Abstract—With one-fifth of the world’s total population, China’s prevention and control of cardiovascular disease (CVD) may affect the success of worldwide efforts to achieve sustainable CVD reduction. Understanding China’s current cardiovascular epidemic requires awareness of the economic development in the past decades. The rapid economic transformations (industrialization, marketization, urbanization, globalization, and informationalization) contributed to the aging demography, unhealthy lifestyles, and environmental changes. The latter have predisposed to increasing cardiovascular risk factors and the CVD pandemic. Rising CVD rates have had a major economic impact, which has challenged the healthcare system and the whole society. With recognition of the importance of health, initial political steps and national actions have been taken to address the CVD epidemic. Looking to the future, we recommend that 4 priorities should be taken: pursue multisectorial government and nongovernment strategies targeting the underlying causes of CVD (the whole-of-government and whole-of-society policy); give priority to prevention; reform the healthcare system to fit the nature of noncommunicable diseases; and conduct research for evidence-based, low-cost, simple, sustainable, and scalable interventions. By pursuing the 4 priorities, the pandemic of CVD and other major noncommunicable diseases in China will be reversed and the global sustainable development goal achieved. (Circulation. 2016;133:2545-2560. DOI: 10.1161/CIRCULATIONAHA.115.008728.)

Key Words: cardiovascular diseases ■ China ■ prevention & control ■ risk factors ■ socioeconomic factors

China is the most populous country in the world; the total population was >1.36 billion in 2014.1,2 The status in prevention and control of cardiovascular disease (CVD) in this large and aging country with approximately one-fifth of the world total population bears a huge potential impact on global health. It may also affect the global success in achieving the Sustainable Development Goal of a one-third reduction in premature deaths from noncommunicable diseases by 2030.3 To better understand China’s status in prevention and control of CVD, we will start from China’s evolving socioeconomic context to introduce the accompanying environmental and lifestyle changes, the consequent changes in major risk factors and burden of CVD, and the resulting challenges to the economy, healthcare system, and whole society. We also identify China’s opportunities and responses to the challenge. Priorities are recommended at the end of the article as the critical steps to curb increasing CVD in China, which should help achieve the global sustainable development goals.

Socioeconomic Context, Demography, and General Health Status

The rapid economic expansion started in 1978 when China implemented the open-door policy. With this policy, China started to reform its planned economy and encouraged outside investment from other countries.4 The reform movement has resulted in rapid changes that have driven economic growth: industrialization, marketization, urbanization, globalization, and informationalization. The key economic and health sequelae of the economic transformations are listed in Table 1. Meanwhile, China has gradually switched from a planned economy to a socialist market economy. As the result, the average annual rate of increase in gross domestic product (GDP) has been ≈9% from 1983 to 2011.2 From 2000 to 2010, China’s total GDP grew from 1.5 to 6.5 trillion USDs per year, while GDP per capita increased from $1000 to $4500, overall a 3- to 4-fold increase in both over just 10 years. In 2011, China became the world’s second largest economy.1

During the same period there have been dramatic changes in health as well. Life expectancy increased from 67.9 years in 1981 to 74.8 in 2010.3 In 2013, life expectancy at birth in China was reported as 73.5 years for males and 80.0 years for females.6 Infant mortality declined from 50.2 per 1000 live births in 1991 to 9.5 per 1000 live births in 2013; the same trend was observed for children ≤5 years and maternal mortality.7 And the deaths from communicable diseases remained ≤1 per 100,000.7

As a consequence of rapid economic and health changes, the proportion of the Chinese older population is increasing...
exponentially. Today, 10% of the population is ≥65 years. By 2030, 17% (240 million) of the population will be >65 years of age. In the next 30-year period, from 2010 to 2040, China will be the fastest aging country in the world.

With the social and economic transformation, the standard of living is greatly improved. However, unhealthy eating patterns and sedentary lifestyles have increased and the environment has become heavily polluted. The aging of the population and the changes in lifestyle and environment are contributing to marked increases in CVD and other noncommunicable diseases (NCDs).

Changes in Lifestyle

Physical Activity and Sedentary Lifestyle

The changes in China’s industrial productivity reflected the dramatic and unhealthy lifestyle changes chosen by most people living in China. Figure 1 shows the changes in the number of major industrial products that were closely related to people’s daily life from 1990 to 2010. Annually the production of cars increased from only 35 thousand to 18.3 million, computers from 82 thousand to 246 million, and televisions from 10.3 million to 118.3 million. However, annual bicycle production declined from 41.2 million in 1990 to 23.1 million in 1998. Production rose steadily to 68.2 million in 2010, the rebound reflecting exports after 2000. Local sales of bicycles have continued to fall. In fact, bicycles were ubiquitous in China 20 to 30 years ago. From 1992 to 2007, the number of households possessing at least 1 bicycle decreased from 97% to 49% in China, exhibiting the most dramatic variation among the 150 participating countries in the study. Declining bicycle use and shifting to motorized vehicle use has contributed to weight gain in China.

Multiple studies have reported declining levels of physical activity in China. For example, nearly half of the United States-People’s Republic of China Joint Study of Cardiovascular and Cardiopulmonary Epidemiology (US-PRC Joint Study) participants from Beijing and Guangzhou, urban and rural, reported that their physical activity reduced significantly from 1988 to 1998. Data from samples in 9 provinces in the China Health and Nutrition Survey (CHNS) showed that total physical activity fell by 31% among adult men, from 382 metabolic equivalent of task (MET) hours per week in 1991 to 264 MET hours per week in 2011, and fell by 42% among adult women, from 420 MET hours per week in 1991 to 243 MET hours per week in 2011. In the 2002 Chinese National Nutrition and Health Survey, only 34% of adults in large cities and 45% in medium and small cities reported adequate physical activity. In 2012, only 18.7% of Chinese adults reported getting regular exercise. In China, occupational physical activities (77.6%)

Table 1. Transformations Driving China’s Economy in the Past Decades, and the Link Between Health Hazards and Major Noncommunicable Diseases

<table>
<thead>
<tr>
<th>Rapid Transformations</th>
<th>Major Indications of the Transformations*</th>
<th>Intermediate Health Hazard Factors Driven by the Transformations</th>
<th>Cardiovascular Risk Factors</th>
<th>Major Noncommunicable Diseases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrialization</td>
<td>Industrial production is the largest in the world</td>
<td>↑Air, water, and soil pollution</td>
<td>Obesity</td>
<td>Coronary heart disease</td>
</tr>
<tr>
<td></td>
<td>GDP per capita is &gt;$4000</td>
<td>↑Processed foods</td>
<td>Hypertension</td>
<td>Heart failure</td>
</tr>
<tr>
<td></td>
<td>50% of GDP from rapid industrialization</td>
<td>↑Physical activity</td>
<td>Diabetes mellitus</td>
<td>Stroke</td>
</tr>
<tr>
<td></td>
<td>↑Air, water, and soil pollution</td>
<td>↑Processed foods</td>
<td>Dyslipidemia</td>
<td>Chronic obstructive pulmonary disease</td>
</tr>
<tr>
<td></td>
<td>↑Physical activity</td>
<td>↑Physical activity</td>
<td>Smoking</td>
<td>Type 2 diabetes mellitus</td>
</tr>
<tr>
<td></td>
<td>↑Health inequity</td>
<td>↑Mental stress</td>
<td>Alcohol drinking</td>
<td>Cancer</td>
</tr>
<tr>
<td></td>
<td>↑Mental stress</td>
<td>↑Sedentary lifestyle</td>
<td>Sedentary lifestyle</td>
<td></td>
</tr>
<tr>
<td></td>
<td>↑Sedentary lifestyle</td>
<td>↑Physical activity</td>
<td>Depression and other mental disorders</td>
<td></td>
</tr>
<tr>
<td></td>
<td>↑Mental stress</td>
<td>↑Sedentary lifestyle</td>
<td>Alcohol drinking</td>
<td></td>
</tr>
<tr>
<td></td>
<td>↑Unhealthy diet</td>
<td>↑Sedentary lifestyle</td>
<td>Sedentary lifestyle</td>
<td></td>
</tr>
<tr>
<td></td>
<td>↑Air and water pollution</td>
<td>↑Sedentary lifestyle</td>
<td>Depression and other mental disorders</td>
<td></td>
</tr>
<tr>
<td></td>
<td>↑Mental stress</td>
<td>↑Sedentary lifestyle</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>↑Physical activity</td>
<td>↑Sedentary lifestyle</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>↑Face-to-face social interactions</td>
<td>↑Physical activity</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

GDP indicates gross domestic product.

*Data from China national statistics annual reports.
and 59.8%, respectively, in men and women) accounted for most of the daily activities, while leisure time physical activities accounted for the least (3.1% in both men and women).\textsuperscript{18} Occupational physical activity dropped in Chinese men and women and in both urban and rural areas.\textsuperscript{15} Conversely, Chinese individuals are spending more time watching television. CHNS showed that urbanization factors predicted more than four-fifths of the decline in occupational physical activity over the 1991 to 2006 period for men and nearly two-thirds of the decline for women.\textsuperscript{19}

Sedentary lifestyle has serious health and economic consequences.\textsuperscript{11,20} CHNS reported that physical inactivity contributes to 12% to 19% of the risks associated with the 5 major NCDs in China, including coronary heart disease, stroke, hypertension, cancer, and type 2 diabetes mellitus. Physical inactivity is estimated to be responsible for >15% of the medical and nonmedical yearly costs of the main NCDs in the country.\textsuperscript{21}

**Diet**

The economic reform brought economic prosperity, a growing openness to international markets, and domestic policy changes to enhance agricultural productivity and end food rationing. Compared with data in early 1980s, the National Nutrition Surveys showed that Chinese are eating much more meat, dairy products, eggs, and edible oils, and eating much less grains and vegetables (see Table 2 for details).\textsuperscript{22} Dramatic changes in food patterns also have been confirmed in other studies.\textsuperscript{23–26} Studies in other countries and recent Chinese data support the beneficial effect of diets with more fish, more vegetables and fruits, more coarse grains, and less fat and animal foods.\textsuperscript{27–29} China Kadoorie Biobank Study\textsuperscript{28} recently reported that, in comparison with participants who never or rarely consumed fresh fruit, those who ate fresh fruit daily had lower systolic blood pressure (by 4.0 mmHg) and blood glucose levels (by 0.5 mmol/L). The adjusted hazard ratios for daily consumption versus nonconsumption were 0.60 (95% confidence interval [CI], 0.54–0.67) for cardiovascular death, and 0.66 (95% CI, 0.58–0.75), 0.75 (95% CI, 0.72–0.79), and 0.64 (95% CI, 0.56–0.74), respectively, for incident major coronary events, ischemic stroke, and hemorrhagic stroke. They also reported that the habitual consumption of spicy foods was inversely associated with total and certain cause-specific mortality, independent of other risk factors of death.\textsuperscript{29} However, data from China are still lacking on the relationship of foods or food patterns with CVD.

According to the China Industry Information report, beverage production in China increased from 26.2 million tons in 2004 to 167.05 million tons in 2014,\textsuperscript{30} and many of these products were sugar sweetened. CHNS data from 9 provinces showed that the proportion of adults exposed to sugar-sweetened beverages increased from 15.1% to 29.3%. The average energy from added sugar and sugar-sweetened beverages also increased to 10.7% of the total energy intake, which exceeded the World Health Organization (WHO) and Food and Agriculture Organization recommendations.\textsuperscript{31} A recent meta-analysis on data from 32,678 children and 183,629 adults in 19 studies across the world showed that sugar-sweetened beverages significantly increase the risk of obesity (pooled odds ratio,1.41; 95%CI, 1.12–1.76 for children; and 1.39; 95%CI, 1.07–1.80 for adults), indicating that increasing sugar-sweetened beverage consumption may contribute to poorer Chinese health.\textsuperscript{32}

Another marked Chinese temporal trend is the increase of processed foods. First introduced by global food companies, the processed food sector has grown rapidly in China to meet the huge demand for better food quality, safety, and convenience. Using data from 14,976 participants at least 2 years of age in 2011, CHNS showed that 74.5% of participants consumed processed foods, excluding edible oils and other condiments, and 28.5% of participants’ total daily energy intake was from processed foods.\textsuperscript{33} The percentage of processed foods was 40.2% for children and teenagers in megacities. People who lived in megacities or highly urbanized neighborhoods with higher incomes and educational achievement consumed more processed foods.\textsuperscript{33} Furthermore, the processed food purchases are growing at the rate of 50% per year.\textsuperscript{33} The high salt, high fat, high sugar, and other potential hazards often contained in processed foods have concerning implications for the future.
Table 2. Changes of Food Pattern in China in the Past Decades

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Grains</td>
<td>509.7</td>
<td>439.9</td>
<td>401.7</td>
</tr>
<tr>
<td>Potato and tubers</td>
<td>179.9</td>
<td>86.6</td>
<td>49.5</td>
</tr>
<tr>
<td>Vegetables</td>
<td>316.1</td>
<td>310.3</td>
<td>275.2</td>
</tr>
<tr>
<td>Meat</td>
<td>34.2</td>
<td>58.9</td>
<td>79.5</td>
</tr>
<tr>
<td>Dairy</td>
<td>8.1</td>
<td>14.9</td>
<td>26.3</td>
</tr>
<tr>
<td>Eggs</td>
<td>7.3</td>
<td>16.0</td>
<td>23.6</td>
</tr>
<tr>
<td>Fish and seafood</td>
<td>11.1</td>
<td>27.5</td>
<td>30.1</td>
</tr>
<tr>
<td>Edible oil</td>
<td>18.2</td>
<td>29.5</td>
<td>41.1</td>
</tr>
<tr>
<td>Salt</td>
<td>12.7</td>
<td>13.9</td>
<td>12.0</td>
</tr>
<tr>
<td>Soy sauce</td>
<td>14.2</td>
<td>12.6</td>
<td>9.0</td>
</tr>
</tbody>
</table>

The average amount of each food group is given in grams per reference man per day. Data source: Chinese Journal of Cardiovascular Review.22

Salt (Sodium) Intake
China has a long history of using salt to preserve and flavor foods, and the average salt intake is among the highest of all countries.34,35 The most recent data announced by the National Health and Family Planning Commission indicated that the current average salt intake is ≈10 g per day, which is lower than what had been reported in previous national nutrition surveys (see Table 2), but still 2-fold the amount recommended by the WHO.56 Although the relation between salt and health can be traced back thousands of years to traditional Chinese medicine, the studies on the relationship between salt and hypertension took place in China mostly after 1980. The nutritional salt studies included single-center and multicenter cross-sectional studies, cohort reexamination studies, and randomized trials in human subjects.37-59

Many of the salt studies were part of international collaborations examining the relations between sodium intake and blood pressure, including International Cooperative Study on Electrolytes and Blood Pressure (INTERSALT),35 WHO Cardiovascular Diseases and Alimentary Comparison (CARDIAC) study,42 US-PRC Joint Study,46 International Study on Macronutrients and Blood Pressure (INTERMAP),46,47 and more recently CHNS.51,52 In general, The results were in agreement that dietary high-sodium and low-potassium intake was associated with high blood pressure. In contrast, the reduction of salt intake or replacing regular salt with salt substitute significantly reduced blood pressure among patients with hypertension or high cardiovascular risk.54-59 For example, the multivariable-adjusted data from 3 Chinese populations in the INTERMAP study showed that ≈66% of the Chinese north-south difference in systolic blood pressure could be explained by differences in sodium and potassium intake between the regions.47 And about one-third of the north-south difference in systolic blood pressure could be explained by the difference in sodium intake alone.47

Recently, a cluster randomized, controlled trial found that an innovative school-based salt reduction education program reduced systolic blood pressure by 1.9 mmHg on average in parents.56 The China Salt Substitute Study demonstrated, among 608 individuals with high cardiovascular risk from rural northern China, that after 12 months of intervention with salt substitute, systolic blood pressure was significantly reduced by 5.4 mmHg (P=0.001) on average in comparison with the regular salt group.77 The blood pressure-lowering effect of salt substitutes has been reconfirmed in trials in patients with hypertension in other Chinese populations.56,59 Based on data from the China Salt Substitute Study, using a salt substitute only among those with hypertension would reduce the number of cardiovascular events by 300,000 annually, and would save hundreds of millions of medical costs.77 The evidence strongly argues for population salt reduction to be a national strategy for prevention and control of hypertension and CVD.

Alcohol Intake
Alcohol drinking has a special role in Chinese life, being used as a tool for socializing.60 It is often an indispensable part of a meal or banquet in celebrating traditional festivals, weddings, the birth of babies, moving into new houses, promotions, etc. Alcohol is also commonly used, particularly by men, as part of business meetings or social networking to maintain good relationships between partners and colleagues. As the economy developed, alcohol drinking increased dramatically in China.61 The average annual consumption of alcohol among Chinese people ≥15 years of age has increased progressively, from 0.4 L of pure alcohol in 1952 to 2.5 L in 1978 at the beginning of the economic reform, to 4.9 L in 2009.62 A recent national survey revealed that 55.6% of the men and 15.0% of the women were current drinkers.63 Among respondents who endorsed alcohol consumption, 62.7% of the men and 51.0% of the women reported excessive drinking, and 57.3% and 26.6%, respectively, reported binge drinking.63

The cardiovascular health harms of alcohol drinking have been studied in China. Similar to other populations, moderate alcohol drinking was associated with a lower risk of CVD.64 However, excessive alcohol drinking was found to be significantly associated with a higher risk of stroke. In comparison with nondrinkers, the relative risks of incident ischemic stroke for those who drank alcohol <5 g/d, 15 to 30 g/d, 30 to 60 g/d, and >60 g/d were 0.86 (95% CI, 0.57–1.27), 1.20 (95% CI, 0.87–1.65), 1.26 (95% CI, 0.86–1.84), and 1.96 (95% CI, 1.30–2.93), respectively.65

The great challenge now is how to get the Chinese people, in particular, the poor, to adopt healthy lifestyles. A countervailing force is the allure of the unhealthy Western lifestyle, which has been an aspiration for many years because of very recent experiences of poverty.

Smoking
Smoking remains one of the most prevalent unhealthy behavioral risk factors in China. The total number of smokers in China is estimated at >300 million.66 In 2010, 52.9% of Chinese men but only ≈2.4% of Chinese women smoked. Although first-hand women smokers are uncommon, three-fourths of women in rural and one-half of women in urban regions have been exposed to second-hand smoking.67 It is estimated that 556 million individuals in China are exposed to second-hand smoking.67 There have been multiple cohort,
case-control, and meta-analytic studies showing that second-hand smoke increases the risk of coronary heart disease by 25% to 30%. It is interesting to observe the very low rate of smoking among Chinese women, and the expected rise in smoking in women after opening doors to Western countries never materialized. Chinese culture discourages women from smoking.

The Chinese government has been gradually strengthening the policies against tobacco use, and the smoking rates are slowly but continuously declining. Recently, local laws to ban smoking in public places have been established in Beijing and other cities. Monitoring data show that second-hand smoking has started to drop. The Chinese government raised tobacco taxes in 2015, from 49% to 56% of the retail price. However, the percentage is still relatively low compared with the WHO-recommended benchmark, which is 70% of the retail price. Therefore, ample room remains for the Chinese government to further increase cigarette taxes.

Changes in Environment

Industrialization has polluted water, air, and soil to a great extent. According to the China Environment Status Report 2012, underground water in 57.3% of cities had poor (not usable as drinking water) or very poor quality (not directly be used for drinking) or poor quality (usable as drinking water) according to the national quality standard for ground water. Of the 113 core cities, 88.5% met the old, but only 23.9% met the new standard of air quality. The new national ambient air quality standards set limits for particulate matter 2.5 μm in diameter and smaller (PM2.5) at an average 75 μg/m³ in 24 hours, which is much higher than the WHO standards (25 μg/m³) and those of the United States (35 μg/m³). Few Chinese cities can meet the international standards. It was estimated that 1 of 10 farmlands had been either polluted or destroyed by sewage or solid waste in 2006 and 1200 tons of grains were polluted annually by heavy metals.

There have been numerous epidemiological studies on air pollution and cardiovascular mortality in China, using time series, case-crossover, or cross-sectional designs. The increased cardiovascular mortality risks observed in the Chinese population are similar in magnitude, per amount of pollution, to the risks found in other parts of the world. Recently, a randomized, double-blind crossover trial among 35 healthy college students in Shanghai found that air purification reduced mean systolic and diastolic blood pressure significantly by 2.7% and 4.8%, respectively, in addition to decreases in several circulating inflammatory and thrombogenic biomarkers.

As well as deteriorating cardiovascular health, ambient air pollution causes lung cancer, respiratory illness and symptoms, infant mortality, and total mortality, as well. In China, ambient air pollution was estimated to cause 300,000 premature deaths in the year 2000 and 1.2 million in the year 2010. The economic cost of ambient air pollution—related disease burden is substantial, ranging from 8% to 16% of the city’s GDP for a typical Chinese city.

In China, chronic exposure to high concentrations of arsenic in drinking water was associated with peripheral vascular disease and hypertension, and nonvascular diseases, as well.

Increasing of Conventional CVD Risk Factors

Hypertension

As a consequence of the changes in lifestyle and environment, and population aging, major CVD risk factors have started to increase. The recent official prevalence of hypertension in China in 2012 was 25.2% among adults aged ≥20 years, 5-fold of that in 1959. Figure 2 shows the remarkable increasing trend in both crude and age-standardized prevalence of hypertension in China over the past decades. The age-standardized national hypertension prevalence rate, according to the national standard population of 1964, increased from 7.5% in 1979 to 1980 to 9.4% in 1991, then further to 12.4% in 2002 for population aged ≥15 years. These data clearly demonstrated that even if the rapid aging of the Chinese population did not happen, Chinese people would be still at significantly increased risk of developing hypertension. The increased risk mainly can be attributed to lifestyle changes, including increases in overweight and obesity, alcohol drinking, high salt intake, and mental stress. There are large disparities in hypertension prevalence between regions (Figure 3), in general, higher in the north and lower in the south. The map of regional differences in prevalence of hypertension mirrors the regional differences in salt intake, overweight/obesity, and binge drinking, and the regional differences in cardiovascular mortality, as well.

Dyslipidemia

With the rising standard of living, malnutrition has been greatly diminished, but overnutrition has emerged as a new health problem and caused dramatic increases in obesity, diabetes mellitus, and dyslipidemia. The first nationally representative sample on serum lipids was from the China National Nutrition and Health Survey organized by the Ministry of Health and implemented by China Center for Disease Control and Prevention in 2002, which showed that 2.9% of Chinese aged ≥18 years had total cholesterol >240 mg/dL. In 2007 to 2008, a national survey conducted by the Chinese Society of Diabetes reported that 9.0% of Chinese adults aged ≥20 years had total cholesterol >240 mg/dL. Because of the...
differences in methodology, population demography, and quality control measures, it is hard to judge the amount of the increase over the past decades. The only available comparable data on the secular trends of blood lipids among Chinese populations was from the Study on Trends of CVDs and Preventive Strategy, which was conducted as a series of cross-sectional surveys of population samples in 1982 to 1984, 1992 to 1994 and 1998 in the same 9 geographical locations and at the same age of 35 to 59 years. The result showed that the age-standardized rate (according to the world standard population) of high cholesterol (defined as total cholesterol $\geq 200$ mg/dL) was 17.6% in the early 1980s, 24.0% in the early 1990s, and 33.1% in the late 1990s (Figure 4).104

Diabetes Mellitus

There also have been large increases in the prevalence of type 2 diabetes mellitus. The first national diabetes survey conducted in 300,000 individuals from 14 provinces in 1980 reported a prevalence of 0.67%.105 The subsequent national surveys reported the prevalence of diabetes mellitus was 2.5% in 1994 and 5.5% in 2000 to 2001.106,107 The China National Nutrition and Health Survey reported a prevalence of 2.6% in 2002.102 The Chinese Society of Diabetes national survey reported that the prevalence of diabetes mellitus was 9.7% in 2007,108 and the most recent national survey done in 2010 reported that the prevalence of diabetes mellitus was 11.6%, and the prevalence of prediabetes was 50.1% among Chinese adults. The prevalence rates translate into an estimated 113.9 million Chinese adults with diabetes mellitus and 493.4 million with prediabetes.109 More recently, a global study used a spatial temporal regression model and Gaussian process regression to synthesize the time series cross-sectional data from multiple sources and years in China and reported the prevalence of overweight (body mass index, $25.0–29.9$ kg/m$^2$) and obesity (body mass index, $\geq 30$ kg/m$^2$) according to the WHO criteria.113 The results showed that from 1980 to 2013, overweight and obesity prevalence more than doubled in adults and more than tripled in youngsters (Figure 5).114

Overweight and Obesity

An alarming increase in overweight and obesity has been seen over the past decades, in both children and adults.110,111 Using the Chinese criteria of overweight (body mass index, $24.0–27.9$ kg/m$^2$) and obesity (body mass index, $\geq 28$ kg/m$^2$),112 China National Nutrition and Health Survey reported that 22.8% of adults were overweight and 7.1% were obese in 2002.102 In 2012, the corresponding rates increased to 30% and 12%, respectively. The prevalence of overweight and obesity were 9.6% and 6.4% in 2012 in children aged 6 to 17 years, an absolute increase of 5.1% and 4.3%, respectively, in comparison with that in 2002.17

Figure 3. Map showing provincial differences in age-adjusted prevalence of hypertension in China in 1991.96 NA indicates not available.

Figure 4. The increasing trend in high cholesterol (total cholesterol $\geq 200$ mg/dL) in China in the past decades, age-standardized rate on pooling data from 9 populations at 35 to 59 years and with urban-rural and geographic diversity. Data source: Chinese Journal of Cardiology.104
obesity was high, ≈3 to 1, it is anticipated that many of these overweight persons may become obese in the near future. As a result of the rising prevalence of overweight and obesity, the number of patients with hypertension, diabetes mellitus, and dyslipidemia is also projected to increase.

Increasing Pandemic of CVD

The increase in classical CVD risk factors has been followed by a major rise in the incidence and mortality of CVD. CVD has been the leading cause of death in both urban and rural areas since the late 1980s. Furthermore, the proportion of deaths attributable to cardiovascular causes has continued to increase (Table 3). The increase in rural populations has been particularly large; and now CVD accounts for 40% of all deaths in both urban and rural populations, with >80% attributable to NCDs.7

In comparison with the selected high-income and upper-middle-income countries (Figure 6), China now has similar rates of heart disease deaths, but much higher rates of death from stroke, of which 62% are ischemic, 30% hemorrhagic, and 8% unknown.115 The overall rate of cardiovascular death in China now far exceeds the rates of the upper-income countries and is higher than those of the upper-middle-income countries as well. In particular, the rate of total cardiovascular death is almost 3 times higher than the rate of total cardiovascular death of China’s neighbor Japan116 (Figure 6).

Although maternal and infant mortality rates continue to decline, the recent increase in CVD death rates has actually caused a slight increase in total mortality after many decades of decline. It is anticipated that rising CVD death rates may also slow down the increase in life expectancy (Figure 7).1,7 Looking to the future, the World Bank has projected that the prevalence of major NCDs in China will double or even triple over the next 2 decades, risking the possibility of a reversal in life expectancy if nothing changes.117

The Economic Impact

The economic consequences of the increasing disease burden from cardiovascular and other NCDs are likely to be substantial. The economic burden is particularly notable as China’s economy moves into a new stage and GDP growth rate has dropped from the rapid increase in the past decades. Even if the rapid increase of the economy remains at 9%, it is far below the increase in health costs. From 1987 to 2003, the overall health costs increased annually by 12% on average,118 and the cost of CVD care is increasing by ≈18.6% per year.119 The National Bureau of Statistics data showed that the recent increase of health costs after 2003 was even faster, at 16.6% on average from 2004 to 2013, with the peak at 25% in 2008.120 Further expansion of the CVD epidemic is likely to have important adverse effects on economic development through increasing the direct and indirect health costs and loss of productive workers.

The precipitous increase in health costs is not only a problem for society as a whole, but it is also a major problem for the individuals personally affected. Government healthcare spending has been increasing >20% annually in the past decade. At the same time, private expenditures on health care accounts for more than a third of total costs and has been increasing at ≈10% per year.121 The high personal expenditures on healthcare affects communities heterogeneously. For example, the average cost of a hospital admission of acute myocardial infarction in cardiology would cost ≈77% of disposable annual per capita income in urban areas in 2011. By contrast, in the rural areas, the cost is 240% of annual per capita net income (ie, 27 months of wages).7 Because healthcare costs are high relative to income in China, families face considerable economic hardship after developing CVD. Among 4739 3-month survivors of stroke in 62 hospitals across the country, 71% of patients had experienced catastrophic out-of-pocket expenditures.122

Although China’s total economy is the second largest in the world, the per capita GDP ranks only 79,123 it is still home to vast numbers of people living in poverty. According to Chinese authorities, China still has >70 million people living under the local poverty line (defined as 2300 Ren Min Bi [RMB] annual per capita net income in rural in 2010, equivalent to ≈1 US dollars [USDs] per day),124 and the number would be >250 and 800 million if the standard of poverty were raised to <2 and 5 USDs per day, respectively, according to the World Bank.125 The burden of CVD is the largest among individuals living in poverty.

Studies showed that cardiovascular risk factors were positively associated with socioeconomic status in early 1980s.126,127 The relationship quickly became an inverse one in the 1990s in urban cities,128 and recently studies generally have reported more prominent cardiovascular risk factors among participants with low socioeconomic status, such as less educated and rural residents.129,130 These people often have no or

<table>
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<tbody>
<tr>
<td>Infectious</td>
<td>7.9</td>
<td>1.5</td>
<td>0.7</td>
<td>2.3</td>
<td>0.9</td>
</tr>
<tr>
<td>Tuberculosis</td>
<td>7.5</td>
<td>1.5</td>
<td>0.3</td>
<td>3.0</td>
<td>0.3</td>
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<tr>
<td>Heart disease</td>
<td>6.6</td>
<td>15.1</td>
<td>21.5</td>
<td>11.4</td>
<td>18.1</td>
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<tr>
<td>Stroke</td>
<td>5.5</td>
<td>20.9</td>
<td>19.6</td>
<td>16.1</td>
<td>20.6</td>
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Data source: China annual health statistics reports.7
inadequate health insurance. Without sufficient health insurance, the risk of experiencing catastrophic payments after major NCDs in China is very high. For example, for patients with acute stroke, those without insurance incur 7 times the cost. With inadequate health insurance, poor patients used less outpatient services than richer ones. Socioeconomic inequality is contributing to health inequity. Therefore, one major challenge is to provide acute care that is affordable for both society and individuals.

Challenges for the Healthcare System
The increasing pandemic of CVD and other major chronic diseases poses a number of major challenges for the healthcare system in various areas.

Primary Care
The primary healthcare system cannot cope well with the CVD pandemic. For example, the majority of patients with hypertension, dyslipidemia, or type 2 diabetes mellitus are not aware of their condition, fewer are on treatment, and those well controlled are rare, and there has been little improvement over time. The most updated data from a national survey in 2007 to 2008 showed that among hypertensive patients, 45.0% were aware of their condition, 36.2% were treated, and 11.1% were adequately controlled. A recent meta-analysis with a total of 387,825 Chinese adults showed that the prevalence, awareness, treatment, and control rates of dyslipidemia were 41.9%, 24.4%, 8.8%, and 4.3%, respectively. The most recent national diabetes survey showed that only 25.8% of individuals with diabetes mellitus received treatment for the condition, and only 10.2% had adequate glycemic control. In contrast in the United States, the awareness, treatment, and control of hypertension were 80%, 73%, and 50% in 2007 to 2008, and 85.6% of diabetic patients were on treatment in 2012.

Data from the Prospective Urban Rural Epidemiology (PURE) study showed that China was among the worst-performing countries in the world in terms of secondary prevention. Among patients living in the communities participating in the PURE study, <20% of people with coronary disease were taking an antiplatelet agent, and much smaller proportions were taking any of the other core components of standard secondary prevention care.

The poor performance of primary care system is largely attributable to the poor resources. In 2012, there were <0.7 million primary care providers in China. In contrast, 1.3 million doctors practiced in hospitals. Furthermore, 63.8% of physicians in hospitals had an undergraduate or graduate medical degree in 2012, but it was only 33.2% and 10% in primary care, respectively, for urban and rural. The low capacity of primary care providers contributes to patients’ distrust and further prevents their access to primary care. For example, aware of the poorer quality of their health care, residents often bypass primary care facilities to seek care in the tertiary hospitals, leading to underuse of the former and overuse of the latter. Both increase health costs. The overuse of hospital, particularly tertiary hospital services, increases direct medical costs. The underuse of primary care leads providers to try multiple strategies to overuse or misuse their services to maintain their earnings. It was estimated that one-third of drugs dispensed in rural areas are counterfeit, enabling their vendors to earn huge markups. So, the challenge faced by China is...
how to strengthen the primary care system to improve both primary and secondary prevention of CVD.

**Hospital Care**

Hospital care also poses a major challenge for China. Early data from WHO Multinational Monitoring of Trends and Determinants in Cardiovascular disease (MONICA) Project showed that the case fatality rates for coronary events were among the highest in the world. More than 60% of men and >80% of women died following an acute coronary event in the early 1990s in Beijing, which has the most advanced and most ample health and medical care resources in China.\(^\text{139}\)

In 2004 to 2005, the Clinical Pathways in Acute Coronary Syndrome in China (CPACS) Phase-1 study, a prospective registry established in 51 hospitals across China, investigated the quality of hospital care provided to patients admitted with acute coronary syndromes. The results revealed that two-thirds of patients with ST-segment–elevation myocardial infarction in China received no reperfusion therapy and fewer than half (48%) of patients were discharged on 4-drug combination therapy (antiplatelet, \(\beta\)-blocker, angiotensin-converting enzyme inhibitor/angiotensin receptor blocker, and statin), even though the participating hospitals were mainly large tertiary care centers.\(^\text{140,141}\) The Bridging the Gap on CHD Secondary Prevention in China study confirmed the findings and reported a much worse situation among secondary hospitals.\(^\text{142}\)

In addition, 52% of patients with acute coronary syndrome were discharged without appropriate secondary prevention.\(^\text{140,141}\) A major contributor to the lack of secondary prevention was the frequent view (21%–30%) of cardiologists that drugs such as statins, angiotensin-converting enzyme inhibitor/angiotensin receptor blocker, and \(\beta\)-blockers were not indicated.\(^\text{141}\) It is therefore not surprising that surveys of hospitalized patients showed that very few patients meet national targets for cholesterol control.\(^\text{143}\)

However, in contrast to the lack of secondary prevention, the number of percutaneous coronary interventions (PCIs) has climbed steeply and continuously at an annual rate of 30% to 60% for the past decade, reaching more than half a million in 2012.\(^\text{145}\) The factors driving the increase include the increasing incidence of myocardial infarction, the marketing of stent companies, and the competition among the hospitals because of inadequate funding from the government, the pay-for-service policy, and higher profit margin for advanced technologies such as stents.\(^\text{144}\)

But in the absence of adequate primary and secondary prevention, there are serious questions as to whether the proliferation of revascularization is appropriate. Despite an increase in the use of primary PCI among 12,264 patients with acute ST-segment–elevation myocardial infarction in the recent China Patient-Centered Evaluative Assessment of Cardiac Events study,\(^\text{145}\) there was no significant change in the proportion of patients who did not receive reperfusion and in the adjusted in-hospital mortality between 2001 and 2011. CPACS-1 has shown that patients at low risk were much more likely to receive PCI (25.1% in nontertiary hospitals and 47.5% in tertiary hospitals) than those at high risk (9.7% in nontertiary hospitals and 35.5% in tertiary hospitals).\(^\text{140}\) The inverse relation between disease severity and likelihood of revascularization may help to explain the dilemma regarding why the number of PCIs increased but mortality did not change. The government and society of cardiology should take actions to better regulate PCI practice to ensure maximizing the benefits to be gained from these expensive technologies.

**Beyond the Healthcare System**

The challenges are far beyond the healthcare system. If population health is not included in the agendas of other societal sectors, the healthcare system will not completely succeed. For example, it is hard to ask people to exercise outdoors in polluted air. It is clearly beyond the ability of the healthcare system to improve health through improving environmental protection, but individuals need an unpolluted environment to have a healthy lifestyle. The greatest challenge is how to leverage the central leadership for coordinated whole government policies/actions.

**China’s Opportunity and Responses**

The challenges in China also create opportunities. One important opportunity that has arisen is the political realization that there are conflicts between various aspects of the economic growth that has been achieved and sustainable development, social equity, and community harmony that are aspirations of the Chinese people. For example, China’s industrialization consumes tremendous natural resources and pollutes the environment heavily. Ongoing pollution causes enormous disease burden and thus is being criticized widely by the public. The urbanization of economic development leaves families in rural settings having only children and elderly adults at home. Urbanization has created many social problems such as disparities in childhood education and elderly care, and more urban but unhealthy lifestyles and health inequalities, as well.\(^\text{146}\) The long-term economy-focused national development policy has led to uneven development of society and an underresourced healthcare system, resulting in patients’ dissatisfaction of health care and doctors’ injuries by patients both happening frequently in China, as just one of many examples of disharmony.\(^\text{147}\) The realization of the conflicts has led to a political transition from the politics of GDP to the politics of people’s livelihood.\(^\text{148,149}\) The new politics has already stimulated healthcare reforms designed to improve health care for the most disadvantaged groups in Chinese society.

Examples of new political approaches include the rapid development of the community health services system in urban China,\(^\text{150}\) the introduction of the new rural cooperative medical scheme,\(^\text{151}\) and the establishment of Basic Public Health Services Package\(^\text{152}\) and the National Essential Drugs List.\(^\text{153}\)

In 1997, the central government decided to develop China’s community health services to optimize its healthcare system to meet the unmet needs by hospital services.\(^\text{150}\) The main required functions of the community health services centers include disease prevention, basic medical services, health management, rehabilitation, health education, and family planning services. By 2013, there were 33,965 community health centers and clinics in urban areas and another 221,065 health stations and 648,619 health clinics in rural areas.\(^\text{7}\)
By 2015, >95% of China’s population had some sort of basic medical insurance, whereas the number was only 15% in 2000. The improved insurance rates are largely attributable to the introduction of the new rural cooperative medical scheme, which was initiated in 2003 and covered 802 million (98.7% of its target population) in 2013. Although there is still a lot of out-of-pocket expenditure on health care, with basic insurance coverage for all, there is the potential for the benefits to grow. The growth is clearly indicated by the large increase in per capita compensation from the government for new rural cooperative medical scheme. The new rural cooperative medical scheme started with >8 USDs (50 RMB) per capita in 2003 and quickly increased to ≈60 USDs (370 RMB) per capita in 2013.7

In 2009, China initiated a national program named Basic Public Health Services (BPHS) to provide community residents free basic public health services under 10 categories with an initial total budget of 15 RMB per capita.152 The services included establishing health records for all residents, community health education, elderly health management, chronic disease (hypertension and diabetes mellitus) management, etc. By 2014, the budget for BPHS had increased to 35 RMB per capita,7,50 and >85 million patients with hypertension have been regularly managed through the program (informal communications with National Health and Family Planning Commission). Studies found that patients with hypertension and diabetes mellitus had equal and high accessibility to BPHS with >90% of them receiving BPHS across socioeconomic status.154,155 Individuals willing to receive services had the most positive results on effective management and control in blood pressure and blood glucose. But unsatisfactory quality of BPHS still exists; just 44% of individuals receiving BPHS had their blood pressure and glucose under control.153 A case from Rushan county in eastern China showed that among nearly 100,000 patients with high blood pressure, 73% were managed through BPHS and 31% had blood pressure under control, which is far better than the national average control rate of 11%.132

The national basic drug list was initiated, as part of the new healthcare reform in 2009, to ensure the supply and safety of basic drugs and control of health care costs.156 The current version of the list includes 205 Western medicines and 102 traditional Chinese medicines.157 The common generic anti-hypertensive medicines are included. The policy significantly increased the use of basic drugs at the beginning. For example, the use of basic drugs in 15 community health facilities increased the use of basic drugs at the beginning. For example, the use of basic drugs in 15 community health facilities in Zhongshan, China increased by 54%.158 However, whether the basic drug list enhanced the supply and safety of drugs while reducing healthcare expenditures remains unclear. A study based on a sample of primary healthcare facilities in 83 counties or cities nationwide showed variable and small reductions in inappropriate drug prescriptions and expenditure in facilities with an essential medicine program, but most of the changes were not statistically significant.158 A study reported that the mean availability of essential medicines was low and further decreased from 2010 to 2012, particularly in primary hospitals (from 27-4% to 22.3% for lowest priced generics; *P*<0.0001).159 There are also reports of adverse events from using the essential medicines and shortage or delayed supply of the essential medicines because of corruption or inappropriate bidding for low prices.160–162 The problems indicate the need for better management of the national basic drug system.

In addition, National Action on Healthy Lifestyle for All was initiated in 2007 with the aim to promote healthy lifestyle across the country.163 By the end of 2014, the program had been initiated in 2401 county/districts (77% of all) and created 32,989 health-supporting environments, including health schools, communities, canteens/restaurants, institutions, parks/gardens, streets, etc.164

The establishment of exercise facilities in communities across the country was initiated by the General Administration of Sports in 2000 as part of its National Plan on Public Exercise: Healthy Body for All.165

A few months after the UN High Level Meeting in 2011,166 China issued its first country level (not ministry level) national work plan in NCDs prevention and control.167 The plan was an important milestone in history, because it was the first time 15 ministries signed onto 1 document agreeing to work together on NCDs. The whole-of-government and whole-of-society policy adopted by the UN High Level Meeting166 has been well recognized and endorsed by the Chinese government and was reflected in the plan.

As the effects of environmental pollution have become increasingly apparent to the public, China also has become more serious about environmental protection. In 2013, China initiated the Air Pollution Control Action Plan with the aim to reduce the inhaled particulate matter >10% in all cities across the country.168 On the first day of January 2015, the new Environment Protection Law was implemented.169 Also in 2015, the Plan for Water Pollution Prevention and Control in Key River Basin was implemented.170 The surface water with very poor quality dropped from 15.6% in 2010 to 8.8% in 2015, nationwide.170 Monitoring ambient air quality was established in 2015 in all 338 cities across the country with the capacity to monitor PM2.5 and other 5 major pollutants.170 In the 74 cities that have implemented the new ambient air quality monitoring since 2012, the average concentration of PM2.5 decreased by 14.1% in 2015 in comparison with the previous year.170

**Future Directions**

Looking into the future, there are 4 policy priorities that should be further developed and implemented in China to prevent and control CVD, and other NCDs, as well, and to improve the health of all Chinese (Table 4).

First, the whole-of-government and whole-of-society policy adopted by the UN High Level Meeting166 should be the number 1 priority. China faces challenges from increasing unhealthy lifestyles, environmental pollution, disabled healthcare system, and backward policies that fundamentally drive the increased burden from CVD and other NCDs. To address the multiple challenges will require the strong leadership of the government and other nongovernmental entities. The responsibility for improved health care can no longer be left to the health system alone.

Second, “Give priority to prevention,” an old policy issued by Mao to fight against infectious disease epidemics since the 1950s, should be implemented as an essential policy to guide
all other policies and actions against NCDs. Under the original prevention policy, the incidence of acute infectious diseases significantly dropped from 20% in early 1950s to 203/100,000 in 1998, and life expectancy increased from ≈35 years to ≈70 years at the same time. China achieved these gains with very low average income during that time period; the available data showed that average per capita GDP increased from only 62 USDs in 1978 to 1102 USDs in 1998. The marked improvements were realized because infectious population prevention measures such as vaccination and environmental hygiene were much less expensive but more effective than treatment of individual patients.

With the new pandemic of CVD and other chronic diseases, the costly treatments with medicines and advanced technologies such as PCI are effective but not the optimal solution. Any policy that relies on costly treatments will either not be scalable or will have yet to be eliminated. In China, we have yet to fully implement population-wide prevention. As was acknowledged when the declaration was signed, “The prescription is simple. To implement it is much more difficult.” In truth we do not have the knowledge to implement the prescription. We believe that research has a critical role to play in generating this knowledge. Unfortunately, many people including researchers themselves hold a belief that finding a way to implement knowledge is not research. We must shift the research agenda to focus on effective implementation of prevention at the population level.

The examples of implementation research in prevention and control of CVD in China include the Simplified Cardiovascular Management Study (SimCard), school-based education program to reduce salt intake in children and their families (School EduSalt), China Rural Health Initiative (CRHI), CPACS, China Da Qing Diabetes Prevention Study, etc. For example, the recently completed SimCard trial demonstrated that a simplified cardiovascular management program, only 2 drugs (antihypertensive and aspirin) and 2 lifestyle recommendations (smoking cessation and salt reduction), delivered by community health workers with the aid of a smartphone-based electronic decision support system, was effective. The SimCard intervention significantly increased antihypertensive medication use by 25.5% and aspirin use by 17.1%, and reduced systolic blood pressure by 2.7 mmHg for individuals at high cardiovascular risk in rural Tibet, China, and Haryana, India, both places with very scarce healthcare resources, in comparison with the control group. The School EduSalt trial demonstrated that a school-based health education program effectively reduced salt intake by ≈25% in both children and adult family members and significantly reduced systolic blood pressure by 2.3 mmHg in adults in 1 school term. As the first successful randomized, controlled trial on salt reduction by health education in the community, School EduSalt trial showed the great value of nonhealthcare social sectors (here, the education system) and health in all policies in prevention and control of CVD. Findings from these studies have generated much knowledge that is guiding policy making and clinical practice in China and other low-resource settings.

In summary, after several decades of rapid economic development, China faces a huge and expanding pandemic of CVD, which poses challenges for both prevention and treatment. The challenges are not limited to the healthcare system but to the whole society, particularly in terms of healthy lifestyle and environmental protection. Fortunately, realization of the challenges has been made. China has embarked on important initiatives such as primary care–prioritized health reform and multisector-endorsed national NCDs work plan. China needs to pursue research that will expand the knowledge necessary to implement innovative, practical, low-cost, scalable interventions for both the prevention and treatment of CVD. China needs to implement these evidence-based interventions through
the new healthcare reform program, under the direction of the whole government and whole society policy, giving priority to prevention. With these strategies, we anticipate a reduction of cardiovascular mortality and morbidity in the coming decade.

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References
Hypertens Res. WHO Cardiovascular Diseases and Alimentary Comparison (CARDIAC) Chinese Han and three other minority peoples of China: results from the references in various markers of dietary intake and blood pressure among Chinese Han and three other minority peoples of China: results from the WHO Cardiovascular Diseases and Alimentary Comparison (CARDIAC) Study. Hypertens Res. 2001:24:315–322.


The CPC Central Committee and the General Office of the State Council. The circular on the leading cadre to take the lead in public places to ban smoking in public places. Beijing: December 2013.


Hu TW, Zhang X, Zheng R. China has raised the tax on cigarettes: what’s next? Tob Control. 2015;0:1–3.


Gulland A. Countries should raise taxes on tobacco, says WHO. BMJ. 2015;351:h3691.


The circular on the leading cadre to take the lead in public places to ban smoking in public places. Beijing: December 2013.


112. World Bank. Toward a healthy and harmonious life in China: Stemming the rising tide of non-communicable diseases. World Bank
Socioeconomic status and metabolic syndrome in the general population

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