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ORIGINAL ARTICLE

Average life expectancy of the Chinese population in 1949–2019: trends, contributors and prospects

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Abstract
This paper provided an overview of literature on life expectancy of Chinese population, elaborated the characteristics of the significant increase in the average life expectancy (ALE) of Chinese population over the past 70 years since the founding of PRC, analyzed the major factors contributing to the improvement in the ALE, and highlight the needs to put greater emphasize to increase average healthy life expectancy (AHLE), to narrow the regional differences in AHLE, to advocate and promote healthy lifestyles, and to prevent and control pollution persistently and effectively.

Keywords 70 years since the founding of PRC · Average life expectancy · Average healthy life expectancy

1 Increase in average life expectancy of Chinese population since the founding of PRC

1.1 Average life expectancy of Chinese population has increased significantly over the past 70 years

In regard to the changes in average life expectancy (ALE) of Chinese population, according to a large-scale survey of agricultural population in 17 provinces in 1929–1931 conducted by NanjingJinling College, Seifert estimated that the ALE of Chinese population was 34.85 years for males and 34.63 years for females before the founding of PRC (Lu 2004). According to the statistics released by the National Bureau of Statistics, after the founding of PRC, the ALE of Chinese people (excluding those living in Hong Kong, Macao and Taiwan, as well as in Kinmen

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and Matsu of Fujian Province, the same below) rapidly increased from 40.3 years in 1953–61.2 years in 1963, 67.7 years in 1981, 71.4 years in 2000 and 74.8 years in 2010. According to the *Statistical Communique of the People's Republic of China on the Development of Health Undertaking in 2018* issued by the Department of Planning and Information of the National Health Commission, the ALE of Chinese population was 77.0 years in 2018. Therefore, the ALE of Chinese population increased by 36.7 years in the period from 1953 to 2018.

Globally, the increase in ALE of Chinese population was also noteworthy over the past 70 years. According to the data from the World Development Indicators database of the World Bank, the ALE of Chinese population was 65 years in 1978, ranking 106th in 238 countries or regions worldwide; in 2017, it went up to 76 years, ranking 76th in 264 countries or regions worldwide.

1.2 The increase in ALE varied in different regions of China

Although the ALE of Chinese population is higher than a number of developing countries, there are still large variations between different regions of China. According to the data from the 5th Census conducted in 2000, significant differences in ALE were found between Eastern China (73 years), Central China (70–73 years) and Western China (66–70 years). Still, the gap in ALE between different regions has narrowed from 15.26 years at the time of the 4th Census in 1990 to 13.77 years, suggesting that regional differences in ALE showed a downward trend (Gou 2011). In terms of provincial differences, based on the data from the 5th Census in 2000, we noticed that Shanghai, Beijing and Tianjin had the highest ALEs, while Tibet, Yunnan, Guizhou and Qinghai had the lowest ALEs. According to the data from the 6th Census conducted in 2010, we also found regional differences in ALE. Specifically, cities with ALE greater than 80 years were mainly distributed in Eastern China, including Shanghai, Beijing, Tianjin, and Hainan, while the lowest ALEs were observed in the Tibetan Plateau and Yunnan-Guizhou Plateau of Western China, including Tibet, Qinghai, Yunnan, Ningxia and Guizhou (Zhang and Liu 2014). By comparing the results of the 5th Census and the 6th Census, ALE was found to be the highest at the municipal level, followed by the township level and the village level. Still, both urban and rural areas witnessed the upturn in ALE, with villages showing a larger increase than cities and townships (Wang 2017). In a word, although provinces with lower baseline ALEs have seen significant growth since 2000, the original landscape stands firm, i.e., the ALE in Eastern China is higher than that in Western China, and the ALEs at municipal and township levels are higher than that at village level.

2 Main contributors to the increase in the ALE of Chinese population since the founding of PRC

2.1 Direct causes of the significant increase in ALE

In calculating ALE, whether it is direct or indirect calculation, the underlying data should be the age-specific mortality rates. The obvious upturn in ALE over the 70 years since the founding of PRC can be attributed to the significant decline in the infant mortality rate, the under-five mortality rate and the maternal mortality rate. Over the past 70 years, China has seen a quick plummet in its infant mortality rate. According to the *China Demographic Data Handbook* and the *China Demographic Yearbook*, China's infant mortality rate dropped from around 200‰ in 1929–1931 to 138.5‰ in 1954, and further to 84.3‰ in 1963 after minor fluctuations. According to the *Report of China on the Development of Maternal and Child Health Undertaking* (2019) released by the National Health Commission, China's infant mortality rate has dropped by 87.8% from 50.2‰ in 1991 to 6.1‰ in 2018 (National Health Commission 2019).

Over the 70 years from the founding of PRC, China has also undergone the rapid decline in under-five mortality rate. According to the data from the World Development Indicators released by the World Bank, China's under-five mortality rate dropped sharply from 111.5‰ in 1970 to 65.7‰ in 1979. The pace of decline slowed down in the 1980s, dropping at an annual rate of 1.15‰ from 1980 to 1999. After 2000, China's under-five mortality rate once again ushered in a rapid slump, dropping to below 10‰ in 2016 at an annual rate of 1.52‰ in the period from 2000 to 2017 (see Fig. 1). The "UN Millennium Development Goals (MDGs)" were the goals set forth in the 1990–2015 action plan in the *United Nations Millennium*

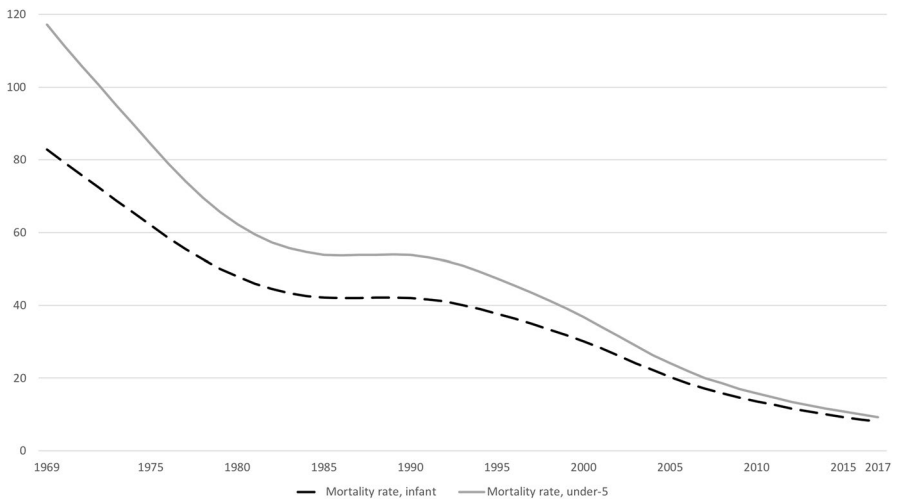

Fig. 1 Infant mortality rate and under-five mortality rate in China (1969–2017, ‰). Source: World Development Indicators of World Bank (http://datatopics.worldbank.org/world-development-indicators/)

Declaration, which was drafted and signed by 189 countries that attended the Millennium Summit of the United Nations held in September 2000. Among the core eight goals put forward in the Declaration, the fourth goal was to "reduce by two-thirds, between 1990 and 2015, the under-five mortality rate". According to the *Report on China's Implementation of the Millennium Development Goals* (*2000–2015*) jointly released by the Chinese Ministry of Foreign Affairs and the United Nations System in China, "in 2013, the mortality rate of children under five in China stood at 12.0‰, 80.3% lower than that in 1991", and "China has achieved the overall MDGs of reducing child mortality rate ahead of schedule" (Chinese Ministry of Foreign Affairs and the United Nations System in China 2015). According to *Report on Women and Children's Health Development in China* (2019) released by the National Health Commission further points out that "China achieved this goal in 2007, 8 years ahead of schedule". It also shows that China's under-five mortality rate has rapidly dropped from 61.0‰ in 1991 to 8.4‰ in 2018, a decrease of 86.2%, and draws the following conclusion through relevant estimates: "The decline in the under-five mortality rate has made an important contribution to the extension of life expectancy in China. In the period from 2000 to 2015, the average life expectancy of Chinese people went up by 4.9 years, 23.5% of which was contributed by the decline in under-five mortality" (National Health Commission 2019).

Over the 70 years since the founding of PRC, the maternal mortality rate also demonstrated an evident downward trend. The maternal mortality rate (MMR) is the proportion of the annual number of maternal deaths from any cause related to or aggravated by pregnancy or its management during pregnancy, childbirth or within 42 days of termination of pregnancy, to the total number of pregnant women in the same year in a country or region. Among the eight goals set out in the *United Nations Millennium Declaration*, the fifth goal is to "reduce maternal mortality by three-quarters from 1990 to 2015" and to "achieve universal access to reproductive health by 2015". According to the *Report on China's Implementation of the Millennium Development Goals* (*2000–2015*)," in 2013, the MMR nationwide was 23.2 per 100,000, which was 73.9% lower compared with the rate of 88.8 per 100,000 in 1990, meaning that China has reached its MDG target of reducing the MMR by three quarters" (Chinese Ministry of Foreign Affairs and the United Nations System in China 2015). According to the *Report on Women and Children's Health Development in China* (2019), the maternal mortality rate in China was 18.3 per 100,000 in 2018, a decrease of 79.4% from 1990 (National Health Commission 2019).

In addition, the decline in age-specific mortality rates among the youth population, the middle-age population and the elderly population also contributed to the significant increase in China's ALE over the past 70 years. It was evident through the comparisons between age-specific probabilities of dying in the "Life Tables for the Total Population in China (1981)" and "Life Tables for the Total Population in China (1989–1990)" in the book of *Mortality Tables in China*, which was edited by Huang and Liu (1995). The authors converted the age-specific mortality rates obtained from the two census in 1982 and 1990 into the age-specific probabilities of dying, in an effort to learn about the probability of a group of people who have lived to a specific age of x years to die within an age range (such as in 1 year), and found that not only the probability of dying in the 0-year and 5-year age groups

dropped significantly in the period from 1981 to 1990: (1) the probability of dying in the 20-year and 34-year age groups also dropped from 0.00144 and 0.00189 in 1981 to 0.00128 and 0.00167 respectively in 1989–1990; (2) that in the 40-year and 50-year age groups also decreased from 0.00289 and 0.00684 in 1981 to 0.00254 and 0.00564 respectively in 1989–1990; and (3) that in the 60-year, 70-year and 80-year age groups also dwindled from 0.01804, 0.04552 and 0.11019 in 1981 to 0.01514, 0.04183 and 0.10150 respectively in 1989–1990.

2.2 Economic, educational and environmental factors contributing to the significant increase in ALE

Over the past 70 years since the founding of PRC, economic development has provided the financial ground for the noticeable increase in ALE. On one hand, ALE in regions with higher level of economic development is generally higher than the ALE in regions with lower level of economic development; On the other hand, ALE shows a relatively faster growth rate during periods of faster economic development. According to estimates by Qi Yaqiang and Li Lin (2018), for every 10% growth in China's per capita GDP, ALE would pick up by roughly 0.3%. Since the launch of reform and opening-up, China has witnessed the boom in economic development, which helped to scale up the development of medical and health services, social security and education, and in turn made positive contributions to improving the health conditions and ALE of Chinese people. However, once the economic development reaches a certain level, its impact on ALE will show the effect of "diminishing marginal utility"—that is, the contribution of further economic development to ALE will weaken gradually.

Over the 70 years, the swift development of education undertaking and the upturn in the average schooling years have also contributed to the increase in ALE. People with a higher education level are more likely to stay informed of knowledge relating to health management and disease prevention, and are more likely to adopt a healthy workstyle and lifestyle and to avoid risk factors that are harmful to health (such as smoking, alcohol abuse, etc.). Because people with higher education generally have a higher income, they are more likely to improve their own and their family members' nutritional intake and to afford self-paying medical services, thus contributing to the improvement of ALE. Since the launch of reform and opening-up, with the popularization of compulsory education and the launch of strategies such as "rejuvenating the nation through science and education" and "making the nation powerful though talent fostering", the cultural literacy and education level of the Chinese people have been greatly improved, which have in turn contributed to the increase in ALE to a certain extent.

Over the 70 years, the environmental improvements in China have contributed to the health improvements among Chinese people, thereby bolstering the increase in ALE. According to data from the Global Burden of Disease (GBD), among the environmental risk factors accounting for deaths in China between 1990 and 2017, except for the ambient particulate matter pollution which is still rising slowly and the ambient ozone pollution which appears no significant decline, unimproved

water, unimproved sanitation and household air pollution from solid fuels (coal or firewood) accounted for an increasingly lower share of deaths in China (see Fig. 2). Safe drinking water and improved sanitation can help reduce the incidence of infectious and non-communicable diseases, thereby contributing to the increase in ALE.

2.3 Close cooperation between the health, family planning and social security authorities

Over the past 70 years since the founding of PRC, China has set up the following organs at the national level: Ministry of Health which takes charge of urban and rural medical and health affairs (and used to preside over the new Rural Cooperative Medical Care System for a long time); National Family Planning Commission which took charge of population control and healthy pregnancy and scientific nurture, and was later successively renamed as National Population and Family Planning Commission, National Health and Family Planning Commission and National Health Commission; Ministry of Civil Affairs which takes charge of social assistance, social welfare and pension services; Ministry of Labor which took charge of the social insurance for corporate employees and Ministry of Personnel which took charge of the social security for employees from public institutions (the two later merged into the Ministry of Human Resources and Social Security). In 2018, China newly established the National Healthcare Security Administration which takes charge of the medical insurance and long-term care insurance for employees and urban and rural residents, and the Ministry of Veterans Affairs which integrates the social security functions of Ministry of Civil Affairs and Ministry of Human Resources and Social Security, such as the preferential treatment and pension of veterans and their family members.

Due to the persistent and fruitful efforts of these authorities and their staffs, China has successfully reduced the number of deaths caused by infectious diseases such as smallpox, cholera, malaria, tuberculosis and schistosomiasis. According to the data from Global Burden of Disease (GBD), the number of deaths caused by intestinal

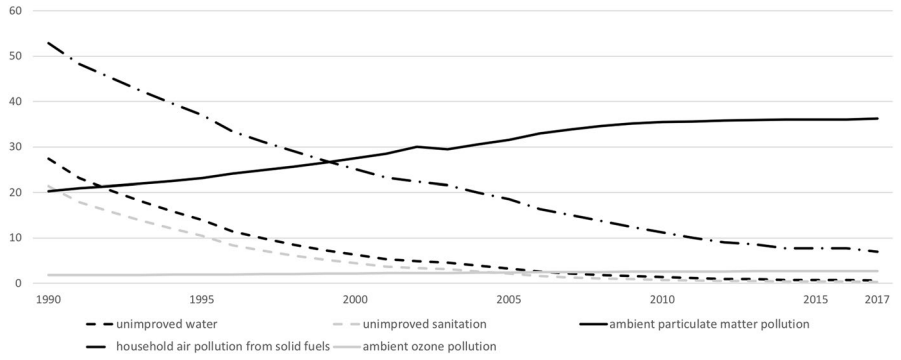

Fig. 2 Changes in the environmental risk factors accounting for deaths in China from 1990 to 2017 (per 100,000 deaths, corrected values). Source: Global Burden of Disease (GBD) (http://www.healthdata.org/gbd)

infections, respiratory infections, tuberculosis and other infectious diseases dropped by 77.7% from 1990 to 2017, and that caused by neglected tropical diseases and malaria went down by 77.3% during that 27 years (see Fig. 3). China has strengthened premarital screening, genetic counseling, prenatal diagnosis, perinatal care and the promotion of new delivery methods, thereby effectively reducing the incidence of birth defects associated with hereditary and various harmful factors, as well as the under-five mortality rate associated with premature birth, low birth weight, pneumonia, birth asphyxia, congenital heart disease and accidental asphyxia. China has shifted from providing "five guarantees" (of food, clothing, housing, medial care and burial expenses, as well as the compulsory education for minors) for rural residents with neither source of income nor working capability, nor legal guardian, supporter or fosterer, to providing subsistence relief, medical aid, educational assistance and old-age subsidy for urban and rural "low-income" residents. In particular, in recent years, China has vigorously launched "precision poverty relief" to ensure "lifting all rural residents living below the current poverty line out of poverty and

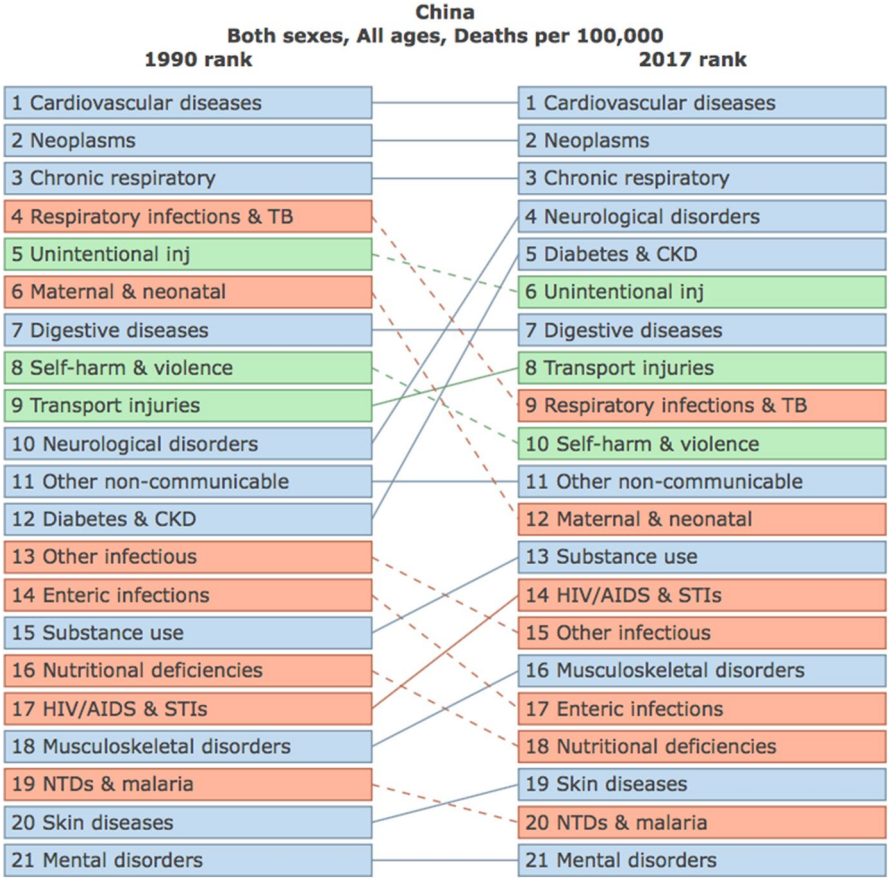

Fig. 3 Changes in the rankings of death causes in China (1990–2017). Source: same as Fig. 2

eliminating poverty in all poor counties and regions by 2020". China has expanded its social welfare system for disabled people which focused on employment, assistance, education and rehabilitation to the "comprehensive establishment of a living allowance system for disabled people with disabilities and a subsidized care system for severely disabled people". China has also shifted from employees' labor insurance and free medical service for cadres to the establishment of a comprehensive social security system covering basic endowment and medical insurance for urban employees, rural basic endowment insurance, basic medical insurance for urban and rural residents, critical illness insurance, work injury insurance, unemployment insurance, and maternity insurance, as well as the reward and support system for rural family planning families and the special support system for family planning families with difficulties. China has also broadened its efforts from supporting the army and giving preferential treatment to the families of army men and martyrs to continuously raising the standard of disability pensions for the disabled army men and policemen, the standard of regular pensions for the families of martyrs and army men who died on duty or of illness, the standard of living allowance for elderly or ill veterans, and the standard of subsidy for elderly rural conscripts, as well as guaranteeing the standard and quality of living for the special support recipients (especially for rural conscripts and their families).

Over the past 70 years, China has achieved fruitful results in carrying out the aforementioned efforts, which played an important role in providing effective social security, improving people's livelihood and increasing the ALE of Chinese population. Still, we must also notice that the undertaking of urban and rural medical and health services and the work of healthy pregnancy and scientific nurture still need to deepen the reform of the medical and health system and to promote the balanced development of high-quality medical care and MCH resources in the eastern, central and western regions and in both urban and rural areas. In addition, the social security system established by China needs to be further improved in accordance with the goals put forward by General Secretary Xi Jinping (2017) in the Report of the 19th CPC National Congress, namely to "act on the policy requirements to help those most in need, to build a tightly woven safety net, and to build the necessary institutions, as we work to develop a sustainable multi-tiered social security system that covers the entire population in both urban and rural areas, with clearly defined rights and responsibilities".

3 Prospects: China should put greater emphasis on improving the average healthy life expectancy

3.1 Relevant goals and indicators put forward in "Healthy China 2030"

With the increase in ALE, how to improve the quality of a healthy life while continuing to extend ALE has become a main focus of research and policies in all countries across the globe. Compared with some developed countries or regions where ALE has reached 80 years, there is still room for China to extend ALE in the future. In the meantime, accelerating the improvement of average healthy life expectancy

(AHLE) has increasingly become the future focus of China. AHLE refers to the average number of years that a birth cohort is expected to live in good health based on the healthiness rate of the current age group. The World Health Organization (WHO) believes that improving healthy life expectancy is way more important than increasing the number of years of survival without good quality of life. In 2000, WHO took it as an important indicator for assessing the population health and the performance of health system. On October 25, 2016, CPC Central Committee and the State Council pointed out in the *Outline of the Plan on "Healthy China 2030"* that "health and longevity are an important token of national wealth and prosperity, representing the common wishes of people of all ethnic groups in the country", and also proposed to achieve the following goals by 2030: "extending average life expectancy to 79.0 years", "reducing infant mortality to 5.0‰", "reducing under-five mortality to 6.0‰", "reducing maternal mortality to 12.0 per 100,000", and "significantly increasing the average healthy life expectancy" (CPC Central Committee, State Council 2016).

3.2 Average healthy life expectancy in China

The measurement of AHLE requires to distinguish between the healthy and unhealthy parts of ALE, during which the definition and measurement of health is the most important part of health life expectancy. The AHLE data of China was originally derived from the paper submitted by Grab and Dowd to the Fourth Annual Conference of International Network on Health Expectancy (REVES) in 1991. Based on the National Disability Survey of China conducted in 1987 and the National Population Census conducted in 1982, they estimated the AHLE of non-disabled people born in China in 1987, in which the AHLE for non-disabled males was 62.3 years, accounting for 92.5% of ALE for males, and the AHLE for non-disabled females was 64.5 years, accounting for 91.3% of ALE for females (Qiao 2009). Since 2000, WHO has been releasing the AHLE data of its member states every 5 years. During the period from 2000 to 2016, the AHLE of China went up slightly from 64.8 years (89.9% of ALE at birth) in 2000 to 68.7 years (still 89.9% of ALE at birth) in 2016. However, compared with the AHLE at birth of the Japanese population as released by WHO—72.5 years in 2000, 73.2 years in 2005, 73.8 years in 2010, 74.7 years in 2015 and 74.8 years in 2016, China still have a long way to go in working toward the goal of "significantly improving AHLE by 2030. The gender difference in AHLE at birth in China has remained stable over the past two decades. In 2016, the AHLE for males was 1.3 years lower than that for females, yet the ratio of AHLE to ALE for males was 1.7% higher than that for females (see Table 1).

3.3 Strive to reduce the regional differences in AHLE in China

There are very few studies on the regional differences in AHLE at birth in China, and the relevant papers focus mainly on the regional differences in the AHLE of elderly population. As early as in the early 1990s, based on the gender-specific morbidity rate among urban and rural elderly population as shown in the "Survey of the

Table 1 Gender-specific AHLE since 2000

	Overall			Males			Females		
	ALE at birth (years)	AHLE at birth (years)	% of AHLE at birth	ALE at birth (years)	AHLE at birth (years)	% of AHLE at birth	ALE at birth (years)	AHLE at birth (years)	% of AHLE at birth
2000	72.1	64.8	89.9	70.7	64.1	90.7	73.7	65.6	89.0
2005	74.2	66.7	89.9	72.8	66.1	90.8	75.6	67.3	89.0
2010	75.2	67.6	89.9	73.8	67.0	90.8	76.7	68.3	89.0
2015	76.2	68.4	89.8	74.8	67.8	90.6	77.7	69.1	88.9
2016	76.4	68.7	89.9	75.0	68.0	90.7	77.9	69.3	89.0

Source: WHO Global Health Observatory (https://www.who.int/gho/zh/)

Elderly Support System in 12 Provinces, Autonomous Regions and Municipalities of China" (launched by China Research Center on Aging in 1992), as well as the data from National Population Census in 1990, Wang (1993) calculated the average expected healthy years of Chinese elderly aged 60 + in 1992) and found 5.95 years (36.5% of their average remaining life) for urban elderly males, 5.03 years (26.1%) for urban elderly females, 6.75 years (42.8%) for rural elderly males and 5.98 years (32.6%) for rural elderly females. Zhang and Du (2009) used the data from the National Population Change Sample Survey conducted by the National Bureau of Statistics in 1994 and 2004 to analyze the regional differences in the AHLE of Chinese elderly. In 1994, AHLE at the age of 60 was the highest in Eastern China, followed by Western China and Central China. In the period from 1994 to 2004, AHLE at the age of 60 went up slightly in all regions, with Eastern China outperforming Central and Western China. With regard to the ratio of AHLE to ALE at the age of 60, during the period from 1994 to 2004, the ALE at the age of 60 grew faster than the AHLE at the age of 60 in Eastern, Central and Western China, and the growth rate of AHLE in the 60-year-old females living in Eastern China was higher than that of ALE at the age of 60.

With regard to the provincial differences in the AHLE of the 60-year-old elderly population, based on the data from the 6th Census conducted in 2010, Qiao and Hu (2017) estimated that the longest AHLE at the age of 60 for males was observed in Shanghai (14.27 years), followed by Tianjin, Zhejiang and Beijing, and the shortest AHLE was observed in Tibet (9.14 years) and Gansu (9.49 years); the longest AHLE at the age of 60 for females was also observed in Shanghai (16.10 years), followed by Guangdong and Zhejiang, and the shortest AHLE was also observed in Tibet (10.39 years) and Gansu (9.98 years). Furthermore, the ratio of AHLE to ALE at the age of 60 was higher than 84% in Guangdong, Fujian, Shanghai, Zhejiang and Jiangsu, whilst this ratio was lower than 70% in Tibet, Gansu and Hunan.

In response to the abovementioned salient problems, the *Outline of the Plan on "Healthy China 2030"* has taken "fairness and justice" as a key principle for promoting the construction of a healthy China in the coming years, emphasizing "to put focus on rural areas and grassroots, to promote equal access to health-related basic public services, to maintain the non-profit nature of basic medical and health

services, to gradually narrow the gaps in health services and health conditions between urban and rural areas, between different localities and between different groups, to achieve universal health coverage, and to promote social equity".

3.4 Continuously and effectively promote the healthy lifestyle and the work of pollution prevention and control

Overall, ALE and AHLE all witnessed significant improvement over the past 70 years since the founding of PRC. Still, unhealthy lifestyles and behaviors as well as air pollution will have a severe impact on the future health of Chinese population, thereby hindering the further growth of ALE and AHLE. Along with the high-quality economic development in China and the rapid growth of the disposable income of urban and rural residents in the future, the negative impact of unhealthy lifestyles and behaviors on improving health and ALE would become even more salient. In response to these salient problems, the *Outline of the Plan on "Healthy China 2030"* has added specific targets into the main indicators for the construction of healthy China, with the action plan calling to: (1) "promote the healthy lifestyle and strengthen healthy lifestyle guidance and interventions for families and high-risk individuals"; (2) "incorporate health education into the national education system, take health education as an important part of quality education for all education stages, and establish a school-based health education promotion mechanism that focuses on primary and secondary schools; and (3) "carry out in-depth prevention and control of air, water and soil pollutions", "implement the initiative to ensure that all industrial polluters comply with discharge standards" and "strengthen food safety supervision". In 2018, China announced "pollution prevention and control" as one of its three must-win "battles", and called to adhere to pollution prevention and control from the source, to accelerate the adjustment and optimization of economic structure, to fundamentally ease the pressure of pollution discharge, to strengthen institutional and legal construction, and to build a long-term mechanism for ecological and environmental protection. All these efforts will certainly help China effectively improve AHLE in the future on the basis of the ever-higher ALE.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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