[Environmental Health and Preventive Medicine 8, 90–94, July 2003]

Original Article

Serial Study on the Association between Body Mass Index and Hypertension in Rural Japanese

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Abstract

The objective of this study was to examine the association between body mass index (BMI) and blood pressure. Two sets of cross-sectional data were obtained from annual health examinations for adults aged 40 years and over (n=1,327 in 1993; n=1,302 in 2000) in Tsunagi area of Kumamoto Prefecture, Japan. BMI was associated with mean blood pressure and with prevalence of hypertension both in 1993 and 2000. The association was independent of age, smoking status and alcohol consumption. A significant increase in risk of hypertension was found in most categories of BMI 25.0 and above, and a greater than three fold increase in those with BMI of 27 and above compared with those with BMI of 18.5–22.9. Although mean blood pressure and prevalence of hypertension sharply decreased in 2000 compared with that in 1993, BMI was positively and independently associated with increased blood pressure.

Key words: body mass index, obesity, adult, hypertension, blood pressure

Introduction

Most studies from Western countries showed body mass index (BMI) has been consistently associated with blood pressure (1). Some cross-sectional (1–5) and longitudinal (6–10) studies reported such an association between overweight and hypertension, independent of age. Several clinical trails (11–13) also showed an effect of weight reduction in lowering blood pressure.

Based on the classification of the World Health Organization (WHO), persons with BMIs below 18.5 are considered underweight, those with BMIs 18.5–24.9 are in normal range, those with BMIs above this range are considered overweight or "at risk", and those with BMIs greater than or equal to 30 are considered obese. For Asian adults, the WHO Obesity Task Force (1) recommended that overweight status should be defined as BMIs of 23.0–24.9, and BMIs of 25.0 and above should be classified as obese considering the higher prevalence of disease at lower BMI levels in adult Asians.

In Japan, the association between BMI and blood pressure was reported to be weak in the 1960s, but became stronger in the 1970s and the 1980s (14). More recently, there has been a rapid change in living and eating patterns along with accelerated urbanization in rural communities and increased medical care use and awareness (14). However, how the association of BMI and blood pressure changed in rural Japanese when their related behaviors and socio-environment factors are changing remains to be clarified.

In the present study, two cross-sectional studies were conducted in 1993 and 2000 among residents of Tsunagi area, a small village in Kumamoto Prefecture in Japan with the total population about 6,000. The association between BMI and blood pressure was examined, in addition to age, alcohol consumption, and smoking variations.

Materials and Methods

Study population

The data were obtained from annual health examinations in Tsunagi area, which is based on the Health and Medical Service Law for the Aged (15). Tsunagi area is a small village of Kumamoto Prefecture, located in the southern part of Japan. The main occupation of the residents in the village is small-scale fishing (about 20%) and agriculture (about 40%). Most

Received Aug. 29 2002/Accepted Mar. 29 2003
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occupations required strenuous physical activity. Annual health examinations in this area have been performed since 1982 including a questionnaire survey, physical examination, and collection of blood samples for laboratory analysis. The questionnaire survey was accomplished by interviews with regard to the past medical history, present medical care use, cigarette smoking (smoker vs non-smoker), alcohol consumption (g/week), and general health status.

In this study, two sets of cross-sectional data were used (n=1,327 in 1993; n=1,302 in 2000). Subjects (aged 40 and over) who participated in the health examinations in 1993 or 2000 were selected, representing approximately 75% of local adult residents. Though the health examination started in 1982, the analyses of data began in 1993 when all criteria of diagnosis were unified and the computerized management of data was implemented in Tsunagi area.

Procedures

Standard procedures for measurement of blood pressure were used in both surveys. We used automatic sphygmomanometers (TM-2520: A&D Co. Ltd. Tokyo, Japan) with quality control by the manufacturers every two years. Blood pressure was measured by a trained nurse on the right arm of each participant in the seated position after resting for 5 minutes. Automatic sphygmomanometer's readings were recorded at the first appearance of a pulse sound (Korotkoff phase 1) as systolic blood pressure (SBP) and diastolic blood pressure (DBP) at Korotkoff phase 5. Hypertension was defined as SBP ≥140 mmHg or DBP ≥90 mmHg, or current use of antihypertensive medication.

Height was measured in centimeters while the subjects stood without shoes, and weight was measured in kilograms while the subjects stood without shoes and with lightly clothed. BMI was calculated as weight in kilograms over height in meters squared. The subjects were classified into five categories according to their BMI as follows: <18.5, 18.5–22.9, 23.0–24.9, 25.0–26.9, ≥27.0 kg/m^2, which were based on the characteristics of Asian populations and published data (16–18). Alcohol consumption was determined by interview and recorded in go (a Japanese unit of alcohol beverage corresponding to 28 g), then average weekly alcohol consumption was also obtained. Data from both surveys were pooled and all analyses stratified by gender.

Statistical methods

Within each survey years, a descriptive analysis was performed for the sample BMI and the blood pressure. Age-adjusted mean SBP and DBP were calculated for each BMI category by the weighted least squares regression analysis, excluding those subjects on antihypertensive medication. Age-adjusted prevalence of hypertension by BMI categories was also estimated using the direct method using 10-year age group with the total Tsunagi adult population (age 40 years and above) in 2000 as the reference population. Second, logistic regression was used to calculate the odds ratios of hypertension across a range of BMI categories. There are a number of factors that may confound the relation between BMI and hypertension. In preliminary analyses, the confounding of this association by age, smoking status, and alcohol consumption was identified, in addition to age, the β coefficient did not change more than 10 percent, and the significance of BMI-hypertension association was not changed. Thus, only age, as a continue variable was controlled for in the models. In addition, considering the sample size of the group with BMI<18.5 is too small to be evaluated both in males and females, the category 18.5-22.9 was used as the reference group.

Statistical significance was accepted at P<0.05, and all analyses were carried out using SPSS software Version 10.0.

Results

A total of 1,327 subjects (1993) and 1,302 subjects (2000) aged 40 years and above were included in this analysis. The characteristics of the subjects were shown in Table 1. The most marked differences between the 1993 and 2000 were the signif-

Table 1 Selected characteristics of the subjects aged 40 years and above who participated in the annual health examinations in 1993 or 2000*

	1993		2000	
	Males	Females	Males	Females
No. of subjects in study	521	806	500	802
Age (years)	56.9 (15.0)	55.7 (14.9)	65.9 (15.0)	64.7 (14.9)
Systolic blood pressure (mmHg)	141.2 (22.9)	140.1 (26.5)	127.4 (20.9)	122.8 (24.3)
Diastolic blood pressure (mmHg)	83.7 (12.7)	81.3 (13.5)	75.2 (12.2)	71.9 (11.9)
Hypertension † (%)	51.4	49.9	40.0	34.1
Antihypertensive medication (%)	15.1	14.9	53.0	64.0
Height (cm)	161.7 (6.8)	149.9 (6.5)	161.7 (6.8)	149.9 (6.5)
Weight (kg)	59.6 (9.9)	51.7 (8.1)	60.9 (10.3)	51.4 (8.2)
Body mass index ‡	23.1 (3.0)	23.3 (3.4)	23.2 (3.2)	22.8 (11.9)
Body mass index 23.0–24.9 (%)	26.3	23.2	23.2	21.2
Body mass index ≥ 25.0 (%)	24.6	28.9	23.1	24.5
Smokers (%)	38.1	2.5	29.8	2.6
Alcohol consumption (%)	56.6	12.2	58.4	10.8

*All values are means with the standard deviation in parentheses, unless otherwise specified.
† Systolic blood pressure ≥140 mmHg or diastolic blood pressure ≥90 mmHg or antihypertensive medication use.
‡ Weight (kg)/height (m)^2

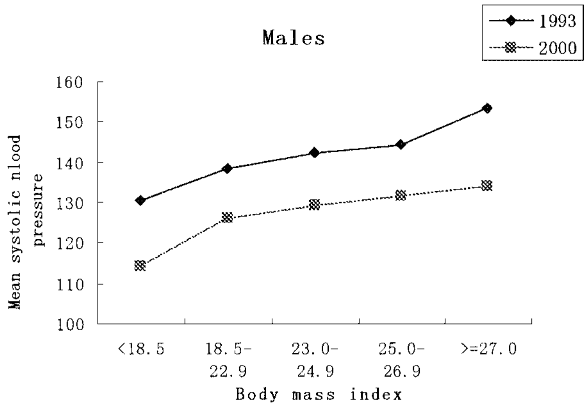

Fig. 1 Age-adjusted mean systolic blood pressure over a range of body mass index (weight (kg)/height (m)^2) in males both in 1993 and 2000.

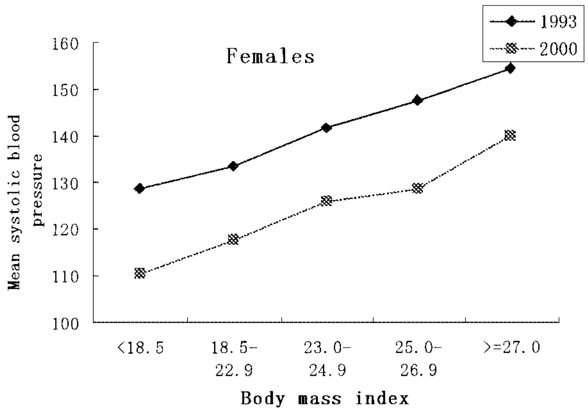

Fig. 2 Age-adjusted mean systolic blood pressure over a range of body mass index (weight (kg)/height (m)^2) in females both in 1993 and 2000.

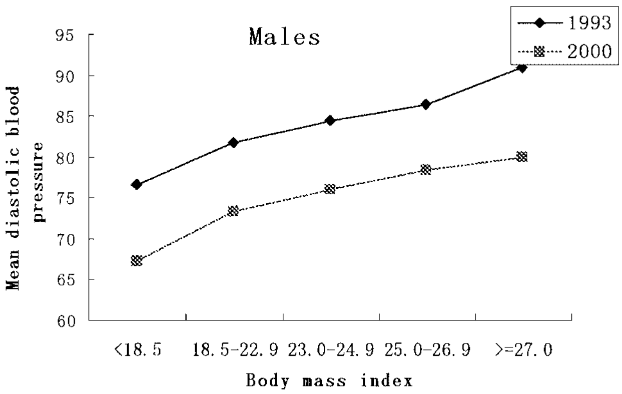

Fig. 3 Age-adjusted mean diastolic blood pressure over a range of body mass index (weight (kg)/height (m)^2) in males both in 1993 and 2000.

icant decrease in mean blood pressure and the prevalence of hypertension both in males and females, though the subjects were about 9 years older in 2000 than in 1993. There were no significant differences in mean body mass index or prevalence of overweight (BMI of 23.0–24.9) or obesity (BMI of 25.0 and over) between the two surveys. The proportion of smokers was significantly lower in 2000 than in 1993 in males, but not in females. The proportion of drinkers was revealed to be similar

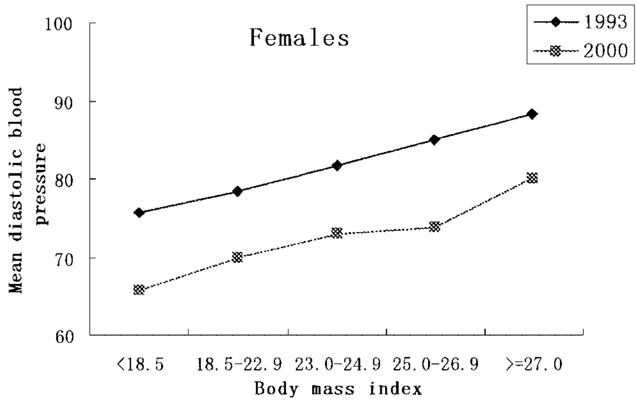

Fig. 4 Age-adjusted mean diastolic blood pressure over a range of body mass index (weight (kg)/height (m)^2) among in females both in 1993 and 2000.

Table 2 Age-adjusted prevalence of hypertension over a range of body mass index categories by year (1993, 2000) and gender

Body mass index†	1993				2000			
	Males		Females		Male		Female	
	n	%	n	%	n	%	n	%
<18.5	9	32.1	19	43.2	5	16.7	7	9.7
18.5–22.9	103	45.4	129	39.1	50	23.5	62	17.5
23.0–24.9	48	50.4	93	50.8	31	30.7	39	23.6
25.0–26.9	66	57.1	70	58.3	30	35.7	32	30.8
≥27.0	34	72.3	78	72.5	24	42.9	39	43.5

† Weight (kg)/height (m)^2.

Table 3 Odds of hypertension over a range of body mass index categories by year (1993, 2000) and gender

	1993		2000	
Body mass index†	OR	95% CI	OR	95% CI
Males				
18.5–22.9	ref		ref	
23.0–24.9	1.17	(0.73, 1.88)	1.64	(0.93, 2.87)
25.0–26.9	1.48	(0.86, 2.54)	1.95	(1.07, 3.56)
≥27.0	3.68	(1.74, 7.77)	3.32	(1.62, 6.80)
Females				
18.5–22.9	ref		ref	
23.0–24.9	1.37	(0.90, 2.08)	1.38	(0.85, 2.24)
25.0–26.9	2.04	(1.25, 3.32)	1.61	(0.92, 2.81)
≥27.0	3.92	(2.25, 6.83)	4.03	(2.32, 7.00)

in the two surveys both in males and females.

Age-adjusted mean SBP and DBP in BMI categories are illustrated in Figures 1–4, after excluding those who were taking antihypertensive medication. A linear positive relation of BMI on SBP and DBP were observed in 1993 and in 2000 both in males and females. These differences were all significant even though age adjusted mean SBP or DBP in each BMI category was significantly lower in 2000 than in the corresponding BMI category in 1993.

The age-adjusted prevalence of hypertension by BMI was calculated (Table 2). Although the sample size of the group with BMI<18.5 was too small to be evaluated, a higher prevalence of hypertension was observed in the higher BMI categories in both genders in both surveys. The difference in the prevalence of hypertension between the lowest and highest BMI categories was greater in 1993 than in 2000 in both genders. The shape of the effect of BMI on blood pressure appeared to be similar in both surveys, but the magnitude of the effect was attenuated in 2000 in comparison with the findings in 1993.

The odds ratios for developing hypertension in BMI categories are presented in Table 3 with the BMI 18.5-22.9 group as the reference. BMI are associated with an increased risk of hypertension in both genders in both surveys although the odds ratios were not significant in some groups. The subjects with BMI≥27.0 showed a greater than three fold increase in the risk of hypertension compared with those with BMI of 18.5–22.9 both in males and females in both surveys.

Discussion

Hypertension is an antecedent of heart disease and stroke, both are leading causes of morbidity and mortality worldwide (19). In present study, the presence of a significant positive association between BMI and blood pressure in Tsunagi adults in 1993 and 2000 was documented. Although mean BP and the prevalence of hypertension significantly decreased after seven years, such an association remained. The association was independent of age, smoking status and alcohol consumption.

More recently, a positive association between BMI and hypertension has been well documented in Asian studies. For example, Ko et al. (20) found that the optimal BMI cut-off for predicting hypertension in Hong Kong Chinese was 23.8, lower than that of 25.0 recommended by WHO. Another study in Japan (21) suggested that the risk of hypertension for adults with BMI greater than or equal to 25.0 was twice that of persons with BMI of 22.0. The present findings add to the evidence of the Japanese report. In this study, a significant increased risk of hypertension was found among Tsunagi adults at the cut-off 25.0 or greater of BMI. Furthermore, an increase of greater than three fold in risk of hypertension was found in BMI group (≥27.0) in all study groups (excluding men studied in 2000) compared with that in BMI group 18.5–22.9.

A possible mechanism for the association between BMI and hypertension is uncertain, but several hypotheses have been advanced. Hemodynamic studies have shown that overweight is associated with elevated cardiac output, expanded blood volume, and elevated peripheral vascular resistance (22). Clinical trials have also shown that weight reduction increases urinary sodium excretion (23). In addition, enhanced salt sensitivity among obese individuals may also be responsible for the development of hypertension (24).

Substantial changes in blood pressure distributions were observed in rural Japanese between 1993 and 2000 by our population-based study with a relatively high response rate. Several possible explanations may be proposed. First, it was partly due to improvement in hypertension control with medication. Tsunagi area is a small village, the main occupations of the residents are small-scale fishing and agriculture, which required strenuous physical activity. A high proportion of hypertension was found among subjects in 1993, suggesting this high prevalence had an association with hard manual labor. Although we do not have adequate information to support this hypothesis, some studies in rural Japan have also reported similar findings. For example, hypertension in rural northeast Japan was associated with hard manual work (14). Since annual health examinations have been conducted there for about 20 years, it was evident that medical care played an important role in the decrease. For example, among 676 subjects who were hypertensive in 1993, 224 (33.14%) showed blood pressure in the normal range in 2000. In addition, the proportion of anti hypertensive medication use was found to be increased significantly in 2000 when compared with that in 1993 (Table 1). Second, these findings suggest that the significant decline in population blood pressure levels between 1993 and 2000 was not only due to the hypertension control by medication, but also due to the changes in traditional lifestyles and environment factors. It is suggested that overall improvement in nutrition, specifically better protein and fat intake, lower salt intake and reduced hard manual work may have contributed to the blood pressure decline. Finally, our conclusion might have been influenced by the change in the subjects who participated in the annual health examinations. Every year, about one-fifth new participants took part in the examinations and meantime similar numbers were missing. For example, of 1,327 original subjects in 1993, only 802 (60.4%) completed the examination in 2000 and about one-fourth of the subjects who were hypertensive in 1993 did not attend the examination in 2000 because of death, rejection or moving out of the study site.

This study was limited by the use of cross-sectional data. To truly test for differences in risk of hypertension with the increase of BMI, one would need to monitor people from this population over time (1). Moreover, our analysis was based on an annual health examination data, hence, the result might be biased since the sample was not randomly recruited. Furthermore, blood pressure is somewhat sensitive to salt intake, and we did not have adequate measures of salt consumption in this study. Finally, the two time points of survey were too few for evaluating the time trend of the association between BMI and blood pressure.

In summary, the findings of the present study clearly suggest that although a significant decrease in the mean blood pressure and the prevalence of hypertension in the 7-year interval survey in Tsunagi adults, BMI was positively and independently associated with increased blood pressure.

Acknowledgements

The efforts of the fieldwork team and the cooperation of the participants are acknowledged.

The first author is grateful for the invitation of the School of Medicine, Kumamoto University, Japan for research coordination.

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