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Original Article

Impact of Elevated Systolic Blood Pressure Levels on Mortality and Life Expectancy in Southeast Chinese Residents

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Abstract

Background: We aimed to analyse the impact of elevated systolic blood pressure (SBP) levels on mortality and life expectancy among ≥25 yr adults in the municipality of Ningbo, China.

Methods: The death cause data were collected from the Internet-based Comprehensive Chronic Disease Surveillance System in Zhejiang Province in 2015, and SBP level data were obtained from the Ningbo Adult Chronic Disease Surveillance survey. According to the comparative risk assessment theory, the population attributable fraction (PAF) of elevated SBP levels by gender and urban-rural regions has been calculated. The deaths and life expectancy loss due to elevated SBP levels were estimated.

Results: In 2015, the average SBP level among ≥25 yr adults in Ningbo was 129.01 ± 17.73 mmHg, which was higher in men (131.67 ± 16.89 mmHg) than in women (126.24 ± 18.15 mmHg) and was higher among adults in rural regions (130.55 ± 18.75 mmHg) than among adults in urban regions (127.15 ± 16.19 mmHg). A total of 6181 deaths were attributed to elevated SBP levels among adults in Ningbo. The PAF of deaths caused by elevated SBP levels among adults was 16.14%, which was higher in women (18.73%) than in men (14.31%). The overall loss of life expectancy caused by elevated SBP levels among adults was 1.76 yr, which was higher in women (1.99 yr) than in men (1.53 yr) and was higher in rural regions (1.91 yr) than in urban regions (1.49 yr).

Conclusion: Elevated SBP levels had a serious impact on the death and life expectancy loss of residents in Ningbo.

Keywords: Elevated systolic blood pressure; Population attributable fraction; Attributed death; Life expectancy

Introduction

Cardiovascular disease (CVD) represents a severe disease burden due to its high morbidity and mortality. The global burden of disease (GBD) study showed that approximately 485 million patients and 17.79 million deaths attributed to CVD occur in the 2017 world word (1-3). Meanwhile, it is estimated that more than 23 million deaths due to CVD will occur around the world in 2030 (4). According to the WHO, more than three-quarters of CVD deaths occur in low - and middle-income countries, becoming an increasing public health problem (5).While in China, the

number of CVD patients, including hypertension, is 270 million in 2018. CVD mortality still ranks first among all causes of death [6]. In addition, both mortality and disability-adjusted life-years (DALYs) caused by CVD in China in 2017 are significantly higher than the global average (7). Because of the acceleration of population aging, changes in a traditional lifestyle and rapid economic development in China, the disease burden of CVD will remain substantial in the future.

High systolic blood pressure (SBP) is one of the main modifiable risk factors for CVD. In 2017, the death and the DALY attributed to elevated SBP were 10.4 million and 218 million worldwide, respectively (2-3). The corresponding burden associated with elevated SBP ranked first in all 84 risk factors examined in 2017 (8). In recent years, the prevalence of hypertension in China has been on the rise. It has increased from 18.8% in 2002 to 23.2% in 2015 (9,10). More than 50% of patients with hypertension are undiagnosed (10). In addition, the control rate of hypertension in China remains relatively low compared with that of developed countries (11,12). Hypertension is one of the major interventions to reduce the burden of CVD, and various types of community-based hypertension prevention and control programs have been initiated in different countries (13-17). Hypertension intervention programs have demonstrated effectiveness in controlling hypertension and CVD (18-20).

Life expectancy (LE) is an essential indicator that comprehensively reflects the health status of residents and social and economic development levels [21,22]. In 2016, the Chinese Government announced the Outline of the Healthy China 2030 Plan. A key goal in this plan was to increase LE by 3 yr by 2030 (23). CVD is one of the leading causes of death in Ningbo, and elevated SBP is the predominant preventable risk factor for CVD. In addition, elevated SBP levels are associated with lower LE (24,25). According to the results of the Chinese Center for Disease Control and Prevention (CDC), LE would increase by 4.9 yr if the rate of high SBP was 25% lower in 2030 than in 2013. To achieve the goal of a 3-yr increase in LE by 2030 in Ningbo, good control efforts for high SBP are effective measures (26). We aimed to estimate the LE loss attributed to elevated SBP in Ningbo municipal in 2015.

Methods

Study population

Ningbo municipal, situated at 120°55'-122°16' east longitude, and 28°51'-30°33' north latitude, is a famous port city on the southeast coast of China. It comprises six districts and four counties with a total land area of 9816 km^2 and a registered population of 5.85 million. Ningbo is one of the economic center cities of The Yangtze River delta. The urbanization rate is 72.9%, and the proportion of adults aged over 65 yr is 18.14%.

Data collection

The data of SBP values among residents aged over 25 yr were retrieved from the Ningbo Adult Chronic Disease Surveillance survey. This representative study covered all 10 counties/districts of the Ningbo municipal and was conducted in 2015. All respondents were randomly enrolled by a multistage stratified cluster random sampling method. The sampling procedure, sample size and blood pressure measurement had been reported elsewhere (27). Eventually, 5,160 respondents participated in the present study, of whom 4,800 of them aged over 25 yr. The mortality data extract from the Internet-based Comprehensive Chronic Disease Surveillance System in Zhejiang Province, which covered 5.85 million people in all counties/districts of the city. In 2015, a total of 38,401 deaths were reported in Ningbo with a mortality rate of 6.56‰, including 38,304 deaths of those over 25 yr of age.

Diseases associated with elevated SBP

According to the GBD study 2017, diseases identified as health outcomes etiologically correlated with elevated SBP levels were as follows: rheumatic heart disease, ischaemic heart disease, ischaemic stroke, haemorrhagic stroke, aortic aneu-

rysm, hypertension heart disease, endocarditis, cardiomyopathy and myocarditis, atrial fibrillation, peripheral vascular disease and other circulatory diseases, chronic kidney disease (28).The above-mentioned ICD-10 code of the diseases can be found on the website of the Global Health Data Exchange [29].

Mortality attributable to elevated SBP

We used population attributable fraction (PAF) to evaluate the burden of excess SBP for each specified sex–age and area–age group. The formula for calculating PAF was

$$\mathrm{PAF} = \frac{\int_l^h RR(x)P(x) - \int_l^h RR(x)P^*(x)dx}{\int_l^h RR(x)P(x)dx}$$

RR(x) is the relative risk of SBP level for each disease causally correlated with elevated SBP levels. The specific RR value was identified from the GBD study in 2015 (30). *P(x)* is the SBP level of the surveyed population, and considering the regression dilution bias, we corrected the population distribution of SBP by using the regression dilution coefficient. $P^*(x)$ is the theoretical minimum SBP level with a value of 115 mmHg in this study (30). In addition, h and l represent the maximum and minimum SBP levels, respectively. The mortality for each disease attributable to elevated SBP levels was calculated by multiplying the PAF with the reported deaths based on specific sex and area with different age groups, and then the total attributable disease mortality was summed as the whole mortality attributable to elevated SBP levels.

Calculate the impact of elevated SBP levels on LE

We utilised the simple life table method to calculate the LE of different genders and regions in Ningbo in 2015. After subtracting the total number of deaths from the deaths attributable to elevated SBP levels, the LE of different genders and regions was calculated similarly. The difference between the two is the impact of elevated SBP levels on LE.

Statistical analysis

We used Microsoft Excel 2007 to calculate the PAF by different gender, ages and health outcomes. For statistical analysis, we utilised the R 3.5.0 software. The SBP levels between groups of different characteristics were compared by *t*-test; $P < 0.05$ indicated a statistically significant difference.

Results

The SBP level among residents in Ningbo

Figure 1 shows that in 2015, the average SBP level among adults aged 25 and above in Ningbo was 129.01±17.73 mmHg. The average SBP level was significantly higher in men (131.67 ± 16.89 mmHg) than in women (126.24 ± 18.15 mmHg), with a statistically significant difference (t = 8.352, P<0.05). With the increase in age, the average SBP level of both sexes showed an upward trend. Under the age of 60 yr, men had a higher mean SBP level, and over the age of 65 yr, women had a higher average SBP level.

The number of deaths and PAF attributed to diseases related to elevate SBP

There were 38,304 deaths among adults aged 25 and above in Ningbo in 2015. Table 1 shows that there were 6181 deaths caused by elevated SBP levels, that is,3057 in men and 3124 in women. In different regions, the number of deaths caused by elevated SBP levels in rural regions (4329) was higher than those in urban regions (1862). Among all disease outcomes, hypertensive heart disease had the highest number of deaths (1747), followed by ischaemic stroke (1506) and ischaemic heart disease (1254). In 2015, the PAF of death caused by elevated SBP levels in Ningbo was 16.14%, and the PAF of women (18.73%) was higher than of men (14.31%). Hypertensive heart disease (100%) had the highest PAF among all diseases associated with elevated SBP levels, followed by haemorrhagic stroke (56.94%) and ischaemic heart disease (54.08%).

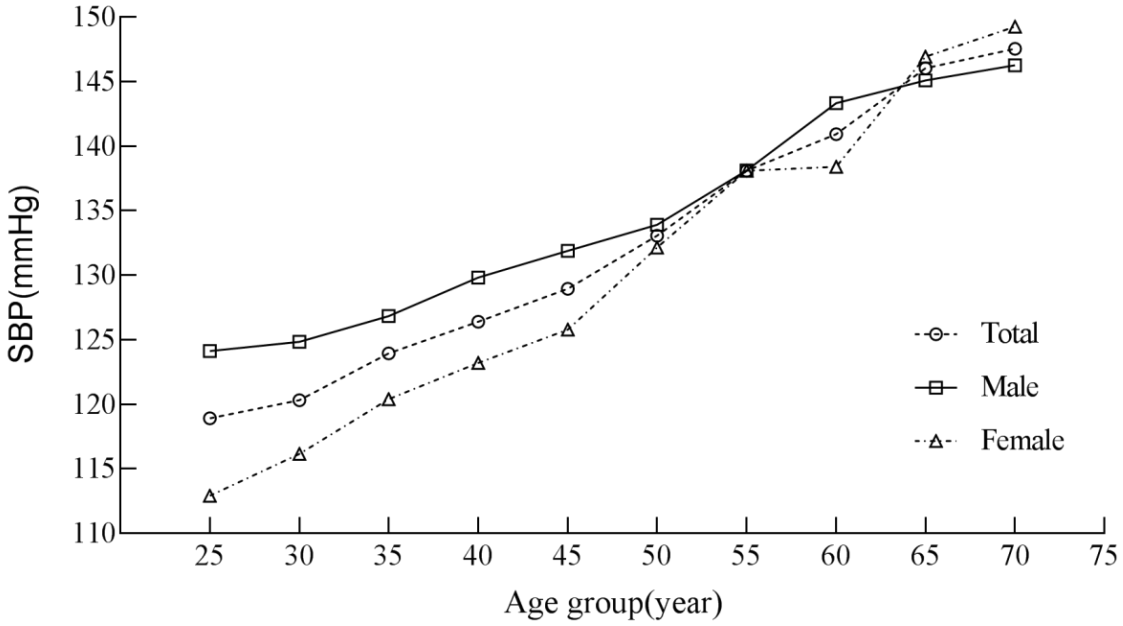

Fig. 1: The average SBP level among ≥25 yr-old adults in Ningbo, 2015

Table 1: The number of deaths and PAF attributed to elevated SBP

Health outcomes	***Gender***		***Region***		***Total***
	Men	Women	Urban	Rural	
IHD	647(52.90)	607(55.38)	471(50.86)	783(56.21)	1254(54.08)
Istroke	755(46.63)	751(48.45)	437(44.46)	1069(48.90)	1506(47.52)
Hstroke	657(56.54)	582(57.40)	372(52.99)	867(58.82)	1239(56.94)
RHD	10(25.64)	10(27.03)	4(22.22)	16(27.59)	20(26.32)
ECM	14(34.15)	9(28.13)	14(32.56)	9(30.00)	23(31.51)
AA	2(22.22)	2(28.57)	0(0.00)	4(33.33)	4(25.00)
HHD	793(100.00)	954(100.00)	416(100.00)	1331(100.00)	1747(100.00)
APO	21(34.43)	17(38.64)	9(27.27)	29(40.28)	38(36.19)
CHD	158(50.00)	192(52.75)	140(48.44)	210(53.71)	350(51.47)
Total	3057(14.31)	3124(18.73)	1863(13.57)	4318(17.76)	6181(16.14)

Abbreviations: IHD = ischaemic heart disease; Istroke = ischaemic stroke; Hstroke = hemorrhagic stroke; RHD = rheumatic heart disease; ECM = endocarditis, cardiomyopathy, and myocarditis; AA = aortic aneurysm; HHD = hypertensive heart disease; APO = atrial fibrillation, peripheral vascular disease, and other circulatory diseases; CKD = chronic kidney disease

The impact of elevated SBP levels on LE

Table 2 shows the LE in Ningbo in 2015 was 81.47 yr, that is, 79.35 yr for men and 83.77 yr for women. The overall loss of LE caused by elevated SBP levels among adults in Ningbo was 1.76 yr, which was higher in women (1.99 yr) than in men (1.53 yr) and higher in rural regions (1.91 yr) than in urban regions (1.49 yr).

Table 2: The impact of elevated SBP levels on life expectancy by gender and region

	Life expectancy	*Life expectancy after removing elevated SBP level effects*	*Life expectancy gain after removing elevated SBP level effects*
Gender			
Men	79.35	80.88	1.53
Women	83.77	85.76	1.99
Region			
Urban	82.26	83.75	1.49
Rural	81.00	82.91	1.91
Total	81.47	83.23	1.76

Discussion

LE can be used to evaluate the burden of health outcomes caused by related risk factors, but these studies were mostly conducted at the national and provincial levels (31,32). This study analysed the impact of elevated SBP levels on LE at the municipal level and obtained quantitative analysis results. These results can provide a basis for the municipality of Ningbo to formulate policies for elevated SBP level prevention and control.

A previous study that was based on 1749 studies from 200 countries of 19.1 million participants showed that the mean SBP remained unchanged in men and declined slightly in women from 1975 to 2015 (33). In some high-income countries, such as Japan (34), United States (35, 36), England (37) and Canada (38), the mean SBP decreased substantially. By contrast, the upward trend of the mean SBP was observed in China (39). A few surveys conducted in Ningbo showed that a rising trend of SBP level was found among residents (40,41), suggesting the possibility of a higher death toll attributed to elevated SBP levels in the future.

In 2013, the PAF attributed to elevated SBP levels accounted for 22.7% in China (18), whereas the PAF worldwide was 18.9% (42). The burden of disease resulting from elevated SBP levels in China was higher than the average level globally. However, the PAF in Ningbo was 16.14%, lower than the average levels worldwide and in China. This might be due to the prosperous economic development, abundant medical resources, high resident consciousness of health and well-managed SBP level among hypertension patients in the local regions. To date, there are already 846,100 patients with hypertension registered by local communities of Ningbo. The blood pressure control rate was 61.08%. Consequently, the proportion of deaths due to circulatory diseases remained relatively low (29.39%). By contrast, the same ratio all over the country was 45.79%(43). Circulatory diseases were the primary health outcomes of elevated SBP levels. This might be explained by the PAF difference between Ningbo and other regions.

The findings of this study revealed that the death toll and PAF attributed to elevated SBP levels were higher in women than in men. This was inconsistent with the studies conducted in other areas of China (24, 25, 31,44), indicating that the effect of elevated blood pressure was more severe in women than in men. The death toll and PAF attributed to elevated SBP levels were higher in rural areas than in urban areas. This is consistent with the results of other researches (24, 25, 31, 44), indicating that rural areas should be given greater attention in hypertension control in Ningbo.

Stroke was one of the primary complications of hypertension. In this study, the proportion of haemorrhagic stroke and ischaemic stroke attributed to elevated SBP levels was 44.41% of the total attributable death toll. Recently, due to the efforts made through the health Management

Program for Hypertensive Patients, stroke mortality showed a significant decreasing trend in Ningbo. According to the surveillance results, the standardised mortality of stroke in Ningbo has declined from 101.03/100,000 in 2002 to 35.49/100,000 in 2018. A similar decreasing trend from 80.65/100,000 in 2002 to 14.89/100,000 in 2018 is also witnessed in ischaemic stroke mortality. The health Management Program for Hypertensive Patients was one of the national fundamental public health service programs, offered for free by the government and implemented since 2009. The implementation of the program provides policies, funds and staffing guarantees for the management of hypertension patients in communities. It played a pivotal role in lowering stroke mortality in recent years.

The LE loss due to elevated SBP was 1.76 yr, which was quite similar to the results reported in Nanjing (44), but lower than that in Chongqing and Jiangxi Province (24,25). In 2015, LE in Ningbo was 81.47 yr. When the impact of elevated SBP was eliminated, LE could reach 83.23 yr. It reflects the severe impact of elevated SBP on LE. As demonstrated by previous literature, elevated SBP levels had the greatest impact on the LE among all risk factors (45). Hypertension prevention and control should thus be prioritised in future works. The health Management Program for Hypertensive Patients should be continued to increase the number of hypertensive patients managed, improve the SBP control rate and further weaken the impact of elevated SBP on disease burden and LE.

The present study has some limitations. First, the Ningbo Adult Chronic Disease Surveillance survey covered residents aged 15–74 yr; thus, the blood pressure level of people aged over 75 yr as analysed in this paper was substituted with the level of the group aged 70–74 yr. This may produce a certain impact on the results. Second, risk ratio values of related diseases were obtained from the global disease burden study in 2015. Because of differences in terms of country and nationality, this would lead to certain deviations in our study. Lastly, only the single factor of elevated blood pressure was analysed in this study. The synergistic impact between different risk factors was not considered.

Conclusion

In 2015, there were a total of 6181(16.14%) deaths attributable to elevated SBP levels among adults in the municipality of Ningbo and appeared higher in women than in men, in rural regions than in urban regions. The life expectancy loss caused by elevated SBP was 1.76 yr, suggesting the targeted measures must be taken to control SBP in Ningbo, especially for females and rural residents.

Ethical considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

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Conflicts of interest

The authors declare that there is no conflict of interest.

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