Fifty-year Time Trends in Blood Pressures, Body Mass Index and their Relations in a Japanese Community:  
The Circulatory Risk in Communities Study (CIRCS)

Miyuki Hori1, Akihiko Kitamura2,3, Masahiko Kiyama3, Hironori Imano1,3, Kazumasa Yamagishi3,4, Renzhe Cui1, Mitsumasa Umesawa4,5, Isao Muraki3, Takeo Okada3, Tomoko Sankai4, Tetsuya Ohira6, Isao Saito7, Takeshi Tanigawa8, Hiroyasu Iso1, for the CIRCS Investigators

1 Public Health, Department of Social Medicine, Osaka University Graduate School of Medicine, Suita, Japan  
2 Research team for social participation and community health, Tokyo Metropolitan institution of gerontology, Tokyo, Japan  
3 Osaka Center for Cancer and Cardiovascular Diseases Prevention, Osaka, Japan  
4 Department of Public Health Medicine, Faculty of Medicine, University of Tsukuba, Tsukuba, Japan  
5 Department of Public Health, Dokkyo Medical University School of Medicine, Mibu, Japan  
6 Department of Epidemiology, School of Medicine, Fukushima Medical University, Fukushima, Japan  
7 Department of Community Health Systems Nursing, Ehime University Graduate School of Medicine, Toon, Japan  
8 Department of Public Health, Graduate School of Medicine, Juntendo University, Tokyo, Japan

Aim: Data for long-term trends in blood pressures, body mass index (BMI), and their relations are needed to set future intervention priorities for prevention of cardiovascular disease. The objective of this study was to investigate these trends revealed by repeated cross-sectional surveys conducted from 1963 to 2013 in a Japanese community.

Methods: Men and women aged 40–79 years who participated in annual cardiovascular checkups were enrolled, and the number of participants ranged between 1,776 and 2,366 with consistently high participation rates for both sexes aged 60–69 years. Sex- and age-specific mean systolic and diastolic blood pressures were calculated using mixed effects modeling for repeated measurement, and the prevalence of hypertension with and without obesity (BMI ≥ 25 kg/m²) were also calculated.

Results: Sex- and age-specific mean systolic and diastolic blood pressures declined irrespective of anti-hypertensive medication use in both men and women from 1963–1966 to 2009–2013, while mean BMI increased among men of all ages and women of ages 60–69 and 70–79 years. For both sexes aged 60–69 years, the prevalence of hypertension with obesity increased, but the prevalence of hypertension without obesity was still higher that with obesity.

Conclusions: Despite the transition to increased BMI levels, targeting non to obese hypertension remains important in addition to targeting obese hypertension for cardiovascular disease prevention.

Key words: Blood pressure, Body mass index, Hypertension, Obesity, Long-term trends
(BMI) levels have increased worldwide\(^7\). In 2008, the prevalence of obesity (BMI ≥ 25 kg/m\(^2\)) was 34% for men and 35% for women aged >20 years in the world\(^7\). Overweight or obesity is a major risk factor for hypertension and coronary heart disease\(^8\), \(^9\). Increased BMI leads to increased cardiac output and peripheral vascular resistance, insulin resistance, substances released from adipocytes, increased sympathetic nervous system response, and obstructive type of sleep apnea\(^10\), \(^14\).

Worldwide, the increasing trend in BMI may have had an impact on trends in blood pressure levels and on the prevalence of hypertension. However, in Japan, where the prevalence of obesity has been low\(^7\), the impact has not been well elucidated. Data on long-term trends in blood pressures, BMI, and their relations are useful to build future intervention priorities for the prevention of cardiovascular disease in Japan and other countries where the prevalence of obesity is low.

**Aim**

The objectives of this study were to investigate the longer-term trends for blood pressure, BMI, and their relations revealed by repeated cross-sectional surveys conducted from 1963 to 2013 in a Japanese community.

**Methods**

**Study Population**

The Circulatory Risk in Community Study (CIRCS) is an ongoing dynamic cohort study that was started in Ikawa in 1963. Ikawa is a rural community of Akita prefecture, 550 km northeast of Tokyo. It covers an area of 48 km\(^2\), and its total census population was 7,030 in 1965 and 5,493 in 2010.

Non-institutionalized residents aged >40 years in Ikawa were invited to undergo annual cardiovascular surveys and follow-up surveillance for the development of cardiovascular disease and stroke events. Details of the study methods have been previously reported\(^15\)-\(^17\). Participation rates for the annual check-ups are displayed in Table 1. Participants aged 40–79 years were enrolled to investigate the long-term trends for BMI and blood pressure levels.

Consent was implied by the participation in health checkups under a community-based program for stroke prevention and was approved by the municipal government and local physicians’ association\(^15\). The study was also approved by the ethics committees of the Osaka Centre for Cancer and Cardiovascular Disease Prevention, the University of Tsukuba, and Osaka University.

**Bp Status at Baseline and at Follow-Up**

Systolic and fifth-phase diastolic pressures in the right arm were measured by trained physicians using standard mercury sphygmomanometers with 14 × 51-cm cuffs according to the standard epidemiological method. Participants were seated and had rested for 5 min before the measurement. From 1963 to 1980, the blood pressure measurement was repeated after five deep breaths when systolic blood pressure ≥ 160 mmHg or diastolic blood pressure ≥ 95 mmHg; from 1981 to 2007, when systolic blood pressure ≥ 140 mmHg or diastolic blood pressure ≥ 90 mmHg; and from 2008 to 2013, when systolic blood pressure ≥ 130 mmHg or diastolic blood pressure ≥ 85 mmHg. To standardize the conditions, we used the first reading for the analyses. We defined hypertension as those with systolic blood pressure ≥ 140 mmHg and/or diastolic blood pressure ≥ 90 mmHg and/or taking antihypertensive medication. Controlled hypertension were persons under antihypertensive medication with systolic blood pressure <140 mmHg and diastolic blood pressure <90 mmHg. BMI was calculated by dividing weight in kilograms by height in meters squared, and BMI ≥ 25 kg/m\(^2\) was considered obese.

The health checkups were performed every year and offered free of charge to all residents aged ≥ 40 years. From 1963, we conducted face-to-face interviews based on the CIRCS questionnaire related to participants’ health conditions and dietary habits\(^9\). From 1975, we asked about smoking habits and usual daily alcohol intake (g/day).

**Statistical Analysis**

Sex-specific and age-adjusted mean systolic and diastolic blood pressure levels were calculated according to 11 periods (4–5 years for each period). We also calculated mean systolic and diastolic blood pressure levels according to antihypertensive medication use or not. When persons participated in annual cardiovascular risk surveys twice or more in each period, data in the earliest year were used. The significance of trends for blood pressure and BMI variables was examined using mixed effects modeling for repeated measurement adjusting for age, with the 11 periods represented as median year\(^18\). The repeated analysis was conducted because approximately 80% of the participants appeared in the next survey period.

All statistical analyses were performed using SAS for Windows version 9.4 (SAS Institute, Inc., Cary, NC, USA) for the analyses. All probability values for statistical tests were two-tailed, and values <0.05 were regarded as statistically significant.
Results

The number of men and women aged 40–79 years who participated in health checkups were 1,846 in 1963–1966, 2,101 in 1972–1975, 1,976 in 1976–1979, 2,144 in 1980–1983, 2,366 in 1984–1987, 2,194 in 1988–1991, 2,083 in 1992–95, 2,123 in 1996–1999, 2,036 in 2000–2003, 1,889 in 2004–2008 and 1,776 in 2009–2013 (Table 1). Participation rates were consistently high (≥ 60%) for men aged 60–69 and 70–79 years and for women aged 50–59 and 60–69 years. Therefore, the results for men and women aged 60–69 years were regarded as the primary finding for long-term trends.

Downward trends of mean systolic and diastolic blood pressure levels were observed for men and women of all age groups, except for men aged 70–79 years in diastolic blood pressure from 1963–1966 to 2009–2013 (Table 2 and Fig. 1). These blood pressure declines were observed for persons without antihypertensive medication use as well as those with it (Table 2). The prevalence of antihypertensive medication use increased from 8.5% in 1963–1966 to 47.2% in 1976–1979 for men and from 8.7% to 42.2% for women, and thereafter along with downward trends for blood pressure levels, it declined to 38.0% for men
### Table 2: Sex- and age-specific means and prevalence or proportions of cardiovascular risk characteristics from 1963-66 to 2009-13

#### Men

| Age Group | 1963-66 | 1972-75 | 1976-79 | 1980-83 | 1988-91 | 1992-95 | 1996-99 | 2004-08 | 2009-13 | p for trend |
|-----------|---------|---------|---------|---------|---------|---------|---------|---------|---------|-------------|
| 40-49     | 63.1%   | 79.3%   | 78.5%   | 79.3%   | 78.5%   | 77.8%   | 77.2%   | 76.9%   | 76.6%   | <0.001     |
|          | 25.6%   | 34.9%   | 35.1%   | 35.0%   | 34.8%   | 34.6%   | 34.4%   | 34.3%   | 34.3%   | <0.011     |
|          | 22.2%   | 26.9%   | 27.1%   | 27.1%   | 27.0%   | 26.9%   | 26.8%   | 26.8%   | 26.8%   | <0.001     |
|          | 13.3%   | 17.6%   | 17.9%   | 17.7%   | 17.6%   | 17.6%   | 17.6%   | 17.6%   | 17.6%   | <0.001     |
|          | 10.6%   | 14.7%   | 15.0%   | 15.0%   | 15.0%   | 15.0%   | 15.0%   | 15.0%   | 15.0%   | <0.001     |
| 50-59     | 13.3%   | 17.6%   | 17.9%   | 17.7%   | 17.6%   | 17.6%   | 17.6%   | 17.6%   | 17.6%   | <0.001     |
|          | 10.6%   | 14.7%   | 15.0%   | 15.0%   | 15.0%   | 15.0%   | 15.0%   | 15.0%   | 15.0%   | <0.001     |
|          | 13.3%   | 17.6%   | 17.9%   | 17.7%   | 17.6%   | 17.6%   | 17.6%   | 17.6%   | 17.6%   | <0.001     |
|          | 10.6%   | 14.7%   | 15.0%   | 15.0%   | 15.0%   | 15.0%   | 15.0%   | 15.0%   | 15.0%   | <0.001     |
| 60-69     | 13.3%   | 17.6%   | 17.9%   | 17.7%   | 17.6%   | 17.6%   | 17.6%   | 17.6%   | 17.6%   | <0.001     |
|          | 10.6%   | 14.7%   | 15.0%   | 15.0%   | 15.0%   | 15.0%   | 15.0%   | 15.0%   | 15.0%   | <0.001     |
|          | 13.3%   | 17.6%   | 17.9%   | 17.7%   | 17.6%   | 17.6%   | 17.6%   | 17.6%   | 17.6%   | <0.001     |
|          | 10.6%   | 14.7%   | 15.0%   | 15.0%   | 15.0%   | 15.0%   | 15.0%   | 15.0%   | 15.0%   | <0.001     |
| 70-79     | 13.3%   | 17.6%   | 17.9%   | 17.7%   | 17.6%   | 17.6%   | 17.6%   | 17.6%   | 17.6%   | <0.001     |
|          | 10.6%   | 14.7%   | 15.0%   | 15.0%   | 15.0%   | 15.0%   | 15.0%   | 15.0%   | 15.0%   | <0.001     |
|          | 13.3%   | 17.6%   | 17.9%   | 17.7%   | 17.6%   | 17.6%   | 17.6%   | 17.6%   | 17.6%   | <0.001     |
|          | 10.6%   | 14.7%   | 15.0%   | 15.0%   | 15.0%   | 15.0%   | 15.0%   | 15.0%   | 15.0%   | <0.001     |
### Antihypertensive medication use, %

| Age Group | 1963-66 | 1972-75 | 1976-79 | 1980-83 | 1984-87 | 1988-91 | 1992-95 | 1996-99 | 2000-03 | 2004-08 | 2009-13 | **p** for trend |
|-----------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|-----------|
| 40-49     | 14.0%   | 13.0%   | 13.0%   | 13.0%   | 13.0%   | 13.0%   | 13.0%   | 13.0%   | 13.0%   | 13.0%   | 13.0%   | 0.001     |
| 50-59     | 15.0%   | 14.0%   | 14.0%   | 14.0%   | 14.0%   | 14.0%   | 14.0%   | 14.0%   | 14.0%   | 14.0%   | 14.0%   | 0.001     |
| 60-69     | 16.0%   | 15.0%   | 15.0%   | 15.0%   | 15.0%   | 15.0%   | 15.0%   | 15.0%   | 15.0%   | 15.0%   | 15.0%   | 0.001     |
| 70-79     | 17.0%   | 16.0%   | 16.0%   | 16.0%   | 16.0%   | 16.0%   | 16.0%   | 16.0%   | 16.0%   | 16.0%   | 16.0%   | 0.001     |

*Test of differences from the 1963-66 values: \(^p < 0.05\), \(^p < 0.01\), \(^p < 0.001\).*

*Prevalence: the denominator is the participants of each sex- and age-specific group. *Proportion: the denominator is the hypertensive persons of each sex- and age-specific group. *The proportion of controlled hypertension among hypertensive persons aged 40-69 and 50-59 years fluctuated because of the small number of persons who took antihypertensive medication. *Systolic blood pressure ≥ 140 mmHg and/or diastolic blood pressure 90 mmHg and/or antihypertensive medication use.*
from 23.1 kg/m² in 1963–1966 to 25.0 kg/m² in 2000–2003 for women aged 60–69, and thereafter, declined to 24.5 kg/m² for women in 2009–2013 (Table 2 and Fig. 2). When adjusted for BMI as well as age, the declining trend for mean diastolic blood pressure was somewhat enhanced for men aged 40–49 years, but otherwise, no substantial changes were observed (data not shown).

Table 3 and Fig. 3 show the sex- and age-specific prevalence of hypertension with and without obesity for men and women from 1963–1966 to 2009–2013. The prevalence of hypertension with obesity increased from 10.5% in 1963–1966 to 23.1% in 2009–2013 and to 31.7% for women in 2009–2013. The proportion of hypertension controlled under antihypertensive medication among hypertensive persons increased from 5.9% in 1963–1966 to 56.3% in 2009–2013 for men and from 5.0% to 60.2% for women. The prevalence of hypertension declined from 76.9% in 1963–1966 to 60.0% in 2009–2013 for men and from 67.7% to 53.8% for women.

Age-adjusted mean values of BMI and prevalence of obesity increased for men and women of all age groups, except for women aged 40–49 years (Table 2). Mean BMI increased from 22.2 kg/m² in 1963–1966 to 24.0 kg/m² in 2009–2013 for men aged 60–69 and from 23.1 kg/m² in 1963–1966 to 25.0 kg/m² in 2000–2003 for women aged 60–69, and thereafter, declined to 24.5 kg/m² for women in 2009–2013 (Table 2 and Fig. 2). When adjusted for BMI as well as age, the declining trend for mean diastolic blood pressure was somewhat enhanced for men aged 40–49 years, but otherwise, no substantial changes were observed (data not shown).

Table 3 and Fig. 3 show the sex- and age-specific prevalence of hypertension with and without obesity for men and women from 1963–1966 to 2009–2013. The prevalence of hypertension with obesity increased from 10.5% in 1963–1966 to 23.1% in 2009–2013 and to 31.7% for women in 2009–2013. The proportion of hypertension controlled under antihypertensive medication among hypertensive persons increased from 5.9% in 1963–1966 to 56.3% in 2009–2013 for men and from 5.0% to 60.2% for women. The prevalence of hypertension declined from 76.9% in 1963–1966 to 60.0% in 2009–2013 for men and from 67.7% to 53.8% for women.
Table 3. Sex and age-specific prevalence of hypertension with and without obesity from 1963-66 to 2009-13

|                | 1963-66 | 1972-75 | 1976-79 | 1980-83 | 1984-87 | 1988-91 | 1992-95 | 1996-99 | 2000-03 | 2004-08 | 2009-13 | P for trend |
|----------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|------------|
| **Men**        |         |         |         |         |         |         |         |         |         |         |         |            |
| 40-49          |         |         |         |         |         |         |         |         |         |         |         |            |
| Hypertension with obesity, % | 5.3     | 11.0    | 13.8    | 14.8    | 17.1    | 12.9    | 16.4    | 19.8    | 17.8    | 17.5    | 27.0    | <0.001     |
| Hypertension without obesity, % | 42.9    | 39.0    | 31.4    | 27.9    | 25.4    | 25.9    | 19.2    | 24.5    | 31.9    | 26.8    | 19.1    | <0.001     |
| 50-59          |         |         |         |         |         |         |         |         |         |         |         |            |
| Hypertension with obesity, % | 12.3    | 12.5    | 11.7    | 13.3    | 13.3    | 17.5    | 15.5    | 23.5    | 26.2    | 21.8    | 24.6    | <0.001     |
| Hypertension without obesity, % | 49.3    | 52.6    | 43.6    | 43.5    | 38.0    | 32.7    | 35.1    | 24.3    | 30.8    | 27.1    | 28.7    | <0.001     |
| 60-69          |         |         |         |         |         |         |         |         |         |         |         |            |
| Hypertension with obesity, % | 10.5    | 10.8    | 18.6    | 11.6    | 13.8    | 16.3    | 13.3    | 17.5    | 26.2    | 21.6    | 23.1    | <0.001     |
| Hypertension without obesity, % | 65.3    | 68.5    | 57.7    | 56.0    | 48.3    | 50.6    | 50.7    | 40.8    | 38.8    | 36.4    | 37.3    | <0.001     |
| 70-79          |         |         |         |         |         |         |         |         |         |         |         |            |
| Hypertension with obesity, % | 8.7     | 13.3    | 13.3    | 14.2    | 11.9    | 17.5    | 14.8    | 18.7    | 14.3    | 19.9    | 21.1    | <0.001     |
| Hypertension without obesity, % | 78.3    | 73.3    | 73.3    | 67.0    | 65.1    | 57.7    | 51.9    | 52.0    | 50.3    | 43.3    | 44.7    | <0.001     |

| **Women**      |         |         |         |         |         |         |         |         |         |         |         |            |
| 40-49          |         |         |         |         |         |         |         |         |         |         |         |            |
| Hypertension with obesity, % | 7.9     | 13.0    | 11.8    | 11.0    | 11.7    | 12.3    | 12.1    | 12.5    | 10.0    | 10.5    | 10.9    | 0.02       |
| Hypertension without obesity, % | 22.8    | 15.1    | 14.2    | 12.3    | 13.9    | 18.5    | 13.2    | 12.9    | 13.8    | 11.2    | 8.6     | 0.02       |
| 50-59          |         |         |         |         |         |         |         |         |         |         |         |            |
| Hypertension with obesity, % | 14.2    | 24.8    | 23.0    | 23.5    | 22.4    | 20.9    | 17.9    | 23.1    | 20.6    | 19.4    | 13.6    | 0.001      |
| Hypertension without obesity, % | 36.4    | 27.8    | 22.5    | 23.5    | 24.6    | 24.1    | 22.0    | 16.1    | 22.0    | 17.5    | 15.5    | 0.001      |
| 60-69          |         |         |         |         |         |         |         |         |         |         |         |            |
| Hypertension with obesity, % | 18.8    | 24.7    | 33.3    | 29.5    | 29.0    | 28.6    | 24.7    | 28.9    | 30.8    | 25.1    | 25.0    | <0.001     |
| Hypertension without obesity, % | 47.3    | 43.2    | 29.7    | 32.1    | 32.2    | 31.3    | 32.0    | 27.3    | 30.3    | 27.6    | 28.7    | <0.001     |
| 70-79          |         |         |         |         |         |         |         |         |         |         |         |            |
| Hypertension with obesity, % | 15.6    | 32.6    | 31.9    | 26.8    | 28.5    | 37.2    | 29.4    | 30.6    | 31.7    | 34.9    | 32.3    | 0.003      |
| Hypertension without obesity, % | 60.9    | 56.2    | 52.1    | 48.6    | 47.5    | 41.4    | 36.1    | 37.4    | 35.5    | 39.9    | 40.2    | 0.003      |

*Test of differences from the 1963-66 values: *p < 0.05 , **p < 0.01 , ***p < 0.001

Fig. 3. Trends in the prevalence of hypertension with and without obesity for men and women aged 60–69 years between 1963–1966 and 2009–2013

Hypertension is shown as colored, and non-hypertension is shown as dotted.
for men aged 60–69 years and from 18.8% to 25.0% for women aged 60–69 years. The corresponding prevalence of hypertension without obesity for ages 60–69 years decreased from 65.3% to 37.3% for men and from 47.3% to 28.7% for women, but it was mostly higher than that of hypertension with obesity over time.

**Discussion**

The present study showed a substantial and consistent decline in systolic blood pressure levels, while BMI levels increased and correspondingly prevalence of hypertension with obesity increased over the past 50 years for both men and women in a Japanese rural community. The prevalence of hypertension with obesity increased for both sexes of all age groups, but the prevalence of hypertension without obesity still overwhelmed that with obesity for men and women aged 60–69 years and other age groups except for ages of 40–49 years in 2009–2013. The previous study using Japanese national data showed that the prevalence of obesity increased in men and remained stable in women, and the odd ratio of hypertension associated with obesity increased from 1.94 in 1980 to 2.82 in 2010 for men and from 2.37 to 3.48 for women. In that study population aged 30–79 years, the PAF increased from 14.6% in 1980 to 39.3% in 2010 for men, and from 23.9% to 34.8% for women. The PAF estimated in the present study population aged 40–79 years was 12.6% in 1980–1983 and 24.4% in 2009–2013 for men, and 36.7% and 40.1% for women. Although hypertension attributable to obesity increased overtime, there remained a large fraction of hypertension attributable to non-obesity.

Long-term blood pressure trends were reported from Japanese, Finnish, and US studies. According to the National Health and Nutrition Survey in Japan, mean systolic and diastolic blood pressures for men and women aged 60–69 years declined between 1961 and 2010. Mean BMI increased from 22.0 kg/m² in 1976–1980 to 23.7 kg/m² in 2011 for men aged 60–69 years, whereas for women, it did not change: 23.0 kg/m² and 22.9 kg/m² for 1976–1980 and 2011, respectively. As shown in Supplementary Fig. 1, the prevalence of obesity increased from 16.0% in 1976–1980 to 31.0% in 2011 for men aged 60–69 years, but it decreased from 27.2% to 24.0% for women.

A 35-year population survey in the province of North Karelia in Finland showed that both mean systolic and diastolic blood pressure levels for men and women aged 30–59 years declined between 1972 and 2002, but plateaued between 2002 and 2007. For men, mean BMI continuously increased from 26.0 kg/m² in 1972 to 27.1 kg/m² in 2002 and to 27.4 kg/m² in 2007, whereas for women, it did not change: 26.8, 26.8, and 26.6 kg/m² for 1972, 2002, and 2007, respectively. As shown in Supplementary Fig. 1, the corresponding prevalence of obesity was 57%, 68%, and 70% for men, and 61%, 54%, and 54% for women.

The National Health and Nutrition Examination Survey (NHANES) in the United States indicated that mean systolic and diastolic blood pressure for individuals aged 18–74 years decreased between 1960–1962 and 2001–2008 (age ≥ 18 in 2001–2008) for men and women. As shown in Supplementary Fig. 1, the prevalence of obesity increased from 50% in 1960–1962 to 61% in 1988–1994 and to 73% in 2009–2012 for men, and from 40% to 51% and to 65%, respectively, for women.

The declining trend in systolic blood pressure levels were commonly observed among men and women of Japanese, Finnish, and US samples. The improvement of hypertension treatment and the reduction of salt consumption may have favored the change in blood pressure in these countries. Other dietary factors which contributed to the systolic blood pressure decline for Japanese may include increased intakes of fresh fruits, vegetables, and dairy products. The prevalence of obesity was much lower in Japanese than in Finnish and Americans (Supplementary Fig. 1). Globally, people in countries of east, southeast, and south Asia and central Africa are less obese and have high risk of mortality from stroke. Lean hypertensives had the greater risk of mortality from cardiovascular disease than obese hypertensives. Therefore, the prevention and control for hypertension may be also important in countries with less obese populations.

The strengths of this study are its investigation of long-term time trends and the high response rates among men and women aged 60–69 years in addition to among men aged 70–79 years and women aged 50–59 years. To the best of our knowledge, no other population-based study has been conducted to investigate long-term trends for the relations between blood pressures and BMI.

The limitations of the study warrant discussion. First, we did not have individual information on salt intake, which is a major determinant of blood pressure levels. According to our nutrition survey of a subsample of the present study, mean salt intake decreased from 20 g/day in the 1960s to 14 g/day in the 1980s for men aged 40–59 years. The large decline in the prevalence of hypertension without obesity may be partly explained by this reduction in salt intake,
although this was not directly shown here because of the subsample nutrition survey. Second, this study was performed in one rural community in Japan, and the participation rates were not high enough for men aged 40–59 years, nor for women aged 40–49 years in the 1990’s and thereafter. Therefore, caution should be taken in applying our findings to other Japanese populations. However, comparing our results with Japanese national survey (National Health and Nutrition Survey), we found similar trends in blood pressure levels in the general Japanese population, although the prevalence of obesity among women was higher by 5 to 23 point in the present study than in the national sample. Third, because we used the first reading of blood pressure measurement to analyze the data consistently through 50 years, blood pressure levels may be overestimated compared with usual values. However, when we used the second reading, if the first reading was high, the prevalence of hypertension did not change materially; the difference = −0.3% to 0.0%. Lastly, hypertensive persons can move from non-obese in one survey to obese in another or vice versa. However, the percentage for the shift to the other category between one to the next periods was small (approximately 5%).

In conclusion, we found a substantial decline in blood pressure levels over the past 50 years for both men and women aged 40–79 years in a Japanese rural community. The prevalence of hypertension without obesity declined and that with obesity increased along with increased BMI levels. In spite of the transition for increased BMI levels, the targeting for non-obese hypertension remained important in addition to the targeting for obese hypertension in order to control of hypertension. Our findings may be applicable to other countries where the prevalence of hypertension is high and that of obesity is low.

Acknowledgments

The authors thank professors emeriti Yoshio Komachi and Takashi Shimamoto, of the University of Tsukuba, and Professor David R. Jacobs Jr. of the University of Minnesota for their valuable comments on this study. We also thank Ms Flaminia Miyamasu, University of Tsukuba, for editorial assistance. The full list of CIRCS investigators is presented in reference 17).

Funding Sources

This work was supported by a grant-in-aid for scientific research A [no. 22249022, 2010-2013] and B [no. 22249022, 2010-2013] from the Japan Society for the Promotion of Science and sciences research grant [Research on Cardiovascular Diseases H24-018, 2012] from the Ministry of Health, Labour and Welfare of Japan.

Conflict of Interest

None declared.

References

1) World Health Organization: Global status report on non-communicable diseases 2010. World health Organization. Geneva; 2011
2) Danaei G, Finucane MM, Lin JK, Singh GM, Paciorek CJ, Cowan MJ, Farzadfar F, Stevens GA, Lim SS, Riley LM, Ezzati M; Global Burden of Metabolic Risk Factors of Chronic Diseases Collaborating Group (Blood Pressure): National, regional, and global trends in systolic blood pressure since 1980: systematic analysis of health examination surveys and epidemiological studies with 786 country-years and 5·4 million participants. Lancet, 2011; 377: 568-577
3) Shimamoto T, Komachi Y, Inada H, Doi M, Iso H, Sato S, Kitamura A, Iida M, Konishi M, Nakanishi N, Terao A, Naito Y, Koijima S: Trends for coronary heart disease and stroke and their risk factors in Japan. Circulation, 1989; 79: 503-515
4) Kannel WB, Wolf PA, Verter J, McNamara PM: Epidemiologic assessment of the role of blood pressure in stroke: the Framingham Study. 1970. JAMA, 1996; 276: 1269-1278
5) Lawes CM, Bennett DA, Lewington S, Rodgers A: Blood pressure and coronary heart disease: a review of the evidence. Semin Vasc Med, 2002; 2: 355-368
6) Martiniuk AL, Lee CM, Lawes CM, Ueshima H, Suh I, Lam TH, Gu D, Feigin V, Jamrozik K, Okhubo T, Woodward M; Asia-Pacific Cohort Studies Collaboration: Hypertension: its prevalence and population-attributable fraction for mortality from cardiovascular disease in the Asia-Pacific region. J Hypertens, 2007; 25: 73-79
7) Finucane MM, Stevens GA, Cowan MJ, Danaei G, Lin JK, Paciorek CJ, Singh GM, Gutierrez HR, Lu Y, Bahalim AN, Farzadfar F, Riley LM, Ezzati M; Global Burden of Metabolic Risk Factors of Chronic Diseases Collaborating Group (Body Mass Index): National, regional, and global trends in body-mass index since 1980: systematic analysis of health examination surveys and epidemiological studies with 960 country-years and 9.1 million participants. Lancet, 2011; 377: 557-567
8) Ni Mhurchu C, Rodgers A, Pan WH, Gu DF, Woodward M; Asia Pacific Cohort Studies Collaboration: Body mass index and cardiovascular disease in the Asia-Pacific Region: an overview of 33 cohorts involving 310 000 participants. Int J Epidemiol, 2004; 33: 751-758
9) Prospective Studies Collaboration: Body-mass index and cause-specific mortality in 900 000 adults: collaborative analyses of 57 prospective studies. Lancet, 2009; 373: 1083-1096
10) Rahmouni K: Obesity-Associated Hypertension: Recent
Progress in Deciphering the Pathogenesis. Hypertension, 2014; 64: 215-221
11) Poirier P, Lemieux I, Maurière P, Dewailly E, Blanchet C, Bergeron J, Després JP: Impact of waist circumference on the relationship between blood pressure and insulin: the Quebec Health Survey. Hypertension, 2005; 45: 363-367
12) Kim DH, Kim C, Ding EL, Townsend MK, Lipsitz LA: Adiponectin levels and the risk of hypertension: a systematic review and meta-analysis. Hypertension, 2013; 62: 27-32
13) Bjorntorp P: Obesity and adipose tissue distribution as risk factors for the development of disease: a review. Infusionstherapie, 1990; 17: 24-27
14) Tshihour PV, Larkin EK, Schluter MD, Redline S: Incidence of sleep-disordered breathing in an urban adult population: the relative importance of risk factors in the development of sleep-disordered breathing. JAMA, 2003; 289: 2230-2237
15) Iso H, Shimamoto T, Naito Y, Sato S, Kitamura A, Iida M, Konishi M, Jacobs DR Jr, Komachi Y: Effects of a long-term hypertension control program on stroke incidence and prevalence in a rural community in northeastern Japan. Stroke, 1998; 29: 1510-1518
16) Kitamura A, Sato S, Kiyama M, Imano H, Iso H, Okada T, Ohira T, Tanigawa T, Yamagishi K, Nakamura M, Konishi M, Shimamoto T, Iida M, Komachi Y: Trends in the incidence of coronary heart disease and stroke and their risk factors in Japan, 1964 to 2003: the Akita-Osaka study. J Am Coll Cardiol, 2008; 52: 71-79
17) Imano H, Iso H, Kiyama M, Yamagishi K, Ohira T, Sato S, Noda H, Maeda K, Okada T, Tanigawa T, Kitamura A; CIRCS Investigators: Non-fasting blood glucose and risk of incident coronary heart disease in middle-aged general population: the Circulatory Risk in Communities Study (CIRCS). Prev Med, 2012; 50: 603-607
18) Jacobs DR Jr, Hannon PJ, Wallace D, Liu K, Williams OD, Lewis CE: Interpreting age, period and cohort effects in plasma lipids and serum insulin using repeated measures regression analysis: the CARDIA Study. Stat Med, 1999; 18: 655-679
19) Nagai M, Ohkubo T, Murakami Y, Takashima N, Kadota A, Miyagawa N, Saito Y, Nishi N, Okuda N, Kiyohara Y, Nakagawa H, Nakamura Y, Fujiyoshi A, Abbott RD, Okamura T, Okayama A, Ueshima H, Miura K, NIPDOS DATA80/90/2010 Research Group: Secular trends of the impact of overweight and obesity on hypertension in Japan, 1980-2010. Hypertens Res, 2015; 38: 790-795
20) Rockhill B, Newman B, Weinberg C: Use and misuse of population attributable fractions. Am J Public Health, 1998; 88: 15-19
21) Ikeda N, Gakidou E, Hasegawa T, Murray CJ: Understanding the decline of mean systolic blood pressure in Japan: an analysis of pooled data from the National Nutrition Survey, 1986-2002. Bull World Health Organ, 2008; 86: 978-988
22) Miura K, Nagai M, Ohkubo T: Epidemiology of hypertension in Japan: where are we now? Circ J, 2013; 77: 2226-2231
23) Yoshiike N, Seino F, Tajima S, Arai Y, Kawano M, Furuhata T, Inoue S: Twenty-year changes in the prevalence of overweight in Japanese adults: the National Nutrition Survey 1976-95. Obes Rev, 2002; 3: 183-190
24) Vartiainen E, Laakikainen T, Peltonen M, Juelo M, Männistö S, Sundvall J, Jousilahti P, Salomaa V, Valsta L, Puska P: Thirty-five-year trends in cardiovascular risk factors in Finland. Int J Epidemiol, 2010; 39: 504-518
25) Puska P, Vartiainen E, Laakikainen T, Jousilahti P, Paavola M, editors: The North Karelia Project: from North Karelia to national action. Helsinki: Helsinki University Press; 2009
26) Burt VL, Cutler JA, Higgins M, Horan MJ, Labarthe D, Whelton P, Brown C, Roccella EJ: Trends in the prevalence, awareness, treatment, and control of hypertension in the adult US population: Data from the health examination surveys, 1960 to 1991. Hypertension, 1995; 26: 60-69
27) Wright JD, Hughes JP, Ostchega Y, Yoon SS, Nwankwo T: Mean systolic and diastolic blood pressure in adults aged 18 and over in the United States, 2001-2008. Natl Health Stat Report, 2011; 35: 1-22
28) National Center for Health Statistics: Health, United States, 2013: With Special Feature on Prescription Drugs. Hyattsville, MD. 2014
29) Chan Q, Stamlar J, Griep LM, Davilugus ML, Horn LV, Elliott P: An Update on Nutrients and Blood Pressure. J Atheroscler Thromb, 2016; 23: 276-289
30) Ministry of Health, Labour and Welfare: National Health and Nutrition survey in Japan. Internet: http://www.mhlw.go.jp/bunya/kenkou/kenkou_eiyou_chousa.html (in Japanese, accessed 9 August 2016)
31) Ng M, Fleming T, Robinson M, Thomson B, Graetz N, Margono C, Mullany EC, Biryukov S, Ababati C, Ahera SF, Abraham JP, Abu-Rmeileh NM, Achoki T, AlBuHahiran FS, Alemu ZA, Alfonso R, Ali MK, Ali R, Gutzman NA, Ammar W, Anwari P, Banerjee A, Barquera S, Basu S, Bennett DA, Bhutta Z, Blore J, Cabral N, Nonato IC, Chang JC, Chowdhury R, Courville KJ, Criqui MH, Cundiff DK, Dhabhadkar KC, Dandonoa L, Davis A, Dayama A, Dharmaratne SD, Ding EL, Durrani AM, Esteeghamati A, Farzadfar F, Fay DF, Feigin VL, Flaxman A, Forouzanfar MH, Goto A, Green MA, Gupta R, Hafiez-Nejad N, Hankey GJ, Harewood HC, Havmoeller R, Hay S, Hernandez L, Hussein A, Idrisov BT, Ikeda N, Ismaili F, Jahangir E, Jassal SK, Jee SH, Jeffreys M, Jonas JB, Kabagambe EK, Kalifa SE, Kengne AP, Khader YS, Khang YH, Kim D, Kimokoti RW, King JM, Kubo Y, Kosen S, Kwan G, Lai T, Leinsalu M, Li Y, Liang X, Liu S, Logroscino G, Lotufo PA, Lu Y, Ma J, Mainoo NK, Men-sah GA, Merriman TR, Mokdad AH, Moschandreas J, Naghavi M, Naheed A, Nand D, Narayan KM, Nelson EL, Neuhouser ML, Nisar MI, Ohkubo T, Oti SO, Pedroza A, Prabhakaran D, Roy N, Sampson U, Seo H, Sepanlou SG, Shibuya K, Shiri R, Shiue I, Singh GM, Singh JA, Skirbekk V, Stapelberg NJ, Sturua L, Sykes BL, Tobias M, Tran BX, Trasande L, Toyoshima H, van de Vijver S, Vasankari TJ, Veerman JL, Velasquez-Melendez G, Vlassov VV, Vollset SE, Yoon J, Yoon SJ, Zhao Y, Zhou S, Lopez AD, Murray CJ, Gakidou E: Global, regional, and national prevalence of overweight and obesity in children and adults during 1980-2013: a systematic analysis for the
Global Burden of Disease Study 2013. Lancet, 2014; 384: 766-781

32) Kim AS, Johnston SC: Global variation in the relative burden of stroke and ischemic heart disease. Circulation, 2011; 124: 314-323

33) Carman WJ, Barrett-Connor E, Sowers M, Khaw KT: Higher risk of cardiovascular mortality among lean hypertensive individuals in Tecumseh, Michigan. Circulation, 1994; 89: 703-711

34) Irie F, Iso H, Noda H, Sairenchi T, Otaka E, Yamagishi K, Doi M, Izumi Y, Ota H: Associations between metabolic syndrome and mortality from cardiovascular disease in Japanese general population, findings on overweight and non-overweight individuals. Ibaraki Prefectural Health Study. Circ J, 2009; 73: 1635-1642
**Supplementary References**

1) Vartiainen E, Laatikainen T, Peltonen M, Juolevi A, Mannistö S, Sundvall J, Jousilahti P, Salomaa V, Valsta L, Puska P: Thirty-five-year trends in cardiovascular risk factors in Finland. Int J Epidemiol, 2010; 39: 504-518

2) National Center for Health Statistics: Health, United States, 2013: With Special Feature on Prescription Drugs. Hyattsville, MD. 2014

3) Yoshiike N, Seino F, Tajima S, Arai Y, Kawano M, Furu-hata T, Inoue S: Twenty-year changes in the prevalence of overweight in Japanese adults: the National Nutrition Survey 1976-95. Obes Rev, 2002; 3: 183-190