

## ORIGINAL ARTICLE

# Secular trends of the impact of overweight and obesity on hypertension in Japan, 1980–2010

This article has been corrected since Advance Online Publication, and an erratum is also printed in this issue.

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The prevalence of overweight (body mass index (BMI) = 25.0–29.9 kg m<sup>-2</sup>) and obesity ( $\geq 30.0$  kg m<sup>-2</sup>) has been increasing over the last several decades in Japan. We examined trends of the impact of overweight and obesity on hypertension (systolic/diastolic blood pressure  $\geq 140/90$  mm Hg or antihypertensive drugs use) using four national surveys in Japan, from which the participants were randomly sampled from the entire population. Study participants aged 30–79 years were selected for each survey (10 370 in 1980, 8005 in 1990, 5327 in 2000 and 2547 in 2010). The results showed that the impact of overweight and obesity on hypertension had increased significantly ( $P=0.040$  and  $0.006$  in men and women, respectively). From 1980 to 2010, the multivariable-adjusted odds ratios for hypertension, comparing overweight and obesity with normal weight (BMI = 18.5–24.9 kg m<sup>-2</sup>), went from 1.94 (95% confidence intervals: 1.64, 2.28) to 2.82 (2.07, 3.83) in men, and from 2.37 (2.05, 2.73) to 3.48 (2.57, 4.72) in women. Most of the association was observed in overweight participants, as only 3% of the Japanese were obese. In addition to the relationship between excessive BMI and other adverse health conditions, the rise in the association with hypertension increases the urgency in addressing weight control. We need to address the overweight and obesity epidemic. *Hypertension Research* (2015) 38, 790–795; doi:10.1038/hr.2015.81; published online 16 July 2015

**Keywords:** epidemiology; Japan; obesity; overweight; trend

## INTRODUCTION

Cardiovascular disease mortality, especially stroke mortality, has decreased dramatically during the last several decades in Japan.<sup>1</sup> This tendency has been attributed to a decrease in the population's blood pressure level.<sup>1–3</sup> A major reason for this blood pressure decrease is considered to be the reduction in salt intake. In northern Japan, salt intake had reached 25 g per day in the 1950s.<sup>4</sup> However, it had decreased to 10.5 g per day in 2011.<sup>5</sup> In addition, the prevalence of overweight and obesity, which is another determinant of hypertension, has increased.<sup>3,5–7</sup> Particularly in men, this prevalence has almost doubled during the last several decades. Even though the trend in blood pressure level has decreased,<sup>1–3</sup> the prevalence of determinants of hypertension has changed.<sup>8,9</sup> The impact of each determinant on hypertension may also

have changed. For instance, Nakamura *et al.*<sup>10</sup> showed that the impact of overweight and obesity on hypertension had increased between 1980 and 1990. However, recent long-term trends on the impact of overweight and obesity on hypertension have not been studied.

In the present study, we examined long-term secular changes on the impact of overweight and obesity on hypertension using data from four national surveys during the last 30 years in Japan.

## METHODS

### Study participants

The National Integrated Project for Prospective Observation of Non-communicable Disease and Its Trends in the Aged (NIPPON DATA) is a series of cohort studies conducted using the third National Survey on Circulatory

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**Table 1** Characteristics of participants who were recruited from national survey in 1980–2010, Japan

	Years				P-values <sup>a</sup>
	1980	1990	2000	2010	
<i>Men</i>					
Number of participants	4568	3357	2188	1081	
Number of hypertension <sup>b</sup> (%)	2285 (50.0)	1664 (49.6)	1201 (54.9)	655 (60.6)	
Mean age (years) (s.d.)	49.9 (12.8)	52.4 (12.9)	55.9 (12.9)	59.8 (12.8)	<0.001
Mean BMI (kg m <sup>-2</sup> ) (s.d.)	22.5 (2.9)	23.0 (3.0)	23.6 (3.1)	24.0 (3.2)	<0.001
Underweight (%)	6.5	5.6	3.7	2.5	<0.001
Normal weight (%)	74.5	69.9	66.2	62.5	
Overweight and obesity (%)	19.1	24.6	30.1	35.0	
<i>Smoking status (%)</i>					
Never smoker	17.9	20.9	26.4	26.8	<0.001
Past smoker	18.6	23.4	27.6	43.1	
Current smoker	63.5	55.8	46.0	30.1	
<i>Alcohol drinking (%)</i>					
Nonhabitual drinker	19.7	34.6	35.9	57.3	<0.001
Past drinker	5.5	6.7	9.2	3.1	
Habitual drinker	74.8	58.7	54.9	39.7	
Salt intake <sup>c</sup> (g per day)	15.1 (5.6)	14.7 (4.6)	14.5 (5.9)	12.0 (4.6)	<0.001
SBP (mm Hg) (s.d.)	138.0 (20.9)	137.4 (19.9)	137.9 (19.7)	137.7 (18.4)	0.552
DBP (mm Hg) (s.d.)	83.6 (12.4)	83.6 (11.6)	83.3 (11.9)	83.3 (11.0)	0.652
Antihypertensive drug use	10.1	13.7	20.1	30.8	<0.001
<i>Women</i>					
Number of participants	5803	4648	3139	1466	
Number of hypertension (%)	2346 (40.4)	1975 (42.5)	1353 (43.1)	657 (44.8)	
Mean age (years) (s.d.)	50.0 (12.9)	51.7 (13.1)	54.3 (13.1)	57.7 (13.7)	<0.001
Mean BMI (kg m <sup>-2</sup> ) (s.d.)	22.8 (3.4)	22.9 (3.3)	23.0 (3.5)	22.8 (3.5)	0.082
Underweight (%)	7.2	6.5	7.0	7.6	0.200
Normal weight (%)	70.1	69.4	68.2	69.2	
Overweight and obesity (%)	22.7	24.2	24.8	23.2	
<i>Smoking status (%)</i>					
Never smoker	87.8	87.7	87.0	84.0	<0.001
Past smoker	2.4	2.7	2.7	9.0	
Current smoker	9.8	9.6	10.4	7.0	
<i>Alcohol drinking (%)</i>					
Nonhabitual drinker	77.9	92.2	89.4	92.1	<0.001
Past drinker	1.7	1.1	1.5	1.4	
Habitual drinker	20.5	6.7	9.1	6.6	
Salt intake (g per day)	13.0 (4.7)	12.8 (4.0)	12.6 (5.1)	10.4 (4.1)	<0.001
SBP (mm Hg) (s.d.)	133.5 (21.5)	133.0 (20.5)	132.2 (21.7)	130.8 (19.8)	<0.001
DBP (mm Hg) (s.d.)	79.6 (12.0)	79.5 (11.7)	78.9 (12.3)	78.3 (10.8)	<0.001
Antihypertensive drug use	11.6	15.9	18.8	23.0	<0.001

Abbreviations: BMI, body mass index; DBP, diastolic blood pressure; SBP, systolic blood pressure; s.d., standard deviation.

<sup>a</sup>P-values were calculated by chi-squared test (categorical variables), or analysis of variance (continuous variables).<sup>b</sup>Hypertension was defined as a systolic blood pressure  $\geq 140$  mm Hg, diastolic blood pressure  $\geq 90$  mm Hg or the use of antihypertensive drugs.<sup>c</sup>Salt intake was estimated by the weighing record method for three consecutive days.

Disorders in 1980,<sup>11–13</sup> the fourth National Survey on Circulatory Disorders in 1990,<sup>14–16</sup> and the National Health and Nutrition Survey in 2010.<sup>17</sup> We also used data from the fifth National Survey on Circulatory Disorders in 2000.<sup>18</sup> Community-based participants in 300 census tracts were randomly selected from health districts throughout Japan for all surveys. Medical examinations, blood pressure measurements, blood tests and a self-administered questionnaire about lifestyle were conducted among 10 546 participants aged  $\geq 30$  years in 1980, 8383 participants aged  $\geq 30$  years in 1990, 5565 participants aged  $\geq 30$  years in 2000 and 2898 participants aged  $\geq 20$  years in 2010.

For the current analysis, we excluded participants without data on body mass index (BMI; 1980: 2 participants, 1990: 122 participants, 2000: 5 participants and 2010: 10 participants) and participants who were aged  $< 30$  years or  $\geq 80$  years (1980: 173 participants, 1990: 256 participants, 2000: 233 participants and

2010: 341 participants). Consequently, a final total of 10 371 participants (men: 4568, women: 5803) in 1980, 8005 participants (men: 3357, women: 4648) in 1990, 5327 participants (men: 2188, women: 3139) in 2000 and 2547 participants (men: 1081, women: 1466) in 2010 were included in the study analysis.

The study protocol was approved by the Review Board of Shiga University of Medical Science.

### Body mass index

BMI was calculated as measured weight divided by the square of measured height (kg m<sup>-2</sup>). We divided the participants into groups according to the following BMI categories:  $< 18.5$  (underweight), 18.5–24.9 (normal weight) and  $\geq 25.0$  kg m<sup>-2</sup> (overweight and obese).<sup>19</sup> In Japan, the prevalence of a BMI  $\geq 30$  kg m<sup>-2</sup> is only 3%.<sup>20</sup>

## Blood pressure

Blood pressures were measured once in 1980 and 1990 and twice in 2000 and 2010 by trained observers using a standard mercury sphygmomanometer on the right arm of seated participants after being at rest for >5 min.<sup>18</sup> We used the first blood pressure values in 2000 and 2010 to ensure comparability between periods. Information on the use of antihypertensive drugs was obtained by public health nurses. Hypertension was defined as a systolic blood pressure  $\geq 140$  mm Hg, diastolic blood pressure  $\geq 90$  mm Hg or the use of antihypertensive drugs.<sup>21</sup>

## Statistical analysis

The age-standardized prevalences of overweight and obesity and of hypertension in men and women were calculated by the direct method using the Japanese population aged  $\geq 30$  years from the 2010 census.<sup>22</sup> Five-year age groups (30–34, 35–39, 40–44, 45–49, 50–54, 55–59, 60–64, 65–69, 70–74 and 75–79 years) were used for this standardization. We also calculated the age-standardized prevalence of hypertension among participants, stratified by normal weight, or overweight and obesity.

The odds ratios (ORs) and 95% confidence intervals for hypertension were compared for overweight and obese participants with normal-weight participants. These statistics were calculated by multiple logistic regression analyses after adjusting for age (continuous), smoking status (never smoker, past smoker and current smoker), alcohol consumption (nonhabitual drinker, past drinker and habitual drinker) and salt intake (g per day) in each period. A habitual drinker was defined as one drink  $\geq 3$  days per week and consuming  $\geq 22.4$  g per day of alcohol. Salt intake was estimated by the weighed food record method for three consecutive days.<sup>23</sup> The trend of ORs during periods was assessed using linear regression weighted by the inverse of the variance of ORs in each year.<sup>24</sup>

The data were analyzed with SAS Release 9.4 software (SAS Institute, Cary, NC, USA). All *P*-values were two-tailed, and differences at *P*<0.05 were accepted as statistically significant.

## RESULTS

### Characteristics in 1980, 1990, 2000 and 2010

The characteristics of the study participants are shown for each year (Table 1). In both sexes, increasing trends of mean age and antihypertensive drug use were observed, as was a decreasing trend in salt intake over the three decades. An increasing trend of mean BMI and a decreasing trend of the proportion of current smokers and habitual drinkers was also observed in men. The proportion percentage of those who had never smoked and those who were habitual

drinkers was the highest in 1980. A decreasing trend in mean blood pressure level was observed in women.

### Age-standardized prevalence of obesity and hypertension

The age-standardized prevalences of overweight and obesity and of hypertension are shown in each period among men and women (Figure 1). Even though the age-standardized prevalence of overweight and obesity have apparently increased in men and remained stable in women during this 30-year period, hypertension has apparently decreased in both sexes. The age-standardized prevalence of overweight and obesity increased by 17.4% points (1980: 18.2%, 2010: 35.6%) in men and decreased by 1.4% points (1980: 22.9%, 2010: 21.5%) in women. Hypertension also decreased by 4.1% points (1980: 54.2%, 2010: 50.1%) in men and by 9.6% points (1980: 47.4%, 2010: 37.8%) in women.

However, compared with normal-weight participants, the reduction of age-standardized prevalence of hypertension from 1980 to 2010 was 8.0% points less in men and 7.8% points less in women among overweight and obese participants (Figure 2). In normal-weight participants, the corresponding rates decreased by 9.7% points in men (1980: 52.8%, 2010: 43.1%) and by 11.0% points in women (1980: 44.9%, 2010: 33.9%) over 30 years. In overweight and obese participants, these rates decreased by 1.7% points in men (1980: 65.0%, 2010: 63.3%) and by 3.2% points in women (1980: 59.8%, 2010: 56.6%).

### Hypertension risk by obesity

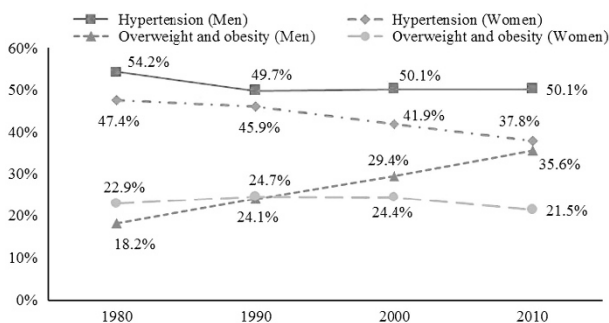
The ORs (95% confidence intervals) for hypertension in overweight and obese participants compared with normal-weight participants are shown for each period from 1980 to 2010 (Figure 3). We observed an ~1.5-fold significantly increased impact of overweight and obesity on hypertension during this time period (*P*=0.040 in men and 0.006 in women). The multivariable-adjusted ORs in women were higher than those in men in each period. In 1980 and 2010, the multivariable-adjusted ORs (95% confidence intervals) were 1.94 (1.64, 2.28) and 2.82 (2.07, 3.83) in men, and 2.37 (2.05, 2.73) and 3.48 (2.57, 4.72) in women.

## DISCUSSION

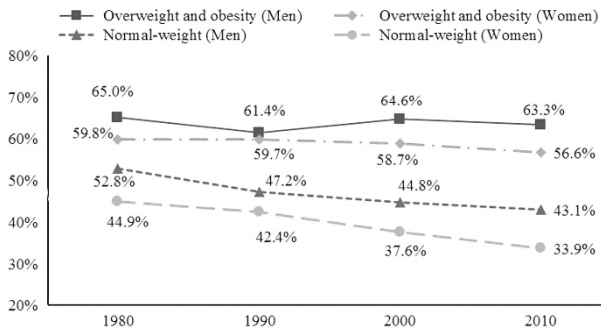
The present results indicate that although the secular trend of prevalence of hypertension decreased in Japanese participants during a 30-year period, overweight and obesity increased in men and remained stable among women recruited nationally. The overweight and obesity risk on hypertension increased significantly, ~1.5-fold between 1980 and 2010. Currently, the impact of overweight and obesity on hypertension is stronger than that in previous decades.

Our previous report showed that the impact of overweight and obesity on hypertension had increased between 1980 and 1990.<sup>10</sup> The present report showed that the impact of overweight and obesity on hypertension has continued to increase over the past 30 years.

However, even though the impact of overweight and obesity on hypertension has increased, the prevalence of hypertension has decreased in Japan. Similar trends of a decreasing prevalence of hypertension and increasing prevalence of obesity have been observed in other Western countries.<sup>25–28</sup> This discrepancy might be caused by the decreasing prevalence of other determinants for hypertension.<sup>8,9</sup> For example, in Japan, even though the difference in age during the survey years was not adjusted for, the amount of salt intake estimated by the weighed food record method for 3 consecutive days, which is the major determinant of hypertension, has decreased by 2.3 g per day during this period (1980: 12.5 g per day, 2010: 10.2 g per day).<sup>17,29</sup> Systolic blood pressure has decreased 1–4 mm Hg with a 3 g per day decrease in salt intake.<sup>30,31</sup> Similarly, vegetable intake has increased as



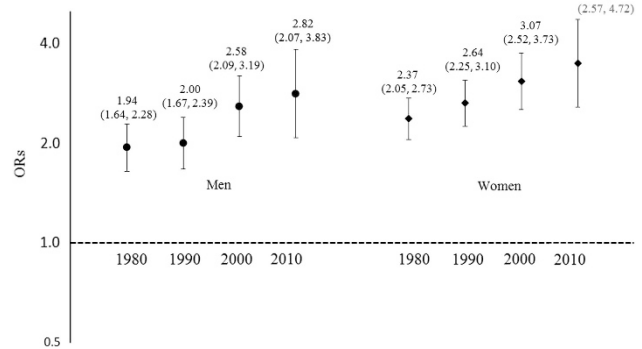
**Figure 1** Age-standardized prevalence of hypertension and of overweight and obesity in participants who were recruited from national surveys in 1980, 1990, 2000 and 2010, Japan. Age-standardized prevalence of hypertension, overweight and obesity was calculated by the direct method using the Japanese population aged  $\geq 30$  years from the 2010 census in each year. Hypertension was defined as a systolic blood pressure  $\geq 140$  mm Hg, diastolic blood pressure  $\geq 90$  mm Hg or the use of antihypertensive drugs. Overweight and obesity were defined as BMI  $\geq 25.0$  kg m<sup>-2</sup>. A full color version of this figure is available at *Hypertension Research* online.



**Figure 2** Age-standardized prevalence of hypertension stratified by normal weight, and overweight and obesity in participants who were recruited from national surveys in 1980, 1990, 2000 and 2010, Japan. Age-standardized prevalence of hypertension was calculated by the direct method using the Japanese population aged  $\geq 30$  years from the 2010 census in each year. Hypertension was defined as a systolic blood pressure  $\geq 140$  mm Hg, diastolic blood pressure  $\geq 90$  mm Hg, or the use of antihypertensive drugs. Normal weight and obesity were defined as BMI = 18.5–24.9 and  $\geq 25.0$  kg m<sup>-2</sup>, respectively. A full color version of this figure is available at *Hypertension Research* online.

well (1980: 243.3 g per day, 2010: 267.9 g per day).<sup>17,29</sup> Conversely, the prevalence of habitual alcohol consumption has decreased.<sup>17</sup> The intake of vegetables and alcohol is an important determinant for hypertension.<sup>30</sup> For these reasons, we considered whether the impact of overweight and obesity on hypertension has strengthened relatively rather than absolutely during the past 30 years. Thus, whereas the prevalence of hypertension has been decreasing, it may increase again in the future. In Japan, the prevalence of hypertension did not decrease during the last decade in men aged  $\geq 50$  years, likely due to the increasing trend in overweight and obesity.<sup>2</sup>

A major strength of our study is that study participants were recruited from 300 community-based census tracts, which were randomly selected from all over Japan. Height, weight and blood pressure were measured by standardized methods in each national survey over a 30-year period. In addition, we adjusted for salt intake in a statistical model. Such a study is impossible to conduct in other Asian countries, because they do not have comparable long-term mature nutritional data in their national data. However, limitations of our study should also be considered. First, the present study was based on cross-sectional studies at each previous time period. Some overweight- and obesity-related hypertensive participants may be categorized as normal weight because they tried to lose weight. As a result, there is a possibility that the present results underestimate the impact of overweight and obesity on hypertension. However, we consider the impact of this misclassification on the present results as minimal because blood pressure levels also may have decreased following a body weight reduction among the participants with obesity-related hypertension. Second, the number of participants has decreased in national surveys. It is possible that comparability between each national survey has not been preserved because of selection bias. Third, we could not estimate the impact on hypertension divided by overweight and obesity because of a lower prevalence of obesity (BMI  $\geq 30$  kg m<sup>-2</sup>) in Japan (1980: 2.1%, 1990: 2.5%, 2000: 3.2%, 2010: 3.4%).<sup>20</sup> The present results mainly reflected the impact of overweight (BMI: 25.0–29.9 kg m<sup>-2</sup>). Although there is a need for further study, contributions to hypertension are likely stronger in more obese Westernized countries during the period under review. Fourth, compared with women in 1980, the present results overestimated the risk of hypertension among women in later periods



**Figure 3** The ORs (95% CIs) for hypertension in overweight and obese participants compared with normal-weight participants who were recruited from national surveys in 1980, 1990, 2000 and 2010, Japan. The ORs were adjusted for age, smoking status, alcohol consumption and salt intake. Hypertension was defined as a systolic blood pressure  $\geq 140$  mm Hg, diastolic blood pressure  $\geq 90$  mm Hg or the use of antihypertensive drugs. OR, odds ratio; CI, confidence interval.

because the prevalence of postmenopausal women has increased over the last 30 years. The mean age has also increased over this period (1980: 50.0 years, 2010: 58.6 years). It is well known that the prevalence of hypertension, overweight and obesity increases after menopause. However, we could not adjust for this effect because there is no information available on menopausal status.

In conclusion, overweight and obesity have been a major risk factor for hypertension during the past 30 years in Japan. In future, a decreasing tendency in the prevalence of hypertension might change to an increasing tendency because of an increased prevalence of overweight and obesity. This increasing trend of prevalence in overweight and obese participants has occurred not only in developed countries but also in developing countries.<sup>32</sup> In addition to the relationship between excessive body mass, diabetes and other adverse health conditions, the rise in associations with hypertension adds increased importance for encouraging weight control. Preventing people from being overweight and obese will become more important for the prevention of hypertension in Japan and other Asian countries. We need to tackle the overweight and obesity epidemic and work toward its prevention.

#### CONFLICT OF INTEREST

The authors declare no conflict of interest.

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*Author contributions:* MN, T Ohkubo and KM contributed to the design of the study. T Ohkubo, YM, NT, AK, NM, YS, NN, NO, T Okamura, AO, HU and KM participated in the data collection. MN, T Ohkubo, YM, RD and KM participated in the data analysis. MN, T Ohkubo and KM participated in writing the report. All authors participated in critical revision of the manuscript and approved the final version of the report for submission.

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