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Joint Effects of Age and Body Mass Index on the Incidence of Hypertension Subtypes in the China Health and Nutrition Survey: A Cohort Study over 22 Years

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Abstract

Objectives.—We seek to investigate the joint effects of age and body mass index (BMI) on the incident hypertension subtypes among Chinese adults during 1989–2011.

Methods.—We investigated the Incidence rates (IRs, per 100 person-years) of hypertension subtypes, adjusted relative risks (RRs) and population attributable risk percent (PAR%) of BMI for hypertension, and clarified the age-specific effect of BMI on incident hypertension utilizing a dynamic cohort study from the China Health and Nutrition Survey (CHNS) 1989–2011.

Results.—Normotensive participants (n=53,028) at baseline were included, with mean age was 41.7 (95% CI, 41.6–41.7) years old. During a total of 118,694 person years (average was 6.38 years) of follow-up, a total of 5,208 incident cases of hypertension were documented. The IRs of hypertension were 4.4 (95% CI, 4.3–4.5), which increased gradually by age and BMI ($P_{\text{trend}} < 0.001$). Compared with those with BMI $< 22 \text{ kg/m}^2$, the RR of hypertension was 3.13 (95% CI, 2.84–3.45) in the group with BMI $\geq 28 \text{ kg/m}^2$. The PAR% (BMI > 22 vs BMI < 22) for hypertension in Chinese population was 32% (95% CI, 29–34%). Similar trends were observed in all age and BMI groups for both isolated systolic hypertension and systolic-diastolic hypertension,

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Conflict of interest

No conflicts of interest

Appendix

Please see the supplemental figures of this article.

which were mainly affected by age. In contrast, the peak IR of isolated diastolic hypertension was observed in participants aged 30–49 years with higher BMIs.

Conclusions.—The PAR% (IR of BP $\geq 140/90$ /or treatment for BMI >22 vs. IR for BMI <22) of elevated body weight for hypertension was 32% in Chinese population.

Keywords

Chinese; hypertension; incidence; relative risk; Population attributable risk

Introduction

Hypertension is the main risk factor for cardiovascular disease (CVD) mortality, causing more than 7 million deaths worldwide every year (Ezzati et al., 2002; Lewington et al., 2002). In China, the CVD deaths resulted in a 4.79-year life expectancy loss in the Chinese population (Fan et al., 2014). Reducing the burden of diseases associated with hypertension has been identified as a public health priority in the world as well as in China.

Many cross-sectional studies have reported the prevalence of hypertension (Burt et al., 1995; Lee et al., 2004; Yamagishi et al., 2003). In contrast, longitudinal studies of incident hypertension in large populations have been relatively scarce. In most of these studies, the cumulative incidence rate (CIR, %) was calculated as a measurement indicator of incident hypertension, which was expressed as the percentage of incident cases in a fixed cohort. Average annual CIRs of hypertension ranged from 1.29% to 4.53% in Americans (Levine et al., 2011; Weng et al., 2013), depending on age, period, gender, ethnicity, and body size of the population. However, previous studies using the incidence rate (IR, per 100 person-years) as an indicator for hypertension in long cohort have been relatively rare. There are two reports that have shown that IRs range from 1.8 to 7.4 in Americans (Diez Roux et al., 2002; Gillum et al., 2004).

Similarly, several cross-sectional studies have reported the prevalence of hypertension in Chinese adults (Gao et al., 2013; Ke et al., 2014; Wu et al., 1995). However, so far, few studies have calculated incident hypertension in large cohort studies. Over a mean of 8.2 years of follow-up among 10,525 individuals, the CIR of hypertension was 28.9% of men and 26.9% of women, meaning that the average annual CIR was 3.61% in men and 3.36% in women from 1991 to 1999 (Gu et al., 2007). Over a mean of 3.23 years of follow-up among 3,357 individuals in Taiwan, the IR of hypertension was 2.9 in 1994–1997 (Yeh et al., 2001).

Based on data from the China Health and Nutrition Survey (CHNS), several studies (Nguyen et al., 2008; Niu and Seo, 2014; Xi et al., 2012) have reported the prevalence and incidence of hypertension in Chinese adults. The annual CIR ranged from 2.23% to 3.98% in Chinese adults. However, only one study to date has reported that the IR of hypertension increased from 2.9 per 100 person-years in CHNS 1991–1997 to 5.3 in 2004–2009 (Liang et al., 2014). The above incidence of hypertension is inconsistent and could not represent the reality of incident hypertension in the large-scale longitudinal cohort study. The main drawback is the confounding effect of age on the prevalence, since a cohort will be aging and prevalence would increase, thus age adjusted prevalence could have been used to

overcome this result. To overcome this weakness and considering the CHNS is a dynamic cohort design, we used IR as an indicator in this study.

In this study, we sought to investigate the IR of hypertension and subtypes according to the number of person-years of follow-up utilizing a dynamic cohort study from the CHNS from 1989–2011. More importantly, because elevated body weight is the important modifiable risk factor for hypertension, we further calculated the population attributable risk percent (PAR%) to quantify the contribution of body mass index (BMI) to developing incident hypertension.

Methods

Study design and population

We utilized data from the CHNS 1989–2011, a Chinese cohort using multistage random cluster sampling over a 22-year period (Popkin et al., 2010). The CHNS was conducted in 1989, 1991, 1993, 1997, 2000, 2004, 2006, 2009, and 2011. A detailed description of the survey design and procedures has been published elsewhere (Popkin et al., 2010; Zhang et al., 2014). The CHNS is a representative sample, and is the only large-scale longitudinal, household-based survey in China to the present (Zhang et al., 2014). Since the age-specific incidence of hypertension did not show a period effect (for example, the IR of hypertension for participants aged 40–50 years old in different periods (1991–2000, 2000–2011 and 1991–2011) were 4.98 (95% CI, 4.14–5.82) in 1991, 3.98 (95% CI, 3.48–4.48) in 2000 and 4.77 (95% CI, 3.99–5.56) in 2011, respectively (P for trend=0.91)), we regrouped the baseline age and BMI between two surveys to reveal the joint effects of age and BMI on the incidence of hypertension subtypes.

To determine incident hypertension and subtypes, we identified a dynamic cohort study covering eight time periods, which included the CHNS in 1989 and consequent follow-up surveys. The consequent follow-up surveys were considered as follow-up surveys of the former time period, and the surveys simultaneously added normotensive participants as new baseline surveys of follow-up time periods. To limit the biases caused by pre-existing factors, we excluded participants with ineligible factors in their baseline surveys, which is summarized in Figure 1.

We calculated the IRs (per 100 person-years) of hypertension and subtypes according to the number of person-years of follow-up. For participants who did not develop hypertension at a later follow-up survey, the follow-up time was calculated from the date of the baseline survey to the date of later survey of follow-up. For participants who developed hypertension, the date of the onset of hypertension was assumed to be the midpoint between the two surveys because of the insidious onset of hypertension. For participants who did not complete the follow-up survey, the loss-to-follow-up date was also assumed to be the midpoint between the two surveys. Thus, the follow-up time was estimated to be the entire time during which the subjects remained free of hypertension plus half of the follow-up time during which hypertension developed or they were lost in the follow-up survey. This method was also a common technique to cope with the censored data (CDC, 1998).

Data collection and definitions

Data on demographics (age, gender, and living region), blood pressure, weight, height, lifestyles (ever smoking, alcohol intake), and use of antihypertensive medication were collected. Weight and height were measured by trained health workers following standardized protocols from WHO (WHO., 1995). The bodyweight of participants dressed in light clothing was measured without shoes to the nearest 0.1 kg with a calibrated beam scale (Seca North America, Chino, CA). The height of barefoot subjects was measured to the nearest 0.1 cm using a portable stadiometer (Seca North America). BMI was calculated as participants' weight in kilograms divided by their height in meters squared, as kg/m^2 . Smoking was defined if participants have smoked cigarettes (including hand-rolled or device-rolled) and alcohol intake was defined if participants have drunk beer or any other alcoholic beverage during the last year before the each survey. Because the percentages of ever smoker and alcohol drinker were not investigated in 1989, so we filled the missing value using the data from the same participants in 1991 (3,783 were found among 4,763 participants). Blood pressure (BP) was based on the mean of 3 measurements collected after 10 minutes of seated rest using standard mercury sphygmomanometers (Lenfant et al., 2003).

Consistent with World Health Organization conventions (1999) and the seventh Joint National Commission guidelines (JNC7) (Lenfant et al., 2003), hypertension was defined as systolic blood pressure (SBP) ≥ 140 mm Hg, diastolic blood pressure (DBP) ≥ 90 mm Hg, or current use of antihypertensive medication. The following hypertension subtypes were included in the analysis: 1) isolated systolic hypertension (ISH), defined as SBP ≥ 140 mm Hg and DBP < 90 mm Hg; 2) isolated diastolic hypertension (IDH), defined as SBP < 140 mm Hg and DBP ≥ 90 mm Hg; 3) systolic-diastolic hypertension (SDH), defined as SBP ≥ 140 mm Hg and DBP ≥ 90 mm Hg; and 4) current use of antihypertensive medication. We were unable to distinguish between ISH, IDH or SDH in incident cases taking antihypertensive medication because their original BP values were unknown, so we classified "current use of antihypertensive medication" into a specific group. This classification has been also reported in other cohort study (Yeh et al., 2001).

Statistical analysis

Subjects were stratified into the following age groups: 18–34, 35–49, 50–64 and ≥ 65 years and/or into the following BMI groups: < 22 , 22–23, 24–25, 26–27 and ≥ 28 kg/m^2 . The number of each age subgroup were 18,525 (35.0%), 19,427 (36.6%), 10,838 (20.4%) and 4,238 (8.00%), respectively. The number of each BMI subgroup were 24,804 (46.8%), 13,118 (24.7%), 8,181 (15.4%), 4,240 (8.00%) and 2,685 (5.10%), respectively. Stratified analyses were performed to calculate the incidence rates (IRs) and examine the relationship between age, baseline BMI, and joint risks for hypertension and subtypes. Trends of incident hypertension (P for trend) with classifications of age or BMI were assessed using Cox proportional hazards models.

Using the ideal BMI ($\text{BMI} < 22$ kg/m^2) as the referent, we calculated the adjusted relative risks (RRs) of BMI for hypertension by Cox models to control for covariates, such as age, region, ever smoking, alcohol intake, and we used the attributable risk percent (AR%) to

reflect BMI as risk factor for developing hypertension. Further, we calculated the population attributable risk percent (PAR%) to quantify the contribution of BMI to developing incident hypertension using the following equation:

$$\text{PAR\%} = (\text{IR}_{\text{total}} - \text{IR}_{\text{reference}}) \div \text{IR}_{\text{total}} \times 100\%,$$

Where the IR_{total} signifies the IR of hypertension among all participants, and the $\text{IR}_{\text{reference}}$ signifies the IR of hypertension among participants with BMI <22 kg/m².

We calculated the adjusted relative risks (RRs) of the age-specific effect of BMI on incident hypertension and subtypes by Cox models to control for covariates, such as age, region, ever smoking, alcohol intake; for each analysis, the lowest IR was used as the referent.

All statistical tests were performed using SPSS statistical software. Statistical significance was set at a two-tailed $P < 0.05$, and confidence intervals (CI) were calculated at the 95% level.

Results

The CHNS is a dynamic cohort study that began in 1989 and was followed for 22 years. The flow chart of the selection procedure of participants in this study is summarized in Figure 1. After excluding ineligible participants, a total of 53,028 normotensive participants at baseline and consequent follow-up surveys were included. The total follow-up person-years were 118,694, and the mean length of the follow-up period was 6.38 person-years.

The anthropometric characteristics of all of the participants in each survey are presented in Table 1. The mean age of the participants increased from 31.7 (95% CI, 31.5–32.0) years old in 1989 to 46.9 (95% CI, 46.5–47.2) years old in 2009. Accordingly, in this confined cohort study population, the mean BMI increased from 21.4 (95% CI, 21.4–21.5) kg/m² in 1989 to 22.8 (95% CI, 22.7–22.9) kg/m² in 2009.

Incident cases of hypertension and subtypes

During the 22 years of follow-up, a total of 5,208 Individuals developed hypertension, including 2,732 (52.5%) men and 2,476 (47.5%) women. Among the 5,208 cases, 1,187 (22.8%), 2,110 (40.5%), 1,275 (24.5%) and 636 (12.2%) had ISH, IDH, SDH and had taken antihypertensive medications, respectively. The age of onset of the cases ranged from 18.0 to 96.0 years old, with a median of 51.5 years of age. The onset BMI of the cases ranged from 14.0 to 39.0 kg/m², with a median of 23.3 kg/m².

Incident rates of hypertension

In this dynamic cohort, the crude IR of hypertension was 4.4 (95% CI, 4.3–4.5) per 100 person-years over the 22 years, with an IR of 5.0 (95% CI, 4.8–5.1) in men and 3.9 (95% CI, 3.7–4.0) in women ($P < 0.001$), respectively (Table 2). The IR increased gradually with age from 1.5 (95% CI, 1.4–1.6) in those aged 18–34 years to 11.3 (95% CI, 10.7–12.0) in those aged ≥ 65 years ($P_{\text{trend}} < 0.001$). The IR also increased gradually with BMI from 3.0 (95% CI,

2.9–3.1) in those with BMI <22 to 9.9 (95% CI, 9.1–10.6) in those with BMI ≥28 ($P_{\text{trend}} < 0.001$). Similar significant trends were observed in both men and women (eFigures 1 and 2).

RRs and PAR% of BMI for hypertension

The effect of BMI on incident hypertension was further estimated by Cox models to control for potential covariates (Table 3). Because the IR increased sharply in those with BMI ≥22 kg/m², we used the IR of BMI <22 kg/m² group as the referent. Compared with the referent, the adjusted RR for the group with BMI ≥28 kg/m² was 3.13 (95% CI, 2.84–3.45), the AR% was 70% (95% CI, 64–76%). The PAR% (IR of BP ≥140/90 or treatment for BMI ≥22 vs. IR for BMI <22) for hypertension was 32% (95% CI, 29–34%) in the Chinese population, respectively. Correspondingly, the PAR% was 28% (95% CI, 26–32%) in men and 36% (95% CI, 30–40%) in women.

Age-specific effect of BMI on incident hypertension

To further clarify the joint effects of age and BMI on incident hypertension and subtypes, we calculated adjusted RRs to estimate the age-specific effect of BMI using Cox models (Figure 2 and 3). The corresponding IRs are shown in Figure 4 (A). Because the IR increased steadily by age and/or BMI, we used the IR of those aged 18–34 and BMI <22 group as the referent. The stratified RRs increased with age and/or BMI, further confirming that both age and BMI were important determinants of hypertension (Figure 2). The peak RR of 19.2 (95% CI, 15.2–24.4) was seen in the group of those aged ≥65 and a BMI of 26–27, and the stratified IR was 17.8 (95% CI, 14.7–20.8). More importantly, the RR in the group of those aged 18–34 and a BMI ≥28 was similar to the group of those aged 35–49 and a BMI of 26–27 (Figure 2), which means the effect of increasing one category of BMI on the risk for hypertension was equivalent to that of increasing ten years old of age.

Age-specific effect of BMI on incident hypertension subtypes

The age-specific effects of BMI on incident hypertension subtypes are shown in Figure 3 (A–D). The reference IRs of ISH and SDH were 0.1 (95% CI, 0.0–0.1 and 0.1–0.2, respectively) in those aged 18–34 and those with a BMI <22, while the IDH was 0.7 (95% CI, 0.6–0.8), which indicated that IDH was the main subtype in young people; thus, the RRs of incident ISH and SDH were larger than the IDH. Similar trends were observed in nearly all ages and BMIs for ISH, SDH and current use of antihypertensive medication (Figure 3, A, C and D), which were mainly affected by age. In contrast, the pattern of age-BMI-specific incidence of IDH was different from that of ISH, which was mainly influenced by BMI (Figure 3, B). Subjects with the highest risks of IDH were mainly those aged <64 years and with a BMI ≥26. The peak RR of 6.36 (95% CI, 4.89–8.28) was seen in the group of those aged 35–49 years and a BMI ≥28, with a stratified IR of 4.0 (95% CI, 3.2–4.7). The corresponding IRs are shown in Figure 4 (B–E). Of note, IR of IDH does not increase much for higher BMI categories in older age group, with even some decrease in some instances (Figure 4, C), which means there was much larger difference of BMI-specific IR between younger and older age groups. The age-specific effects of BMI on incident hypertension and subtypes stratified by gender are shown in eFigures 3–12.

Discussion

In this study, the crude IR of hypertension was 4.4 among all participants. Several studies have used CIR as an indicator of incident hypertension in Chinese adults (Gu et al., 2007; Nguyen et al., 2008; Niu and Seo, 2014). Similar results have been seen in the CHNS from 2000–2004, with an average annual CIR of 3.93% (Nguyen et al., 2008). Two inconsistent studies have reported that the average annual CIR was 3.48% from 1991–1999 (Gu et al., 2007) and 2.24% from 1997–2009 (Niu and Seo, 2014). These data did not consider how to address the censored data of those who were lost to follow-up. These discrepant findings could have resulted from period effects or the bias of follow-up.

In the only study that used the IR as an indicator of incident hypertension, the crude IR significantly increased from 2.9 in the cohort from 1991–1997 to 5.3 in the cohort from 2004–2009 (Liang et al., 2014). They identified five cohorts (intervals of 5–7 years) that covered five time periods. The mean age of the participants increased from 40.6 years of age in 1991–1997 to 46.6 in 2004–2009 ($P_{\text{trend}} < 0.001$), and the mean BMI and prevalence of overweight or obesity significantly increased accordingly across five cohorts. The difference of IRs can be explained by the mixed effects of age and cohort (Gordon-Larsen et al., 2014; Jaacks et al., 2013) because most participants were derived from the same cohort from 1991–2009, and the age increased over time. Moreover, the IR was calculated without dealing with the bias of lost-to-follow-up. Therefore, the result could not represent the reality of incident hypertension in the CHNS from 1991–2009. In our study, we used a dynamic cohort of the CHNS from 1989–2011 and calculated the IR of hypertension and subtypes and included participants who did not exactly complete the follow-up survey to reduce follow-up bias.

Here we show that the incidence of hypertension has increased with age and/or BMI. Similar results have been seen in cohorts of Americans (Gelber et al., 2007; Gillum et al., 1998; Shihab et al., 2012), Japanese (Fujita and Hata, 2014; Ishikawa-Takata et al., 2002; Lee et al., 2004; Yamagishi et al., 2003), and Chinese (Gordon-Larsen et al., 2014; Gu et al., 2007; Luo et al., 2013; Yeh et al., 2001), also from the CHNS (Nguyen et al., 2008; Niu and Seo, 2014). As an age-specific effect of BMI on incident hypertension subtypes, incident IDH has been mainly influenced by BMI, while age was the primary factor for incident ISH. Similar results were found in Taiwan (Yeh et al., 2001). Our findings are not completely consistent with the Framingham Heart Study (Wilking et al., 1988), which showed that the major determinants of ISH (SBP ≥ 160 mm Hg and DBP ≥ 90 mm Hg) were age, female gender, obesity in women, and all BP components among participants aged ≥ 30 years. It is unclear whether these discrepant findings have resulted from differential definitions of ISH, follow-up times, or differences in multivariable adjustments. Of note, there was much larger difference of IR by BMI in younger than older age group. This result raises the question of ideal BMI (in relation to health) at older ages and overweight is not as detrimental at older age as in younger age group. The possible explanation could be survival bias or overweight people receive more treatment resulting in reduced CVD risk/vascular protection at older age group (Elia, 2001; Heiat et al., 2001).

BMI was the important modifiable risk factor for incident hypertension and subtypes. The PAR% (IR of BP $\geq 140/90$ /or treatment for BMI >22 vs. IR for BMI <22) for hypertension was 32% in the Chinese population. Considering the cut-off dependency of PAR%, as described in Systolic Blood Pressure Intervention Trial (SPRINT) for SBP intervention (Group et al., 2015), we calculated cut-off specific PAR%. The PAR% were 36% (BMI >20 vs. BMI <20), 70% (BMI ≥ 28 vs. BMI <22), and 58% (BMI 26–28 vs. BMI <22), respectively, suggesting that the benefit of obesity control could be larger in higher BMI groups. As the CHNS populations were a representative sample (Zhang et al., 2014), we could expect to prevent 15.8 million incident cases of hypertension every year by controlling BMI to less than 22 in the Chinese population. Furthermore, because BMI also increased gradually with age and the median of BMI in Chinese adults of 20 years of age was shown to be 22 kg/m² in previous research (Zong and Li, 2013), 1.9 million incident cases in China would be reduced every year if individuals' BMIs were controlled to less than 22 kg/m². Thus, maintaining one's body weight at 20 years of age for life is important to control hypertension, especially against IDH in middle-aged persons.

Study limitations

Some limitations should be considered when interpreting our data. First, we did not have sufficient information on the family history, physical activity, or diets to control for these potential covariates in individuals over 22 years. Second, approximately one-fourth of the eligible participants at baseline did not return for a follow-up survey, and this remains a source of potential follow-up bias. Fortunately in our study design, a portion of participants who were lost came back in other follow-up surveys, which reduced the bias.

Conclusions

This population-based dynamic cohort study suggested that the incidence of hypertension was 4.4 per 100 person-years among Chinese adults over 22 years. The IR of hypertension increased gradually by age and/or BMI. The PAR% of BMI (IR of BP $\geq 140/90$ /or treatment for BMI >22 vs. IR for BMI <22) for incident hypertension was 32% (95% CI, 29–34%) in the Chinese population. As a joint effect of age and BMI, incident IDH was mainly influenced by BMI, while age was the primary factor for incident ISH.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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ABBREVIATIONS AND ACRONYMS:

CHNS China Health and Nutrition Survey

BMI	body mass index
BP	blood pressure
SBP	systolic blood pressure
DBP	diastolic blood pressure
CIR	cumulative incidence rate
IR	Incidence rates
AR%	attributable risk percent
RR	relative risk
PAR	population attributable risk percent
ISH	isolated systolic hypertension
IDH	isolated diastolic hypertension
SDH	systolic-diastolic hypertension
CI	confidence intervals

Reference

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Highlights

- The population attributable risk percent of BMI for hypertension was 32% in Chinese
- Incident isolated diastolic hypertension was mainly influenced by BMI
- Age was the primary factor for incident isolated systolic hypertension

FIGURE 1.
Flow chart illustrating the sample selection for the present study.

FIGURE 2. Relative risks of incident hypertension stratified by age and body mass index (BMI, kg/m²). Relative risks were adjusted for gender, region, and drinking alcohol and ever smoking cigarettes by Cox models. Relative risks and 95% confidence intervals (RR, 95% CI) of hypertension is shown, the group of those aged 18–34 years and BMI <22 kg/m² was used as referent. The bars indicate 95% CI.

FIGURE 3.

Relative risks of incident hypertension subtypes stratified by age and body mass index (BMI, kg/m²). Relative risks were adjusted for gender, region, and drinking alcohol and ever smoking cigarettes by Cox models. Relative risks and 95% confidence intervals (RR, 95% CI) of isolated systolic hypertension (A), isolated diastolic hypertension (B), systolic-diastolic hypertension (C), current use of antihypertensive medication (D) are shown. The group of those aged 18–34 years and BMI <22 kg/m² was used as referent. The colors of blue, yellow and red represent the low, high and the highest risks for incident hypertension and subtypes.

* Relative risk and 95% confidence interval (RR, 95% CI)

FIGURE 4.

Incidence rates of incident hypertension subtypes stratified by age and body mass index (BMI, kg/m²). Incidence rates and 95% confidence interval (IR, 95% CI) of hypertension (A), isolated systolic hypertension (B), isolated diastolic hypertension (C), systolic-diastolic hypertension (D) and current use of antihypertensive medication (E) are shown. The bars indicate 95% CI.

Table 1.

Baseline Characteristics of the Participants who were Free of Hypertension in This Study N/A[‡]

Characteristics	Eight time periods							
	1989–1991	1991–1993	1993–1997	1997–2000	2000–2004	2004–2006	2006–2009	2009–2011
All Participants (n)	4763	7279	6784	6801	7240	6770	6872	6519
Age (y) *	31.7 (31.5–32.0)	38.6 (38.3–39.0)	39.7 (39.4–40.0)	40.7 (40.4–41.0)	42.1 (41.7–42.4)	44.9 (44.5–45.2)	46.4 (46.0–46.7)	46.9 (46.5–47.2)
SBP (mm Hg) *	109.2 (108.9–109.5)	109.7 (109.4–110.0)	110.4 (110.1–110.7)	112.8 (112.5–113.1)	113.5 (113.2–113.8)	115.0 (114.8–115.3)	114.9 (114.7–115.2)	116.1 (115.8–116.3)
DBP (mm Hg) *	71.0 (70.8–71.3)	71.4 (71.2–71.6)	72.5 (72.3–72.7)	73.6 (73.4–73.8)	74.0 (73.8–74.2)	74.8 (74.6–75.0)	75.1 (74.9–75.3)	75.9 (75.7–76.0)
BMI (kg/m ²) *	21.4 (21.4–21.5)	21.4 (21.4–21.5)	21.6 (21.5–21.7)	22.0 (21.9–22.0)	22.4 (22.3–22.5)	22.6 (22.5–22.6)	22.7 (22.6–22.8)	22.8 (22.7–22.9)
Ever smoking [‡]	34.0 (32.5–35.5) [‡]	35.0 (33.9–36.1)	33.8 (32.7–34.9)	32.1 (31.0–33.2)	30.9 (29.–31.9)	32.0 (30.8–33.3)	31.1 (29.8–32.4)	30.8 (29.7–32.0)
Alcohol drinker [‡]	39.0 (37.5–40.6) [‡]	37.8 (36.7–38.9)	35.7 (34.5–36.8)	36.0 (34.8–37.1)	34.5 (33.4–35.6)	32.4 (31.2–33.6)	31.3 (30.2–32.5)	33.6 (32.4–34.8)
Urban resident [‡]	31.5 (30.2–32.8)	31.1 (30.1–32.2)	30.9 (29.0–31.2)	33.7 (32.6–34.8)	32.9 (31.8–34.0)	33.6 (32.5–34.7)	33.2 (32.1–34.3)	32.8 (31.6–33.9)
Male (n)	2219	3474	3240	3257	3427	3146	3165	3013
Age (y) *	31.8 (31.5–32.2)	38.3 (37.8–38.8)	39.3 (38.8–39.8)	40.0 (39.5–40.5)	41.6 (41.1–42.1)	44.6 (44.1–45.1)	46.3 (45.7–46.8)	46.9 (46.3–47.4)
SBP (mm Hg) *	111.5 (111.1–111.9)	111.7 (111.3–112.1)	112.4 (112.0–112.8)	114.5 (114.1–114.9)	115.4 (115.1–115.8)	117.0 (116.6–117.3)	116.9 (116.5–117.2)	117.8 (117.4–118.1)
DBP (mm Hg) *	72.2 (71.9–72.5)	72.6 (72.3–72.9)	73.7 (73.5–74.0)	74.7 (74.4–74.9)	75.3 (75.1–75.6)	76.0 (75.8–76.3)	76.5 (76.2–76.7)	77.2 (76.9–77.4)
BMI (kg/m ²) *	21.1 (21.0–21.2)	21.2 (21.1–21.3)	21.4 (21.4–21.5)	21.8 (21.7–21.9)	22.2 (22.2–22.3)	22.5 (22.4–22.6)	22.7 (22.6–22.8)	22.8 (22.7–22.9)
Ever smoking [‡]	72.5 (70.3–74.6) [‡]	68.7 (67.2–70.3)	66.1 (64.4–67.7)	62.1 (60.5–63.8)	60.6 (59.0–62.3)	64.6 (62.7–66.6)	63.3 (61.1–65.4)	62.5 (60.7–64.3)
Alcohol drinker [‡]	69.9 (67.7–72.1) [‡]	64.8 (63.2–66.4)	61.5 (59.9–63.2)	63.1 (61.4–64.8)	61.4 (59.7–63.1)	59.3 (57.4–61.2)	57.9 (56.0–59.8)	61.0 (59.2–62.8)
Urban resident [‡]	30.6 (28.7–32.6)	30.1 (28.5–31.6)	30.2 (28.6–31.7)	32.79 (31.17–34.40)	32.2 (30.6–33.7)	33.5 (31.9–35.2)	33.1 (31.5–34.8)	32.8 (31.1–34.5)
Female (n)	2544	3805	3544	3544	3813	3624	3707	3506
Age (y) *	31.7 (31.4–31.9)	38.9 (38.5–39.4)	40.0 (39.6–40.5)	41.3 (40.8–41.8)	42.5 (42.0–42.9)	45.1 (44.6–45.6)	46.5 (46.0–47.0)	46.9 (46.4–47.3)
SBP (mm Hg) *	107.2 (106.8–107.6)	107.8 (107.5–108.2)	108.5 (108.1–108.9)	111.2 (110.8–111.6)	111.8 (111.4–112.1)	113.3 (113.0–113.7)	113.3 (112.9–113.7)	114.6 (114.2–115.0)
DBP (mm Hg) *	70.1 (69.7–70.4)	70.4 (70.1–70.6)	71.4 (71.1–71.6)	72.6 (72.3–72.8)	72.8 (72.6–73.1)	73.7 (73.5–74.0)	73.9 (73.7–74.2)	74.7 (74.5–75.0)
BMI (kg/m ²) *	21.7 (21.6–21.8)	21.7 (21.6–21.7)	21.8 (21.7–21.9)	22.1 (22.0–22.2)	22.5 (22.4–22.6)	22.7 (22.6–22.8)	22.7 (22.6–22.8)	22.8 (22.6–22.9)
Ever smoking [‡]	1.80 (1.28–2.49) [‡]	4.23 (3.58–4.87)	4.15 (3.49–4.82)	3.98 (3.33–4.64)	3.82 (3.20–4.44)	3.79 (3.02–4.56)	3.67 (2.92–4.42)	3.59 (2.82–4.37)
Alcohol drinker [‡]	13.3 (11.8–14.8) [‡]	13.1 (12.0–14.2)	11.9 (10.8–13.0)	10.6 (9.55–11.6)	10.1 (9.09–11.0)	9.07 (8.03–10.1)	8.63 (7.73–9.54)	10.0 (8.84–11.2)

Characteristics	Eight time periods							
	1989–1991	1991–1993	1993–1997	1997–2000	2000–2004	2004–2006	2006–2009	2009–2011
Urban resident [‡]	32.2 (30.4–34.1)	32.1 (30.6–33.6)	30.0 (28.5–31.5)	34.5 (32.9–36.1)	33.6 (32.1–35.1)	33.7 (32.2–35.3)	33.2 (31.7–34.7)	32.8 (31.2–34.3)

SBP, systolic blood pressure; DBP, diastolic blood pressure; BMI, body mass index;

* Mean with 95% confidence interval (95% CI).

[‡]Percentage with 95% confidence interval (95% CI).

[‡]Because the percentages of ever smoker and alcohol drinker were not investigated in 1989, so we fill the missing value using the data from the same participants in 1991

Table 2.

Incident Rates of Hypertension and Subtypes in All Participants (IR, 95%CI)

Characteristics	Subtypes				Medicine	Hypertension
	ISH	IDH	SDH			
Gender						
Male	1.0 (0.9–1.1)	2.3 (2.1–2.4)	1.2 (1.1–1.3)		0.5 (0.4–0.5)	5.0 (4.8–5.1)
Female	1.0 (0.9–1.1)	1.4 (1.3–1.5)	0.9 (0.9–1.0)		0.6 (0.5–0.6)	3.9 (3.7–4.0)
Region						
Rural	1.1 (1.0–1.1)	1.8 (1.7–1.9)	1.1 (1.1–1.2)		0.4 (0.4–0.5)	4.4 (4.3–4.6)
Urban	0.9 (0.8–1.0)	1.8 (1.7–1.9)	0.9 (0.8–1.0)		0.6 (0.5–0.6)	4.3 (4.1–4.5)
Age [*]						
18–34	0.2 (0.1–0.2)	1.1 (1.0–1.2)	0.2 (0.2–0.3)		0.1 (0.0–0.1)	1.5 (1.4–1.6)
35–49	0.5 (0.4–0.5)	2.1 (2.0–2.3)	1.0 (0.9–1.1)		0.3 (0.3–0.4)	3.8 (3.7–4.0)
50–64	2.0 (1.9–2.2)	2.4 (2.2–2.6)	2.0 (1.9–2.2)		1.2 (1.0–1.3)	7.6 (7.3–8.0)
65	4.8 (4.4–5.3)	1.6 (1.3–1.9)	2.8 (2.4–3.1)		2.1 (1.8–2.4)	11.3 (10.7–12.0)
BMI [†]						
< 22	0.8 (0.8–0.9)	1.2 (1.2–1.3)	0.7 (0.6–0.7)		0.3 (0.2–0.3)	3.0 (2.9–3.1)
22–23	0.9 (0.8–1.0)	1.8 (1.7–2.0)	1.0 (0.9–1.1)		0.5 (0.4–0.5)	4.2 (4.0–4.4)
24–25	1.2 (1.1–1.4)	2.4 (2.2–2.6)	1.4 (1.2–1.6)		0.8 (0.7–0.9)	5.8 (5.5–6.1)
26–27	1.4 (1.2–1.6)	2.6 (2.3–2.9)	2.0 (1.8–2.3)		1.2 (1.0–1.4)	7.2 (6.7–7.8)
28	1.9 (1.5–2.2)	3.5 (3.1–4.0)	2.7 (2.3–3.1)		1.7 (1.4–2.0)	9.9 (9.1–10.6)
All participants	1.0 (0.9–1.1)	1.8 (1.7–1.9)	1.1 (1.0–1.1)		0.5 (0.5–0.6)	4.4 (4.3–4.5)

BMI, body mass index, kg/m²; IR, incidence rate, per 100 person-years; CI, confidence interval;

ISH, isolated systolic hypertension; IDH, isolated diastolic hypertension; SDH, systolic-diastolic hypertension; Medicine, current use of antihypertensive medication; Hypertension, total of the four subtypes.

^{*} IR of hypertension increased by age (*P*_{trend} <0.000), adjusted for gender, BMI, region, drinking alcohol, and ever smoking cigarettes.

[†] IR of hypertension increased by BMI (*P*_{trend} <0.000), adjusted for gender, age, region, drinking alcohol, and ever smoking cigarettes.

Table 3. Relative risk (RR) and Population Attributable Risk Percent (PAR %) of Body Mass Index for Incident Hypertension

BMI	IR (95% CI)	RR (95% CI) *	AR [†]	AR% (95% CI) [‡]	PAR	PAR% (95% CI) [§]
All Participants					1.39	32 (29–34)
overall	4.4 (4.3–4.5)					
<22 (reference)	3.0 (2.9–3.1)	1.00				
22–23	4.2 (4.0–4.4)	1.46 (1.35–1.57)	1.20	29 (26–31)		
24–25	5.8 (5.5–6.1)	1.92 (1.78–2.08)	2.81	48 (45–52)		
26–27	7.2 (6.7–7.8)	2.31 (2.11–2.52)	4.23	58 (54–64)		
28	9.9 (9.1–10.6)	3.13 (2.84–3.45)	6.86	70 (64–76)		
Male					1.36	28 (26–32)
overall	5.0 (4.8–5.1)					
<22 (reference)	3.6 (3.3–3.8)	1.00				
22–23	4.9 (4.6–5.3)	1.41 (1.28–1.56)	1.31	28 (24–31)		
24–25	6.8 (6.2–7.3)	1.86 (1.67–2.07)	3.15	47 (43–53)		
26–27	8.4 (7.5–9.2)	2.20 (1.95–2.53)	4.75	58 (51–65)		
28	10.3 (9.1–11.6)	2.87 (2.48–3.53)	6.73	66 (57–75)		
Female					1.39	36 (30–40)
overall	3.9 (3.7–4.0)					
<22 (reference)	2.5 (2.3–2.7)	1.00				
22–23	3.6 (3.3–3.9)	1.52 (1.36–1.70)	1.07	30 (26–35)		
24–25	5.1 (4.6–5.5)	2.03 (1.81–2.27)	2.57	51 (45–57)		
26–27	6.5 (5.8–7.1)	2.42 (2.13–2.75)	3.96	61 (55–69)		
28	9.6 (8.6–10.5)	3.38 (2.96–3.86)	7.05	74 (66–83)		

BMI, body mass index, kg/m²; RR, Relative risk; AR, Attributable Risk; AR%, Attributable Risk Percent; PAR, Population Attributable Risk; PAR%, Population Attributable Risk percent (PAR%); CI, confidence interval.

* RR: Relative risk of BMI for hypertension adjusted for age, region, drinking alcohol, and ever smoking cigarettes by Cox models.

[†] AR is the adjusted difference in hypertension incidence rate among the higher risk group minus the incidence rate among the lower risk group (BMI <22).

[‡] AR% is the percentage of new hypertension cases in higher BMI group that would hypothetically not have occurred if people had been in the low-risk group (BMI <22).

[§] PAR %, is the percentage of new hypertension cases in the population that would hypothetically not have occurred if all people had been in the low-risk group (BMI <22).