89	Total
Decrease in average SBP [mmHg]	Men	4	4	4	–	4	4	4	–
	Women	4	4	4	–	4	4	4	–
Decrease in the number of deaths due to CVD [people/year]	Men	862	783	4,469	6,113	506	834	1,185	2,525
	Women	371	386	2,482	3,239	25	194	1,958	2,177
Number of deaths due to CVD in Japan [people/year]	Men	5,349	8,483	54,952	68,784	4,947	8,040	34,166	47,153
	Women	2,322	3,793	49,967	56,081	1,008	2,273	26,918	30,199

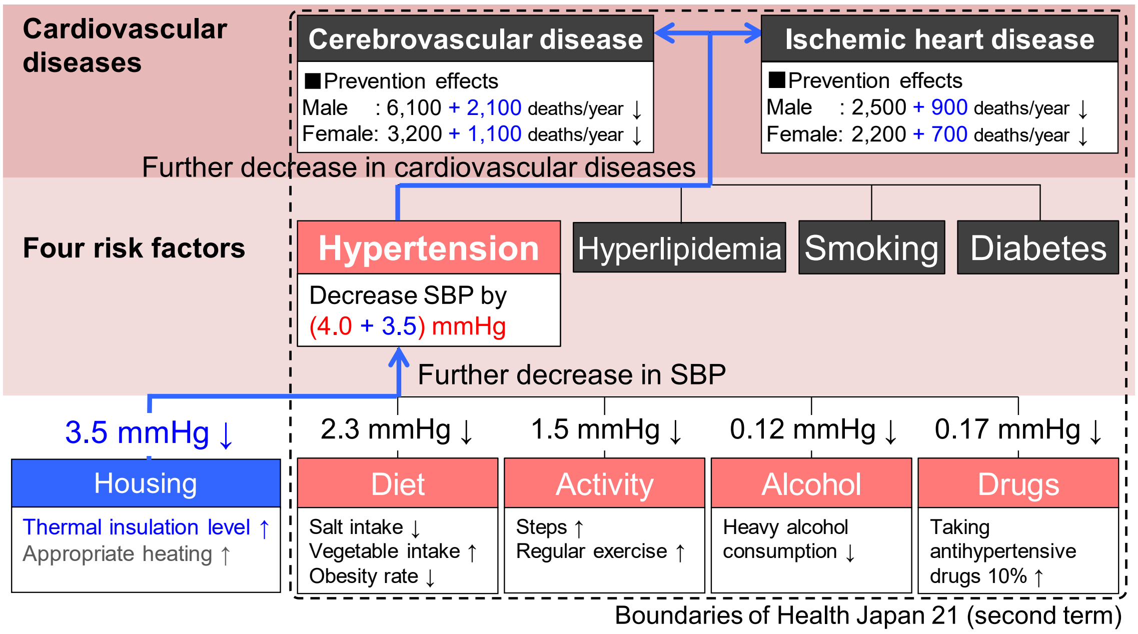


Fig.6-5 | Preventive effect of housing improvement on cardiovascular diseases

Chapter 7

Relationship between indoor temperature and biomarkers of CVD

Chapter 7 | Relationship between indoor temperature and biomarkers of CVD

7.1 Introduction

Excess winter mortality (EWM) is a phenomenon in which the mortality rate, particularly due to cardiovascular disease (CVD), rises sharply in winter [50−52]. EWM is known to be particularly profound in cold houses [49]. According to estimations by the WHO, at least 30% of EWM is caused by low indoor temperatures at home [176]. Previous studies indicate that part of the mechanism of EWM is explained by a rise in blood pressure due to cold exposure, and findings related to the relationship between indoor temperature and blood pressure are accumulating [113]. Aside from hypertension (raised blood pressure), CVD is associated with three interim risk factors: (1) diabetes (raised blood glucose level); (2) hyperlipidemia (raised blood lipids); and (3) obesity (raised body weight) [8, 9]. However, there is very limited evidence on the relationship between biomarkers of CVD like blood glucose, blood lipids, and body weight and indoor temperature. As such, data collected from participants who did and did not undergo insulation retrofit of housing across Japan were analyzed for these biomarkers in this chapter. Specifically, data from the health exam obtained through the baseline survey were used to analyze the relationship between cardiovascular biomarkers and the indoor temperature at home.

7.2 Method

7.2.1 Measurements

Participants were asked to submit their results for basic items in the health exam. Table 7-1 shows the items of the health exam, the standard range for each item, and suspected diseases if the measured value deviated from the standard range [177].

Participants were asked to measure their home blood pressure (HBP) twice after getting out of bed in the morning and twice before getting into bed in the evening while seated, in accordance with the guidelines of the Japanese Society of Hypertension (JSH 2009) [119]. HBP was measured in the living room for two weeks using an automatic oscillometric device (HEM-7251G; Omron Healthcare Co., Ltd.). Indoor temperature and relative humidity at 1.0 m above the floor were measured in the living room, bedroom, and changing room at 10-min intervals (TR-72wf; T&D Corp.). Outdoor temperature was obtained from the closest local meteorological observatory to each participant's house.

In addition, a questionnaire on individual attributes, lifestyle and housing was also conducted. The questionnaire covered individual attributes, such as age, sex, and weight; and lifestyle indicators, such as eating habits, smoking, alcohol consumption, and health conditions, focusing on diseases associated with hypertension. As an indication of socio-economic status, questions about household income and educational status were included in the questionnaire.

Table 7-1 | Health exam items and standard ranges [177]

Classification	Item	Standard range		Diseases suspected when outside the standard range
Physical parameters	BMI	18.5–24.9	kg/m^2	Obesity
	Abdominal girth	Men: <85	cm	
		Women: <90	cm	
Blood pressure	SBP	<140	mmHg	Hypertension, arteriosclerosis
	DBP	<90	mmHg	heart disease, cerebrovascular disease
Blood	White blood cell count	4,000–9,000	/μL	Bacterial infection, inflammation, tumor
	Red blood cell count	Men: 450–560	10^4/μL	Polycythemia
		Women: 380–520	10^4/μL	
	Hemoglobin content	Men: 13–17	g/dL	(below standard range)
		Women: 12–15	g/dL	iron-deficiency anemia
	Hematocrit	Men: 40–54	%	(above standard range)
		Women: 35–47	%	Polycythemia, dehydration
				(below standard range)
				iron-deficiency anemia
	Platelet count	15–50	10^4/μL	(above standard range) thrombocythemia, iron-deficiency anemia (below standard range) aplastic anemia, cirrhosis of liver
Blood lipids	Total cholesterol	130–220	mg/dL	(above standard range) arteriosclerosis, abnormality of lipid metabolism, familial hyperlipidemia
	HDL cholesterol	40–80	mg/dL	(below standard range) arteriosclerosis
	LDL cholesterol	60–140	mg/dL	(above standard range) arteriosclerosis
	Neutral fat	35–150	mg/dL	(above standard range) arteriosclerosis
Blood glucose	Blood glucose level	<110	mg/dL	Diabetes, pancreas cancer, hormone abnormality
	Hemoglobin A1c	<6.5	%	Diabetes
	Urinary sugar	Negative	—	Diabetes
Liver function	AST (GOT)	10–40	IU/L	Acute hepatitis, chronic hepatitis, fatty liver, liver cancer, alcoholic hepatitis
	ALT (GPT)	5–40	IU/L	
	ALP	110–340	IU/L	
	γ-GTP	Men: 5–80	IU/L	Alcohol liver disease, chronic hepatitis,
		Women: 5–70	IU/L	hepatopathy
Kidney function	Cr (creatinine)	Men: 0.8–1.2	mg/dL	Decline in renal function
		Women: 0.6–0.9	mg/dL	
	UP (uric protein)	Negative	—	Nephritis, diabetic nephropathy
	UB (uric blood)	Negative	—	Renal glomerulus nephritis, urolithiasis
Uric acid	Uric acid	Men: 3.0–8.3	mg/dL	Hyperuricemia, gout
		Women: 2.5–6.3	mg/dL	
Heart	Electrocardiogram	—	—	Irregular heartbeat (bradycardia, tachycardia, premature contraction), cardiomegaly, atrial fibrillation
Lung	Chest X-ray	—	—	Pneumonia, pulmonary tuberculosis, lung cancer, emphysema, pleural effusion, pneumothorax

BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; AST, aspartate aminotransferase; GOT, glutamate oxaloacetate transaminase; ALT, alanine aminotransferase; GPT, glutamate pyruvate transaminase; ALP, alkaline phosphatase; γ-GTP, gamma-glutamyl transpeptidase

7.2.2 Statistical analysis

For continuous variables that formed a normal distribution, the results were presented as mean and standard deviation. For continuous variables that formed a non-normal distribution, the results were presented as median and interquartile range. For the former and latter distributions, differences between groups were analyzed using the student's t-test and Mann-Whitney's U-test, respectively. Inter-group comparisons of the proportions were performed using the χ^2-test.

To examine the influence of indoor temperature on health exam parameters, analysis of covariance (ANCOVA) was conducted with health exam parameters as the objective variable. The analysis was adjusted for the participants' basic characteristics such as age, sex, body mass index (BMI), use of antihypertensive agents, salt intake, vegetable intake, exercise, smoking, drinking, sleep, outside temperature, and household income. The salt check sheet score [137] was used as a measure of salt intake, while the Pittsburgh Sleep Quality Index questionnaire score [133, 134] was used as a measure of sleep.

Furthermore, logistic regression analysis was performed by inputting health exam parameters as a categorical variable (whether or not each item in the health exam was within the standard range), and the odds ratio was determined.

7.3 Results

7.3.1 Relationship between health exam data and self-reported hospital visits

Initially we analyzed the relationship between health exam parameters and the presence or absence of hospitalization due to each disease related to cardiovascular disease (Table 7-2). The LDL/HDL ratio and total/HDL ratio, which were calculated from biomarker data, are known risk indicators with greater predictive power of cardiovascular disease than each biomarker alone. We therefore also used these indicators [178]. Among the obesity parameters, participants who visited the hospital had significantly greater BMI and abdominal girth than those who did not. For hypertension, various indices of BP were significantly higher in participants who visited the hospital than those who did not. For hyperlipidemia, there were significant differences in relevant biomarkers and indices between those who were and were not hospitalized. For diabetes, all relevant indices were significantly higher in participants who visited the hospital than those who did not. These findings indicate that health exam parameters are useful indicators with relevance to disease.

Table 7-2 | Relationship between health exam data and self-reported hospital visits

A. Obesity

Classification	Item	Hospital visits due to obesity: Yes	Hospital visits due to obesity: No	Difference	*p* value
		Mean ± SD	Mean ± SD		
Physical parameters	BMI, kg/m^2	27.4 ± 2.7	22.5 ± 3.1	5.0	**0.000**
	Abdominal girth, cm	94.4 ± 8.0	80.8 ± 8.7	13.7	**0.000**

B. Hypertension

Classification	Item	Hospital visits due to hypertension: Yes	Hospital visits due to hypertension: No	Difference	*p* value
		Mean ± SD	Mean ± SD		
Blood pressure	SBP at clinic, mmHg	134 ± 15	120 ± 16	14	**0.000**
	DBP at clinic, mmHg	80 ± 11	73 ± 11	7	**0.000**
	MSBP at home, mmHg	141 ± 13	126 ± 16	14	**0.000**
	MDBP at home, mmHg	85 ± 10	80 ± 10	5	**0.000**
	ESBP at home, mmHg	131 ± 14	120 ± 15	10	**0.000**
	EDBP at home, mmHg	77 ± 10	73 ± 10	3	**0.000**

C. Hyperlipidemia

Classification	Item	Hospital visits due to hyperlipidemia: Yes	Hospital visits due to hyperlipidemia: No	Difference	*p* value
		Mean ± SD	Mean ± SD		
Blood lipids	Total cholesterol, mg/dL	206 ± 38	205 ± 34	1	0.814
	HDL cholesterol, mg/dL	61 ± 15	65 ± 17	−4	**0.000**
	LDL cholesterol, mg/dL	125 ± 34	123 ± 31	2	0.344
	Neutral fat, mg/dL	136 ± 87	106 ± 93	30	**0.000**
	LDL/HDL cholesterol	2.16	2.04	0.12	**0.004**
	Total/HDL cholesterol	3.59	3.37	0.22	**0.003**

D. Diabetes

Classification	Item	Hospital visits due to diabetes: Yes	Hospital visits due to diabetes: No	Difference or %Difference	*p* value
		Mean ± SD or Number (%)	Mean ± SD or Number (%)		
Blood glucose	Blood glucose level, mg/dL	134 ± 40	95 ± 13	40	**0.000**
	Hemoglobin A1c, %	6.9 ± 0.9	5.6 ± 0.4	1.3	**0.000**
	Urinary sugar				**0.000**
	Negative	102 (78.5)	1,816 (98.7)	−20.2	
	Positive	28 (21.5)	23 (1.3)	20.2	

7.3.2 Comparison of health exam data between warm houses and cold houses

First, cold houses and warm houses were defined. The changes in indoor/outdoor temperature throughout one day are shown in Fig.7-1. The living room temperature was lowest at 5 am. Given that the UK guidelines recommend maintaining the minimum room temperature above 18˚C [71, 72], we defined warm houses as those with a living room temperature at 5 am ≥18°C and cold houses as those with a living room temperature at 5 am <18°C. To match the sample size of cold and warm houses, we also defined warm houses as those with a living room temperature at 5 am ≥12.5°C (median of living room temperature at 5 am) and cold houses as those with a living room temperature at 5 am <12.5°C.

Health exam and HBP measurement data of participants living in warm houses (≥12.5°C) and cold houses (<12.5°C) are shown in Table 7-3. ANCOVA showed that there was no significant difference between these groups in physical parameters, blood, liver function, kidney function or uric acid. In contrast, there was a significant difference in blood pressure, blood lipids and blood glucose. For blood lipids, LDL cholesterol, and total/HDL ratio were significantly higher in participants living in cold houses than warm houses.

Subsequently, logistic regression analysis was performed and the results are shown in Table 7-4. In this analysis, whether or not blood lipid and blood glucose parameters were outside the standard range and the presence or absence of an abnormality in electrocardiogram or chest X-ray findings were used as two-valued objective variables. Compared to those living in warm houses (≥12.5°C), the probability that total cholesterol and LDL cholesterol exceeded the standard range was 1.6 times and 1.3 times higher in participants living in cold houses (<12.5°C), respectively. Furthermore, there was a significant difference in the presence of an abnormality in electrocardiogram findings between participants living in warm and cold houses. Compared to those living in warm houses (≥12.5°C), the probability of an abnormality in electrocardiogram findings was 1.5 times higher in participants living in cold houses (<12.5°C).

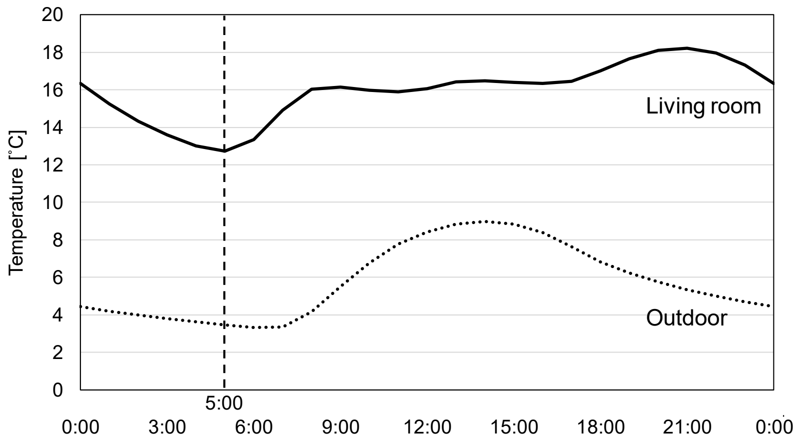


Fig.7-1 | Changes in indoor/outdoor temperature throughout one day

Table 7-3 | Health exam data of participants living in warm houses (≥12.5°C) and cold houses (<12.5°C)

Classification	Item	Unadjusted				Adjusted *			
		Cold houses	Warm houses	Differ-ence	*p* value	Cold houses	Warm houses	Differ-ence	*p* value
Physical parameters	BMI, kg/m^2	22.7	22.8	−0.1	0.397	22.8	22.8	0.0	0.838
	Abdominal girth, cm	81.4	81.7	−0.3	0.554	81.4	81.6	−0.2	0.440
Blood pressure	SBP at clinic, mmHg	124	123	2	**0.012**	122	123	0	0.714
	DBP at clinic, mmHg	75	74	1	0.202	74	75	0	0.647
	MSBP at home, mmHg	131	128	3	**0.000**	130	128	2	**0.000**
	MDBP at home, mmHg	82	81	1	**0.023**	82	81	1	**0.028**
	ESBP at home, mmHg	124	122	2	**0.008**	122	121	1	0.186
	EDBP at home, mmHg	75	74	1	0.114	74	74	0	0.384
Blood	White blood cell count, /μL	5,579	5,593	−14	0.866	5,639	5,611	28	0.763
	Red blood cell count, 10^4/μL	460	460	0	0.821	464	461	2	0.207
	Hemoglobin content, g/dL	14.0	14.1	−0.1	0.394	14.2	14.1	0.0	0.479
	Hematocrit, %	42.3	42.5	−0.2	0.412	42.6	42.6	0.0	0.822
	Platelet count, 10^4/μL	25.9	24.4	1.5	0.303	27.5	23.9	3.6	0.055
Blood lipids	Total cholesterol, mg/dL	208	203	5	**0.011**	208	203	4	0.063
	HDL cholesterol, mg/dL	64	64	1	0.406	64	64	0	0.870
	LDL cholesterol, mg/dL	125	122	3	**0.012**	125	122	4	**0.024**
	Neutral fat, mg/dL	113	111	3	0.523	117	110	7	0.148
	LDL/HDL cholesterol	2.08	2.06	0.03	0.466	2.10	2.04	0.05	0.137
	Total/HDL cholesterol	3.46	3.38	0.07	0.194	3.51	3.37	0.14	**0.020**
Blood glucose	Blood glucose level, mg/dL	98.5	96.9	1.6	0.068	97.6	95.7	1.8	**0.037**
	Hemoglobin A1c, %	5.70	5.68	0.02	0.599	5.68	5.66	0.02	0.533
Liver function	AST (GOT), IU/L	23.4	22.9	0.4	0.288	23.2	22.9	0.3	0.560
	ALT (GPT), IU/L	21.5	21.5	0.0	0.979	21.9	21.8	0.1	0.919
	ALP, IU/L	212	204	8	**0.038**	209	204	5	0.253
	γ-GTP, IU/L	33	34	−1	0.494	33	34	−1	0.600
Kidney function	Cr (creatinine), mg/dL	0.78	0.78	0.00	0.964	0.80	0.79	0.01	0.674
Uric acid	Uric acid, mg/dL	5.3	5.6	−0.3	0.136	5.3	5.6	−0.4	0.156

*Adjusted for age, sex, body mass index, salt check sheet score, vegetable consumption, exercise, smoking, alcohol consumption, Pittsburgh Sleep Quality Index, antihypertensive drug use, household income

MSBP, systolic blood pressure in the morning; MDBP, diastolic blood pressure in the morning; ESBP, systolic blood pressure in the evening; EDBP, diastolic blood pressure in the evening.

Table 7-4 | Cold houses (<12.5°C) and odds ratio of being outside the standard range

Classification	Item	Unadjusted			Adjusted *		
		Odds ratio **	(95%CI)	*p* value	Odds ratio **	(95%CI)	*p* value
Blood lipids	Total cholesterol	1.585	(1.238, 2.029)	**0.000**	1.565	(1.167, 2.100)	**0.003**
	HDL cholesterol	0.756	(0.512, 1.115)	0.158	0.866	(0.526, 1.425)	0.570
	LDL cholesterol	1.243	(1.029, 1.502)	**0.024**	1.271	(1.013, 1.595)	**0.039**
	Neutral fat	1.020	(0.824, 1.263)	0.855	1.072	(0.823, 1.396)	0.606
Blood glucose	Blood glucose level	1.386	(1.063, 1.807)	**0.016**	1.264	(0.892, 1.791)	0.188
	Hemoglobin A1c	0.955	(0.648, 1.407)	0.816	1.019	(0.613, 1.693)	0.942
	Urinary sugar	1.026	(0.591, 1.779)	0.928	1.095	(0.568, 2.113)	0.786
Heart	Electrocardiogram	1.368	(1.085, 1.726)	**0.008**	1.455	(1.094, 1.934)	**0.010**
Lung	Chest X-ray	0.995	(0.749, 1.323)	0.974	0.936	(0.667, 1.314)	0.704

*Adjusted for age, sex, body mass index, salt check sheet score, vegetable consumption, exercise, smoking, alcohol consumption, Pittsburgh Sleep Quality Index, antihypertensive drug use, household income

** vs warm house (≥12.5°C)

As in the case when threshold was defined as 12.5°C, ANCOVA showed that there was a significant difference in blood pressure and blood lipids between participants living in cold (<18°C) and warm houses (≥18°C) (Table 7-5). For blood lipids, total cholesterol, LDL cholesterol, and total/HDL ratio were significantly higher in participants living in cold houses than warm houses.

The results of logistic regression analysis are shown in Table 7-6. Compared to those living in warm houses (≥18°C), the probability that total cholesterol and LDL cholesterol exceeded the standard range was 2.6 times and 1.6 times higher in participants living in cold houses (<18°C), respectively. Furthermore, compared to those living in warm houses (≥18°C), the probability of an abnormality in electrocardiogram findings was 1.9 times higher in participants living in cold houses (<18°C).

Table 7-5 | Health exam data of participants living in warm houses (≥18°C) and cold houses (<18°C)

Classification	Item	Unadjusted				Adjusted *			
		Cold houses	Warm houses	Differ-ence	*p* value	Cold houses	Warm houses	Differ-ence	*p* value
Physical parameters	BMI, kg/m^2	22.7	22.9	−0.2	0.441	22.7	22.9	−0.2	0.092
	Abdominal girth, cm	81.6	81.3	0.3	0.714	81.5	81.5	0.0	0.993
Blood pressure	SBP at clinic, mmHg	124	122	2	0.203	123	123	0	0.802
	DBP at clinic, mmHg	75	75	0	0.944	74	75	0	0.808
	MSBP at home, mmHg	130	127	4	**0.002**	129	127	2	0.060
	MDBP at home, mmHg	81	80	1	0.059	81	80	2	**0.032**
	ESBP at home, mmHg	123	122	1	0.270	122	122	0	0.946
	EDBP at home, mmHg	74	74	0	0.943	74	74	1	0.490
Blood	White blood cell count, /μL	5,558	5,861	−303	**0.024**	5,610	5,797	−187	0.216
	Red blood cell count, 10^4/μL	460	462	−2	0.606	463	461	2	0.571
	Hemoglobin content, g/dL	14.1	14.1	0.0	0.776	14.2	14.2	0.0	0.974
	Hematocrit, %	42.4	42.5	−0.1	0.667	42.6	42.6	0.0	0.967
	Platelet count, 10^4/μL	25.4	23.0	2.5	0.308	26.0	23.1	2.9	0.341
Blood lipids	Total cholesterol, mg/dL	206	198	8	**0.035**	206	197	9	**0.034**
	HDL cholesterol, mg/dL	64	63	1	0.435	64	64	0	0.948
	LDL cholesterol, mg/dL	124	118	6	**0.017**	124	117	7	**0.021**
	Neutral fat, mg/dL	112	114	−2	0.808	114	106	8	0.314
	LDL/HDL cholesterol	2.07	2.02	0.05	0.359	2.08	1.96	0.12	0.057
	Total/HDL cholesterol	3.42	3.36	0.07	0.495	3.46	3.21	0.25	**0.020**
Blood glucose	Blood glucose level, mg/dL	97.6	98.5	−0.9	0.557	96.5	97.7	−1.2	0.438
	Hemoglobin A1c, %	5.7	5.7	0.0	0.778	5.7	5.7	−0.1	0.150
Liver function	AST (GOT), IU/L	23.1	23.5	−0.4	0.561	22.9	23.8	−0.8	0.322
	ALT (GPT), IU/L	21.3	23.1	−1.7	0.078	21.7	23.5	−1.8	0.118
	ALP, IU/L	208	213	−6	0.376	206	213	−8	0.302
	γ-GTP, IU/L	33	36	−3	0.230	33	37	−4	0.145
Kidney function	Cr (creatinine), mg/dL	0.78	0.78	0.01	0.827	0.79	0.79	0.00	0.972
Uric acid	Uric acid, mg/dL	5.4	5.3	0.1	0.713	5.5	5.3	0.1	0.784

*Adjusted for age, sex, body mass index, salt check sheet score, vegetable consumption, exercise, smoking, alcohol consumption, Pittsburgh Sleep Quality Index, antihypertensive drug use, household income

MSBP, systolic blood pressure in the morning; MDBP, diastolic blood pressure in the morning; ESBP, systolic blood pressure in the evening; EDBP, diastolic blood pressure in the evening.

Table 7-6 | Cold houses (<18°C) and odds ratio of being outside the standard range

Classification	Item	Unadjusted			Adjusted *		
		Odds ratio **	(95%CI)	*p* value	Odds ratio **	(95%CI)	*p* value
Blood lipids	Total cholesterol	2.300	(1.374, 3.852)	**0.002**	2.616	(1.397, 4.901)	**0.003**
	HDL cholesterol	1.165	(0.496, 2.734)	0.726	1.592	(0.647, 3.920)	0.312
	LDL cholesterol	1.434	(0.950, 2.165)	0.086	1.590	(1.045, 2.419)	**0.030**
	Neutral fat	0.922	(0.606, 1.403)	0.705	1.008	(0.640, 1.587)	0.973
Blood glucose	Blood glucose level	0.943	(0.609, 1.461)	0.792	0.841	(0.461, 1.536)	0.574
	Hemoglobin A1c	1.194	(0.591, 2.414)	0.622	1.318	(0.449, 3.872)	0.616
	Urinary sugar	1.251	(0.446, 3.507)	0.671	1.101	(0.313, 3.875)	0.880
Heart	Electrocardiogram	2.190	(1.227, 3.911)	**0.008**	1.915	(1.061, 3.456)	**0.031**
Lung	Chest X-ray	1.956	(0.994, 3.848)	0.052	1.669	(0.837, 3.329)	0.146

*Adjusted for age, sex, body mass index, salt check sheet score, vegetable consumption, exercise, smoking, alcohol consumption, Pittsburgh Sleep Quality Index, antihypertensive drug use, household income

** vs warm house (≥18°C)

7.4 Discussion

7.4.1 Ambient temperature and biomarkers of cardiovascular disease

Several previous studies have investigated the relationship between ambient temperature and cardiovascular biomarkers. The relationship between cardiovascular biomarkers and outdoor temperature was examined by Sartini et al. [179], who showed that SBP/DBP, total cholesterol, and LDL cholesterol increased as the outdoor temperature decreased. Hong et al. [180] also confirmed that SBP/DBP, platelet count, and LDL cholesterol increased and HDL cholesterol decreased as the outdoor temperature decreased.

Examples of studies that examined the relationship between indoor temperature at home and cardiovascular biomarkers are those by Saeki et al. [181] and Shiue et al [182]. Saeki et al. showed, in a study of 1,095 elderly participants, that the platelet count increased in participants living in houses with low room temperatures. Shiue et al. analyzed the relationship between indoor temperature and biomarkers during nurses' interviews among 7,997 participants and showed that residents living in houses with indoor temperatures below 18°C had high blood pressure and high cholesterol levels. However, because this relationship was observed at one point in time – during the nurses' interviews – it is not possible to extrapolate the long-term relationship between biomarkers and indoor temperature, to which the participants are exposed on a daily basis.

In the present survey, the relationship between the indoor thermal environment and health exam data was examined by accounting for the daily indoor temperature to which the participants were exposed, based on actual measurements taken across two weeks in winter. The analysis identified a significant relationship between indoor temperature and abnormal cholesterol levels and electrocardiogram findings. These findings suggest that the relationship between the indoor thermal environment in a house and CVD biomarkers is not temporary.

7.4.2 Cholesterol level and risk of cardiovascular disease

Many clinical trials have examined the relationship between blood cholesterol levels and CVD, and a causal relationship has now been established [183−188]. Through the review of previous studies, a guideline has been issued on how to reduce cholesterol levels, with improvements to lifestyle habits being a recommended measure [189−192]. However, because improvements to lifestyle habits must be conducted and maintained by the individual, these measures place limitations on the population level effect of such improvements. While evidence on health education interventions to promote the establishment of healthy lifestyle habits has accumulated, in practice, these interventions have not been sufficiently effective in long-term studies [193] or community interventional studies [194], thereby highlighting the difficulty of promoting lifestyle changes at the individual level. It may therefore be more effective to improve the environment in which individuals interact in their daily life. However, at present, the guideline mentioned above does not address improvements to the living environment, such as in housing and protection from the cold. In the future, evidence on the relationship between environmental factors inside the house and cholesterol levels is expected to accumulate, which will likely prompt the inclusion of interventions related to environmental factors in the guidelines, rather than depending on lifestyle habit changes for intervention.

7.4.3 Cold homes and arteriosclerosis

Progression of arteriosclerosis, which is a known risk factor of CVD, occurs as vascular endothelial cells become damaged or injured due to high blood pressure, and cholesterol accumulates on these injuries. When cholesterol accumulates and blood vessels become constricted, a vicious cycle arises leading to further increases in blood pressure [195−197].

The present analysis identified a significant relationship between high cholesterol levels and residents living in houses with low room temperatures. Similarly, low room temperature environments increase blood pressure, as shown in Chapter 5. As such, residents of cold houses likely experience the vicious cycle that leads to increasingly high blood pressure, such that the speed of arteriosclerosis progression is greater than in residents living in warm houses.

The present analysis additionally showed a significant relationship between living in low room temperature housing and the arteriosclerotic index, although this was based on a cross-sectional study. In the future, the relationship between arteriosclerosis progression and housing should be clarified by comparing a cold housing group with a warm housing group in long-term follow-up studies.

Chapter 8

Conclusions and future studies

This study examined the effect of improving housing environment on the prevention of cardiovascular disease (CVD). In particular, field measurements were conducted to measure blood pressure, which is a widely measured risk factor of CVD, and the relationship between the thermal environment inside the house and blood pressure was analyzed and discussed. Furthermore, data from health exams were collected to examine the relationship between cold homes and biomarkers of CVD. The following is a summary of the conclusions drawn in this thesis.

8.1 Relationship between indoor temperature and home blood pressure

This study analyzed the relationship between room temperature and home blood pressure (HBP) and was based on data obtained in a baseline survey of 2,095 households and 3,775 participants conducted before insulation retrofit in the SWH survey. The analysis showed that 1) the effect of living room temperature on SBP in the morning (6.4 mmHg increase/10°C decrease) was greater than that in the evening (5.0 mmHg increase/10°C decrease); 2) there was a cubic relationship between living room temperature and SBP; 3) indoor temperature had a stronger effect on SBP in older residents and women; and 4) SBP in the morning increased when the temperature disparity between the living room and bedroom increased, suggesting the importance of warming the entire house rather than just the living room.

To make the above results applicable at the individual level, sensitivity analysis was conducted to demonstrate the odds of morning SBP increasing to ≥135 mmHg (diagnostic threshold for hypertension or normotension) at various living room temperatures (10–25°C) according to age and sex. The results of this analysis can be used as basic data for a proposed recommended room temperature to prevent hypertension.

8.2 Identification of residents living in low room temperature environments

With the significant influence of indoor temperature at home on blood pressure now clear, we made use of the strengths of the nationwide survey to identify residents who were living in low room temperature environments. It was clear that houses in area 4 of the energy-saving criteria had low room temperatures. Although insulation standards have been established for each energy-saving area classification in Japan, these findings suggest that the insulation standards of area 4 may be inadequate. In terms of resident’s attributes, factors like low income status, duration of residence in the house and living alone were significantly related to low room temperature. Furthermore, ways of living, such as the use of heating and the amount of clothes worn, were also related to room temperature. This method allowed the identification of high-risk residents that require active intervention to prevent hypertension. This result is expected to lead to the adoption of a high-risk approach used in public health interventions for the implicated area and residents.

8.3 Effect of insulation retrofit on home blood pressure

To demonstrate causality in the significant relationship between indoor temperature and blood pressure identified in the baseline survey, analysis was conducted to compare the blood pressure of residents before and after intervention in those who received home insulation retrofit (intervention group) and those who did not (control group). Even after adjusting for differences in baseline characteristics between the intervention group and the control group, the analysis showed that insulation retrofit significantly reduced SBP and DBP in the morning.

Currently, preventive measures for hypertension, provided by WHO reports and Health Japan 21 (the second term), include suggestions for improving lifestyle habits, such as diet, exercise, and alcohol consumption and the use of antihypertensive agents. However, many studies have clearly shown that there are limitations to suggestions for individual improvement of lifestyle habits, which is dependent on individuals' efforts. This study showed the efficacy of insulation retrofit for decreasing blood pressure, and we believe that in the future, measures that include improving the living environment, such as insulation retrofit, will be necessary to prevent hypertension and CVD.

8.4 Relationship between indoor temperature and biomarkers of CVD

Progression of arteriosclerosis, which is a known risk factor of CVD, occurs as vascular endothelial cells become damaged or injured due to high blood pressure and cholesterol accumulates on these injuries. When cholesterol accumulates, and blood vessels become constricted, a vicious cycle arises leading to further increases in blood pressure.

This analysis identified a significant relationship between high cholesterol levels and residents living in low room temperature houses. Furthermore, as this study additionally showed that low room temperature environments increase blood pressure, the abovementioned vicious cycle likely occurs in residents of cold houses such that the speed of arteriosclerosis progression is greater than in residents living in warm houses. In fact, this analysis showed that residents living in cold houses had a poor arteriosclerotic index.

Furthermore, logistic regression analysis indicated that low room temperature was significantly related to abnormal electrocardiogram findings, even after adjusting for the influence of age, sex, and lifestyle habits. Based on the above, we propose that, in addition to blood pressure, indoor temperature affects biomarkers of CVD and that indoor temperature may be an important risk factor in the development of CVD.

8.5 Conclusions

In recent years, there have been clear health disparities not only between nations, but also within nations. These cannot be ignored, and reducing these health disparities has become a global issue. The WHO, which promotes the concept of "Health for all," emphasizes the importance of social determinants of health [198], conditions in which people are born, raised, work, live, and age, to correct the disparity [199]. Even in Japan, Health Japan 21 (the second term) holds "reduction of health disparities" and "establishment of a social environment" as its key values and states that the "health of an individual is affected by such social environment as family, schools, the community, and workplaces" [145]. In particular, given that humans spend 60–70% of their time at home [60−62], and elderly people with declining physiological function or children with undeveloped physiological function spend even more time at home [63], the living environment at home is of great importance to health.

This study focused on excess winter mortality (EWM), where the number of deaths, particularly due to CVD, surges during winter [45−47], and examined the relationship between the thermal environment inside houses, hypertension, and CVD from various perspectives. The results suggest that the influence of the thermal environment inside the house on hypertension and CVD is significant and cannot be ignored. A resident's health is affected by the quality of the housing in which they live. Therefore, to improve the public health of citizens and to reduce the health disparity, it is important to provide appropriate housing facilities.

In the field of public health, not only high-risk approaches but also population approaches are important. Unlike improvements in lifestyle habits, interventions that improve housing have the potential to indirectly change the distribution of risk factors (e.g., blood pressure) at the population level in a positive direction. In the future, strategies for preventing risk factors by improving living environment (primordial prevention) prior to disease prevention by improving lifestyle habits (primary prevention) is likely to garner a lot of attention. Furthermore, in addition to "lifestyle diseases", hypertension and CVD will likely be known as "life-environment diseases" in the future (Fig.8-1).

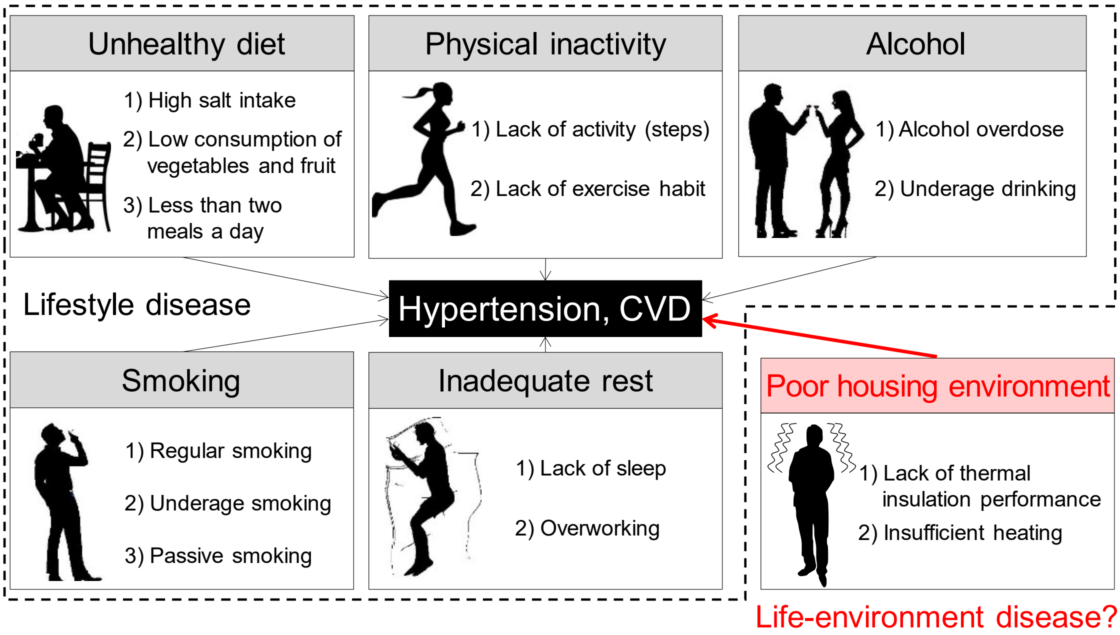


Fig.8-1 | A new concept of "life-environment disease" for hypertension and cardiovascular disease

Why are Japanese houses cold inside? I surmise that a hint appears in three major medieval Japanese essays; 'The Pillow Book (*The Makura no soshi*),' 'Essays in Idleness (*The Tsurezuregusa*)' and 'Visions of a Torn World (*The Hojoki*).' One reason is that there are clear four seasons in Japan. At the beginning of the 'The Pillow Book,' the Lesser councilor Sei (*Sei Shonagon*) described the attractiveness of the four seasons in Japan as "In spring, the dawn (…). In summer, the night – moonlit night, of course, but also at the dark of the moon, it's beautiful when fireflies are dancing everywhere in a mazy flight. And it's delightful too to see just one or two fly through the darkness, growing softly. Rain falling on a summer night is also lovely. In autumn, the evening (…). In winter, the early morning – if snow is falling, of course, it's unutterably delightful, but it's perfect too if there's a pure white frost, or even just when it's very cold, and they hasten to build up the fires in the braziers and carry in fresh charcoal" [200]. Despite the cold winter climate (noted above), in the 'Essays in Idleness,' the Buddhist priest Kenko (*Kenko Hoshi*) stated that "a house should be built with the summer in mind. In winter it is possible to live anywhere, but a badly made house is unbearable when it gets hot" [201]. Thus, the second reason is the adverse effect of attitudes to housing in Japan, in which an excessive importance is attached to summer, rather than winter. Moreover, at the beginning of 'Visions of a Torn World,' Kamo-no-chomei described the impermanence of housing as "The flowing river never stops and yet the water never stays the same. Foam floats upon the pools, scattering, re-forming, never lingering long. So, it is with man and all his dwelling places here on earth" [202]. In fact, the lifespan of Japanese houses is less than half that of houses in European and American countries, and the notion that the value of a house declines year after year from the time of its construction (yearly depreciation) is widely spread. Therefore, the third reason is that Japanese have a stereotyped idea of yearly depreciation of houses, and accordingly construct low-performing houses at low cost.

As described above, considering from the three major essays of Japan, possible causes of the coldness of Japanese houses are (1) the Japanese climatic characteristics with four distinct seasons, (2) the emphasis of inhabitants on summer, and (3) the perceptions of the real estate value of houses in Japan. However, since ancient times it has been said that “coldness can lead to more serious illnesses,” and this study also revealed the effect of cold on hypertension. Therefore, it is necessary for houses in Japan to place emphasis on winter.

8.6 Future prospects

This research showed the influence of indoor temperature on blood pressure through cross-sectional studies and a relatively short-period interventional study that compared participants' blood pressure before and after intervention. However, at present, it is difficult to conclude whether the decrease in blood pressure due to the rise in room temperature is a temporary or long-term effect. To resolve this question, this study intends to follow up with the participants who received insulation retrofit of housing (insulation retrofit group) and those who continued to live in low-insulation housing (control group) in the future.

The present thesis suggests that arteriosclerosis may be more advanced in residents living in cold houses compared to residents living in warm houses. Therefore, there may be a measurable effect of continuing to live in a cold house for a long period of time. We hypothesize that residents of cold houses and warm houses will exhibit a different trend in blood pressure changes with age. This hypothesis will need to be examined in a long-term cohort study (Fig.8-2). In such a long-term cohort study, we will examine the second hypothesis described in chapter 1: chronic effects. Specifically, we will examine whether the state of hypertension due to chronic cold exposure damages vascular endothelial cells and promotes vascular aging (Fig.8-3).

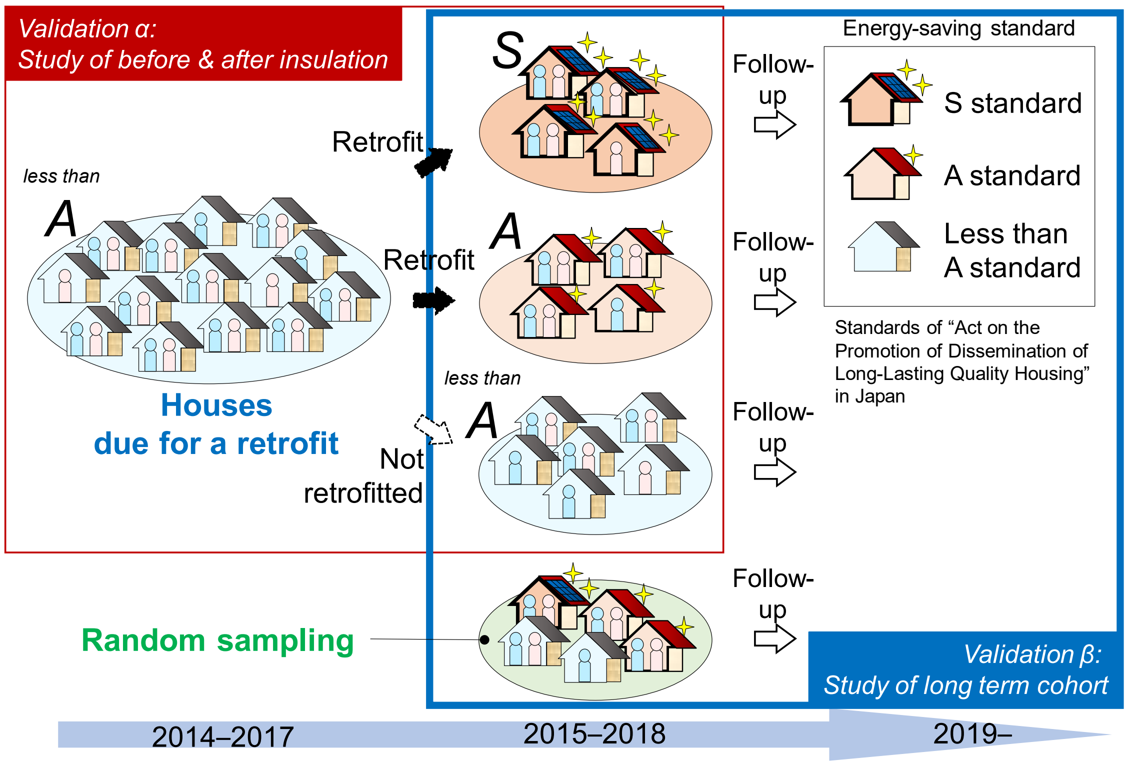


Fig.8-2 | Overview of the long-term cohort study in Japan (SWH survey)

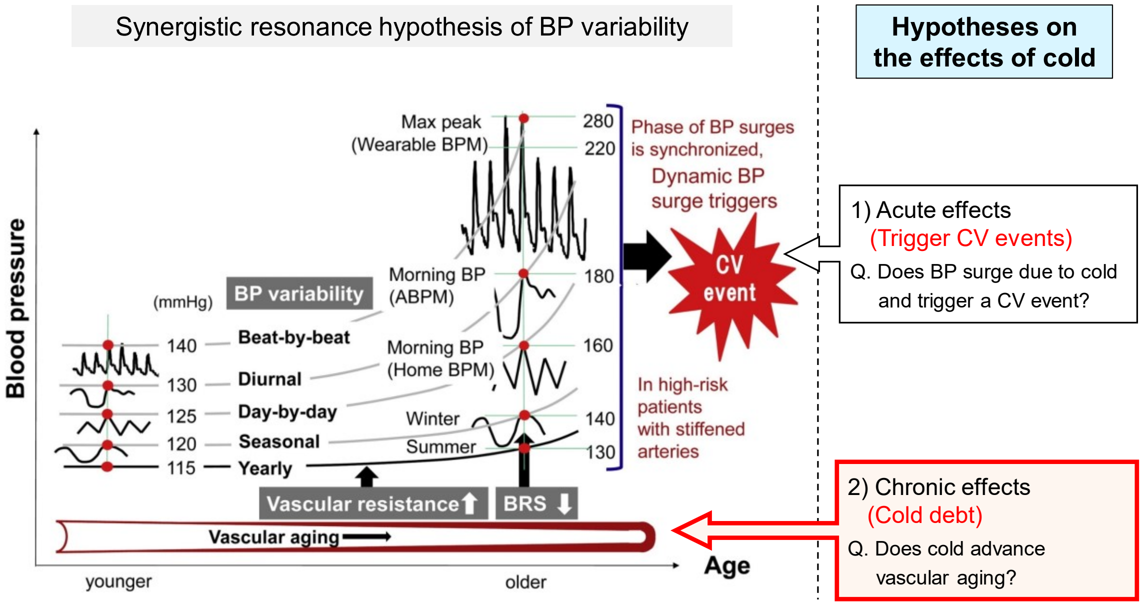


Fig.8-3 | Synergistic resonance hypothesis on blood pressure variability and the chronic effects of cold (modified from [73])

ABPM, ambulatory blood pressure monitoring; BPM, blood pressure monitoring; CV, cardiovascular; BRS, baroreceptor sensitivity

If the long-term cohort study indeed reveals that cold has long-term chronic effects, we then intend to model the human circulatory system with consideration to both the acute and chronic effects of cold (Fig.8-4). The human circulatory system [203, 204] is made up of components similar to those a building circulation system such as (1) a pump (the left ventricle): supplies blood to peripheral vessels, (2) a closed chamber (the aorta): adjusts vascular compliance and pressure in the blood vessels, and (3) a proportional solenoid valve (peripheral vessels): adjusts heat dissipation by vasoconstriction and vasodilatation. The role of each of these components is similar to those in the building circulation system: (1) a pump: supplies chilled/heated water to air conditioners at the pipe end, (2) a closed expansion tank: adjusts pressure in the pipe, and (3) a proportional solenoid valve: adjusts heat dissipation from air conditioners. Therefore, the blood pressure of humans under diverse environments may be predicted using the analogy between the human circulatory system and the building circulation system. In the building circulation system, the operational point (pressure/flow) of the pump is determined by the intersection point of the performance curve for the pump and the resistance curve for the pipe (Fig.8-5A). The performance curve changes due to deterioration of the pump function, and the resistance curve for the pipe changes due to aging of the pipe and valve opening/closing. By applying these relationships to the human circulatory system and identifying the parameters that represent the change in the performance curve with the decrease in cardiac function, the change in the resistance curve due to the chronic effect of cold exposure (vascular aging) and the acute effect of cold exposure (vasoconstriction), the mechanism of pressure determination in the building circulation system may be applicable to the human circulatory system (Fig.8-5B). As described above, the ultimate goal of this research is to develop a model that integrates the two effects of cold exposure in the hypothesis summarized in Fig.8-3.

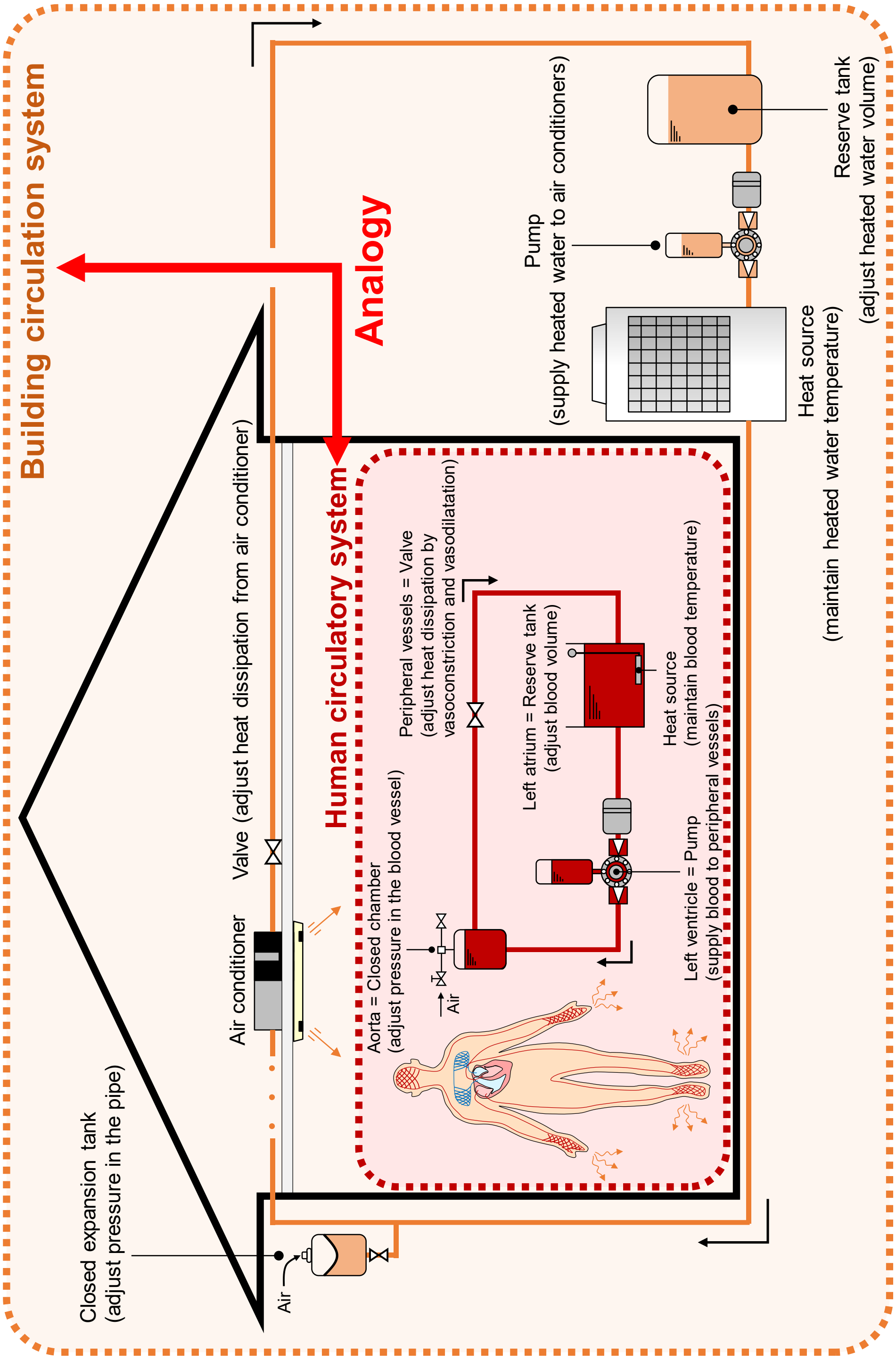


Fig.8-4 | Analogy between building and human circulation systems

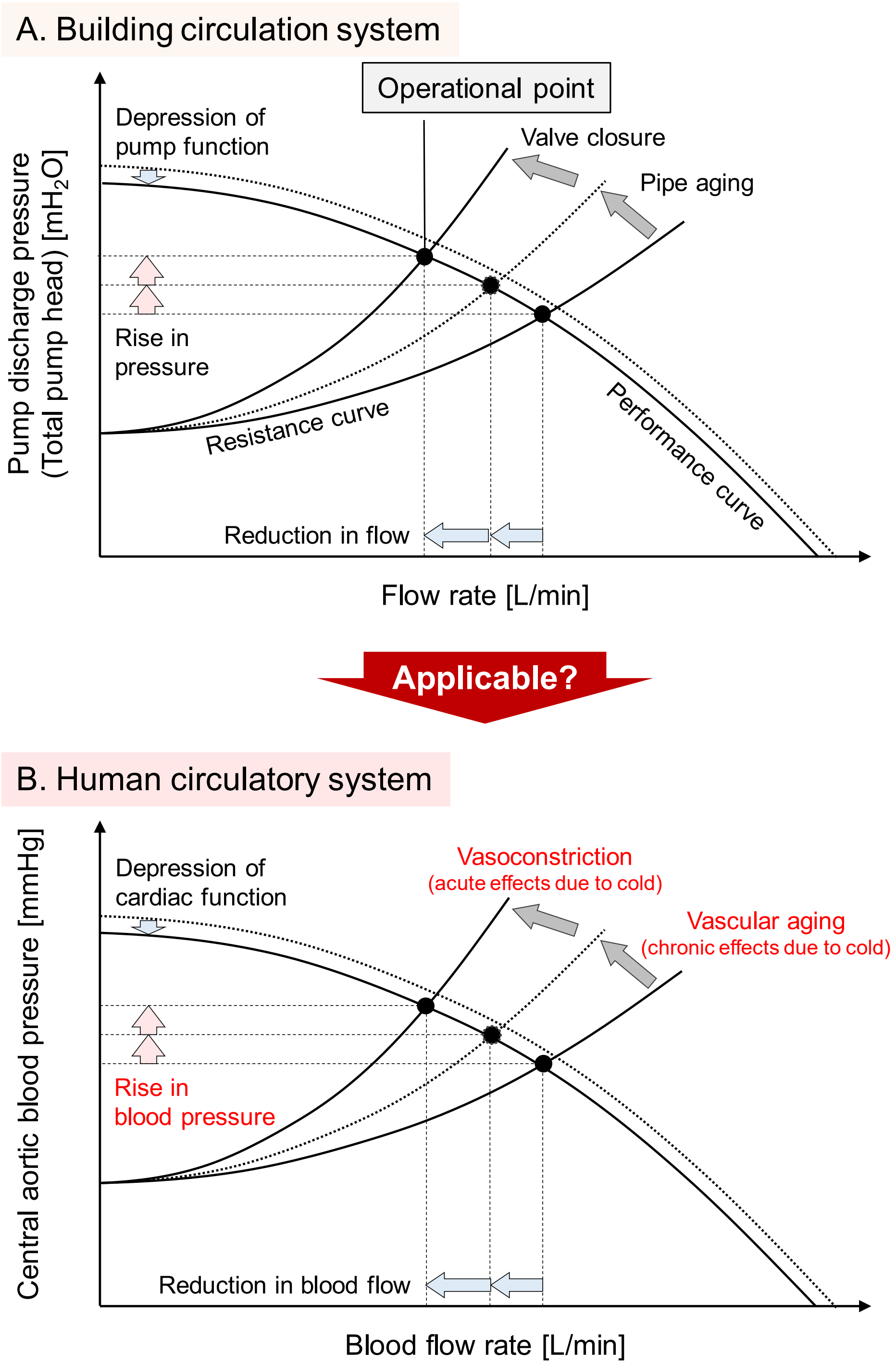


Fig.8-5 | Modeling the human circulatory system by applying methods of the building circulation system

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Publications

Publications

1. Peer-reviewed journals relevant to Ph.D. thesis

(1) Wataru UMISHIO, Toshiharu IKAGA, Shintaro ANDO, and Kuniaki OTSUKA, Comparison of home blood pressure before-and-after moving to high thermal insulation performance houses: A field survey on the effect of indoor thermal environment on blood pressure in winter (Part III), *Journal of Environmental Engineering (Japan)*, Vol.81, No.722, pp.357-366, 2016.4 (in Japanese)

(2) Wataru UMISHIO, Toshiharu IKAGA, Kuniaki OTSUKA, and Shintaro ANDO, Impacts of bedroom temperature on blood pressure variability in the early morning based on ambulatory blood pressure monitoring, *Journal of Environmental Engineering (Japan)*, Vol.80, No.716, pp.867-875, 2015.10 (in Japanese)

(3) Wataru UMISHIO, Toshiharu IKAGA, Shintaro ANDO, and Kuniaki OTSUKA, The impact of indoor temperature on home blood pressure based on a multilevel model: A field survey on the effect of indoor thermal environment on blood pressure in winter (Part II), *Journal of Environmental Engineering (Japan)*, Vol.80, No.715, pp.703-710, 2015.9 (in Japanese)

(4) Wataru UMISHIO, Toshiharu IKAGA, Kuniaki OTSUKA, and Shintaro ANDO, Multivariate analysis of the rise in home blood pressure by personal factors: A field survey on the effect of indoor thermal environment on blood pressure in winter, *Journal of Environmental Engineering (Japan)*, Vol.79, No.701, pp.571-577, 2014.7 (in Japanese)

Total 4 papers

2. Other peer-reviewed journals

(1) Wataru UMISHIO, Toshiharu IKAGA, and Chika OHASHI, Impact of moving to houses with high thermal insulation performance on sleep quality in winter, *Journal of Environmental Engineering (Japan)*, Vol.82, No.736, pp.513-523, 2017.6 (in Japanese)

(2) Eri HONDA, Toshiharu IKAGA, Noboru Ohira, Keiji OKAJIMA, and Wataru UMISHIO, Economic evaluation on the effect of thermal environment control in summer on sleep and work efficiency, *Journal of Environmental Engineering (Japan)*, Vol.81, No.724, pp.523-533, 2016.6 (in Japanese)

Total 2 papers

3. Peer-reviewed international conference papers

(1) ＊Wataru UMISHIO, Toshiharu IKAGA, Kuniaki OTSUKA, and Shintaro ANDO, Impacts of indoor thermal environment and personal factors on home blood pressure in winter, *Indoor Air 2014*, Hong Kong, China, 2014.7

(2) ＊Shintaro ANDO, Takumi MAEKAWA, Toshiharu IKAGA, Tanji HOSHI, and Wataru UMISHIO, Assessment of risk factors for cardiovascular disease in cold environments based on 10-years of follow-up data: A cohort study of residential environments and health in residents of mountainous and intermountainous regions in western Japan—part 1, *Healthy Buildings 2017 Asia*, Tainan, Taiwan, 2017.9

(3) ＊Chika OHASHI, Toshiharu IKAGA, Shintaro ANDO, Wataru UMISHIO, Naoto TAKAYAMA, and Megumi YANAGISAWA, Field studies on the effect of the indoor thermal environment on sleep in summer and winter, *Healthy Buildings 2015 Europe*, Eindhoven, The Netherlands, 2015.5

(4) ＊Eri HONDA, Toshiharu IKAGA, Noboru OHIRA, and Wataru UMISHIO, Effect of thermal environmental control in summer on energy consumption and sleep, *Healthy Buildings 2015 Europe*, Eindhoven, The Netherlands, 2015.5

(5) ＊Naoto TAKAYAMA, Toshiharu IKAGA, Shingo HORI, Masaru SUZUKI, and Wataru UMISHIO, Bathing and indoor thermal environment: Modeling body temperature and preventing heat stroke, *Indoor Air 2014*, Hong Kong, China, 2014.7

Total 5 papers

4. Conference proceedings (International)

(1) ＊Wataru UMISHIO, Toshiharu IKAGA, Kazuomi KARIO, Yoshihisa FUJINO, Tanji HOSHI, Shintaro ANDO, Masaru SUZUKI, and Shuzo MURAKAMI, Impact of indoor temperature on morning home blood pressure in winter: Baseline data from a non-randomized controlled trial in Japan, *Pulse of Asia 2018*, Kyoto, Japan, 2018.5

Total 1 paper

5. Conference proceedings (Japan)

(1) ＊Wataru UMISHIO, Toshiharu IKAGA, Shuzo MURAKAMI, Kazuomi KARIO, Yoshihisa FUJINO, Tanji HOSHI, Masaru SUZUKI, and Shintaro ANDO, Multilevel analysis of morning systolic blood pressure at home and indoor air temperature: Nationwide survey on insulation retrofit of housing and resident's health impact, Part 8, *Proceedings of AIJ annual conference* at Tohoku University, 40024, pp.57-58, 2018.9 (in Japanese)

(2) ＊Wataru UMISHIO, Toshiharu IKAGA, Shuzo MURAKAMI, Kazuomi KARIO, Yoshihisa FUJINO, Shintaro ANDO, Tatsuhiko KUBO, and Masaru SUZUKI, Relationship between home blood pressure and indoor air temperature: Results of a baseline survey: Nationwide survey on insulation retrofit of housing and resident's health impact, Part 3, *Proceedings of AIJ annual conference* at Hiroshima Institute of Technology, 40020, pp.51-52, 2017.8 (in Japanese)

(3) ＊Wataru UMISHIO, Toshiharu IKAGA, Chika OHASHI, and Tomio MABUCHI, Field measurement of blood pressure, sleep quality and body temperature before and after moving to highly thermal insulated houses (Part.2): Indoor air temperature and home blood pressure changes, *Proceedings of AIJ annual conference* at Tokai University, 41176, pp.361-362, 2015.9 (in Japanese)

(4) ＊Wataru UMISHIO, Toshiharu IKAGA, Kuniaki OTSUKA, and Shintaro ANDO, Field survey on the impacts of room temperature on 24 hour ambulatory blood pressure variability in winter, *Proceedings of AIJ annual conference* at Kobe University, 40057, pp.127-128, 2014.9 (in Japanese)

(5) ＊Wataru UMISHIO, Toshiharu IKAGA, Kuniaki OTSUKA, and Shintaro ANDO, A field survey on resident's 24-hour ambulatory blood pressure affected by thermal environment of a bedroom in winter, *Technical papers of annual meeting, the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan* at Akita University, C-10, pp.37-40, 2014.9 (in Japanese)

(6) ＊Wataru UMISHIO, Toshiharu IKAGA, Kuniaki OTSUKA, and Shintaro ANDO, Field survey on the effect of indoor thermal environment on morning hypertension, *Proceeding of Architectural Research Meetings, Kanto Chapter, Architectural Institute of Japan* at Nihon University, 4018, pp.69-72, 2014.2 (in Japanese)

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6. Other publications

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7. Awards

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(2) Wataru UMISHIO, Toshiharu IKAGA, Kuniaki OTSUKA, Shintaro ANDO, Takashi SHINOZUKA, and Reina OKAMURA, Reviewed research report, Kanto Chapter, Architectural Institute of Japan, Effect of indoor thermal environment on home blood pressure in winter based on field survey, Proceeding of Architectural Research Meetings, 2013.5

(3) Wataru UMISHIO, Encouraging Prize for excellent presentation, the Society of Heating, Air-conditioning and Sanitary Engineers of Japan, Field survey on home blood pressure of residents affected by indoor thermal environment of houses in winter, 2013.10

(4) Wataru UMISHIO, Toshiharu IKAGA, Kuniaki OTSUKA, and Shintaro ANDO, Excellent research report, Kanto Chapter, Architectural Institute of Japan, Field survey on the effect of indoor thermal environment on morning hypertension, Proceeding of Architectural Research Meetings, 2014.3

(5) Wataru UMISHIO, Excellent Presentation Award for young researchers, Kanto Chapter, Architectural Institute of Japan, Field survey on the effect of indoor thermal environment on morning hypertension, 2014.3

(6) Wataru UMISHIO, Excellent Master's Thesis Award, Architectural Institute of Japan, Effect of improving indoor thermal environment on controlling blood pressure and blood pressure variability in winter (Master's thesis of Keio University), 2015.9

(7) Wataru UMISHIO, Excellent Presentation Award for young researchers, Environmental engineering committee, Architectural Institute of Japan, Home blood pressure and indoor air temperature: Results of a baseline survey: Nationwide survey on insulation retrofit of housing and resident's health impact, 2018.1

(8) Wataru UMISHIO, Best Presentation Award, Pulse of Asia 2018, Impact of indoor temperature on morning home blood pressure in winter: Baseline data from a non-randomized controlled trial in Japan, 2018.5

Total 8 awards

Appendix

Appendix 1: Questionnaire for residents
Appendix 2: Diary for residents
Appendix 3: Questionnaire for experts in housing

Appendix

Appendix 1: Questionnaire for residents

Q0 Which of the following describes your living situation at the time of completing this questionnaire?
このアンケートを回答する時期は、下記のいずれに該当しますか。

1) Living in a house where renovation or new construction has been implemented in the previous two years
2 年以内の改修（新築）実施済みの新居に入居している状態
2) Living in a temporary house because renovation work or new construction is under way
改修（新築）工事実施中のため、仮住まいに転居している状態
3) Living in a house before a planned renovation or new construction
改修（新築）の予定であるが、改築（新築）実施前の住宅に居住している状態
4) Other
その他

Part.I Health condition 健康状態

Introductions: Q1–Q8 ask for your views about your health. This information will help you keep track of how you feel and how well you are able to do your usual activities. Answer every question by selecting the answer as indicated. If you are unsure about how to answer a question, please give the best answer you can. For each of the following questions, please mark an [x] in the one box that best describes your answer.
問 1~問 8 は、あなたがご自分の健康をどのように考えているかをおうかがいするものです。
以下のそれぞれの質問について、一番よくあてはまるものに印をつけてください。

Q1 Overall, how would you rate your health during the past 4 weeks?
全体的にみて、過去 1 ヵ月間のあなたの健康状態はいかがでしたか。

1)	Excellent	最高に良い
2)	Very good	とても良い
3)	Good	良い
4)	Fair	あまり良くない
5)	Poor	良くない
6)	Very poor	ぜんぜん良くない

Q2 During the past 4 weeks, how much did physical health problems limit your physical activities (such as walking or climbing stairs)?
過去 1 ヵ月間に、体を使う日常活動（歩いたり階段を昇ったりなど）をすることが身体的な理由で
どのくらい妨げられましたか。

1)	Not at all	ぜんぜん妨げられなかった
2)	Very little	わずかに妨げられた
3)	Somewhat	少し妨げられた
4)	Quite a lot	かなり妨げられた
5)	Could not do physical activities	体を使う日常活動ができなかった

Q3 During the past 4 weeks, how much difficulty did you have doing your daily work, both at home and away from home, because of your physical health?
過去 1 ヵ月間に、いつもの仕事（家事も含みます）をすることが、身体的な理由で
どのくらい妨げられましたか。

1)	Not at all	ぜんぜん妨げられなかった
2)	Very little	わずかに妨げられた
3)	Somewhat	少し妨げられた
4)	Quite a lot	かなり妨げられた
5)	Could not do daily work	いつもの仕事ができなかった

Q4	How much bodily pain have you had during the past 4 weeks? 過去１ヵ月間に、体の痛みはどのくらいありましたか。	
	1) None	ぜんぜんなかった
	2) Very mild	かすかな痛み
	3) Mild	軽い痛み
	4) Moderate	中くらいの痛み
	5) Severe	強い痛み
	6) Very severe	非常に激しい痛み
Q5	During the past 4 weeks, how much energy did you have? 過去１ヵ月間、どのくらい元気でしたか。	
	1) Very much	非常に元気だった
	2) Quite a lot	かなり元気だった
	3) Some	少し元気だった
	4) A little	わずかに元気だった
	5) None	ぜんぜん元気でなかった
Q6	During the past 4 weeks, how much did your physical health or emotional problems limit your usual social activities with family or friends? 過去１ヵ月間に、家族や友人とのふだんのつきあいが、身体的あるいは心理的な理由で、どのくらい妨げられましたか。	
	1) Not at all	ぜんぜん妨げられなかった
	2) Very little	わずかに妨げられた
	3) Somewhat	少し妨げられた
	4) Quite a lot	かなり妨げられた
	5) Could not do social activities	つきあいができなかった
Q7	During the past 4 weeks, how much have you been bothered by emotional problems (such as feeling anxious, depressed or irritable)? 過去１ヵ月間に、心理的な問題（不安を感じたり、気分が落ち込んだり、イライラしたり）に、どのくらい悩まされましたか。	
	1) Not at all	ぜんぜん悩まされなかった
	2) Slightly	わずかに悩まされた
	3) Moderately	少し悩まされた
	4) Quite a lot	かなり悩まされた
	5) Extremely	非常に悩まされた
Q8	During the past 4 weeks, how much did personal or emotional problems keep you from doing your usual work, school or other daily activities? 過去１ ヵ月間に、日常行う活動（仕事、学校、家事などふだんの行動）が、心理的な理由で、どのくらい妨げられましたか。	
	1) Not at all	ぜんぜん妨げられなかった
	2) Very little	わずかに妨げられた
	3) Somewhat	少し妨げられた
	4) Quite a lot	かなり妨げられた
	5) Could not do daily activities	日常行う活動ができなかった

Introductions: In Q9–Q20, we would like to know if you have experienced any medical complaints, and how your health has been in general, over the past few weeks.
問 9～問 20 では、最もあてはまるものにチェックしてください。
あなたは最近（4 週間以内）、ふだんに比べて次のようなことがありますか。

Q9	Have you been able to concentrate on whatever you're doing? 何かをする時いつもより集中して…	
	1) Better than usual	できた
	2) Same as usual	いつもと変わらなかった
	3) Less than usual	いつもよりできなかった
	4) Much less than usual	全くできなかった

Q10	Have you lost much sleep because of worry? 心配事があり、よく眠れないようなことが…		
	1)	Not at all	全くなかった
	2)	No more than usual	あまりなかった
	3)	Rather more than usual	あった
	4)	Much more than usual	度々あった
Q11	Have you felt that you are playing a useful part in things? いつもより自分のしていることに生きがいを感じることが…		
	1)	More so than usual	あった
	2)	Same as usual	いつもと変わらなかった
	3)	Less so than usual	なかった
	4)	Much less than usual	全くなかった
Q12	Have you felt capable of making decisions about things? いつもより容易に物事を決めることが…		
	1)	More so than usual	できた
	2)	Same as usual	いつもと変わらなかった
	3)	Less so than usual	できなかった
	4)	Much less than usual	全くできなかった
Q13	Have you felt constantly under strain? いつもよりストレスを感じたことが…		
	1)	Not at all	全くなかった
	2)	No more than usual	あまりなかった
	3)	Rather more than usual	あった
	4)	Much more than usual	度々あった
Q14	Have you felt you could not overcome your difficulties? 問題を解決できなくて困ったことが…		
	1)	Not at all	全くなかった
	2)	No more than usual	あまりなかった
	3)	Rather more than usual	あった
	4)	Much more than usual	度々あった
Q15	Have you been able to enjoy your normal day-to-day activities? いつもより日常生活を楽しく送ることが…		
	1)	More so than usual	できた
	2)	Same as usual	いつもと変わらなかった
	3)	Less so than usual	できなかった
	4)	Much less than usual	全くできなかった
Q16	Have you been able to face up to your problems? 問題があった時に、いつもより積極的に解決しようとすることが…		
	1)	More so than usual	できた
	2)	Same as usual	いつもと変わらなかった
	3)	Less so than usual	できなかった
	4)	Much less than usual	全くできなかった
Q17	Have you been feeling unhappy and depressed? いつもより気が重くてゆううつになることは…		
	1)	Not at all	全くなかった
	2)	No more than usual	あまりなかった
	3)	Rather more than usual	あった
	4)	Much more than usual	度々あった
Q18	Have you been losing confidence in yourself? 自信を失ったことは…		
	1)	Not at all	全くなかった
	2)	No more than usual	あまりなかった
	3)	Rather more than usual	あった
	4)	Much more than usual	度々あった

Q19	Have you been thinking of yourself as a worthless person? 自分は役に立たない人間だと考えたことは…		
	1)	Not at all	全くなかった
	2)	No more than usual	あまりなかった
	3)	Rather more than usual	あった
	4)	Much more than usual	度々あった
Q20	All things considered, have you been feeling reasonably happy? 一般的に見て幸せといつもより感じたことは…		
	1)	More so than usual	度々あった
	2)	Same as usual	あった
	3)	Less so than usual	なかった
	4)	Much less than usual	全くなかった
Part.II	Lifestyle　生活習慣		
Q21	During the past month, when have you usually gone to bed? 過去 1 ヵ月間の平均的な 1 日で、通常何時ごろ寝床につきましたか。		
	At (____):(____)		(____）時（____）分
Q22	During the past month, how long (in minutes) has it taken you to fall asleep each night? 過去 1 ヵ月間の平均的な 1 日で、寝床についてから眠るまでにどれくらい時間を要しましたか。		
	(____) hours (____) minutes a day		1 日あたり（____）時間（____）分
Q23	During the past month, what time have you usually gotten up in the morning? 過去 1 ヵ月間の平均的な 1 日で、通常何時ごろに起床しましたか。		
	At (____):(____)		(____）時（____）分
Q24	How many hours of actual sleep did you get at night? 過去 1 ヵ月間の平均的な 1 日で、実際の睡眠時間は何時間くらいでしたか。 （注：これは、あなたが寝床の中にいた時間とは異なる場合があるかもしれません。）		
	(____) hours (____) minutes a day		1 日あたり（____）時間（____）分
Q25	During the past month, how often have you had trouble sleeping because you… 過去 1 ヵ月間において、どれくらいの頻度で、以下の理由のために睡眠が困難でしたか。 最もあてはまるものにチェックしてください。		
	(1)	Cannot get to sleep within 30 minutes	寝床についてから 30 分以内に眠ることができなかったから
	1)	Three or more times a week	週に 3 回以上
	2)	Once or twice a week	週に 1~2 回
	3)	Less than once a week	週に 1 回未満
	4)	Not during the past month	なし
	(2)	Wake up in the middle of the night or early morning	夜間または早朝に目が覚めたから
	1)	Three or more times a week	週に 3 回以上
	2)	Once or twice a week	週に 1~2 回
	3)	Less than once a week	週に 1 回未満
	4)	Not during the past month	なし
	(3)	Have to get up to use the bathroom	トイレに起きたから
	1)	Three or more times a week	週に 3 回以上
	2)	Once or twice a week	週に 1~2 回
	3)	Less than once a week	週に 1 回未満
	4)	Not during the past month	なし
	(4)	Cannot breathe comfortably	息苦しかったから
	1)	Three or more times a week	週に 3 回以上
	2)	Once or twice a week	週に 1~2 回
	3)	Less than once a week	週に 1 回未満
	4)	Not during the past month	なし

	(5) Cough or snore loudly	咳が出たり大きないびきをかいたから
	1) Three or more times a week	週に 3 回以上
	2) Once or twice a week	週に 1~2 回
	3) Less than once a week	週に 1 回未満
	4) Not during the past month	なし
	(6) Feel too cold	ひどく寒く感じたから
	1) Three or more times a week	週に 3 回以上
	2) Once or twice a week	週に 1~2 回
	3) Less than once a week	週に 1 回未満
	4) Not during the past month	なし
	(7) Feel too hot	ひどく暑く感じたから
	1) Three or more times a week	週に 3 回以上
	2) Once or twice a week	週に 1~2 回
	3) Less than once a week	週に 1 回未満
	4) Not during the past month	なし
	(8) Have bad dreams	悪い夢を見たから
	1) Three or more times a week	週に 3 回以上
	2) Once or twice a week	週に 1~2 回
	3) Less than once a week	週に 1 回未満
	4) Not during the past month	なし
	(9) Have pain	痛みがあったから
	1) Three or more times a week	週に 3 回以上
	2) Once or twice a week	週に 1~2 回
	3) Less than once a week	週に 1 回未満
	4) Not during the past month	なし
	(10) Other reason(s)	その他の理由
	Please describe, including how often you have had trouble sleeping because of this reason(s)	（自由記述）
Q26	During the past month, how would you rate your sleep quality overall? 過去 1 ヵ月間において、ご自分の睡眠の質を全体として、どのように評価しますか。	
	1) Very good	非常によい
	2) Fairly good	かなりよい
	3) Fairly bad	かなり悪い
	4) Very bad	非常に悪い
Q27	During the past month, how often have you taken medicine (prescribed or “over the counter”) to help you sleep? 過去 1 ヵ月間において、どれくらいの頻度で、眠るために薬を服用しましたか。	
	1) Not during the past month	なし
	2) Less than once a week	週に 1 回未満
	3) Once or twice a week	週に 1~2 回
	4) Three or more times a week	週に 3 回以上
Q28	During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity? 過去 1 ヵ月間において、どれくらいの頻度で、車の運転や食事中、その他の社会活動中に、眠くて起きていられなくなりましたか。	
	1) Not during the past month	なし
	2) Less than once a week	週に 1 回未満
	3) Once or twice a week	週に 1~2 回
	4) Three or more times a week	週に 3 回以上
Q29	During the past month, how much of a problem has it been for you to keep up enthusiasm to get things done? 過去 1 ヵ月間において、物事をやり遂げるために必要な意欲を持続するのに、どのくらい問題がありましたか。	
	1) No problem at all	全く問題なし
	2) Only a very slight problem	ほんのわずかだけ問題があった
	3) Somewhat of a problem	いくらか問題があった
	4) A very big problem	非常に大きな問題があった

Q30 Please only provide answers to Q30 if you are currently working.
Compared to when you are in good condition, how often have you experienced the following conditions?
* Please move on to Q31 if you are not currently working.
【お仕事をしている方のみお答えください】
普段の体調の良い時と比べて、あなたは現在、次のようなことが、どのくらいありますか。
※お仕事をしていない方は、未記入のまま次の問 31 にお進みください。

(1) I haven't been able to behave socially 社交的に振る舞えなかった
1) Almost everyday ほぼ毎日ある
2) Two or more days a week 週に 2 日以上
3) About one day a week 週に 1 日程度
4) One or more days a month 月に 1 日以上
5) Not at all まったくない

(2) I haven't been able to maintain the quality of my work ていねいに仕事をすることができなかった
1) Almost everyday ほぼ毎日ある
2) Two or more days a week 週に 2 日以上
3) About one day a week 週に 1 日程度
4) One or more days a month 月に 1 日以上
5) Not at all まったくない

(3) I have had trouble thinking clearly 考えがまとまらなかった
1) Almost everyday ほぼ毎日ある
2) Two or more days a week 週に 2 日以上
3) About one day a week 週に 1 日程度
4) One or more days a month 月に 1 日以上
5) Not at all まったくない

(4) I have felt tired than usual いつもより疲れた
1) Almost everyday ほぼ毎日ある
2) Two or more days a week 週に 2 日以上
3) About one day a week 週に 1 日程度
4) One or more days a month 月に 1 日以上
5) Not at all まったくない

(5) I have taken more rests during my work 仕事を中断する回数が増えた
1) Almost everyday ほぼ毎日ある
2) Two or more days a week 週に 2 日以上
3) About one day a week 週に 1 日程度
4) One or more days a month 月に 1 日以上
5) Not at all まったくない

(6) I have felt that my work isn't going well 仕事がうまくいかないと感じた
1) Almost everyday ほぼ毎日ある
2) Two or more days a week 週に 2 日以上
3) About one day a week 週に 1 日程度
4) One or more days a month 月に 1 日以上
5) Not at all まったくない

(7) I haven't been able to make rational decisions 冷静に判断することができなかった
1) Almost everyday ほぼ毎日ある
2) Two or more days a week 週に 2 日以上
3) About one day a week 週に 1 日程度
4) One or more days a month 月に 1 日以上
5) Not at all まったくない

(8) I haven't been proactive about my work 自発的に仕事ができなかった
1) Almost everyday ほぼ毎日ある
2) Two or more days a week 週に 2 日以上
3) About one day a week 週に 1 日程度
4) One or more days a month 月に 1 日以上
5) Not at all まったくない

Q31	How often have you experienced the following urinary conditions during the past week? 以下の症状がどれくらいの頻度でありましたか。この 1 週間のあなたの状態に最も近いものを、ひとつずつ選んでチェックしてください。	
	(1) How many times do you typically urinate from waking in the morning until sleeping at night? 朝起きた時から寝る時までに、何回くらい尿をしましたか。	
	0) ≤7	7 回以下
	1) 8–14	8~14 回
	2) ≥15	15 回以上
	(2) How many times do you typically wake up to urinate from sleeping at night until waking in the morning? 夜寝てから朝起きるまでに、何回くらい尿をするために起きましたか。	
	0) 0	0 回
	1) 1	1 回
	2) 2	2 回
	3) ≥3	3 回以上
	(3) How often do you have a sudden desire to urinate, which is difficult to defer? 急に尿がしたくなり、我慢が難しいことがありましたか。	
	0) Not at all	なし
	1) Less than once a week	週に 1 回より少ない
	2) Once a week or more	週に 1 回以上
	3) About once a day	1 日 1 回くらい
	4) 2–4 times a day	1 日 2~4 回
	5) 5 times a day or more	1 日 5 回以上
	(4) How often do you leak urine because you cannot defer the sudden desire to urinate? 急に尿がしたくなり、我慢できずに尿をもらすことがありましたか。	
	0) Not at all	なし
	1) Less than once a week	週に 1 回より少ない
	2) Once a week or more	週に 1 回以上
	3) About once a day	1 日 1 回くらい
	4) 2–4 times a day	1 日 2~4 回
	5) 5 times a day or more	1 日 5 回以上
Q32	Do you currently smoke cigarettes habitually? * People who “smoke cigarettes habitually” refers to those who have smoked “≥100 sticks or for ≥6 months in total” and have smoked within the last month. 現在、たばこを習慣的に吸っていますか。 ※『現在、習慣的に吸っている』とは、「これまで合計 100 本以上、または 6 ヵ月以上」を吸っていて、最近 1 ヵ月以内にも吸っていた方が該当。	
	1) Smoking	はい
	2) None	いいえ
	3) Quit smoking	禁煙した
Q33	How often do you drink alcohol (Japanese sake, shochu, beer, liquor, etc.)? お酒（清酒、焼酎、ビール、洋酒など）を飲む頻度はどの程度ですか。	
	1) Everyday	毎日
	2) Sometimes	時々
	3) None (or lightweight)	ほとんど飲まない（飲めない）

Q34 How much alcohol do you drink per day?
Roughly equivalent to 1 go* of Japanese sake (180ml): a bottle of beer (about 500ml), 35% shochu (80 ml), a cup of whiskey (60 ml), 2 cups of wine (240 ml)
* units of Japanese sake
飲酒日の 1 日当たりの飲酒量はどの程度ですか。
※清酒 1 合（180ml）の目安：
ビール中瓶 1 本（約 500ml）、焼酎 35 度（80ml）、ウィスキーダブル 1 杯（60ml）、ワイン 2 杯（240ml）

1) <1 go*	1 合未満
2) 1–2 go*	1~2 合未満
3) 2–3 go*	2~3 合未満
4) ≥3 go*	3 合以上

Q35 How often do you usually eat the following foods? Please circle the most applicable response for each food.
あなたはふだん、次の食品をどのくらいの頻度で食べますか。
当てはまるもの（言葉）に、それぞれ〇をつけてください。

(1) *Miso* (fermented soybean paste) soup, soup, etc. みそ汁、スープなど

0) Hardly eat	あまり食べない
1) Two-three bowls a week	2~3 杯/週
2) About 1 bowl a day	1 日 1 杯以上
3) More than 2 bowls a day	1 日 2 杯以上

(2) Pickles, pickled plums, etc. 漬物、梅干しなど

0) Hardly eat	あまり食べない
1) Two-three times a week	2~3 回/週
2) About once a day	1 日 1 回以上
3) More than twice a day	1 日 2 回以上

(3) Fish-paste products such as *chikuwa* (tubular fish sausage) and *kamaboko* (steamed fish paste)
ちくわ、かまぼこなどの練り製品

0) Hardly eat	あまり食べない
1) Two-three times a week	2~3 回/週
2) Eat frequently	よく食べる

(4) Horse mackerel cut open lengthwise and dried, dried fish seasoned with *mirin* (sweetened alcohol for use in cooking), salted salmon etc. あじの開き、みりん干し、塩鮭など

0) Hardly eat	あまり食べない
1) Two-three times a week	2~3 回/週
2) Eat frequently	よく食べる

(5) Ham or sausage ハムやソーセージ

0) Hardly eat	あまり食べない
1) Two-three times a week	2~3 回/週
2) Eat frequently	よく食べる

(6) Noodles such as *udon* (Japanese wheat noodles) and *ramen* (Japanese-style Chinese noodles)
うどん、ラーメンなどの麺類

0) Don’t eat	あまり食べない
1) Less than once a week	1 回/週以下
2) Two-three bowls a week	2~3 回/週
3) Almost every day	ほぼ毎日

(7) *Senbei* (Japanese crackers), *okaki* (thinly-cut and dried rice cakes), potato chips, etc.
せんべい、おかき、ポテトチップスなど

0) Hardly eat	あまり食べない
1) Two-three times a week	2~3 回/週
2) Eat frequently	よく食べる

(8) Fruit (apple, strawberry, etc.) 果物（りんご、いちごなど）

0) Hardly eat	あまり食べない
1) Two-three times a week	2~3 回/週
2) Eat frequently	よく食べる

(9) Vegetable (fresh vegetable, boiled vegetable, etc.) 野菜料理（生野菜・煮物など）

0) Hardly eat あまり食べない
1) Two-three times a week 2~3 回/週
2) Eat frequently よく食べる

Q36 Please circle the most appropriate response for each question about your usual diet.
あなたのふだんの食生活について、当てはまるもの（言葉）に、それぞれ○をつけてください。

(1) How frequent do you season with soy sauce or other sauces? しょうゆやソースなどをかける頻度は？

0) Don't season ほとんどかけない
1) Season sometimes 時々かける
2) Once a day 毎日 1 回はかける
3) Season frequently (almost every meal) よくかける（ほぼ毎日）

(2) How much *udon*, *ramen*, or other soups do you consume? 麺類の汁を飲みますか？

0) Little ほとんど飲まない
1) Some 少し飲む
2) About half 半分くらい飲む
3) Entire bowl 全て飲む

(3) Do you eat out or have convenience-store-bought *bento* (lunch plate) for lunch?
昼食で外食やコンビニ弁当などを利用しますか？

0) No 利用しない
1) About once a week 1 回/週くらい
2) About 3 times a week 3 回/週くらい
3) Almost every day ほぼ毎日

(4) Do you eat out or have ready-made side dishes for dinner? 夕食で外食やお惣菜などを利用しますか？

0) No 利用しない
1) About once a week 1 回/週くらい
2) About 3 times a week 3 回/週くらい
3) Almost every day ほぼ毎日

(5) How salty are your home-made dishes compared with those you eat out?
家庭の味付けは外食と比べていかがですか？

0) Light 薄い
2) Same 同じ
3) Heavy 濃い

(6) Do you think you eat a lot? 食事の量は多いと思いますか？

0) Less than others 人より少なめ
1) Same as others 普通
3) More than others 人より多め

Part.III Physical condition/Activity 身体・活動

Q37 Do you have pain in your muscles or joints (it does not matter whether or not the pain is related to a disease)?
あなたは、筋肉や関節の痛みがありますか（病名は問わない）。

0) No ない
1) Yes ある

Q38 Please provide answers on your degree of pain. Please select the appropriate number for each of (1) and (2), with "0" indicating no pain and "10" indicating the most intense pain experienced so far.
痛みの程度についておうかがいします。痛みが全くない状態を「0」、これまでに経験した一番強い痛みを「10」として、（1）と（2）のそれぞれについて、図中の当てはまる数字にチェックをつけてください。

(1) The most intense pain you felt in the last week 最近 1 週間で、最も強い痛みを感じた時の状態

0) No pain 痛みなし
… … …
10) The most intense pain experienced so far これ以上ない痛み

(2) The average level of pain you felt in the last week 最近 1 週間の平均的な状態

0) No pain 痛みなし
… … …
10) The most intense pain experienced so far これ以上ない痛み

Q39	Do you exercise enough to work up a light sweat for more than 30 minutes each time, at least twice a week, for over 1 year? 1 回 30 分以上の軽く汗をかく運動を、週 2 回以上の頻度で、1 年以上実施していますか。	
	0) Rarely	いいえ
	1) Regularly	はい
Q40	Do you engage in walking or equivalent physical activity for more than 1 hour a day in your daily life? 日常生活で、歩行又は同等の身体活動を 1 日 1 時間以上実施していますか。	
	0) Rarely	いいえ
	1) Regularly	はい
Q41	Do you participate in community events and neighborhood hobby activities? (e.g. gateball, summer festivals, athletic festivals, town cleaning, gardening, senior citizens' club, etc.) 地域の行事や、近隣にある趣味の活動に参加していますか。 （例　ゲートボール、夏祭り、運動会、町内清掃、園芸、シルバークラブなど）	
	1) Frequently	よく参加している
	2) Sometimes	ときどき参加している
	3) Rarely	あまり参加しない
	4) Not at all	ほとんど参加しない
Q42	Do you walk a pet?	あなたは、ペットの散歩をすることがありますか。
	1) Almost everyday	ほぼ毎日
	2) 3–5 times a week	週に 3~5 回程度
	3) 1–2 times a week	週に 1~2 回程度
	4) Not at all (do not have any pets)	していない（飼っていない）
Q43	Generally, do you trust people?	一般的に、あなたは人を信用しますか。
	1) I trust people	信用する
	2) I tend to trust people	どちらかと言うと信用する
	3) I tend not to trust people	どちらかと言うと信用しない
	4) I do not trust people	信用しない
Q44	How do you feel about community safety?	地域の治安についてどのようにお感じになりますか。
	1) Very good	とても良い
	2) Good	良い
	3) Have some concerns	少し不安
	4) Have a lot of concerns	不安
Q45	Are there roads around which you can walk safely near your house? 家の近くに安心して散歩できる道路がありますか。	
	0) No	ない
	1) Yes	ある
Part.IV	Symptoms/Disease　症状・持病	
Q46	Please select the degree of nasal-ocular symptoms experienced in the past 1 or 2 weeks. 最近 1~2 週間でもっともひどかった鼻・眼の症状の程度についてチェックしてください。	
	(1) Runny nose	水っぱな
	0) No symptom	症状なし
	1) Mild	軽い
	2) Moderately severe	やや重い
	3) Severe	重い
	4) Very severe	非常に重い
	(2) Sneezing	くしゃみ
	0) No symptom	症状なし
	1) Mild	軽い
	2) Moderately severe	やや重い
	3) Severe	重い
	4) Very severe	非常に重い

	(3) Stuffy nose	鼻づまり	
	0) No symptom		症状なし
	1) Mild		軽い
	2) Moderately severe		やや重い
	3) Severe		重い
	4) Very severe		非常に重い
	(4) Itchy nose	鼻のかゆみ	
	0) No symptom		症状なし
	1) Mild		軽い
	2) Moderately severe		やや重い
	3) Severe		重い
	4) Very severe		非常に重い
	(5) Itchy eyes	目のかゆみ	
	0) No symptom		症状なし
	1) Mild		軽い
	2) Moderately severe		やや重い
	3) Severe		重い
	4) Very severe		非常に重い
	(6) Watery eyes	涙目（なみだめ）	
	0) No symptom		症状なし
	1) Mild		軽い
	2) Moderately severe		やや重い
	3) Severe		重い
	4) Very severe		非常に重い
Q47	During the past year, how often have you experienced the following symptoms in your house? 現在のお住まいで、ここ 1 年、あなたが体感・体験した症状について、 その頻度をそれぞれチェックしてください。		
	(1) Listlessness	体がだるい	
	1) About every day to several times a week		毎日~週数回程度
	2) About once a week to several times a month		週 1~月数回程度
	3) About once a month to several times a year		月 1~年数回程度
	4) About once a year		年 1 回程度
	5) Not at all		全くない
	(2) Headache	頭痛	
	1) About every day to several times a week		毎日~週数回程度
	2) About once a week to several times a month		週 1~月数回程度
	3) About once a month to several times a year		月 1~年数回程度
	4) About once a year		年 1 回程度
	5) Not at all		全くない
	(3) Difficulty hearing	きこえにくい	
	1) About every day to several times a week		毎日~週数回程度
	2) About once a week to several times a month		週 1~月数回程度
	3) About once a month to several times a year		月 1~年数回程度
	4) About once a year		年 1 回程度
	5) Not at all		全くない
	(4) Cough or sputum	せきやたんがでる	
	1) About every day to several times a week		毎日~週数回程度
	2) About once a week to several times a month		週 1~月数回程度
	3) About once a month to several times a year		月 1~年数回程度
	4) About once a year		年 1 回程度
	5) Not at all		全くない

(5)	Stuffy nose or runny nose	鼻がつまる・鼻汁が出る
1)	About every day to several times a week	毎日~週数回程度
2)	About once a week to several times a month	週 1~月数回程度
3)	About once a month to several times a year	月 1~年数回程度
4)	About once a year	年 1 回程度
5)	Not at all	全くない
(6)	Loss of appetite	食欲不振
1)	About every day to several times a week	毎日~週数回程度
2)	About once a week to several times a month	週 1~月数回程度
3)	About once a month to several times a year	月 1~年数回程度
4)	About once a year	年 1 回程度
5)	Not at all	全くない
(7)	Rash (urticarial eruption, blotch, etc.)	発疹（じんま疹・できもの等）
1)	About every day to several times a week	毎日~週数回程度
2)	About once a week to several times a month	週 1~月数回程度
3)	About once a month to several times a year	月 1~年数回程度
4)	About once a year	年 1 回程度
5)	Not at all	全くない
(8)	Itching (eczema, athlete's foot, etc.)	かゆみ（湿疹・水虫等）
1)	About every day to several times a week	毎日~週数回程度
2)	About once a week to several times a month	週 1~月数回程度
3)	About once a month to several times a year	月 1~年数回程度
4)	About once a year	年 1 回程度
5)	Not at all	全くない
(9)	Stiff shoulders	肩こり
1)	About every day to several times a week	毎日~週数回程度
2)	About once a week to several times a month	週 1~月数回程度
3)	About once a month to several times a year	月 1~年数回程度
4)	About once a year	年 1 回程度
5)	Not at all	全くない
(10)	Backache	腰痛
1)	About every day to several times a week	毎日~週数回程度
2)	About once a week to several times a month	週 1~月数回程度
3)	About once a month to several times a year	月 1~年数回程度
4)	About once a year	年 1 回程度
5)	Not at all	全くない
(11)	Wrist joint pain or ankle pain	手足の関節が痛む
1)	About every day to several times a week	毎日~週数回程度
2)	About once a week to several times a month	週 1~月数回程度
3)	About once a month to several times a year	月 1~年数回程度
4)	About once a year	年 1 回程度
5)	Not at all	全くない
(12)	Cold limbs	手足が冷える
1)	About every day to several times a week	毎日~週数回程度
2)	About once a week to several times a month	週 1~月数回程度
3)	About once a month to several times a year	月 1~年数回程度
4)	About once a year	年 1 回程度
5)	Not at all	全くない
(13)	Fracture, sprain, or dislocation	骨折・ねんざ・脱きゅう
1)	About every day to several times a week	毎日~週数回程度
2)	About once a week to several times a month	週 1~月数回程度
3)	About once a month to several times a year	月 1~年数回程度
4)	About once a year	年 1 回程度
5)	Not at all	全くない

	(14) Cut or burn injury, etc.	切り傷・やけど等のけが
	1) About every day to several times a week	毎日~週数回程度
	2) About once a week to several times a month	週 1~月数回程度
	3) About once a month to several times a year	月 1~年数回程度
	4) About once a year	年 1 回程度
	5) Not at all	全くない
	(15) Stumble or falling	つまずき・転倒
	1) About every day to several times a week	毎日~週数回程度
	2) About once a week to several times a month	週 1~月数回程度
	3) About once a month to several times a year	月 1~年数回程度
	4) About once a year	年 1 回程度
	5) Not at all	全くない
	(16) A cold	風邪をひく
	1) About every day to several times a week	毎日~週数回程度
	2) About once a week to several times a month	週 1~月数回程度
	3) About once a month to several times a year	月 1~年数回程度
	4) About once a year	年 1 回程度
	5) Not at all	全くない
Q48	Do you currently visit hospitals, clinics (including dental clinics), masseurs, acupuncture clinics, or osteopathic clinics due to injury or disease? あなたは現在、傷病（病気やけが）で病院や診療所（歯科医院）、あんま・はり・きゅう・柔道整復師（施術所）に通っていますか。	
	0) No	通っていない →Q50
	1) Yes	通っている →Q49
Q49	What kind of injuries or diseases are they?	それは、どのような傷病（病気やけが）ですか。
	(1) Diabetes	糖尿病
	0) No	なし
	1) Yes	あり
	(2) Obesity	肥満症
	0) No	なし
	1) Yes	あり
	(3) Hyperlipidemia (hypercholesteremia etc.)	高脂血症（高コレステロール血症など）
	0) No	なし
	1) Yes	あり
	(4) Mental illness	うつ病やその他のこころの病気
	0) No	なし
	1) Yes	あり
	(5) Nervous system disorder (neuralgia, paralysis, etc.)	神経の病気（神経痛・麻痺など）
	0) No	なし
	1) Yes	あり
	(6) Hypertension	高血圧
	0) No	なし
	1) Yes	あり
	(7) Stroke (cerebral hemorrhage, cerebral infarction, etc.)	脳卒中（脳出血、脳梗塞など）
	0) No	なし
	1) Yes	あり
	(8) Angina/myocardial infarction	狭心症・心筋梗塞
	0) No	なし
	1) Yes	あり
	(9) Allergic rhinitis	アレルギー性鼻炎
	0) No	なし
	1) Yes	あり

	(10) Chronic obstructive pulmonary disease	慢性閉塞性肺疾患
	0) No	なし
	1) Yes	あり
	(11) Asthma	喘息
	0) No	なし
	1) Yes	あり
	(12) Skin disease (atopic dermatitis, hives, etc.)	皮膚疾患（アトピー性皮膚炎、じんましん等）
	0) No	なし
	1) Yes	あり
	(13) Arthropathy	関節症
	0) No	なし
	1) Yes	あり
	(14) Back pain	腰痛症
	0) No	なし
	1) Yes	あり
	(15) Osteoporosis	骨粗しょう症
	0) No	なし
	1) Yes	あり
	(16) Kidney disease	腎臓の病気
	0) No	なし
	1) Yes	あり
	(17) Fracture	骨折
	0) No	なし
	1) Yes	あり
	(18) Injury/burn injury	骨折以外のけが・やけど
	0) No	なし
	1) Yes	あり
	(19) Malignant neoplasm	悪性新生物（がん）
	0) No	なし
	1) Yes	あり
	(20) Other	その他
	(Free response)	（自由記述）
Q50	Are you taking antihypertensive drugs (blood pressure lowering drugs)? あなたは降圧剤（血圧を下げる薬）を服薬していますか。	
	0) No	服薬していない
	1) Yes	服薬している
	→(____) tablets each time/you have taken antihypertensive drugs since age (____) years →1 回（____）錠／服用開始年齢（____）歳から	
Part.V	Housing 住まい	
Q51	Do you experience following conditions in your house? お住まいでの生活の中で、次のように感じることはありますか。	
	(1) Living room: During summer, are there times when you feel hot because the air conditioning for cooling is not effective? 居間・リビングで、夏、冷房が効かずに暑いと感じること	
	1) Frequently	よくある
	2) Sometimes	たまにある
	3) Rarely	めったにない
	4) Not at all	全くない

(2) Living room: During winter, are there times when you feel cold because the air conditioning for heating is not effective?
居間・リビングで、冬、暖房が効かずに寒いと感じること

1) Frequently よくある
2) Sometimes たまにある
3) Rarely めったにない
4) Not at all 全くない

(3) Living room: Are there times when you are bothered by indoor/outdoor sounds or vibrations even after the windows and doors are closed?
居間・リビングで、窓・ドアを閉めても、室内や外の音・振動が気になること

1) Frequently よくある
2) Sometimes たまにある
3) Rarely めったにない
4) Not at all 全くない

(4) Living room: At night, are there times when you feel it is dark due to insufficient lighting?
居間・リビングで、夜、照明が足りずに暗いと感じること

1) Frequently よくある
2) Sometimes たまにある
3) Rarely めったにない
4) Not at all 全くない

(5) Bedroom: During winter, are there times when you cannot sleep because it is cold?
寝室で、冬、寒くて眠れないこと

1) Frequently よくある
2) Sometimes たまにある
3) Rarely めったにない
4) Not at all 全くない

(6) Bedroom: During winter, are there times when your nose/throat is dry when you wake up?
寝室で、冬、起きたときに鼻やのどが乾燥していること

1) Frequently よくある
2) Sometimes たまにある
3) Rarely めったにない
4) Not at all 全くない

(7) Bedroom: Are there times when you cannot sleep because you are bothered by indoor/outdoor sounds or vibrations even after the windows and doors are closed?
寝室で、窓・ドアを閉めても、室内や外の音・振動が気になって眠れないこと

1) Frequently よくある
2) Sometimes たまにある
3) Rarely めったにない
4) Not at all 全くない

(8) Kitchen: Are there times when you have to take an unnatural posture due to a poor layout (too narrow, too high, etc.)?
キッチンで、狭さや高さなどのため無理な姿勢をとること

1) Frequently よくある
2) Sometimes たまにある
3) Rarely めったにない
4) Not at all 全くない

(9) Changing room: During winter, are there times when you feel that the changing room is cold?
脱衣所で、冬、寒いと感じること

1) Frequently よくある
2) Sometimes たまにある
3) Rarely めったにない
4) Not at all 全くない

(10) Bathroom: Are there times when you feel that the bathroom is cold?
浴室で、冬、寒いと感じること

1)	Frequently	よくある
2)	Sometimes	たまにある
3)	Rarely	めったにない
4)	Not at all	全くない

(11) Bathroom & changing room: Are there times when you smell foul odors?
浴室・脱衣所で、嫌なニオイを感じること

1)	Frequently	よくある
2)	Sometimes	たまにある
3)	Rarely	めったにない
4)	Not at all	全くない

(12) Toilet: During winter, are there times when you feel the toilet is cold?
トイレで、冬、寒いと感じること

1)	Frequently	よくある
2)	Sometimes	たまにある
3)	Rarely	めったにない
4)	Not at all	全くない

(13) Toilet: Are there times when you detect foul odors lingering?
トイレで、嫌なニオイがこもると感じること

1)	Frequently	よくある
2)	Sometimes	たまにある
3)	Rarely	めったにない
4)	Not at all	全くない

(14) Entrance: Are there times when you feel it is dangerous because you may trip over a step?
玄関で、段差で転ぶ危険を感じること

1)	Frequently	よくある
2)	Sometimes	たまにある
3)	Rarely	めったにない
4)	Not at all	全くない

(15) Entrance: Are there times when you lose your balance while putting on your shoes?
玄関で、靴をはくときにバランスを崩すこと

1)	Frequently	よくある
2)	Sometimes	たまにある
3)	Rarely	めったにない
4)	Not at all	全くない

(16) Corridors: Are there times when you feel it is dark near your feet while walking even when the light is turned on?
廊下で、移動するときに照明をつけても暗いと感じること

1)	Frequently	よくある
2)	Sometimes	たまにある
3)	Rarely	めったにない
4)	Not at all	全くない

(17) Storage: Are there times when the storage smells of mold or chemical substances?
収納で、カビや化学物質のニオイを感じること

1)	Frequently	よくある
2)	Sometimes	たまにある
3)	Rarely	めったにない
4)	Not at all	全くない

(18) Are there times when insects begin to breed indoors?
家の中で、虫が発生すること

1)	Frequently	よくある
2)	Sometimes	たまにある
3)	Rarely	めったにない
4)	Not at all	全くない

(19) Surroundings: Are there times when you slip or stumble around your home?
家のまわりで、すべる、またはつまずくこと

1) Frequently よくある
2) Sometimes たまにある
3) Rarely めったにない
4) Not at all 全くない

(20) Surroundings: Are there times when you feel anxious about the precautions against crime?
家のまわりで、防犯に不安を感じること

1) Frequently よくある
2) Sometimes たまにある
3) Rarely めったにない
4) Not at all 全くない

(21) Are there times when you are at home and feel that you can be easily seen from outside your house?
家の中で、外からの視線が気になること

1) Frequently よくある
2) Sometimes たまにある
3) Rarely めったにない
4) Not at all 全くない

(22) Kitchen: Is there mold on/around the kitchen counter?
調理台の周辺の、カビの発生

1) Excessively 多くある
2) Partially 部分的にある
3) Scarcely ほとんどない
4) Not at all 全くない

Part.VI Lifestyle in the house 住まい方

Q52 Do you use open-type heating systems (oil fan heater, gas stove, etc.) that generate combustion gas in the room?
Please select an answer for each room.
室内で燃焼ガスが発生する、開放式暖房（石油ファンヒーター、ガスストーブなど）を使用していますか。
部屋ごとにご回答ください。

(1) In the living room 居間
0) No 使用していない
1) Yes 使用している

(2) In the bedroom 寝室
0) No 使用していない
1) Yes 使用している

Q53 Do you use heating systems that heat the floor (floor heating, electric carpet, etc.)? Please select an answer for each room.
床を温める暖房（床暖房、電気カーペットなど）を使用していますか。部屋ごとにご回答ください。

(1) In the living room 居間
0) No 使用していない
1) Yes 使用している

(2) In the bedroom 寝室
0) No 使用していない
1) Yes 使用している

Q54 In the bedroom, do you use heating to avoid getting cold when you wake up in the morning?
(Timer setting, turning a heater on before leaving the bed, etc.)
寝室で、起床時に寒くならないように、暖房を使用していますか。
（タイマー設定、起床後すぐスイッチを入れて布団から出るなど）

0) No 使用していない
1) Yes 使用している

Q55	Please select the most appropriate answer regarding installation and usage of the following heating items/methods in winter. 冬における暖房器具の設置・使用状況をお答えください。	
	(1) Kotatsu table	こたつ
	1) Not installed	設置していない
	2) Installed but not using	設置しているが使用していない
	3) Using	使用している
	(2) Heating in the bathroom	浴室暖房
	1) Not installed	設置していない
	2) Installed but not using	設置しているが使用していない
	3) Using	使用している
	(3) Heating in the changing room	脱衣所暖房
	1) Not installed	設置していない
	2) Installed but not using	設置しているが使用していない
	3) Using	使用している
	(4) Heating in the toilet (including a heated toilet seat)	トイレの暖房※暖房便座を含む
	1) Not installed	設置していない
	2) Installed but not using	設置しているが使用していない
	3) Using	使用している
Q56	How do you take a bath in winter?	冬、あなたはどのように入浴しますか。
	1) Deep bathing	全身浴
	2) Hip bathing	半身浴
	3) Only shower	シャワーのみ
Q57	How long is your bath time (time between entering and leaving the bathroom) in winter? 冬、入浴時間（浴室を出るまでの時間）はどれぐらいですか。	
	1) Short (≤15 minutes)	短め（15 分以下）
	2) Medium (15–30 minutes)	普通（15~30 分未満）
	3) Long (≥30 minutes)	長め（30 分以上）
Q58	How hot is the bathwater temperature in winter?	冬、お湯の温度はどれぐらいですか。
	1) Tepid (<40°C)	ぬるめ（40℃未満）
	2) Warm (40–42°C)	普通（40~42℃未満）
	3) Hot (≥42°C)	あつめ（42℃以上）
Q59	Please select the option closest to the clothing you wear to sleep in winter. If you wear additional clothing that is not listed, please write it under "Other". 冬、就寝時の服装に最も近いものを 6 つの中から選択してください。 また、加えて着ているものがあれば、「その他」に追記してください。	
	1) Long-sleeve pajamas + straight trousers	長袖パジャマ＋長ズボン
	2) Long-sleeve pajamas + long-sleeve long gown + straight trousers	長袖パジャマ+フリース・ダウン+長ズボン
	3) Long-sleeve sweatshirt + sweatpants	スウェット上下
	4) Long-sleeve sweatshirt+ long-sleeve long gown + sweatpants	スウェット上下＋フリース・ダウン
	5) Long-sleeve sweatshirt + straight trousers	ジャージ上下
	6) Long-sleeve long robe	ネグリジェ
	7) Other (____) e.g. socks, tracksuit, parka, cardigan, vest, knit cap, etc. その他（____）を加えて着用 ※例：靴下、トレーナー、パーカー、カーディガン、ベスト、ニット帽など	

Q60 Please select the option closest to the clothing you wear while at home in winter (not during sleep).
If you wear additional clothing that is not listed, please write it under "Other".
冬、自宅滞在時（就寝時以外）の服装に最も近いものをお答えください。
また、加えて着ているものがあれば、「その他」に追記してください。

1) Long-sleeve flannel shirt + straight trousers 長袖シャツ＋長ズボン
2) Long-sleeve flannel shirt + long-sleeve sweater + straight trousers 長袖シャツ＋セーター＋長ズボン
3) Long-sleeve flannel shirt + single-breasted suit jacket + straight trousers 長袖シャツ＋ジャケット＋長ズボン
4) Long-sleeve shirtdress ワンピース
5) Long-sleeve flannel shirt + long-sleeve sweater + skirt 長袖シャツ＋セーター＋長スカート
6) Long-sleeve flannel shirt + single-breasted suit jacket + skirt 長袖シャツ＋ジャケット＋長スカート
7) Long-sleeve pajamas + straight trousers 長袖パジャマ＋長ズボン
8) Long-sleeve pajamas + long-sleeve long gown + straight trousers 長袖パジャマ+フリース・ダウン+長ズボン
9) Long-sleeve sweatshirt + sweatpants スウェット上下
10) Long-sleeve sweatshirt+ long-sleeve long gown + sweatpants スウェット上下＋フリース・ダウン
11) Long-sleeve sweatshirt + straight trousers ジャージ上下
12) Long-sleeve long robe ネグリジェ
13) Other (____) e.g. socks, tracksuit, parka, cardigan, vest, knit cap, etc.
その他（____）を加えて着用
※例：靴下、トレーナー、パーカー、カーディガン、ベスト、ニット帽など

Q61 On average, how much time do you spend at home including time spent sleeping in winter? Please provide an answer for weekdays and holidays.
冬、睡眠時間を含めて自宅にいる時間は平均してどのくらいですか。平日と休日それぞれお答えください。

(1) Weekdays 平日
(____) hours *Please round to the nearest hour.
（____）時間 ※30 分以上は切り上げ、整数でお答えください。

(2) Holidays 休日
(____) hours *Please round to the nearest hour.
（____）時間 ※30 分以上は切り上げ、整数でお答えください。

Q62 On average, how long do you spend watching TV in the living room. Please provide answers for weekdays and holidays.
冬、居間でテレビを見る時間は平均してどのくらいですか。平日と休日それぞれお答えください。

(1) Weekdays 平日
(____) hours *Please round to the nearest hour.
（____）時間 ※30 分以上は切り上げ、整数でお答えください。

(2) Holidays 休日
(____) hours *Please round to the nearest hour.
（____）時間 ※30 分以上は切り上げ、整数でお答えください。

Part.VII Individual attributes 個人属性

Q63 Please answer the following questions about yourself. ご自身について、以下の質問にお答えください。

(1) Birth year and month 生年月
(____) (____) 大正・昭和・平成（____）年（____）月生まれ

(2) Sex 性別
1) Male 男性
2) Female 女性

(3) Height 身長
(____)cm

(4) Weight 体重
(____)kg

(5) Marital status 結婚
1) Married 既婚
2) Not married 未婚
3) Divorced/widowed 離別・死別

	(6) Main means of transportation	主な交通手段
	1) Walking	徒歩
	2) Bicycle	自転車
	3) Public transportation	公共交通機関
	4) Car or motorcycle	自動車・バイク
	5) Other	その他
	(7) Zip code	郵便番号
	〒(____)-(____)	
Q64	How long have you lived in your house?	あなたは今のお住まいにどのくらいの期間住んでいますか。
	(____) years	(____) 年
Q65	What is your employment status?	あなたのお勤め先の雇用形態はどれにあたりますか。
	1) Regular employee	正規
	2) Non-regular employee (temporary worker/contract worker)	非正規（派遣労働・契約社員）
	3) Part-time employee	パート・アルバイト
	4) Self-employed	自営業
	5) Contractor (outsourced)	請負（業務委託）
	6) Fixed-term employee	嘱託
	7) Student	学生
	8) Other (____)	その他（____）
	9) Not working	働いていない
Q66	Please only answer if you are currently working. Please choose the option closest your type of work. 【お仕事をしている方のみお答えください】あなたの仕事内容について、最も近いものを一つ選んでください。	
	1) Desk work (clerical work or computer work)	主にデスクワーク（事務やパソコンでの仕事）
	2) Work dealing with people (sales or marketing)	主に人と話したりする仕事（営業や販売）
	3) Physical work (work at production site or nursing care site, etc.) 主に作業（生産現場でのお仕事、介護など体を使う作業）	
Q67	Which is your highest level of education?	最後に卒業した学校はどちらですか。
	1) Junior high school	中学校
	2) High school	高等学校
	3) Technical/vocational/junior college	高専・専門学校・短期大学
	4) College/graduate college	大学・大学院
	5) Other (____)	その他（____）
Q68	Are you participating in the measurement of blood pressure and activity during this period? あなたは、今回、血圧・活動量測定に参加していますか。	
	0) No	いいえ
	1) Yes (participating in the measurement of blood pressure and activity)	はい（血圧・活動量測定も実施）
Q69	Which applies to your annual household income?	年間の世帯収入（税込み）はどのくらいですか。
	1) <0.5 million JPY	50 万円未満
	2) 0.5–1.0 million JPY	50~100 万円未満
	3) 1.0–1.5 million JPY	100~150 万円未満
	4) 1.5–2.0 million JPY	150~200 万円未満
	5) 2.0–2.5 million JPY	200~250 万円未満
	6) 2.5–3.0 million JPY	250~300 万円未満
	7) 3–4 million JPY	300~400 万円未満
	8) 4–5 million JPY	400~500 万円未満
	9) 5–6 million JPY	500~600 万円未満
	10) 6–7 million JPY	600~700 万円未満
	11) 7–8 million JPY	700~800 万円未満
	12) 8–9 million JPY	800~900 万円未満
	13) 9–10 million JPY	900~1000 万円未満
	14) ≥10 million JPY	1000 万円以上
Q70	Are you currently considering renovation?	あなたは、現在、リフォームを検討していますか。
	0) No	検討していない・改修済み →Q72
	1) Yes	検討している →Q71

Q71	What is the motivation behind you considering renovation?　あなたがリフォームを考えはじめた動機は何ですか。	
	(1) Please select all appropriate options. 当てはまるものをすべてチェックしてください。	
	(2) Please choose up to two motivations behind you considering renovation. また、その中で決定的であった動機を 2 つまでお選びください。	
	1) Change in the number of family members living together/to facilitate growing children 同居する家族人数の変化・子の成長のため 2) To make the house more accessible for elderly people to live in 高齢者が暮らしやすい住宅にするため 3) To change to a favorite layout and interior of the house 好みの間取りやインテリアにするため 4) To improve the lack of storage and poor efficiency 収納の不足や効率の悪さを改善するため 5) To improve the layout and usability of wet areas 間取りや水回りの使い勝手の改善のため 6) To upgrade equipment in the house 設備の劣化・グレードアップのため 7) To enhance seismic capacity 耐震性能を高めるため 8) To enhance crime prevention performance 防犯性能を高めるため 9) To enhance energy saving performance 省エネルギー性能を高めるため 10) Because subsidies are available 補助金が利用できるため 11) Because the mortgage has been paid off 住宅ローンを完済したため 12) Other (Free response) e.g. To lease, influenced by friends その他（自由記述）※賃貸にするため、友人による影響など	
Q72	During the past year, how many times have acquaintances or family members visited your house? 過去 1 年、現在のお住まいに、知人や別居する家族は何度来訪しましたか。	
	(1) Friends or acquaintances (____) times	友人・知人の来訪 （____）回
	(2) Family members (____) times	別居する家族・親族の来訪 （____）回
Q73	Do the following apply to people or pets living in your house?　お住まいに次のような方はいらっしゃいますか。	
	(1) A person who smokes cigarettes indoors 0) No 1) Yes	室内でタバコを吸う方 いない いる
	(2) A person who needs nursing care 0) No 1) Yes	介護を必要とする方 いない いる
	(3) A pet kept indoors 0) No 1) Yes	室内で飼うペット いない いる
Q74	Please provide the total number of people living together.	同居している合計人数をお答えください。
	A total of (　　) people	合計で（____）人

Part.VIII Health condition of children 子供の健康

In Q75–77, “children” refers to the following people:

1) For first-time participants in the survey, “children” refers to elementary school children and younger.

2) For participants who participated in the survey last year, “children” refers to the same children who were subjects of the questionnaire last year.

Q75~77 において、【お子様】とは以下の方を指します。

1) 初めて調査に参加された方 【お子様】＝【小学生以下のお子様】

2) 昨年も調査に参加された方 【お子様】＝【昨年、記入対象とされたお子様】

Q75 Does your family, living together in your house, have children corresponding to the above definitions?
同居するご家族に、上記に該当するお子様はいらっしゃいますか。

0) No	いない
1) Yes	いる

Q76 Please provide answers about the children that live with you. For those who are participating in the survey for the first time, if there are four or more children, please provide answers in order from the smallest child.
同居するお子様についてお答えください。
初めて調査に参加された方で、お子様が 4 名以上いらっしゃる場合は、小さなお子様から順にご記入ください。

(1) Birth order	出生
A (____)-born child e.g. a third-born child	第（____）子
(2) Birth year and month	生年月
(____) (____)	平成（____）年（____）月
(3) Sex	性別
1) Male	男の子
2) Female	女の子

Please provide answers about your children's allergies.
それぞれのお子様のアレルギー疾患についてお尋ねします。

(4) Allergic rhinitis	アレルギー性鼻炎
0) No diagnosis	診断をうけたことがない
1) Received a diagnosis, but not treated	診断をうけたことがあるが、特に治療していない
2) Treated only when symptoms are bad	症状が悪いときのみ受診・治療している
3) Treated regularly	定期的に受診・治療している
(5) Atopic dermatitis	アトピー性皮膚炎
0) No diagnosis	診断をうけたことがない
1) Received a diagnosis, but not treated	診断をうけたことがあるが、特に治療していない
2) Treated only when symptoms are bad	症状が悪いときのみ受診・治療している
3) Treated regularly	定期的に受診・治療している
(6) Otitis media	中耳炎
0) No diagnosis	診断をうけたことがない
1) Received a diagnosis, but not treated	診断をうけたことがあるが、特に治療していない
2) Treated only when symptoms are bad	症状が悪いときのみ受診・治療している
3) Treated regularly	定期的に受診・治療している
(7) Asthma	喘息（ぜんそく）
0) No diagnosis	診断をうけたことがない
1) Received a diagnosis, but not treated	診断をうけたことがあるが、特に治療していない
2) Treated only when symptoms are bad	症状が悪いときのみ受診・治療している
3) Treated regularly	定期的に受診・治療している

Please provide the frequency of experiencing the following symptoms for each child over the past month.
それぞれのお子様の体験した症状についてお尋ねします。過去一ヶ月を振り返り、その頻度をお答えください。

(8) Asthma attack	喘息（ぜんそく）の発作
(____) days a week on average	平均（____）日/週
(9) Bed-wetting	夜尿症（おねしょ）
(____) days a week on average	平均（____）日/週

Q77	Please provide answers about children who have been diagnosed with asthma. Please choose the option closest to your child's condition in the last week. 喘息（ぜんそく）と診断されたことがある、同居するお子様についてお伺いします。 以下のそれぞれの質問について、この１週間の状態に最も近いものに印をつけてください。

(1) During the last week, how often did your child wake up in the middle of the night due to asthma?
この１週間のうち平均してどのくらいの頻度で、ぜんそくのために夜中に目が覚めましたか。

0)	Not at all	まったくない
1)	Rarely	ほとんどない
2)	Occasionally	たまに
3)	Sometimes	時々
4)	Frequently	たびたび
5)	Almost always	ほとんどいつも
6)	Could not sleep because of asthma	ぜんそくのせいで眠れなかった

(2) During the last week, how serious were your child's asthma symptoms when he/she woke up in the morning?
この１週間のうち平均して朝目覚めたときのぜんそく症状はどのくらいだったでしょうか。

0)	None	無症状
1)	Very mild	非常に軽い
2)	Mild	軽い
3)	Moderate	中程度
4)	Moderately severe	やや重い
5)	Severe	重い
6)	Very severe	非常に重い

(3) All things considered, during the last week, how much trouble did asthma cause in your child's life?
全体的にみて、この１週間のうちぜんそくのために同居する小学生以下のご家族の生活には
どのくらい支障がでていましたか。

0)	Not at all	ぜんぜん支障がなかった
1)	Rarely	ほとんど支障がなかった
2)	Occasionally	少し支障があった
3)	Sometimes	ある程度支障があった
4)	Frequently	かなり支障があった
5)	Almost always	非常に支障があった
6)	Could not	まったくできなかった

(4) All things considered, during the last week, how severe was your child's breathlessness symptom due to asthma?
全体的にみて、この１週間のうちぜんそくのためにどれくらい息切れを感じましたか。

0)	None	ぜんぜんない
1)	Very mild	ほとんどない
2)	Mild	少々
3)	Moderate	ある程度
4)	Moderately severe	かなり
5)	Severe	強い
6)	Very severe	非常に強い

(5) All things considered, during the last week, how often did your child experience noisy breathing due to asthma?
全体的にみて、この１週間のうちゼーゼー・ヒューヒューと感じる時間がどれくらいありましたか。

0)	Not at all	まったくない
1)	Rarely	ほとんどない
2)	Occasionally	たまに
3)	Sometimes	時々
4)	Frequently	たびたび
5)	Almost always	ほとんどいつも
6)	Always	いつも

Appendix 2: Diary for residents

Part.I	Items to be completed only once during the measurement period	測定期間中 1 回だけ記入する項目
Q1	Please answer the following questions about yourself.	ご自身について、以下の質問にお答えください。
	(1) Birth year and month	生年月
	(____) (____)	大正・昭和・平成（____）年（____）月生まれ
	(2) Height and weight	体型
	(____)cm, (____)kg	
	(3) Sex	性別
	1) Male	男性
	2) Female	女性
	(4) Measurement period	測定期間
	(____) (____), (____) – (____) (____), (____)	（____）月（____）日～（____）月（____）日
Part.II	Items to be completed after getting up in the morning	朝起きた時に記入する項目
Q1	What time did you go to bed last night?	昨夜の就寝時刻は、
	At (____):(____)	（午前／午後）（____）時（____）分
Q2	What time did you get up this morning?	今日の起床時刻は、
	At (____):(____)	（午前／午後）（____）時（____）分
Q3	Did you take sleeping pills last night?	昨夜は睡眠薬を服用しましたか？
	1) Yes	はい
	2) No	いいえ
Q4	(1) How would you rate your recovery from fatigue when you got up?	起床時、前日の疲れはとれていますか？
	1) Very good	非常に取れている
	2) Fairly good	やや取れている
	3) Fairly bad	やや残っている
	4) Very bad	非常に残っている
	(2) How would you rate your ability to fall asleep last night?	昨夜の寝付きはどうでしたか？
	1) Very good	非常に良い
	2) Fairly good	やや良い
	3) Fairly bad	やや悪い
	4) Very bad	非常に悪い
	(3) How would you rate your sleep quality last night?	昨夜の睡眠の質はどうでしたか？
	1) Very good	非常に良い
	2) Fairly good	やや良い
	3) Fairly bad	やや悪い
	4) Very bad	非常に悪い
Q5	Is today a holiday for you?	今日はあなたにとっての休日ですか？
	1) Yes	休日
	2) No	休日でない
Q6	Did you press the wrong button when performing blood pressure measurements? 血圧測定で、スイッチの押し間違いがありましたか？	
	1) Yes → the (____) measurement	はい → （____）回目の測定
	2) No	いいえ
Part.III	Items to be completed before going to bed in the evening	夜寝る前に記入する項目
Q1	Did you go out today?	今日は外出しましたか？
	1) Yes	はい
	→The earliest time I left home was (____):(____)	最初の外出時刻（午前／午後）（____）時（____）分
	→The latest time I arrived home was (____):(____)	最後の帰宅時刻（午前／午後）（____）時（____）分
	2) No	いいえ
Q2	Did you drink alcohol today?	今日はお酒を飲みましたか？
	1) Yes	はい
	2) No	いいえ

Q3	When did you wear a physical activity meter	活動量計の装着状況について
	1) All day except during sleep or bathing (100%)	就寝・入浴時以外は終始装着（100%）
	2) Some of the day (60–90%)	一部装着漏れがあった（60~90%）
	3) Did not wear for more than half of the day (<50%)	半分以上つけ忘れた（50%未満）
Q4	Did you press the wrong button when performing blood pressure measurements? 血圧測定で、スイッチの押し間違いがありましたか？	
	1) Yes → the (____) measurement	はい　→（____）回目の測定
	2) No	いいえ

Appendix 3: Questionnaire for experts in housing

Q1 Please provide answers regarding the construction site, the total floor area, and building age.
建設地と延床面積、築年数をご回答ください。

(1) Construction site 建設地
Prefecture: (____), city, ward, town, village: (____) （____）都／道／府／県（____）市／区／町／村

(2) Zip code 郵便番号
〒(____)-XXXX * Only provide the first 3 digits ※上 3 桁のみ

(3) Total floor area 延床面積
(____) m^2 （____） m^2

(4) Building age 築年数
(____) years 築（____）年

Q2 What type of house is it? 住宅の種別はどれにあたりますか。

(1) House type 形態
1) Detached house →A (____)-story house
戸建て住宅 →（____）階建
2) Apartment (Collective housing) →A (____)-story apartment, living on the (____) floor
共同住宅（集合住宅） →（____）階建の（____）階に居住

(2) Owner 種別
1) Owner-occupied housing 持ち家
2) Rental housing 賃貸

Q3 Please provide answers regarding the renovation, extension or reconstruction that you have completed so far.
これまでに実施した改修や増改築状況をご回答ください。

(1) Insulation retrofit 断熱改修関連
1) Completed →Room/part: (____), Time: ( ) years ago, Content: (Free response)
した →場所（____） 時期（____）年前 内容（自由記述）
2) None していない

(2) Wet areas 水まわり関連
1) Completed →Room/part: (____), Time: ( ) years ago, Content: (Free response)
した →場所（____） 時期（____）年前 内容（自由記述）
2) None していない

(3) Others その他
1) Completed →Room/part: (____), Time: ( ) years ago, Content: (Free response)
した →場所（____） 時期（____）年前 内容（自由記述）
2) None していない

Q4 What is the structure of the house? 構造は次のうちどれですか。

1) Wooden 木造
2) Reinforced concrete コンクリート造
3) Steel 鉄骨造
4) Others (free description) その他（自由記述）

Q5 Are boilers or electric water heaters installed in the changing room?
脱衣室にボイラーまたは電気温水器を設置していますか。

1) Installed 設置している
2) Not installed 設置していない

Q6 Is whole-house air conditioning installed in the house? 全館空調を設置していますか。

1) Installed 設置している
2) Not installed 設置していない

Q7 Please provide answers regarding the thickness and type of insulation in the floor, walls and roof.
床・壁・屋根の断熱材の厚みや種類をご回答ください。

(1) Thickness 厚み
Floor (____)mm 床
Walls (____)mm 壁
Roof (____)mm 屋根

(2) Type 種類

A-1: 0.052–0.051[W/(mK)]

1) Blown glass wool insulation (equivalent to 13K, 18K) 吹込用グラスウール断熱材(13K, 18K 相当)
2) *Tatami* board (15mm) タタミボード（15mm）
3) Grade-A insulation board (9mm) A 級インシュレーションボード（9mm）
4) Sheathing board (9mm) シージングボード（9mm）

A-2: 0.050–0.046[W/(mK)]

5) Residential glass wool insulation (equivalent to 10K) 住宅用グラスウール断熱材（10K 相当）
6) Blown rock wool insulation (25K) 吹込用ロックウール断熱材（25K）

B: 0.045–0.041[W/(mK)]

7) Residential glass wool insulation (equivalent to 16K, 20K) 住宅用グラスウール断熱材(16K, 20K 相当)
8) Grade-A expanded polystyrene foam (No.4) A 種ビーズ法ポリスチレンフォーム保温板（4 号）
9) Grade-A polystyrene foam A (Type-1, No.1, 2) A 種ポリスチレンフォーム保温板（1 種 1 号, 1 種 2 号）

C: 0.040–0.035[W/(mK)]

10) Residential glass wool insulation (equivalent to 24K, 32K) 住宅用グラスウール断熱材(24K, 32K 相当)
11) High-performance glass wool insulation (equivalent to 16K, 24K, 32K)
高性能グラスウール断熱材（16K, 24K, 32K 相当）
12) Blown glass wool insulation (equivalent to 30K, 35K) 吹込用グラスウール断熱材(30K, 35K 相当)
13) Residential rock wool insulation (mat) 住宅用ロックウール断熱材（マット）
14) Rock wool insulation (felt) ロックウール断熱材（フェルト）
15) Rock wool insulation (board) ロックウール断熱材（ボード）
16) Grade-A expanded polystyrene foam (No.1, 2, 3)
A 種ビーズ法ポリスチレンフォーム保温板（1 号, 2 号, 3 号）
17) Grade-A extruded polystyrene foam (Type-1) A 種押出法ポリスチレンフォーム保温板（1 種）
18) Blown rigid polyurethane foam for building insulation (Type-A3)
建築物断熱用吹付け硬質ウレタンフォーム（A 種 3）
19) Grade-A polyethylene foam (Type-2) A 種ポリエチレンフォーム保温板（2 種）
20) Grade-A phenolic foam (Type-2, No.1; Type-3, No.1, 2)
A 種フェノールフォーム保温板（2 種 1 号, 3 種 1 号, 3 種 2 号）
21) Blown cellulose fiber (25K, 45K, 55K) 吹込用セルローズファイバー（25K, 45K, 55K）
22) Blown rock wool insulation (equivalent to 65K) 吹込用ロックウール断熱材（65K 相当）

D: 0.034–0.029[W/(mK)]

23) High-performance glass wool insulation (equivalent to 40K, 48K)
高性能グラスウール断熱材（40K, 48K 相当）
24) Grade-A expanded polystyrene foam (special)
A 種ビーズ法ポリスチレンフォーム保温板特号
25) Grade-A extruded polystyrene foam (Type-2) A 種押出法ポリスチレンフォーム保温板（2 種）
26) Grade-A rigid polyurethane foam (Type-1) A 種硬質ウレタンフォーム保温板（1 種）
27) Blown rigid polyurethane foam for building insulation (Type-A1, A2)
建築物断熱用吹付け硬質ウレタンフォーム（A 種 1, A 種 2）
28) Grade-A polyethylene foam (Type-3) A 種ポリエチレンフォーム保温板（3 種）
29) Grade-A phenolic foam (Type-2, No.2) A 種フェノールフォーム保温板 (2 種 2 号)

E: 0.028–0.023[W/(mK)]

30) Grade-A extruded polystyrene foam (Type-3) A 種押出法ポリスチレンフォーム保温板（3 種）
31) Grade-A rigid polyurethane foam (Type-2, No.1, 2, 3, 4)
A 種硬質ウレタンフォーム保温板（2 種 1 号, 2 種 2 号, 2 種 3 号, 2 種 4 号）

F: ≤0.022 [W/(mK)]

32) Grade-A phenolic foam (Type-1, No.1, 2) A 種フェノールフォーム保温板（1 種 1 号, 1 種 2 号）

Other その他

33) Other (____) [W/(mK)] その他（____）[W/(mK)]

Q8	Which energy-saving measures (adiabatic level) criteria did the house satisfy before and after renovation? 改修前後の省エネルギー対策の基準は次のうちどれですか。	
	(1) Before renovation	改修前
	1) Greater than S (Supreme) standard	S 基準以上
	2) Greater than A standard, less than S standard	A 基準以上 S 基準未満
	3) Less than A standard	A 基準未満
	4) Other (____)	その他（____）
	(2) After renovation	改修後
	5) Greater than S (Supreme) standard	S 基準以上
	6) Greater than A standard, less than S standard	A 基準以上 S 基準未満
	7) Less than A standard	A 基準未満
	8) Other (____)	その他（____）
	9) No renovation	改修しない
Q9	Please provide the heat loss coefficient, solar heat gain coefficient, and the corresponding gap area. 熱損失係数・日射熱取得係数・相当隙間面積をご回答ください。	
	(1) Heat loss coefficient (____) W/m^2K	熱損失係数
	(2) Solar heat gain coefficient (____)	日射熱取得係数
	(3) Corresponding gap area (____) cm^2/m^2	相当隙間面積
Q10	Please check the windows in the living room and bedroom. 使用している居間・寝室の窓ガラスを選んでチェックしてください。	

(Single) wooden or plastic （一重）木製またはプラスチック製

1) Low emissivity (Low-E) pair glass (Air layer 12mm), reference value: 2.33[W/(mK)]
   低放射複層（A12）参考値：2.33[W/(mK)]
2) Triple glass (Air layer 12mm×2), reference value: 2.33[W/(mK)]
   三層複層（A12×2）参考値：2.33[W/(mK)]
3) Pair glass (Air layer 12mm), reference value: 2.91[W/(mK)]
   複層（A12）参考値：2.91[W/(mK)]
4) Pair glass (Air layer 6mm), reference value: 3.49[W/(mK)]
   複層（A6）参考値：3.49[W/(mK)]

(Single) made of metal and plastic (wood) composite structure （一重）金属・プラスチック（木） 複合構造製

5) Low-E pair glass (Air layer 12mm), reference value: 2.33[W/(mK)]
   低放射複層（A12）参考値：2.33[W/(mK)]
6) Low-E pair glass (Air layer 6mm), reference value: 3.49[W/(mK)]
   低放射複層（A6）参考値：3.49[W/(mK)]
7) Pair glass (Air layer 10–12mm), reference value: 3.49[W/(mK)]
   複層（A10~12）参考値：3.49[W/(mK)]
8) Pair glass (Air layer 6mm), reference value: 4.07[W/(mK)]
   複層（A6）参考値：4.07[W/(mK)]

(Single) metal heat shield structure （一重）金属製熱遮断構造

9) Low-E pair glass (Air layer 12mm), reference value: 2.91[W/(mK)]
   低放射複層（A12）参考値：2.91[W/(mK)]
10) Low-E pair glass (Air layer 6mm), reference value: 3.49[W/(mK)]
   低放射複層（A6）参考値：3.49[W/(mK)]
11) Pair glass (Air layer 10–12mm), reference value: 3.49[W/(mK)]
   複層（A10~12）参考値：3.49[W/(mK)]
12) Pair glass (Air layer 6mm), reference value: 4.07[W/(mK)]
   複層（A6）参考値：4.07[W/(mK)]

(Single) metal, etc. （一重）問わない(金属製等)

13) Low-E pair glass (Air layer 6mm), reference value: 4.07[W/(mK)]
低放射複層（A6）参考値：4.07[W/(mK)]
14) Pair glass (Air layer 6mm), reference value: 4.65[W/(mK)]
複層（A6）参考値：4.65[W/(mK)]
15) Two single glasses (Air layer ≥12mm), reference value: 4.07[W/(mK)]
単板 2 枚（A12 以上）参考値：4.07[W/(mK)]
16) Two single glasses (Air layer <12mm), reference value: 4.65[W/(mK)]
単板 2 枚（A12 未満）参考値：4.65[W/(mK)]
17) Single, the reference value: 6.51[W/(mK)]
単板参考値：6.51[W/(mK)]

(Double) one of the frames is made of wood or plastic （二重）建具の一方が木製または プラスチック製

18) Single + low-E pair glass (Air layer 6mm), reference value: 1.9[W/(mK)]
単板＋低放射複層（A6）参考値：1.9[W/(mK)]
19) Single + pair glass (Air layer 12mm), reference value: 2.33[W/(mK)]
単板＋複層（A12）参考値：2.33[W/(mK)]
20) Single + single, reference value: 2.91[W/(mK)]
単板＋単板参考値：2.91[W/(mK)]

(Double) heat shield structure of intermediate part of frame （二重）枠中間部熱遮断構造

21) Single + single, reference value: 3.49[W/(mK)]
単板＋単板参考値：3.49[W/(mK)]

(Double) metal, etc. （二重）問わない(金属製等)

22) Single + low-E pair glass (Air layer 12mm), reference value: 2.33[W/(mK)]
単板＋低放射複層（A12）参考値：2.33[W/(mK)]
23) Single + pair glass (Air layer 6mm), reference value: 3.49[W/(mK)]
単板＋複層（A6）参考値：3.49[W/(mK)]
24) Single + single, reference value: 4.65[W/(mK)]
単板＋単板参考値：4.65[W/(mK)]

(Triple) metal, etc. （三重）問わない(金属製等)

25) Single + single + single, reference value: 2.33[W/(mK)]
単板＋単板＋単板参考値：2.33[W/(mK)]

Other その他

26) Other (____), reference value: (____)[W/(mK)]
その他（__________）参考値（____）[W/(mK)]

Q11 What is the structure of the glass in the entrance door of the house? 玄関扉のガラスは次のうちどれですか。

1) Single glass 単層（1 枚）ガラス
2) Pair glass 複層（2 枚）ガラス
3) Triple glass 三層（3 枚）ガラス
4) No glass ガラス無

Q12 What material is the entrance door of the house made from? 玄関扉の建具の材質は次のうちどれですか。

1) Wooden (no insulation) 木製（無断熱）
2) Wooden (high insulated) 木製（高断熱）
3) Metal (no insulation) 金属製（無断熱）
4) Metal (high insulated) 金属製（高断熱）

Q13 Please select all options that apply to the design ingenuity (multiple answers allowed).
設計上の工夫で当てはまるもの全てにチェックしてください（複数回答可）。

1) Score by CASBEE for Detached House (BEE:____) CASBEE 戸建による採点を実施（BEE 値：____）
2) Ventilation plan suitable for site and climate 敷地・気候に適した通風計画
3) Lighting plan suitable for site and climate 敷地・気候に適した採光計画
4) Use of geothermal energy 地熱の利用
5) Installation of the Home Energy Management System (HEMS) HEMS の設置
6) Installation of solar panels 太陽光パネルの設置

Q14 1) How much timber* was used for the interior of the floor, walls and ceiling of the living room?
*wood materials including solid wood, veneer, plywood, and printed plywood, etc.
①居間の床・壁・天井の内装に、どの程度木材※を使用していますか。
※木材の定義…無垢材・付き板・合板・プリント合板等を含む木・木質材料

(1) Floor 床
1) None 全く使用していない
2) ー ー
3) Wooden paneling interior (used timber in about 1/2 of the area)
木の板張りの内装であり、面積の約 1/2 に木を使用している
4) Wooden paneling interior (used timber in the whole area)
木の板張りの内装であり、面積の全体に木を使用している

(2) Walls 壁
1) None 全く使用していない
2) Shin-kabe (a type of plastered wall in which structural components such as pillars and beams are exposed)
真壁の内装である（木の柱や梁が現わしで見える内装）
3) Wooden paneling interior (used timber in about 1/2 of the area)
木の板張りの内装であり、面積の約 1/2 に木を使用している
4) Wooden paneling interior (used timber in the whole area)
木の板張りの内装であり、面積の全体に木を使用している

(3) Ceiling 天井
1) None 全く使用していない
2) Shin-kabe (a type of plastered wall in which structural components such as pillars and beams are exposed)
真壁の内装である（木の柱や梁が現わしで見える内装）
3) Wooden paneling interior (used timber in about 1/2 of the area)
木の板張りの内装であり、面積の約 1/2 に木を使用している
4) Wooden paneling interior (used timber in the whole area)
木の板張りの内装であり、面積の全体に木を使用している

2) How much timber did you use for the interior of the floor, walls and ceiling in the bedroom?
②寝室の床・壁・天井の内装に、どの程度木材を使用していますか。

(1) Floor 床
1) None 全く使用していない
2) ー ー
3) Wooden paneling interior (used timber in about 1/2 of the area)
木の板張りの内装であり、面積の約 1/2 に木を使用している
4) Wooden paneling interior (used timber in the whole area)
木の板張りの内装であり、面積の全体に木を使用している

(2) Walls 壁
1) None 全く使用していない
2) Shin-kabe (a type of plastered wall in which structural components such as pillars and beams are exposed)
真壁の内装である（木の柱や梁が現わしで見える内装）
3) Wooden paneling interior (used timber in about 1/2 of the area)
木の板張りの内装であり、面積の約 1/2 に木を使用している
4) Wooden paneling interior (used timber in the whole area)
木の板張りの内装であり、面積の全体に木を使用している

(3) Ceiling 天井
1) None 全く使用していない
2) Shin-kabe (a type of plastered wall in which structural components such as pillars and beams are exposed)
真壁の内装である（木の柱や梁が現わしで見える内装）
3) Wooden paneling interior (used timber in about 1/2 of the area)
木の板張りの内装であり、面積の約 1/2 に木を使用している
4) Wooden paneling interior (used timber in the whole area)
木の板張りの内装であり、面積の全体に木を使用している

Q15		1) When using wood in the floor, walls or ceiling of the living room, what type of timber did you use? Also, if solid wood was used, what was the tree species? ①居間の床・壁・天井に木材を使用している場合、木材の種類は次のうちどれですか。また無垢材を使用している場合は、樹種名は何ですか。	
	(1)	Floor	床
	1)	Solid wood (tree species:____)	無垢材（樹種：____）
	2)	Veneer	突き板
	3)	Plywood	合板
	4)	Printed plywood	プリント合板
	5)	Other (name:____)	その他（名称：____）
	(2)	Wall	壁
	1)	Solid wood (tree species:____)	無垢材（樹種：____）
	2)	Veneer	突き板
	3)	Plywood	合板
	4)	Printed plywood	プリント合板
	5)	Other (name:____)	その他（名称：____）
	(3)	Ceiling	天井
	1)	Solid wood (tree species:____)	無垢材（樹種：____）
	2)	Veneer	突き板
	3)	Plywood	合板
	4)	Printed plywood	プリント合板
	5)	Other (name:____)	その他（名称：____）
		2) When using wood in the floor, walls or ceiling of the bedroom, what type of timber did you use? Also, if solid wood was used, what was the tree species? ②寝室の床・壁・天井に木材を使用している場合、木材の種類は次のうちどれですか。また無垢材を使用している場合は、樹種名は何ですか。	
	(1)	Floor	床
	1)	Solid wood (tree species:____)	無垢材（樹種：____）
	2)	Veneer	突き板
	3)	Plywood	合板
	4)	Printed plywood	プリント合板
	5)	Other (name:____)	その他（名称：____）
	(2)	Walls	壁
	1)	Solid wood (tree species:____)	無垢材（樹種：____）
	2)	Veneer	突き板
	3)	Plywood	合板
	4)	Printed plywood	プリント合板
	5)	Other (name:____)	その他（名称：____）
	(3)	Ceiling	天井
	1)	Solid wood (tree species:____)	無垢材（樹種：____）
	2)	Veneer	突き板
	3)	Plywood	合板
	4)	Printed plywood	プリント合板
	5)	Other (name:____)	その他（名称：____）
Q16		If you answered that solid wood was used in the living room or bedroom in Q15, what was the main painting method used? Q15 で居間・寝室に 1)無垢材を使用していると回答した場合、その塗装方法は次のうち主にどれですか。	
	(1)	Living room	居間
	1)	Permeable paint (oil or beeswax, etc.)	浸透性塗装（オイルや蜜蝋ワックス等）
	2)	Coating (urethane paint, etc.)	コーティング系塗装（ウレタン塗装等）
	(2)	Bedroom	寝室
	1)	Permeable paint (oil or beeswax, etc.)	浸透性塗装（オイルや蜜蝋ワックス等）
	2)	Coating (urethane paint, etc.)	コーティング系塗装（ウレタン塗装等）

Q17	If you answered that solid wood was used in the living room or bedroom in Q15, was domestic timber used? Q15 で居間・寝室に 1)無垢材を使用していると回答した場合、国産材は使用していますか。		
	(1) Living room		居間
	1)	Used domestic timber (mainly produced in ____ Prefecture)	国産材を使用している（主として____県産材）
	2)	Did not use domestic timber	国産材を使用していない
	(2) Bedroom		寝室
	1)	Used domestic timber (mainly produced in ____ Prefecture)	国産材を使用している（主として____県産材）
	2)	Did not use domestic timber	国産材を使用していない
Q18	1) What was the interior material (excluding timber) used in the floor, walls and ceiling in the living room? Please select all applicable items (No response required if not used). ①居間の床・壁・天井で木材以外に使用している内装材は何ですか。 当てはまるもの全てにチェックしてください（未使用の場合は回答不要）。		
	(1) Floor		床
	1)	*Tatami*	畳
	2)	Other natural materials (name: ____)	その他の自然素材（名称：____）
	3)	ー	ー
	4)	Polyvinyl chloride (PVC) sheet	塩ビシート
	5)	Carpet	カーペット
	6)	Other artificial materials (name: ____)	その他の人工素材（名称：____）
	(2) Walls		壁
	1)	Wallpaper	紙クロス
	2)	Plaster	漆喰
	3)	Other natural materials (name: ____)	その他の自然素材（名称：____）
	4)	Vinyl	ビニルクロス
	5)	Emulsion paint	EP 塗装
	6)	Other artificial materials (name: ____)	その他の人工素材（名称：____）
	(3) Ceiling		天井
	1)	Wallpaper	紙クロス
	2)	Plaster	漆喰
	3)	Other natural materials (name: ____)	その他の自然素材（名称：____）
	4)	Vinyl	ビニルクロス
	5)	Emulsion paint	EP 塗装
	6)	Other artificial materials (name: ____)	その他の人工素材（名称：____）
	2) What was the interior material (excluding timber) used in the floor, walls and ceiling in the bedroom? Please select all applicable items (No response required if not used). ②寝室の床・壁・天井で木材以外に使用している内装材は何ですか。 当てはまるもの全てにチェックしてください（未使用の場合は回答不要）。		
	(1) Floor		床
	1)	*Tatami*	畳
	2)	Other natural materials (name: ____)	その他の自然素材（名称：____）
	3)	ー	ー
	4)	Polyvinyl chloride (PVC) sheet	塩ビシート
	5)	Carpet	カーペット
	6)	Other artificial materials (name: ____)	その他の人工素材（名称：____）
	(2) Walls		壁
	1)	Wallpaper	紙クロス
	2)	Plaster	漆喰
	3)	Other natural materials (name: ____)	その他の自然素材（名称：____）
	4)	Vinyl	ビニルクロス
	5)	Emulsion paint	EP 塗装
	6)	Other artificial materials (name: ____)	その他の人工素材（名称：____）

	(3) Ceiling	天井
	1) Wallpaper	紙クロス
	2) Plaster	漆喰
	3) Other natural materials (name: ____)	その他の自然素材（名称：____）
	4) Vinyl	ビニルクロス
	5) Emulsion paint	EP 塗装
	6) Other artificial materials (name: ____)	その他の人工素材（名称：____）
Q19	Please indicate the amount of energy used in the past year.	過去 1 年間の各エネルギーの使用量をご記入ください。
	(1) Electricity usage	電力使用量
	Year and month (____) (____)	年月　（____）年（____）月
	Amount (____) kWh	使用量　（____）kWh
	Rate (____) JPY	使用料金　（____）円
	(2) Kerosene usage	灯油使用量
	0) Did not use	使用しない
	1) Used →(____) tanks with a capacity of (____) liters a year 使用する →1 年間で（____）L タンクを（　）本使用	
	(3) Water usage	水道水使用量
	Date of water meter reading (____) (____) (____)	検針年月日（____）年（____）月（____）日
	Amount (____) m^2	使用量　（____）m^2
	Rate (____) JPY	使用料金　（____）円
	(4) Propane gas/city gas usage	プロパンガス／都市ガス使用量
	Date of gas meter reading (____) (____) (____)	検針年月日（____）年（____）月（____）日
	The number of days of propane gas or city gas use	使用日数　（____）日
	Amount of propane gas (____) kg/amount of city gas (____) m^2 使用量　（____）kg（プロパンガス）／（____）m^2（都市ガス）	
	Rate (____) JPY	使用料金　（____）円
Q20	Please circle the energy sources (electricity, city gas, propane gas, kerosene) used for heating, hot water supply, and cooking (multiple answers allowed). ご家庭のエネルギー用途（暖房、給湯、厨房）に用いているエネルギー源（電力、都市ガス、プロパンガス、灯油）を伺います。該当するものに○を付けてください（複数選択可）。	
	(1) Heating	暖房
	1) Electricity	電力
	2) City gas	都市ガス
	3) Propane gas	プロパンガス
	4) Kerosene	灯油
	5) Other	その他
	(2) Hot water supply	給湯
	1) Electricity	電力
	2) City gas	都市ガス
	3) Propane gas	プロパンガス
	4) Kerosene	灯油
	5) Other	その他
	(3) Cooking	厨房
	1) Electricity	電力
	2) City gas	都市ガス
	3) Propane gas	プロパンガス
	4) Other	その他