Non-communicable diseases are key to further narrow gender gap in life expectancy in Shanghai, China

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Abstract

Background: To address change in gender gap of life expectancy (GGLE) in Shanghai from 1973 to 2018, and to identify the major causes of death and age groups associated with the change overtime.

Methods: Retrospective demographic analysis with application of Joinpoint regression to evaluate the temporal trend in GGLE. Causes of death were coded in accordance with International Classification of Diseases and mapped with the Global Burden of Disease (GBD) cause list. Life table technique and decomposition method was used to express changes in GGLE.

Results: Trend of GGLE in Shanghai experienced two phases ie., a decrease from 8.4 to 4.2 years in the descent phase (1973-1999) and a fluctuation between 4.0 and 4.9 years in the plateau phase (1999-2018). The reduced age-specific mortality rates tended to concentrate to a narrower age range, from age 0-9 and above 30 years in the descent phase to age above 55 years in the plateau phase. Gastroesophageal and liver cancer, communicable, chronic respiratory and digestive diseases were once the major contributors to narrow GGLE in the descent phase. While importance should be attached to a widening effect on GGLE by lung cancer, cardiovascular diseases, other neoplasms like colorectal and pancreatic cancer and diabetes in recent plateau phase.

Conclusions: Non-communicable diseases (NCDs) have made GGLE enter a plateau phase from a descent phase in Shanghai China. Public efforts to reduce excess mortalities for male NCDs, cancers, cardiovascular diseases, chronic respiratory diseases and diabetes in particular and health policies focused on the middle-aged and elderly population might further narrow GGLE and ensure improvement in health and health equity in Shanghai China.

Background

Gender gap in life expectancy at birth (GGLE), which is the difference in life expectancy at birth (LE) by gender was 4.4 years in 2016 (74.2 years for females and 69.8 years for males)¹. There are gender differences in illnesses due to interactions among biological, social, psychological and behavioral factors^{2,3}, which may have led to gender differences in mortality, cause of death and hence life expectancy at birth. Understanding long-term trends in GGLE and cause of death will provide evidence for health professionals and policy makers to prioritize efforts and narrow gender inequity in LE.

Tremendous progress on LE have been found worldwide^{4,5} and recent studies find a narrowing GGLE in most high-income developed countries for example in countries like Sweden^{6,7}. China has also made great achievements in LE⁸⁻¹⁰. Among all its provinces, Shanghai has ranked first in LE in China mainland for many years¹¹, with low mortality even by the standards of high-income countries. Our previous study showed that after a period of decline and recovery, LE in Shanghai finally increased from 71 years in the 1970s to 84 years in 2018, and is still on the rise¹². China has also made great strides in economic development. With economic development, the GGLE should continue decreasing as gender gap is negatively associated with a nation's per capita gross domestic product, meaning as nations develop the gender gap closes¹³. However, GGLE in China,

more specifically in Shanghai-the economic hub of China, continues to persist. Shanghai has yet to see the GGLE inflection with male catching up with females' LE.

To our knowledge, there has been no research on GGLE in Shanghai. Considering that China has attached great importance to LE and its implementation of "Healthy China 2030" program with aims to further improve national LE to 79 years by 2030, this study intends to address changes in GGLE in Shanghai from 1973 to 2018, identify the major cause-of-death and age groups associated with narrowing or widening GGLE overtime. Moreover, the GGLE is both due to biological as well as behavioral factors¹⁴. Identifying the diseases associated with China's GGLE and existent research on disease risk factors will inform Chinese policy makers on risky behaviors, particularly among men. This long-term trend study will also make up for the lack of research on GGLE trends across decades in mainland China.

Methods

Overview

We assessed GGLE trend in Shanghai local residents from 1973 to 2018, which traced back to the earliest time of full coverage of the Shanghai Mortality Registration System. We investigated different stages of the trend in GGLE and quantified the age- and cause-specific contributions to the change.

Data sources

We used the 45-year mortality information from Shanghai Pudong New Area Center for Disease Control and Prevention (CDC). Individual information was anonymized and de-identified prior to analysis. Strict confidentiality of individual data was practiced during the entire study. Shanghai established a comprehensive Mortality Registration System in 1973, with a full coverage of residents' mortality information from medical institutions at all levels¹⁵. The system was further improved through routine verification with local population registry as well as funeral and cremation system and hence ensures the completeness of the registration system to the extent possible¹⁶. Details have been explained in our previous article¹². The dataset in use is available on reasonable request.

Coding and data quality

Rigorously trained clinicians coded cause of death. Historical data and data from 2002 were coded in accordance with the International Classification of Diseases, 10th Revision (ICD-10). Data from 1992 to 2001 were coded based on ICD-9. Moreover, historical records were checked against historical annual reports by cause and age to avoid inconsistency in classification.

According to Global Burden of Disease (GBD) study, garbage codes should be redistributed to enhance the validity of public health analysis and are classified into four categories¹⁷. We redistributed garbage codes such as heart failure, peritonitis and septicemia using the GBD recommended algorithms¹⁷. However, for senility and other unspecified cause of mortality lack medical records or causal inference information, we just kept the original ill-defined data. We evaluated the age-specific proportion of garbage codes and compared the

data quality in different periods with those of other countries/regions. Finally, we mapped the 45-year data in accordance with the GBD cause list to make comparison in the same framework.

Causes of death

We focused our analysis on 14 mutually exclusive and exhaustive cause of death categories, which covered all the leading causes of death across the study years in Shanghai. Causes of death included cardiovascular diseases (cerebrovascular diseases, ischemic heart diseases), neoplasms (lung cancer, stomach cancer, liver cancer, and esophageal cancer), chronic respiratory diseases, communicable diseases, digestive diseases, diabetes, endocrine, blood, and immune disorders, kidney diseases, and injuries. The causes of death we focused and their corresponding ICD-9 and ICD-10 codes have been listed in Appendix Table A1.

Analysis

We applied Joinpoint regression to evaluate the temporal trend in GGLE during the 45-year period. The basic idea of the method is to model the time series using a few continuous linear segments¹⁸. Joinpoint regression tests whether a multi-segmented line is a significant better fit than a straight or less-segmented line on the basis of permutation tests¹⁹ while other regression methods investigate trends to find the best-fit line through years of data²⁰. The application of Joinpoint method helps to find meaningful turning point of trend and avoids artificially dividing of the long study period²¹.

We calculated the gender-specific LE with the conventional life table technique based on annual abridged life tables. The age intervals of the life table were age 0–1, 1–4, 5–9, and in subsequent five-year age groups up to age 85 with an open end. We used age- and cause-specific decomposition method to express changes of GGLE in years widened or narrowed at corresponding periods²². Narrowed GGLE can be attributed to (1) a faster drop in male mortality than female; (2) a slower rise in male mortality than female; (3) male mortality decreases while female's increases. While an expanded GGLE is just the opposite. Details of the formulas can be found elsewhere²³.

Joinpoint regression analyses were carried out using Joinpoint Regression Program, Version 4.0.4 (US National Cancer Institute, MD). Statistical analysis was performed with Stata/SE 13.0 (College Station, TX).

Results

Trend of GGLE

Figure 1 shows that male's LE increased by 12.6 years, from 69.3 to 81.9 and female's LE increased by 8.9 years, from 77.8 to 86.7, between 1973 and 2018 in Shanghai. The GGLE decreased from 8.4 years in 1973 to 4.8 years in 2018. Change of GGLE could be divided into two phases, the descent (1973 to 1999) saw dramatic drop in GGLE from 8.4 to 4.2 (slope is -0.11 with 95% CI $(-0.14, -0.08)$); the plateau (1999 to 2018) where GGLE fluctuated between 4.0 and 4.9 years. Joinpoint regression details can be referred to the additional file (Additional file 2: Appendix Table A2)

Age-specific contributions to GGLE at different phases

Figure 2 shows the age-specific contributions to GGLE in Shanghai in 1973, 1999 and 2018. Male mortality rates from all age groups were higher than female in 1973, especially for age group 0-9 and above 30 years. Gender differences of the age-specific mortality rates in both 1999 (2.42‰) and 2018 (1.46‰) were significantly lower compared to 1973 (4.75‰). The reduced age-specific mortality rates concentrated in a narrower age range over time. Gender difference of the age-specific mortality rates mainly started from age 30 years in 1999, while excess male mortality mainly started from age 40 years in 2018. The age-specific contributions to GGLE were similar in 1999 and 2018, except for a wider GGLE at the advanced age, mainly from age over 55 years, and more pronounced at age above 85 years.

Cause-specific contributions to GGLE

We divided the change of GGLE between 1973 and 2018 into two phases. Age-standardized all-cause mortality decreased by 29.8% in male and 12.9% in female during 1973 and 1999, while by 46.4% and 49.8% during 1999 and 2018. Table 2 shows the age-standardized mortalities of major cause of death for both genders. If male cause-specific mortality is higher than female, we regard the cause a positive contributor to GGLE, and vice versa. Figure 3 showed cause-specific contributions to GGLE in Shanghai in 1973, 1999 and 2018. All causes of death concerned in our study made positive contribution to GGLE in 1973. Among them, gastroesophageal and liver cancer, communicable diseases, chronic respiratory diseases and digestive diseases made over half of total contributions.

As shown in Figure 3, in 1999, gastroesophageal and liver cancer, lung cancer and chronic respiratory diseases were the leading contributors to GGLE, accounting for over 70% of total contribution. Though gastroesophageal and liver cancer and chronic respiratory diseases remained the leading contributors, the contribution decreased. However, lung cancer made a greater contribution of 0.88 years to GGLE in 1999, compared with 0.52 years in 1973, with an excess of 0.36 years. In addition, communicable diseases fell out of the top three to make positive contribution to GGLE.

Gastroesophageal and liver cancer, lung cancer and chronic respiratory diseases remained the leading contributors to GGLE in 2018. Lung cancer itself made 0.95 years of contribution, while gastroesophageal and liver cancer in total made 1.21 years of contribution. It is worth noting that besides lung cancer, the contributions to GGLE of cerebrovascular diseases and other neoplasms (except for gastroesophageal, liver and lung cancer) are increasing during past 45 years. Cerebrovascular diseases contributed to GGLE from 0.46 years in 1973 to 0.70 years in 2018, just second to chronic respiratory diseases. Neoplasms except for gastroesophageal, liver and lung cancer increased the contribution from 0.09 years in 1973 to 0.45 years in 2018.

Age- and cause- specific contributions to GGLE

Figure 4 shows the contribution of age and cause on GGLE. As shown the age- and cause-specific contribution to GGLE concentrated more below the x-axis in the descent phase (1973-1999). Narrowing effect of GGLE mainly attributed to communicable, digestive diseases, liver cancer and other causes of death at age 0-9 years; and communicable, digestive, chronic respiratory diseases, gastroesophageal and liver cancer and other causes of death at age over 30 years. Meanwhile, lung cancer and other neoplasms widened GGLE mainly at age over 70 years.

In the plateau phase (1999-2018), the contributions relatively balanced on both sides of x-axis. Nevertheless, it is worth noting that a widening GGLE attributed to cardiovascular diseases (ischemic heart diseases and cerebrovascular diseases), lung cancer, other neoplasms and other causes of death (diabetes, endocrine, blood, and immune disorders, kidney diseases) at age over 55 years.

We compared change of GGLE between 1973-1999 and 1999-2018. We found chronic respiratory diseases, neoplasms and cerebrovascular diseases at age group above 85 years made the biggest contribution to widen GGLE. Furthermore, neoplasms other than lung, gastroesophageal and liver cancer widened GGLE at a broader age group. They used to widen GGLE mainly from age above 70 years at descent phase, but from age 50 years at plateau phase.

Discussion

Using data across 45 years (1973 to 2018), we studied changes in GGLE across time and contribution by age group and cause of death on changes in GGLE in Shanghai, China. We found two phases in change in GGLE. First, GGLE decreased by 4.2 years from 1973 to 1999, the descent phase, and then fluctuated around 4.5 years from 1999 to 2018, the plateau phase. Age-specific contribution to the change in GGLE concentrates in a narrow and more advanced age group (85 years and above). Non-communicable diseases (NCDs) such as cancer, cardiovascular, chronic respiratory diseases and diabetes are major contributors to the changes in GGLE.

Communicable diseases used to be a major contributor to narrow GGLE in the descent phase (1973 to 1999). Nevertheless, its role diminished in the plateau phase (1999 to 2018). Shanghai suffered from hepatitis B, schistosomiasis and tuberculosis during the descent phase²⁴. Since the implementation of schistosomiasis control programs^{25 26}, hepatitis B vaccinations^{25 26}, modern tuberculosis control program and infectious disease surveillance²⁷, communicable diseases have been greatly reduced. This is a remarkable achievement in public health.

In China and globally the achievement in communicable diseases corroborates an epidemiological shift to NCDs during the second half of last century. NCDs accounted for an increasing proportion of total deaths, for about 60% of total deaths in 1973 and over 90% in 2018. Our study finds that gender differences in mortality due to NCDs are key to reduce GGLE in Shanghai, China. Male mortality of NCDs decreased by 43.9% and female by 35.7% over the past 45 years. NCDs like gastroesophageal and liver cancer, chronic respiratory and digestive diseases were the major contributors to narrow GGLE. While NCDs like lung cancer, other neoplasms, cardiovascular diseases, and diabetes were the major contributors to widen GGLE in our study.

Cancer is the largest contributor to GGLE in Shanghai. However, the effect of cancers on GGLE vary by cancer site. Gastroesophageal and liver cancer in total make positive contribution to GGLE but the contribution declines. Lung cancer and other neoplasms (except for above-mentioned three cancers), however, continue to widen GGLE. Steady declines in mortality rates of gastroesophageal and liver cancers are potentially attributed from the overall achievement in public health²⁸, including HBV-vaccination, sanitation campaign (centralized drinking water supply system), improved treatment of parasitic liver fluke infections and healthy

lifestyle changes (increased fresh fruits and vegetables, limited alcohol consumption, decreased salt-preservative/aflatoxin-contamination foods) ²⁹⁻³³.

Lung cancer has surpassed stomach cancer and become the leading cause of cancer death in Shanghai in the recent years. The prevalence of smoking is much higher in male than female ³⁴. Lung cancer is one of the most preventable cancers ³⁵. Experience from the developed countries show marked decrease in smoking rates and lung cancer occurrence after comprehensive tobacco control program ³⁶. Tobacco control can also reduce risk of cardiovascular diseases ³⁷. Hence, Shanghai should take swift action to promote persistent efforts on tobacco control and attenuate the excess burden of smoking-related diseases experienced in developed countries, to promote the narrowing of GGLE.

Importantly, besides cancer, we also find a widening effect of GGLE by other NCDs like cardiovascular and endocrine diseases (diabetes). Overweight or obesity, sedentary lifestyle, hypertension and hyperlipidemia are the main risk factors for cardiovascular and endocrine diseases (diabetes), which are more prevalent in male than in female ³⁸⁻⁴¹. Several exemplary policy intervention exists to prevent NCDs, such as promoting preventing health care through lifestyle behavioral changes and incorporate prevention into existing health care policy ⁴². Another potential strategy is workplace health promotion to promote physical activity ⁴⁰. Further, we find age-specific contribution to GGLE concentrate in a narrower age range as the decline of gains in LE, which is similar with findings in other high-LE countries ^{43 44}. Promotion of physical activity particularly among adults and elderly seems relevant to our findings that suggest special attention to male at advanced age for further improving LE and reducing GGLE.

The trend pattern and its main contributor of GGLE in Shanghai varied compared with other high-income countries or regions. In some western developed countries like Sweden, GGLE is narrowing constantly ^{6 7 43 45 46}, and cardiovascular diseases made the largest contribution to narrow GGLE ^{6 7}. While in some eastern countries like Japan, GGLE is widening and cardiovascular diseases is an important contributor to the widening ^{7 47}. We however find GGLE fluctuated between 4.0 and 4.9 in recent years and cancer is the major driver to widen GGLE throughout the 45-year study period. It remains to see whether Shanghai's steady GGLE in recent years will gradually narrow as in the western countries or expand as in China's Asian neighbors.

Our study has several limitations. First, since the earliest data we have started from year 1973, we do not know trend of GGLE before. Many high-income countries found that GGLE experienced an expansion period and then declined through over 50 or more years data. Limited by our data, we cannot make a comparison in this respect. However, given that we update the long-term trend study to year 2018, guidance for future disease prevention and control to increase LE and narrow GGLE or at least not to expand is of greater significance. Second, we constrain the study only to major causes of death without breaking down the disease groups into more detailed causes (except for cardiovascular diseases and some major neoplasm). NCDs account for over 90% of total death in Shanghai in 2018, and cardiovascular diseases and neoplasms alone account for over 70% of total death. Therefore, we believe that no breakdown of disease groups such as injuries into more detailed causes has little impact on this study.

Third, our study only contains the information of local residents without that of flowing population and only analyzes GGLE by decomposition of age- and cause-specific contributions. Future study is expected to dive deeper into specific causes of death based on more detailed socio-economic data such as education background and annual income with comparison of different population. Fourth, the 45-year-span is divided into 2 periods based on joinpoint regression result. Considering decompositions of GGLE can provide meticulous change between years, we will also analyze age and cause-specific contributions according to some special time nodes for the development of Shanghai in future study. Lastly, like other long-term trend studies, our data also faces data quality differences in different periods. The percentage of garbage code dropped greatly from above 40% in 1973 to 6.5% in 2018, which reached an excellent quality globally. We listed age-specific percentage of garbage codes in the additional file (Additional file 3: Appendix Figure A1).

NCDs are the biggest cause of death worldwide, and could have largely been prevented. Our findings showed that NCDs like cancer, cardiovascular, chronic respiratory and diabetes were leading causes of death in Shanghai and their proportions of total death have reached above 90%, efforts on prevention and control NCDs are imminent. China has implemented “Healthy China 2030” program, and one of its goals is to prevent and control four major NCDs (cardiovascular diseases, cancer, chronic respiratory diseases and diabetes) and increase the national LE to 79 years by 2030. The Healthy China 2030 aims to ensure that everyone enjoys a full cycle and all-round health and promote health equity⁴⁸. This also includes health equity between male and female. More specifically, as nations develop the longitudinal pattern of declining GGLE turn around and men start to catch up as evident in many high and middle-income countries.

Shanghai being the province with the highest LE in mainland China, the public health challenge facing Shanghai today, is also the challenge faced by other provinces in China now and in the future (Additional file 4: Appendix Table A3). GGLE in Shanghai continues to persist in recent decades despite the ever-increasing LE. Our findings provide evidence for policy makers and health professionals in China and other countries with rapid gains in LE to formulate future strategies for medical resource allocation, system improvement, and disease management to address or prevent GGLE.

Conclusions

NCDs have made GGLE enter a plateau phase from a descent phase in Shanghai China. Public efforts to reduce excess mortalities for male NCDs, cancers, cardiovascular diseases, chronic respiratory diseases and diabetes in particular and health policies focused on the middle-aged and elderly population might further narrow GGLE and ensure improvement in health and health equity in Shanghai China.

Declarations

Ethics approval and consent to participate: The retrospective research did not involve human participants. Individual information was anonymized and de-identified prior to analysis. Strict confidentiality of individual data was practiced during the entire study.

Consent to publish: Not applicable.

Availability of data and materials: The datasets used and/or analysed during the current study available from the corresponding author on reasonable request with permission of Shanghai Pudong New area Center for Disease Control and Prevention.

Competing interests: None.

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Authors' contributions: STX and JRT conceived the whole study and directed its implementation. HYC, YZ, and LHS were involved with the statistical analysis and drafted the manuscript. YCC, XBQ and HC helped conduct the literature review. The authors have read and approved the manuscript.

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Abbreviations

LE, life expectancy at birth; *GGLE*, gender gap in life expectancy at birth; *NCD*, non-communicable diseases.

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Table 1

Table 1 Age-standardized mortality rates for main causes of death in Shanghai, China (1973, 1999, and 2018)

Note: Age-standardized death rate per 100 000 people and its corresponding percentage of total mortality

Cause of Death	Male						Female					
	1973		1999		2018		1973		1999		2018	
	Mortality	%	Mortality	%	Mortality	%	Mortality	%	Mortality	%	Mortality	%
All causes	1010.95	100	709.32	100	380.08	100	536.32	100	466.85	100	234.32	100
Communicable, maternal, neonatal, and nutritional diseases	85.57	9.26	31.60	4.04	6.76	1.45	26.49	5.08	22.50	3.60	3.72	1.27
1. Communicable diseases	83.73	9.02	27.96	3.92	5.45	1.37	24.05	0.00	15.68	3.34	2.52	1.15
1. Neonatal disorders	1.84	0.25	3.42	0.10	1.07	0.07	2.41	0.33	6.30	0.20	1.28	0.07
Non-communicable diseases	611.88	62.94	609.11	86.96	343.4	92.05	324.19	62.44	388.27	84.98	208.50	90.06
1. Neoplasms	184.11	21.19	220.69	34.58	138.04	36.01	80.96	15.84	103.65	21.95	73.17	25.22
I. Tracheal, bronchus, and lung cancer	36.01	4.32	67.73	10.87	43.23	11.55	9.67	1.91	18.75	4.10	14.04	5.04
1. Stomach cancer	43.96	4.82	33.29	5.29	16.30	4.32	19.03	3.83	13.49	2.99	7.20	2.44
1. Liver cancer	38.12	4.20	33.01	5.34	14.65	3.60	14.70	2.90	10.05	2.12	5.34	1.95
1. Esophageal cancer	34.71	3.77	17.11	2.56	5.85	1.56	8.41	1.65	5.33	1.19	1.11	0.51
1. Other neoplasms	29.73	3.83	69.57	10.51	58.01	14.98	29.16	5.54	56.03	11.55	45.48	15.28
1. Cardiovascular diseases	201.44	19.89	218.07	29.99	126.62	34.98	141.56	27.13	174.34	39.21	87.24	44.38
I. Ischemic heart disease	107.44	10.75	62.89	8.36	59.92	16.89	80.47	15.25	49.22	11.08	44.71	24.04
1. Stroke	85.34	8.09	145.88	20.29	59.27	16.23	53.67	10.43	113.91	25.70	38.22	18.60
1. Chronic respiratory diseases	128.64	11.37	109.96	14.24	32.55	9.48	44.41	8.51	49.63	11.16	11.47	5.89
1. Digestive diseases	65.58	6.73	19.01	2.77	9.81	2.53	30.01	5.68	15.62	3.42	7.83	3.54
1. Diabetes, endocrine, blood, and immune disorders	1.32	1.17	13.86	3.06	16.40	6.40	3.04	1.85	17.79	5.12	12.89	1.27
1. Kidney diseases	7.86	0.99	7.04	0.93	7.77	2.07	6.33	1.19	5.13	1.08	5.14	2.05
Injuries	29.64	3.77	43.84	6.17	23.38	4.74	15.98	3.17	32.51	6.24	16.56	5.50

Figures

Figure 1

Life expectancy and its gender gap in Shanghai, 1973 to 2018. LE for both genders increased steadily after a short period of decrease and recovery during the 45 years.

Figure 2

Age-specific contributions to GGLE in Shanghai in 1973, 1999 and 2018. Note: values above zero indicate males' mortality rate is higher than females' at specific age, vice versa.

Figure 3

Cause-specific contributions to GGLE in Shanghai in 1973, 1999 and 2018. Values above zero indicate higher mortality in male. The sum of the positive and negative values results in GGLE of 8.4 years in 1973, 4.2 years in 1999 and 4.8 years in 2018.

Figure 4

Age- and cause-specific contributions to the change of GGLE in Shanghai during 1973-1999 and 1999-2018. Positive values indicate a widening effect on GGLE by cause of death at corresponding age group, while negative values indicate a narrowing effect.

Supplementary Files

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- [FigureA.1.pdf](#)
- [7.Supplementary.docx](#)