ISSN 2096-7071
CN 10-1629/R1

CHINA CDC WEEKLY

Vol. 2 No. 40 Oct. 2, 2020

CCDC weekly

中国疾病预防控制中心周报

ISSN 2096-7071
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Announcements

National Hypertension Day — October 8th, 2020

Hypertension, or elevated blood pressure, is a serious medical condition that significantly increases the risk of heart attack, stroke, kidney failure, and blindness and is one of the leading causes of premature death worldwide (*1*). In order to spread information and increase awareness of hypertension, the World Health Organization (WHO) along with the International Hearts Initiative has marked May 17 of every year starting in 1978 as "World Hypertension Day" (*2*). This year's theme is "Measure Your Blood Pressure, Control It, and Live Longer."

Since 1998, China's National Ministry of Health (now the National Health Commission) has designated October 8 of each year as "National Hypertension Day," which aims to raise public awareness of the disease, focus attention on hypertension prevention and control from governments at all levels, various departments, and different sectors of the society, and also mobilize the entire society to work together on the issue. The theme of this year is "All Persons 18 Years Old and Above Should Know Their Blood Pressure"

doi: 10.46234/ccdcw2020.205

Submitted: August 31, 2020; Accepted: September 11, 2020

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Preplanned Studies

Associations Between Hypertension Status and Increased Heart Rate — China, 2015

Xiao Zhang[1]; Mei Zhang[1]; Chun Li[1]; Linhong Wang[1]; Jing Wu[1]; Zhengjing Huang[1]; Limin Wang[1,#]

Summary

What is already known on this topic?

Hypertension is a major public health concern in China, and hypertensive patients have elevated heart rates (HR), which can synergize with higher blood pressure to promote adverse health outcomes.

What is added by this report?

The risk of increased HR was statistically significant but relatively lower in subjects with treated and controlled hypertension. This lower impact might be modified by sex, marital status, smoking, and physical activity.

What are the implications for public health practice?

To mitigate the substantial burden of increased HR among hypertensive patients, improving blood pressure control and promoting healthy lifestyles should be prioritized.

With rapid economic development and population aging, China has experienced an epidemic of hypertension. In comparison with general population, hypertensive patients have elevated heart rate (HR). Previous studies have documented the effect of elevated HR on all-cause and cardiovascular mortality (*1*), and higher HR and blood pressure can work synergistically to promote negative health outcomes (*2*). As a result, monitoring both blood pressure and HR among hypertensive patients is necessary. Although treatment and control of hypertension are essential for preventing adverse cardiovascular events, their roles in reducing HR are not fully understood. In addition, the extent to which such beneficial effects, if any, are modified by individual-level characteristics remains unexplored. In this study, we recruited a nationally representative sample of the general population from the China Chronic Disease and Risk Factors Surveillance

(CCDRFS) in 2015 and collected their data on HR, blood pressure, and antihypertensive treatment. We found that the risk of increased HR was relatively lower in subjects with treated and controlled hypertension, although it was still significant. Furthermore, the impact on HR varied by subgroups of sex, marital status, smoking status, and physical activity. These results suggest that more efforts aiming to improve blood pressure control and promote healthy lifestyles are required to better regulate HR among hypertensive patients.

CCDRFS was a national survey of Chinese adults aged 18 years old and above and the population in this study were from the wave conducted in 2015. Multistage and cluster-randomized sampling was conducted in 298 counties/districts across 31 provincial-level administrative divisions (PLADs), thus providing a nationally representative sample. A questionnaire covering sociodemographic and lifestyle factors, history of hypertension treatment, and anthropometric measurements were administered to each subject by trained personnel. Among the 189,605 respondents (response rate 95.4%), 7,249 subjects had missing data on blood pressure or HR and 10,194 subjects had incomplete covariates, which resulted in the inclusion of 172,162 subjects in main analyses. Hypertension status was classified as follows: a) not treated (newly diagnosed or not treated with antihypertensive drugs); b) treated and not controlled (treated with antihypertensive drugs and systolic/diastolic blood pressure ≥140/90 mmHg); and c) treated and controlled (treated with antihypertensive drugs and systolic/diastolic blood pressure <140/90 mmHg). Increased HR was defined as more than 80 beats per minute (bpm), which was in accordance with the consensus of the Chinese Specialized Committee on Hypertension (*3*).

Standard descriptive statistics were presented by calculating mean and standard deviation for continuous variables and frequency and proportion for categorical variables. To account for correlation between subjects from the same cluster, a generalized linear mixed model with random intercepts for each county/district was employed to examine the associations between hypertension status and increased HR [expressed as odds ratio (OR) and 95% confidence interval (95% CI)]. Model 1 included age, sex, ethnicity, education, marital status, and household income as confounding variables. Model 2 additionally adjusted for smoking, drinking, exercise, salt intake, obesity, and dyslipidemia. In addition, subgroup analyses were also performed to check the modification effects of aforementioned factors. Because biological interactions had more implications in terms of public health, relative excess risk due to interaction (RERI) and attributable proportion (AP) were used to assess interaction at the additive scale (*4*). RERI and AP>0 meant more than additivity, and otherwise less than additivity. All statistical analyses were performed using R software (version 3.6.0, R Foundation for Statistical Computing), and statistical significance was defined as two-sided $p<0.05$.

Data were available for 172,162 subjects aged ≥18 years, whose characteristics were similar with those excluded (n=17,443) except that they exhibited higher likelihood of being ethnically Han and physically active. Compared with non-hypertensive subjects, hypertensive patients were more likely to be older, less educated, poorer, obese, lipid dysregulated, and having higher salt intake (Table 1). Of the 68,405 hypertensive patients, 65.0% had untreated hypertension, 26.3% had treated and uncontrolled hypertension, and 8.7% had treated and controlled hypertension.

As shown in Table 2, the HR of hypertensive subjects was 1 bpm higher than non-hypertensive subjects (76.4 *vs.* 75.4, $p<0.001$), and the corresponding prevalence of increased HR was 33.3% and 28.4%. Subjects with untreated or treated and uncontrolled hypertension had similar prevalence with overall hypertensive subjects (33.5% and 34.0%, respectively), whereas subjects with treated and controlled hypertension had prevalence closer to non-hypertensive subjects (30.3%). Further stratified analyses by sociodemographic, behavioral, and biological factors showed that the prevalence was significantly higher among people who were younger, female, unmarried, drinker, less physically active, obese, or with dyslipidemia (Supplementary Table S1, available in http://weekly.chinacdc.cn/). Results of the mixed effect logistic model supported these differences. After adjusting for covariates, the odds of increased HR was 35% higher for untreated hypertension (OR=1.35, 95% CI: 1.32 to 1.39), 40% higher for treated and uncontrolled hypertension (OR=1.40, 95% CI: 1.34 to 1.45), and 18% higher for treated and controlled hypertension (OR=1.18, 95% CI: 1.11 to 1.25).

Furthermore, the RERI was 0.17 (95% CI: –0.03 to 0.36) for smoking, 0.22 (95% CI: –0.01 to 0.45) for marital status, and 0.19 (95% CI: 0.01 to 0.36) for physical activity, suggesting synergistic effects of smoking, unmarried, or physical inactivity and treated

TABLE 1. General characteristics of subjects aged 18 years old or above by hypertension status in China, 2015.

Variable	Non-hypertensive subjects (n=103,757)	Hypertensive subjects			
		Total (n=68,405)	Not treated (n=44,435)	Treated and not controlled (n=18,019)	Treated and controlled (n=5,951)
Age (mean±SD)	47.6±14.0	59.3±12.0	57.6±12.5	62.8±10.2	62.2±10.1
Men (n, %)	46,672 (45.0)	33,474 (48.9)	23,016 (51.8)	7,787 (43.2)	2,671 (44.9)
Ethnically Han (n, %)	90,567 (87.3)	61,747 (90.3)	39,483 (88.9)	16,662 (92.5)	5,602 (94.1)
Senior high school or above (n, %)	24,491 (23.6)	10,451 (15.3)	6,438 (14.5)	2,599 (14.4)	1,414 (23.8)
Married (n, %)	94,568 (91.1)	62,125 (90.8)	40,567 (91.3)	16,179 (89.8)	5,379 (90.4)
Household income (n, %)					
<10,000 CNY	9,024 (8.7)	8,596 (12.6)	5,563 (12.5)	2,472 (13.7)	561 (9.4)
10,000–49,999 CNY	48,186 (46.4)	31,592 (46.2)	21,052 (47.4)	8,136 (45.2)	2,404 (40.4)
≥50,000 CNY	30,074 (29.0)	17,028 (24.9)	10,026 (22.6)	4,795 (26.6)	2,207 (37.1)
Don't know/refuse to answer	16,473 (15.9)	11,189 (16.3)	7,794 (17.5)	2,616 (14.5)	779 (13.1)
Current smoking (n, %)	27,247 (26.3)	17,786 (26.0)	12,762 (28.7)	3,755 (20.8)	1,269 (21.3)
Current drinking (n, %)	38,430 (37.0)	24,639 (36.0)	17,467 (39.3)	5,316 (29.5)	1,856 (31.2)
Physical inactivity (n, %)	18,249 (17.6)	12,985 (19.0)	8,491 (19.1)	3,373 (18.7)	1,121 (18.8)
High salt intake (n, %)	62,621 (60.4)	43,909 (64.2)	28,699 (64.6)	11,744 (65.2)	3,466 (58.2)
Obesity (n, %)	10,117 (9.8)	14,409 (21.1)	8,293 (18.7)	4,803 (26.7)	1,313 (22.1)
Dyslipidemia (n, %)	35,565 (34.3)	32,139 (47.0)	18,910 (42.6)	9,926 (55.1)	3,303 (55.5)

TABLE 2. Blood pressure, heart rate, and risk of increased heart rate of subjects aged 18 years old or above by hypertension status in China, 2015.

	SBP (mmHg, mean±SD)	DBP (mmHg, mean±SD)	HR (bpm, mean±SD)	HR >80 bpm (n, %)	OR (95% CI)	
					Model 1*	Model 2†
Non-hypertensive subjects	121.1±10.7	73.8±8.1	75.4±10.4	29,440 (28.4)	ref	ref
Total hypertensive subjects	153.6±17.9	86.8±11.5	76.4±11.8	22,800 (33.3)	1.39 (1.36 to 1.42)	1.35 (1.32 to 1.38)
Not treated	153.8±15.5	87.4±11.0	76.5±11.8	14,872 (33.5)	1.39 (1.35 to 1.42)	1.35 (1.32 to 1.39)
Treated and not controlled	161.5±18.2	88.7±11.9	76.6±12.1	6,122 (34.0)	1.46 (1.41 to 1.51)	1.40 (1.34 to 1.45)
Treated and controlled	128.5±8.5	76.4±7.9	75.9±11.0	1,806 (30.3)	1.23 (1.16 to 1.31)	1.18 (1.11 to 1.25)

Abreviation: SBP=systolic blood pressure; DBP=diastolic blood pressure; HR=heart rate; OR=odds ratio; CI=confidence interval; REF=reference.

* Adjusted for age, sex, ethnicity, education, marital status, and household income.

† Adjusted for the same covariates as model 1 plus smoking, drinking, physical activity, salt intake, obesity, and dyslipidemia.

and controlled hypertension (Table 3). In contrast, the RERI was –0.33 (95% CI: –0.50 to –0.16) for sex, which indicated that the joint effects of being women and treated and controlled hypertension were less than expected sum of the individual effects.

DISCUSSION

Using a nationally representative sample of China's population, we found that the prevalence of increased HR among hypertensive subjects was 33.3%. Compared with non-hypertensive subjects, the excess risk of increased HR for subjects with untreated or treated uncontrolled hypertension was at least 35%, while it reduced to 18% for subjects with treated controlled hypertension. Moreover, the associations between treated controlled hypertension and increased HR seemed to depend on sex, marital status, smoking status, and physical activity.

A prior cohort study demonstrated that hypertensive individuals with HR ≥80 bpm had 51% and 38% higher risk for mortality from cardiovascular diseases and all causes than those with HR <60 bpm (5). Hence, increasing concerns have been raised regarding dysregulated HR among hypertensive patients. However, few Chinese studies have directly assessed its prevalence at the national level. In 2014, Sun et al.

TABLE 3. Additive interaction of treated and controlled hypertension and several characteristics on increased heart rate in China, 2015.

Item	OR (95% CI)*	Additive interaction	
		RERI (95% CI)	AP (95% CI)
Sex			
Men	1.42 (1.30 to 1.55)	−0.33 (−0.50 to −0.16)	−0.22 (−0.34 to −0.10)
Women	1.04 (0.97 to 1.13)		
Marital status			
Married	1.18 (1.11 to 1.26)	0.22 (−0.01 to 0.45)	0.13 (0.00 to 0.26)
Not married	1.28 (1.07 to 1.53)		
Smoking status			
Non-smoker	1.16 (1.09 to 1.24)	0.17 (−0.03 to 0.36)	0.11 (−0.01 to 0.23)
Smoker	1.31 (1.15 to 1.48)		
Physical inactivity			
No	1.18 (1.10 to 1.26)	0.19 (0.01 to 0.36)	0.12 (0.01 to 0.23)
Yes	1.27 (1.11 to 1.44)		

Abreviation: RERI=relative excess risk due to interaction; AP=attributable proportion; CI=confidence interval.
*Adjusted for age, ethnicity, education, household income, drinking, salt intake, obesity, dyslipidemia, and for sex, marital status, smoking, physical activity when appropriate. Reference category: non-hypertensive subjects.

assembled data of outpatients from 136 hospitals located in 21 cities and reported that 38.2% of uncomplicated hypertensive patients had HR ≥80 bpm (*6*). Our analysis extended this result by analyzing the general population, and the corresponding prevalence was 35.1% using the same cutoff value as their study. Despite the modest decrease in prevalence, caution is needed when concluding the trend of increased HR over time because of possibly more severe hypertension in hospital-based patients. Our estimated prevalence 33.3% coupled with the Chinese population size (1.37 billion) and hypertension prevalence (29.0%) translated to a total of 132 million hypertensive patients having increased HR in 2015. This number should urge policymakers to strengthen the regulation of HR in people with hypertension.

We found that the risk of increased HR was relatively lower in people with treated and controlled hypertension than those with untreated or treated uncontrolled hypertension. The biological mechanisms underpinning these differences are unclear. One explanation is that controlled hypertension is merely an indicator of reduced sympathetic activity that negatively controls HR (*7*). Another explanation is that high blood pressure causes damage to cardiovascular system and HR increases to compensate for this damage, so decreasing blood pressure would decrease this compensatory adaptation. However, the sustained higher risk suggested that current criteria designating blood pressure control might not be sufficient to reverse the increased HR to levels observed in non-hypertensive subjects. It is also possible that the antihypertensive drug used, such as β-blocker, can exert impacts on both blood pressure and HR. Thus, it would be valuable to compare HR by classes of antihypertensive drugs. Since this information was not collected in CCDRFS, future studies are warranted to explore this topic.

Interestingly, the impact of treated and controlled hypertension on HR appeared to be modified by several risk factors. First, the estimate seemed to be larger in smokers, which is supported by the direct link between smoking and stimulated sympathetic nervous system (*8*). Second, the stronger association in people exercising less was not surprising as inactive people generally have higher HR than active people (*9*). Third, men were found to have much higher risk than women. This could be explained by the greater likelihood of men being smokers, drinkers, or having inactive lifestyles. Finally, the fast pace of life commonly seen in unmarried people might result in more psychological stress, which in turn might lead to increased HR.

This study was subject to some limitations. Due to lack of data on medication history as mentioned above, the impact of finer categories of hypertension treatment on HR could not be elucidated. In addition, some important covariates including intake of tea and/or coffee were not available, leaving the possibility of residual confounding.

In summary, the risk of increased HR differed by hypertension status, with lower risk in people with

treated and controlled hypertension. The lower risk was more pronounced among women, nonsmokers, and those married or exercising regularly. To mitigate the substantial burden of increased HR among hypertensive patients, improving blood pressure control and promoting healthy lifestyles should be prioritized.

Acknowledgments: We thank all of the health staff who have contributed to implementation of the CCDRFS survey.

doi: 10.46234/ccdcw2020.209

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Submitted: August 31, 2020; Accepted: September 11, 2020

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SUPPLEMENTARY TABLE S1. The prevalence of increased heart rate stratified by both characteristics and hypertension status in China, 2015.

Variable	Non-hypertensive subjects (n=103,757)			Hypertensive subjects (n=68,405)								
				Not treated (n=44,435)			Treated and not controlled (n=18,019)			Treated and controlled (n=5,951)		
	n	%	*p*-value†	n	%	*p*-value†	n	%	*p*-value†	n	%	*p*-value†
Age												
≤52.4 years*	66,077	29.3	<0.001	15,351	37.2	<0.001	3,007	36.2	0.003	1,010	31.2	0.441
>52.4 years*	37,680	26.7		29,084	31.5		15,012	33.5		4,941	30.2	
Sex												
Men	46,672	25.0	<0.001	23,016	32.0	<0.001	7,787	32.3	<0.001	2,671	29.8	0.324
Women	57,085	31.1		21,419	35.1		10,232	35.2		3,280	30.8	
Ethnicity												
Non-Han	13,190	30.1	0.141	4,952	34.7	0.064	1,357	36.3	0.037	349	33.5	0.133
Han	90,567	28.1		39,483	33.3		16,662	33.8		5,602	30.1	
Educational level												
Low	79,266	28.6	0.002	37,997	33.3	0.096	15,420	34.4	0.008	4,537	31.6	0.001
High	24,491	27.8		6,438	34.3		2,599	31.5		1,414	26.3	
Marital status												
Unmarried	9,189	34.2	<0.001	3,868	38.2	<0.001	1,840	38.6	<0.001	572	37.9	<0.001
Married	94,568	27.8		40,567	33.0		16,179	33.5		5,379	29.5	
Household income												
<10,000 CNY	9,024	30.2	ref	5,563	32.6	ref	2,472	34.0	ref	561	36.2	ref
10,000–49,999 CNY	48,186	28.5	0.86	21,052	32.9	0.335	8,136	34.3	0.914	2,404	32.1	0.094
≥50,000 CNY	30,074	27.0	0.109	10,026	34.2	0.032	4,795	32.8	0.222	2,207	27.2	<0.001
Don't know/refuse to answer	16,473	29.4	0.188	7,794	34.6	0.068	2,616	35.1	0.85	779	29.7	0.025
Current Smoking												
No	76,510	29.0	<0.001	31,673	33.5	0.522	14,264	34.2	0.18	4,682	30.2	0.871
Yes	27,247	26.5		12,762	33.4		3,755	33.0		1,269	30.8	
Alcohol use												
No	65,327	30.1	<0.001	26,968	34.5	<0.001	12,703	35.0	<0.001	4,095	31.3	0.042
Yes	38,430	25.5		17,467	31.9		5,316	31.5		1,856	28.2	
Physical activity												
Inactive	182,499	32.0	<0.001	8,491	37.3	<0.001	3,373	39.4	<0.001	1,121	35.2	<0.001
Active	85,508	27.6		35,944	32.6		14,646	32.7		4,830	29.2	
Salt intake												
Low	411,366	28.0	0.392	15,736	33.9	0.307	6,275	34.4	0.561	2,485	30.0	0.98
High	62,621	28.6		28,699	33.3		11,744	33.8		3,466	30.6	
Obesity												
No	936,400	28.2	<0.001	36,142	32.8	<0.001	13,216	34.0	0.527	4,638	29.9	0.084
Yes	10,117	30.1		8,293	36.3		4,803	34.0		1,313	32.1	
Dyslipidemia												
No	68,192	27.7	<0.001	25,525	31.0	<0.001	8,093	32.2	<0.001	2,648	29.4	0.07
Yes	35,565	29.7		18,910	36.8		9,926	35.4		3,303	31.1	

* The median of age among total population.
† *p* values were derived from univariate generalized linear mixed model.

Perspectives

Growing Burden of Hypertension in China: Causes, Challenges, and Opportunities

Zumin Shi[1,#]; Xiaomin Sun[2]; Alice F Yan[3]; Youfa Wang[2,#]

Cardiovascular disease (CVD) is the leading cause of death in China, and an estimated 290 million individuals are affected by CVD in China (*1*). Hypertension is the most important risk factor of CVD (*2*). Good control and management of hypertension are vital to prevent CVD and related health and social consequences. Over the past several decades, China has put a significant amount of effort into the battle against hypertension. Yet, the burden of hypertension continues to increase. Here, we described the burden of hypertension and its important risk factors in China.

BURDEN AND CHALLENGES

The burden of hypertension in China has been increasing over the past several decades. According to the 2002 China National Nutrition and Health Survey, the prevalence of hypertension was 18.0% (*3*). Data from China's nationally representative survey conducted 10 years later recruited 174,621 adults aged over 18 years from 31 provincial-level administrative divisions (PLADs) in the mainland of China between 2013–2014 and showed major reversals (*4*). Overall, the prevalence of hypertension was 27.8 % (*4*), which was lower than that of the US (29.1%) and England (30%) but higher than that of Canada (19.5%) (*5*).

Another serious challenge is that the prevalence of hypertension was substantially increased, but the levels of awareness, treatment, and management remained low. Among those with hypertension in China, only less than half were aware of their condition, 40.7% were taking antihypertensive medication, and only 15.3% achieved blood pressure control (*6*). Among those treated hypertensive patients, only about 37.5% had their blood pressure controlled at the desired level. Although the prevalence of awareness in China improved in 2012 (46.9%) over that of 2002 (24%), it was much lower than that in the US (81%), Canada (83%), and England (65%) (*5*).

It is worth noting that aging is one of the most important risk factors of hypertension. Among those 65 years and older, the prevalence of hypertension was above 55% (*6*). With the population aging, the burden of hypertension and related complications will continue to increase in China. Other important factors that have contributed to the increased burden of hypertension include changes in lifestyle factors (such as dietary patterns) and increased obese/overweight prevalence.

IMPORTANT CAUSES AND DETERMINANTS

Salt Intake in China

Salt reduction has been given priority as a hypertension prevention strategy in China. For example, salt restriction spoons were provided by the government to the public for free to reduce salt consumption and complement other salt reduction campaigns (*7*). Data from China's total diet studies showed that the average amount of sodium consumed from cooking salt decreased from 11.8 grams/day (g/d) in 2000 to 9.2 g/d in 2009–2011 (*8*), but this was still much higher than the recommended daily maximum intake of salt (5 g/d) and sodium level (2 g/d). A meta-analysis of 24-hour urinary sodium excretion found a decreasing trend in the north but an increasing trend in the south (*9*). However, the reduction in salt intake did not translate into a significant reduction in hypertension rates in China. The prevention of hypertension should not be confined to salt reduction as other factors need to be addressed simultaneously.

Role of Obesity

Obesity (including overweight) is one of the major risk factors of hypertension. Presently, about 46% of adults in China are overweight or obese (*10*). In the China Kadoorie Biobank (CKB) study, general adiposity as reflected by BMI was strongly associated with blood pressure, and the association was 50% stronger than that observed in Western populations

(*11*). Due to social and economic development, the prevalence of obesity and overweight was increased substantially in both adults and children in China. For example, national survey data showed that the prevalence of obesity among children aged 6–17 years increased from 2.1% in 2002 to 6.4% in 2012 (*12*). Prevention of obesity and hypertension in children and adolescents should be given priority as these conditions during this period have long-term effects on health outcomes. Furthermore, data from diverse populations showed childhood blood pressure was associated with blood pressure in later life and that interventions in childhood were important (*13*).

Early Life Famine Exposure

In addition to the traditional risk factors of hypertension, early life exposure to famine (such as the Chinese famine between 1959 and 1962) has been shown to increase hypertension risk (*14–16*). Data from the China Health and Retirement Longitudinal Study (CHARLS) suggested that early life exposure to the Chinese famine exacerbated the association between hypertension and CVD (*17*). The odds ratio (OR) of hypertension for CVD were 1.69, 2.35, 2.48, 3.35, and 1.40 among adults in late childhood, mid-childhood, early childhood, fetal, and non-exposed cohorts, respectively (*17*). Regional differences for hypertension may partly be due to different effects of famine exposure in early life as there were also a few studies that showed a link between early life famine exposure and obesity in adulthood in China. Lessons can be learned from famine-related studies. They may also indicate the importance of nutrition intervention during natural disasters such as earthquakes and floods.

Disparities

The substantial disparity of hypertension by socioeconomic status (SES) must be recognized as those with lower education had a much higher prevalence of hypertension than those with higher education (36.5% *vs.* 9.5%) (*6*). Hypertension prevention should target the disadvantaged group. In the past, hypertension was found to impact more people in urban areas than rural areas of China (*3*). However, recent data showed that there was no significant urban/rural difference in the prevalence of hypertension (*6*). The rise in the prevalence of hypertension in rural areas is a challenge due to the relatively limited access to health services, especially in cases of CVD events such as stroke. In general, the prevalence of awareness and control of hypertension was lower in rural areas than urban areas (*4*,*6*).

Regional differences in the prevalence of hypertension have been observed for a long time (*18*). Several potential factors have been proposed to explain this difference including differences in dietary habits, alcohol consumption, temperature, and physical activity levels.

More research is needed to explore other factors that may have affected hypertension rate in China. For example, one factor that needed to be examined was selenium intake in the north because selenium intake is responsible for Keshan disease (*19*). The degree to which selenium levels affected hypertension needed to be studied because several regions of China suffered from inadequate selenium intake. Studying the relationship between serum selenium and hypertension yielded inconsistent findings with both positive and inverse associations being reported (*20–21*), thereby necessitating further studies to establish this relationship.

Gender differences in the prevalence of hypertension has been consistently observed with a higher rate in men than women (*4*,*6*). The gap may be partly due to unhealthy lifestyles (e.g. smoking and alcohol drinking) in men (*22*).

Role of Modern Diet and Lifestyle

In recent decades, there have been substantial changes in people's dietary intakes in China. The consumption of energy-dense diets has increased substantially, and such diets are linked to an increased cardiometabolic risk factors (*23*). Based on the 2002 Chinese National Nutrition Survey, exposure to the modern diet in adulthood modified the association between famine exposure and metabolic syndrome (*24*). Participants who were born in severe famine or had Western dietary habits in adulthood had a particularly high risk of metabolic syndrome (*24*).

Over the past decade, the use of online shopping and home delivery has promoted diets filled with highly processed, energy dense food and increased the risk of sedentary behavior as well. This will further contribute to the burden of hypertension if not addressed well in time.

OPPORTUNITIES

Modern technologies do provide significant opportunities to prevent and manage hypertension. For example, the widespread use of smartphones and social

media apps like WeChat make more health-related knowledge and education materials accessible to people regardless of their locations and SES. Another example is that a smart salt jar was developed by a Chinese company to monitor household salt consumption (*25*). The system not only provided information on household salt usage but also offered health messages and guidance on managing hypertension. Whether it is more efficient than the currently used salt restrictions spoons warrants further research.

The use of modern technologies may also help monitor physical activity, sleep, and the use of hypertension medication. The health and behavior related data collected by different channels provide excellent opportunities for tailored prevention of hypertension as most of them are modifiable risk factors for hypertension.

With the health reform started in 2009, China has delivered a remarkable expansion of health insurance coverage, which provided a better opportunity for treatment of hypertension. The National Basic Public Health Service Project provided hypertension patients aged 35 years old and above with free management service by local primary healthcare workers. The Ministry of Health proposed a "Work plan on NCD prevention and control in China (2012–2015)" and focused on setting up mechanisms of multisectoral cooperation (*26*). The work plan provided a great opportunity to prevent and manage hypertension by increasing the awareness and control of hypertension, especially among those in rural areas, those with a low socioeconomic status, and those in the young labor force (*27*).

In conclusion, the control rate of hypertension is steadily increasing in China. However, China still faces a major challenge with hypertension, and it is likely to become worse in the future due to shifts in the population's socioeconomic status and promotion of unhealthier diets and lifestyles. Poor awareness and control of hypertension put tens of millions of lives at risk. Prevention of hypertension should not only target conventional risk factors but also focus on novel risk factors. Priority should be given to the screening and monitoring of hypertension. The use of modern technologies will facilitate prevention efforts and make them more sustainable and effective.

doi: 10.46234/ccdcw2020.210

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Submitted: September 06, 2020; Accepted: September 25, 2020

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Perspectives

China Can Substantially Reduce Its High Burden of Stroke and Heart Attack

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Hypertension, the leading cause of cardiovascular disease, kills 10.7 million people worldwide each year — more than any other cause, and more than all infectious diseases combined (*1*). Approximately one third of adults globally have elevated blood pressure; of these approximately 1.4 billion people, only 1 in 7 with hypertension are effectively treated so that their blood pressure is reduced to below 140/90 (*2*).

China's hypertension burden mirrors the global situation. A quarter of a billion people in China have hypertension — the most of any country in the world — with 23.5% of the adult population having elevated blood pressure. Only an estimated 10%–15% of those with hypertension are treated effectively such that they have the condition under control (*3*).

Each year, 1.8 million people in China die from hypertension, nearly double the number in India despite similar population sizes and rates of hypertension (*4*). For a productive and healthy future, prevention and control of hypertension is essential. It is also feasible to do so; for example, Canada has improved hypertension control rates to nearly 70% nationwide (*5*), and Thailand's rate of blood pressure control increased more than 3-fold, from 8.6% to 30%, between 2004 and 2014 (*6*), and appears to have continued to increase since.

The two most effective methods of reducing the strokes, heart attacks, and other health problems hypertension causes are to improve hypertension treatment and reduce the intake of sodium, which is a leading contributor to high blood pressure. Globally over the next 25 years, improving control of hypertension from the current 14% of people with high blood pressure to 50% would prevent about 40 million cardiovascular deaths, and reducing population sodium intake by 30% would prevent another 40 million deaths (*7*).

Of all primary care interventions for adults, improvement in control of hypertension can save the most lives, potentially many times the number from many other interventions (*8*). Excess consumption of dietary sodium increases blood pressure and cardiovascular disease; the average sodium intake in China is approximately double the recommendations of World Health Organization (WHO) and other leading health organizations (*9*). These two interventions will be integral to achieving Sustainable Development Goal 3.4.1, which aims to reduce the risk of premature death among people aged 30–69 years from noncommunicable diseases by one third by 2030 (*10*), as well as to achieve the aims of Healthy China 2030 (*11*).

Health systems that succeed in hypertension control ensure provision of a technical package with 5 key components: 1) protocols that establish standard treatment; 2) community-based care, including use of health staff at the community level to do more tasks such as blood pressure measurement, medication refills, and medication titration following a protocol, with or without telemedicine or artificial intelligence support; 3) regular and uninterrupted supply of quality medications and blood pressure monitoring equipment; 4) patient-centered services that reduce barriers to adherence including the complete elimination of fees for medical visits and for anti-hypertension medications; and 5) information systems that allow accurate and reliable real-time feedback on blood pressure control to clinical staff and program managers (*12*). These elements are also reflected in the WHO HEARTS technical package for cardiovascular disease management in primary health care (*13*).

From the perspective of hypertension control, four aspects of this technical package are particularly important in the Chinese context:

1. Adhering to specific, algorithmic treatment protocols to eliminate unwarranted variability in prescribing, and facilitate task-sharing and decentralization, and reduce health system and patient out-of-pocket costs while improving treatment efficacy. Reduced patient costs are demonstrated to increase adherence to treatment regimens and thereby reduce the financial and societal costs of avoidable heart attacks and strokes.

2. Providing three- or six-month refills with appropriate appointment spacing for stable patients, using virtual consultation and patient self-management when feasible. This will also reduce costs for the health

system and for patients and increase patient retention in care. If China is to double, triple, or quadruple the proportion of patients with hypertension who have it under control, it will need to increase the efficiency of treatment — less frequent visits with longer refills are one important way to do this. These reforms, implemented during China's successful campaign to stop COVID-19 by limiting visits to health facilities, are excellent innovations and will benefit patients and the health system if they are made permanent throughout China.

3. Improving patient access to care by reducing reliance on hospital-centric care and increasing use of community-based primary care. China has committed to shifting its focus and resources toward safe, effective, accessible, and affordable basic health services at lower levels of care (*14*), and specifically adopting this more integrated approach by augmenting its primary care workforce (*15*). Making care easier to access will increase treatment adherence, reduce population hypertension rates, and save lives.

4. Developing a functional health information system with interoperability between health facilities and the ability to collect and analyze data on meaningful, consistent, reliable indicators of blood pressure control. This is essential to program evaluation and improvement.

Reducing dietary sodium intake and associated hypertension and cardiovascular disease is possible, as has been documented in the United Kingdom (UK) (*16*) and Finland (*17*). More recently, the Republic of Korea implemented a multicomponent program that reduced dietary sodium consumption among adults by 24% over a 4-year period, with reductions in population blood pressure and hypertension prevalence (*18*). Although there are differences in food consumption profiles, lessons from the Republic of Korea program are likely relevant to China and other Asian countries.

There are 3 primary sources of dietary sodium: 1) sodium added to packaged food during manufacturing; 2) sodium added to food prepared and consumed outside the home (e.g., restaurants, cafeterias, street food vendors); and 3) sodium added in the home, either during cooking or while eating (*9*). In China, two thirds of dietary sodium intake comes from these in-home sources (*19*); sodium reduction efforts will need to address this to be successful.

China already has a model to reduce sodium added in the home: the Shandong-Ministry of Health Action on Salt and Hypertension (SMASH) program. This intensive program used a mix of promotion of potassium-containing, low-sodium salt, community education, mass media, distribution of salt measuring spoons, and collaboration with restaurants and supermarkets to set food standards for sodium content. This intervention led to a reported 25% reduction in sodium intake as measured by 24-hour urine sodium and significant declines in blood pressure (*20*).

Urban populations are more likely to consume commercially packaged foods and foods prepared outside the home, and these sources of dietary sodium must also be addressed. Working with packaged food manufacturers to reduce sodium content has been successful in the UK, Republic of Korea, and other countries; mandatory reductions are much more effective than voluntary initiatives, which usually fail. Establishing specific targets to reduce sodium in different food categories nationwide, along with requirements to label sodium content, is a feasible approach.

In addition, front-of-package labeling highlighting levels of sodium, fats, and sugar help consumers quickly and effectively make healthier choices. In particular, mandatory front-of-package labels that feature warning signs, such as introduced in Chile, have been demonstrated to lead to significant reduction in purchases of sugar-sweetened beverages and are the emerging best practice globally for front-of-pack images (*21*). Chile's front-of-package warning labeling of high-salt and high-fat foods is likely to result in both improved options for consumers and improved choices by consumers. Sodium intake can also be reduced in foods prepared and eaten outside the home. For example, strong and mandatory policies which set standards for food that is procured or served on public property have been demonstrated to improve the availability of healthy food in institutions such as school and public workplaces (*22*).

Adopting a mix of proven interventions such as those demonstrated in SMASH mandatory policies supporting sodium targets, front-of-package labels, and public food procurement can lead to significant reductions in sodium intake, preventing hypertension and improving its control. However, additional innovative measures should also be investigated for use in China. These include increased use of low-sodium salt and other low-sodium condiments as well as interventions to reduce sodium use in restaurant-prepared foods and to provide customers with information on key nutrients in restaurant menu items.

Although China has made some progress improving hypertension treatment and reducing dietary sodium intake, stronger action on both fronts can save millions of lives and billions of yuan. China has the opportunity to become a regional and global model for reducing

hypertension prevalence and preventing cardiovascular disease, which causes nearly half of all deaths in the country each year (*23*). Millions of lives could be saved and much disability from stroke, heart attack, blindness, kidney failure, dementia, and other complications of hypertension could be prevented in China if the laudable Healthy China 2030 commitment to hypertension treatment and sodium reduction become realities in practice.

The fundamental emerging global insight on cardiovascular prevention is clear: the most important issue is economics. High and increasing taxes on tobacco and alcohol, controls on marketing and availability of tobacco and alcohol, much higher, capitated pay for primary care clinicians, a health care payment model that rewards providers substantially for validated hypertension control and eliminates costs for patients, and making healthy, low-sodium food less expensive than unhealthy food are the road not just to health, but also to productivity, economic stability, and societal progress.

doi: 10.46234/ccdcw2020.211

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Submitted: September 15, 2020; Accepted: September 22, 2020

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Healthy China

China CDC in Action — Hypertension Prevention and Control

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Summary

Hypertension contributes to a quarter of all-cause mortality in China. The Chinese government has put forward aims to control and prevent hypertension, and China CDC and other professional public health institutions have carried out a series of related efforts including the promotion of related policies and legislation, the improvement of modifiable risk factors of hypertension in the population, and promoting the National Primary Public Health Services to discover and manage patients with hypertension. China CDC has conducted multiple hypertension-related campaigns such as advocating for salt reduction, weight loss, and increased physical activity. Additionally, on behalf of the Chinese government, China CDC has organized and carried out the construction of national demonstration areas for the comprehensive prevention and control of chronic diseases. As of 2020, 488 national demonstration areas have been established, covering 17.1% of all counties and districts. In these areas, the lifestyle and health literacy of the population and community-based hypertension management measures have been improved. The *Healthy China 2030* calls for a transition from disease treatment to a focus on health, which requires a strategy of hypertension prevention and control that focuses on the whole population rather than on high-risk populations. The *Primary Health Care, Medicine and Health Promotion Law* was officially implemented on June 1, 2020 and provides the legal basis for this strategy change in the prevention and control of hypertension. Ongoing public health legislation should involve non-communicable diseases such as hypertension in addition to communicable diseases.

There are 270 million patients with hypertension in China. The Global Burden of Disease (GBD) showed that hypertension had become the primary contributor to disability-adjusted life years in China, contributing to 24.6% of all-cause mortality (*1–2*). The proportion of lost life years from an early death caused by hypertension in cardiovascular and cerebrovascular disease is 64.5% and 72.8%, respectively, ranking first among all risk factors of cardiovascular and cerebrovascular diseases (*2*). The *Healthy China Initiative (2019–2030)*, which was initiated by the Chinese government in 2019, has established goals for hypertension prevention and control such as regular blood pressure (BP) monitoring for adults aged 18 years or older, increasing awareness rates, and normalizing the management, treatment, and control of hypertension (Table 1). Professional public health institutions, including China CDC, attach great importance to this public health issue, and much work has been conducted in this area. This study aimed to explore the challenges and opportunities of hypertension prevention and control by reviewing the work of the China CDC in changing strategies, life-style interventions, and patient management.

CREATING A SUPPORTIVE ENVIRONMENT FOR CONTROLLING AND PREVENTING HYPERTENSION

Policy Making and Legislation

The prevention and control of hypertension is key to achieving the strategic goal of reducing premature mortality from major chronic diseases by 30% compared with 2015 and increasing the life expectancy per capita in the next 10 years. China has established many policies for hypertension prevention and control (*3*). In 2016, the *Healthy China 2030* calls for a transition from disease treatment to a focus on health. In 2018, China CDC suggested that the prevention and control of hypertension must change from a high-risk population strategy led by the health department to a population-wide strategy that includes all parts of society (*3*); risk factors of hypertension such as high salt intake, overweight or obesity, and insufficient exercise should be addressed while strengthening screening and management for hypertension. This perspective on practicing the population-wide strategy of hypertension has been supported by the 2020 joint

TABLE 1. Goals of hypertension prevention and control in *Healthy China Initiative*.

Indicators (%)	Baseline	In 2022	In 2030
Awareness rate in residents aged 30 years or older	47 (in 2012)	≥ 55	≥ 65
Normalized management rate in patients managed	50 (in 2015)	≥ 60	≥ 70
Treatment rate in patients	41.1 (in 2012)	Rising	Rising
Control rate in patients	13.8 (in 2012)	Rising	Rising

position statement from the World Stroke Organization and the World Heart Federation (*4*). The *Primary Health Care, Medicine and Health Promotion Law*, officially implemented on June 1, 2020, has established health promotion as a legal provision for the first time in China (*5*). This legislation provides the legal foundation for changing the hypertension prevention and control strategy from one focusing on high-risk populations to a strategy that includes the whole population.

Establishment of National Demonstration Areas for the Comprehensive Prevention and Control of Chronic Diseases

The prevention and control of hypertension requires participation from the whole of society. Since 2010, China CDC has organized and carried out construction of national demonstration areas (whole counties or districts) for the comprehensive prevention and control of chronic diseases. The demonstration areas were designed on the principles of a government-led program with departmental cooperation, mobilization of society, and the participation of all residents. In these areas, the government implemented measures to support health, promote a healthy lifestyle, and improve the health literacy of the residents in ways that were closely associated with reducing hypertension. As of 2020, China has established 488 national demonstration areas covering 17.1% of all counties and districts. A study on the effectiveness of implementation indicated residents living in the national demonstration areas with implementation scores of higher than 50% were more likely to be aware of relevant knowledge regarding salt reduction (odds ratio (OR) 1.352, 95% confidence interval (CI): 1.151–1.589), oil reduction (OR 1.477, 95% CI: 1.249–1.746), and recommendations on physical activity (OR 1.975, 95% CI: 1.623–2.403) in comparison to those with 50% or lower implementation scores (*6*). The normalized management rate of patients with hypertension, defined as percent of achieving management standards in patients managed within one year, in the national demonstration areas was found to be 62.1% (*6*).

IMPROVEMENT IN THE MODIFIABLE RISK FACTORS OF HYPERTENSION IN THE WHOLE POPULATION

In 2007, China CDC and the National Patriotic Health Campaign Office launched a national activity — *China Healthy Lifestyle for All* — focusing on "ten thousand steps a day and a balance between eating and moving". In 2016, the *Healthy China* strategy incorporated the goals of salt, oil, and sugar reduction and included a focus on oral, weight, and bone health. Salt reduction and weight loss are of particular importance for the prevention and control of hypertension.

High sodium intake is the leading risk factor of hypertension. The World Health Organization (WHO) recommends a 30% reduction in salt intake by 2025, with an eventual target of less than 5 grams per day worldwide. Beginning in 2011, a 5-year population-based intervention to reduce sodium consumption has been conducted in Shandong Province, which has nearly 100 million people. The intervention is the Shandong Ministry of Health Action on Salt and Hypertension (SMASH) and includes health education, the distribution of salt-restriction spoons, and promotion of low-sodium products. A comparative analysis between two cross-sectional surveys from the SMASH program showed that 24-hour mean urinary sodium excretion among adults decreased by 24.8%, potassium excretion increased by 15.1%, and the Na^+/K^+ ratio decreased by 36.6% (*7*). Another 3-year cohort study from the SMASH program firstly indicated that using a salt-restriction spoon when cooking was associated with reduced salt intake, which slowed BP deterioration in the real world. Particularly, individuals using a 2-gram salt-restriction spoon showed significant decreases in the mean 24-hour urinary Na^+/K^+ ratio in comparison with those who did not use a salt-restriction spoon (–3.49 *vs.* –2.22) (*8*). China CDC is currently sharing the SMASH experience with many provinces

across China.

Overweight and obesity are associated with many chronic noncommunicable diseases, such as hypertension and diabetes, and are linked to a poor diet and lack of physical activity. Losing weight has been listed as a key component of managing patients with hypertension or diabetes, along with health education provided by primary healthcare sites and local CDCs. Weight loss has also been incorporated into the *Rational Diet Action* and *National Fitness Action* of *Healthy China Initiative* with the aim of slowing the increase of the adult obesity rate. In 2020, a national program of obesity prevention and control, particularly implemented in children and adolescents, is being promoted. Currently, *China Healthy Lifestyle for All* is the most popular weight-loss campaign in China and promotes maintaining a healthy weight by reducing oil and sugar intake and increasing sports activities.

SCREENING AND MANAGEMENT OF PATIENTS WITH HYPERTENSION

In 2009, China implemented the National Primary Public Health Services (NPPHS) program, which considerably affects the Chinese public health system. This program provided several free primary healthcare services for all Chinese people, regardless of age, sex, ethnic group, residence, occupation, or income. The funding for the NPPHS was supported by the annual central budget and covered more than 1.3 billion people. The standard budget subsidy gradually increased from 15 RMB per person per year in 2009 to 74 RMB in 2020.

The screening and management of patients with hypertension — a key part of the NPPHS — includes BP measurement at least once a year for residents aged 35 years and over, 4 face-to-face follow-ups (including symptom assessment, check-ups such as measurement of body mass index, and lifestyle intervention), 1 comprehensive physical examination per year for each patient with hypertension, medication guidance, and referral services. These services are provided by community-based medical institutions such as primary hospitals, health centers, and clinics that are supervised by health administrative departments and are guided by the CDC and public hospitals. The NPPHS managed approximately 100 million patients with hypertension in 2020, and this number is set to increase to 110 million by 2025 (*9*).

CHALLENGES AND OPPORTUNITIES

There are approximately 170 million patients with hypertension not covered by the BP management service from the NPPHS so more challenges await China CDC. We should take advantage of the new health promotion law to promote primary hypertension prevention measures in the whole population, such as reducing salt intake, controlling body weight, and increasing physical activity. Furthermore, following the theme of Hypertension Day (October 8 since 1998) — "All Persons 18 Years Old and Above Should Know Their Blood Pressure" — put forward by the National Health Commission of China in 2019, population-wide BP screening policies should be rigorously implemented, including BP measurements at patients' first visits to outpatient clinics, provision of physical examinations for the working population, promotion of health in schools, and instituting an NPPHS documentation service, and considering that more than a half of patients with hypertension do not know their condition with this disease in China (*10*). Next, China CDC and local CDCs need to participate in more NPPHS work such as guidance, supervision, and assessment for the NPPHS and, particularly, allow more patients and more scientific service programming to be involved in the NPPHS. Nevertheless, strengthening public health measures and primary healthcare will result in the effective population-based management of hypertension that would eventually reduce the total cardiovascular risk of this population.

Presently, there was still a gap between legislation and practice for the prevention and control of non-communicable diseases (NCDs), such as hypertension, in China. For example, the orientation of paying more attention to medicine than prevention has not been fundamentally reversed through legislation (*5*). The status and power of CDCs needs to be further elevated by improving legislation. Public health physicians should be given the right of prescribing essential drugs in primary healthcare to enhance their ability to participate in the NPPHS and promote the coordination of medicine and prevention (*3*,*5*). NCD prevention and control, which is the cornerstone of *Healthy China Strategy*, is being challenged by the coronavirus disease 2019 (COVID-19) pandemic worldwide, and ongoing public health legislation should not only include communicable diseases but also involve NCDs. In addition, China CDC is currently set to establish a scientific research institution

whose staff will mostly be scientific researchers. The new health promotion law defines China CDC as a professional public health institutions, which is included in medical and healthcare institutions, but excludes scientific researchers from the definition of medical staff. This limits the public health practice capacity, including hypertension prevention and control, of China CDC and its staff. Nevertheless, location on both medical and healthcare and scientific research are factually essential for the China CDC and its staff. A fundamental change in the system of disease control and prevention is coming following the pandemic, and this change may give a chance to increase the role of China CDC for hypertension prevention and control.

Conflicts of interest: No conflicts of interest were reported.

doi: 10.46234/ccdcw2020.212

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Submitted: August 07, 2020; Accepted: September 16, 2020

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Profiles

Yiming Shao, China CDC's Chief Expert of AIDS

Peter Hao[1,&]; Nankun Liu[1,&]; Zhenjun Li[1]; Jingjing Xi[1,#]; Feng Tan[1,#]

Yiming Shao is China CDC's Chief Expert of AIDS, the Chairman of the Academic Committee of the National Center for AIDS/STD Control and Prevention (NCAIDS), and the Vice President of the Chinese Microbiology Society (CMS) after chairing the CMS's Virology Committee (2001–2010). Shao graduated from Qingdao Medical College in 1983 and pursued a PhD at the Institute of Virology in the Chinese Academy of Preventive Medicine. He participated in the diagnosis of China's first cases of HIV and AIDS, isolated China's first HIV-1 virus, and developed the initial HIV diagnostic reagents for the country. After his PhD study, he served as the deputy director of the Department of HIV and director of the HIV Reference Laboratory in the Institute of Virology.

In 1989, Shao joined the World Health Organization (WHO) as a consultant to the Global Program on AIDS (GPA). Being assigned to develop a virus research program for GPA, Shao proposed to establish a WHO network for HIV isolation and characterization. He structured the network based on a "3 by 3" principle by studying HIV variation at 3 levels (genetic, immunological, and biological) and building 3 repositories to store biological samples and research reagents at the UK's National Institute of Biological Standards and Control (NIBSC) and the US's National Institutes of Health (NIH) and HIV sequences at Los Alamos Laboratory in the US. Shao's proposal was approved by GPA/WHO. He participated in the establishment of the WHO network by selecting the laboratories and drafting the initial guidelines with the help of Prof. Jay Levy of UCSF. The WHO HIV network became a major accomplishment for the WHO as it generated fundamental scientific data with numerous HIV sequences and research reagents to provide free access to the world's AIDS researchers for the development of AIDS diagnostic reagents, antiviral drugs, and vaccine research and development.

Shao's WHO experiences have also benefited his domestic work in China. He was credited for establishing the National AIDS Reference Laboratory and leading the National AIDS Laboratory Expert Committee to help China's Health Ministry to develop 3 continuously-used key infrastructures in the country: 1) the 5-level HIV testing network with over 40,000 laboratories for HIV testing and diagnosis since the mid-1990s; 2) the HIV molecular epidemiology network to trace the origin and spreads of the HIV strains since the late 1990s; and 3) the National HIV Drug Resistance (HIVDR) surveillance network to support the National Antiviral Treatment Program since the early 2000s. These research activities have trained thousands of laboratory staff of CDC networks and hospitals at the provincial, municipal, and county levels. These task forces and infrastructure provided strong technical support to China's AIDS diagnostic capacity, antiviral treatment, and HIV prevention.

In 1998, NCAIDS was built in CAPM by the Chinese government based on his HIV Reference Laboratory in the Institute of Virology and the AIDS Surveillance Center in the Institute of Epidemiology of CAPM. Shao served as the Deputy Director for Research and International Collaboration of NCAIDS and was the Founding Director for the National AIDS Reference Laboratory. Shao served as a lead expert in formulating China's first Mid- and Long-Term Plan for AIDS Prevention and Control and developed the National AIDS Control Goal by 2010. As the Deputy Representative in the Chinese Delegation to the United Nations General Assembly Special Session on HIV/AIDS (UNGASS), he provided technical facilitation to the Chinese delegation for the signing of the Declaration of Commitment on HIV/AIDS.

Shao's research areas include molecular epidemiology, drug resistance, immunology, and vaccinology. His team studied HIV genetic evolution, pathogenesis, and immune responses of the infected people, identified over 20 HIV-1 clades and clusters, and discovered 7 new circulating recombinant forms (CRFs) of HIV-1. They mapped the transmission routes of all major HIV-1 strains in China and found that they were all CRF strains (CRF01, 07, 08, and 55), indicating the presence of high-risk behaviors. They recently discovered that different clusters of the same HIV-1 clade evolved different pathogenic paths with more virulent forms causing rapid immune deficiency and

accelerated disease progression, which signaled the need to expand HIV surveillance from genotype-focused to phenotype-focused to provide earlier warnings for public health interventions.

Shao's team also worked to identify broader neutralizing antibodies and their generating mechanism in Chinese patients. Shao's team was the first to show that infusing anti-HIV cytotoxic T lymphocytes collected and amplified in vaccine immunized monkeys could suppress the rebound in simian-human immunodeficiency virus during ART interruption, which could indicate the possibility of developing an immune therapy strategy for a functional cure for HIV. His laboratory has develop into WHO's regional HIVDR laboratory to provided technical support to other developing countries in Asia and African.

Shao's team developed a novel HIV vaccine based on a) redesigned HIV immunogen, inspired by the first lentivirus (EIAV) vaccine developed by Chinese scientist and b) replication-competent vaccinia vector, derived from the Chinese smallpox vaccine. The DNA and vaccinia vaccines, complemented by priming and boosting regiments, achieved high protection rates against homologous challenges (>85%) and heterologous challenges (50%) in rhesus macaques. They have concluded 3 Phase I (Ia, Ib, Ic) and 1 Phase II clinical trials and induce both anti-HIV-1 antibody and T-cell responses. They are also preparing a Phase III trail Under a joint Sino-US HIV vaccine project, Shao's team's vaccines (DNA/vaccinia) and US NIH's vaccine (gp145) will be combined for clinical trials in China. Shao's group has published around 900 research papers in English and Chinese journals, and they also possessed 2 National Science and Technology Progressive Awards and numerous science awards by Health Ministry and Municipal governments.

Shao is an Adjunct Professor at Medical Schools of Beijing University, Zhejiang University and Nankai University. He served on several WHO Scientific Advisory Committees, including the Scientific and Technical Advisory Committee, HIV Vaccine Advisory Committee, HIVDR and on the Scientific Advisory Board of the Grand Challenge to Global Health from the Bill and Melinda Gates Foundation. He is currently serving in the Chinese Advisory Committee on Infectious Disease Control and Prevention, WHO's Product Development Vaccine Advisory Committee, and HIV Cure Advisory Committee of the International AIDS Society. He is a fellow of the American Academy of Microbiology.

As China CDC's Chief Expert of AIDS, Shao continues to conduct numerous investigations and to draft and submit many proposals to advise and guide the Chinese government. Shao's group served as a bridge between Chinese and international AIDS researchers through numerous domestic and international projects (EU, NIH, IDRC and BMGS etc.) he lead. He aims to strengthen AIDS and infectious disease control to promote public health education and related campaigns and to enhance international research collaborations and health aid to developing countries.

doi: 10.46234/ccdcw2020.213

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Submitted: September 20, 2020; Accepted: September 25, 2020

The inauguration of *China CDC Weekly* is in part supported by Project for Enhancing International Impact of China STM Journals Category D (PIIJ2-D-04-(2018)) of China Association for Science and Technology (CAST).

CCDC weekly

Vol. 2 No. 40 Oct. 2, 2020

Responsible Authority

National Health Commission of the People's Republic of China

Sponsor

Chinese Center for Disease Control and Prevention

Editing and Publishing

China CDC Weekly Editorial Office
No.155 Changbai Road, Changping District, Beijing, China
Tel: 86-10-63150501, 63150701
Email: weekly@chinacdc.cn

CSSN

ISSN 2096-7071
CN 10-1629/R1