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Observed and relative survival trends of lung cancer: A systematic review of population-based cancer registration data

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Abstract

Background: Using the published survival statistics from cancer registration or population-based studies, we aimed to describe the global pattern and trend of lung cancer survival.

Methods: By searching SinoMed, PubMed, Web of Science, EMBASE, and SEER, all survival analyses from cancer registration or population-based studies of lung cancer were collected by the end of November 2022. The survival rates were extracted by sex, period, and country. The observed, relative, and net survival rates of lung cancer were applied to describe the pattern and time changes from the late 1990s to the early 21st century.

Results: Age-standardized 5-year relative/net survival rate of lung cancer was typically low, with 10%–20% for most regions. The highest age-standardized relative/net survival rate was observed in Japan (32.9%, 2010–2014), and the lowest was in India (3.7%, 2010–2014). In most countries, the five-year age-standardized relative/net survival rates of lung cancer were higher in females and younger people. The patients with adenocarcinoma had a better prognosis than other groups. In China, the highest 5-year overall relative/net survival rates were 27.90% and 31.62% in men and women in Jiangyin (2012–2013).

Conclusion: Over the past decades, the prognosis of lung cancer has gradually improved, but significant variations were also observed globally. Worldwide, a better prognosis of lung cancer can be observed in females and younger patients. It is essential to compare and evaluate the histological or stage-specific survival rates of lung cancer between different regions in the future.

KEYWORDS
cancer registry, lung cancer, observed survival rate, population-based survival study, relative survival rate

INTRODUCTION

Lung cancer is the second most common cancer incidence and the leading cause of cancer death in 2020, with an estimated 2.2 million new cases and 1.8 million deaths, representing approximately one in 10 (11.4%) cancers diagnosed and one in five (18.0%) deaths.[1] It is the most frequently occurring cancer (14.3%) and the third cancer (8.4%) in men and women; and the leading cause of cancer death (18.0%) and the second (13.7%) in men and women.[1] Regarding the regions, more than half of these cases occurred in developed countries. Incidence and mortality of lung cancer in high human development index (HDI) regions were at least three times higher compared with low HDI regions in both sex.[1]

As the foundation of cancer prevention and control, population-based cancer registration reflects the cancer burden of the entire population through obtaining comprehensive,

accurate, and timely information on cancer incidence, mortality, and survival.[2] The long-term survival rate of cancer patients might not be available for the countries or regions that have systematically reported data on cancer incidence and/or mortality. There were three different sources of survival data: clinical studies, hospital-based follow-up studies, and population-based cancer registration. They are disparate in research aims and applications. Population-based survival data include the survival information of all patients in the population, which can provide valuable indicators such as relative survival rate (RSR) for the effectiveness of cancer control and reflect the prospects of cure in a country or region.[3]

In the present study, we performed a systematic review of survival analysis from population-based cancer registration and extracted the relative, net, and observed survival rates. The aim of the study was to describe the global pattern and chronological changes in survival rates in lung cancer patients in different populations or regions during the 1990s and into the early 21st century.

METHODS

Data source

A literature search of related studies up to November 30, 2022, was conducted using the databases of SinoMed, PubMed, Web of Science, EMBASE, and SEER, with the following keywords: "lung cancer", "pulmonary neoplasm", "cancer registry", "population-based survival studies", "relative survival", "observed survival", and "net survival". Lung cancer was defined by using the 10th revision of the International Classification of Diseases (ICD-10) codes of C33-34, and the histopathological type of tumor was coded by the International Classification of Diseases-Oncology third edition (ICD-O-3).

Two researchers (JHB, JYT) collected the data independently according to the search criteria, and 576 full-text articles were reviewed based on the initial titles and abstracts retrieved. Studies were included if they met the following criteria: (1) available survival indicators, such as relative survival rate (RSR), observed survival rate (OSR), or net survival rate of patients with lung cancer, and (2) data from population-based studies or cancer registration. In addition, we excluded duplicate, incomplete or unavailable estimates in the original articles. After our screening, 138 studies were included, 17 of which were in Chinese, and the remaining 121 were in English (Figure 1). The present study only displays data from the 1990s.

Statistical analysis

Estimates of OSR, RSR, and net survival rates were extracted from the published studies. RSR is the ratio of the absolute survival rate of cancer patients to the expected survival rate

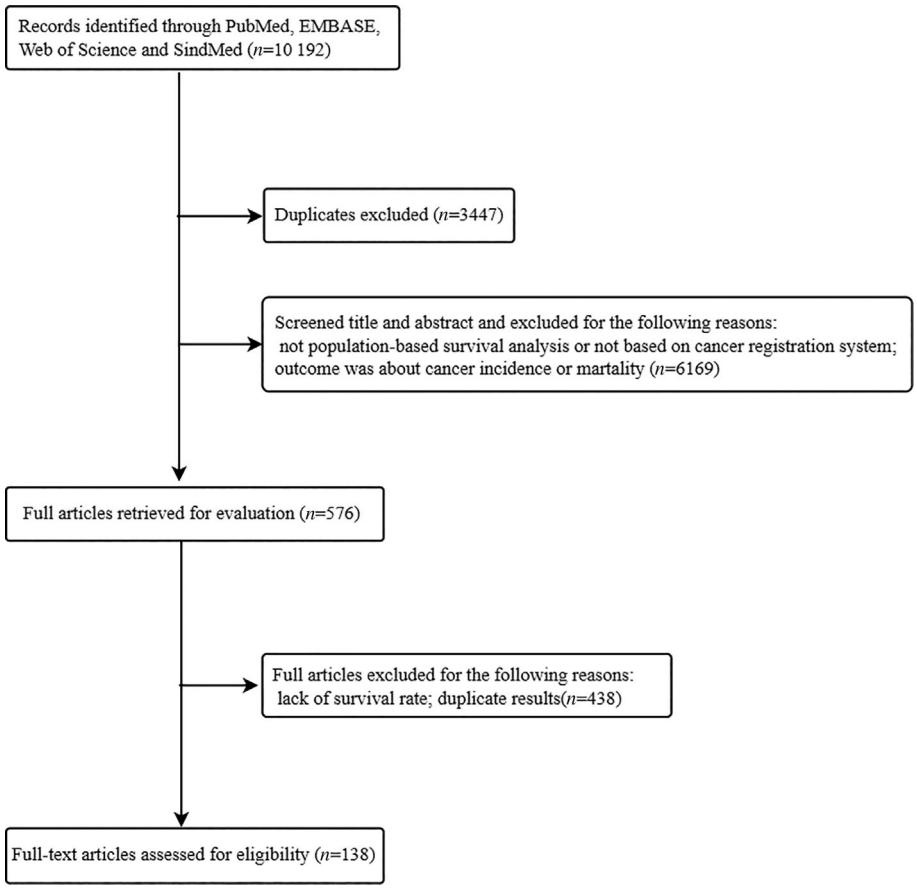

FIGURE 1 Study selection process.

of a group of people of the corresponding sex and age in the general population. Net survival is the cumulative probability of surviving up to a given time since diagnosis (e.g., 5 years) after correcting other causes of death (background mortality). Both net survival and RSR refer to the cumulative survival probabilities in a given period after excluding other causes of death, and we presented them if one or both were available in our study.[4–6] Survival generally depends on age at diagnosis, and the age distribution of cancer patients may vary over time in any one area or country and will almost certainly differ among geographical areas. Age-standardized survival ensures age comparability of survival among different countries and regions. Standard cancer patient population is commonly used to compare the survival of lung cancer.[7] We used overall and age-standardized 5-year RSR or net survival rate to describe and compare the results in different countries or regions, age groups, and sex.

Endnote X9 and Excel 2016 were used for literature management and data analysis.

RESULTS

Global pattern and trends

Table 1 shows the overall observed survival rates (OSRs) of lung cancer in China,[8–14] Japan,[15] India,[16,17] Peru,[18] the

TABLE 1 Overall observed survival rates of lung cancer in selected regions during 1990–2016.

Region		Period	1-year	3-year	5-year
China	Guangdong, Sihui[8]	1997–2006	-	-	4.76
		2007–2009	-	-	10.35
	Hebei, Cixian[9]	2000–2002	18.55	9.17	5.76
	Jiangsu, Qidong[10]	1993–1997	14.52	4.79	3.69
		1998–2002	19.95	6.69	5.13
		2003–2007	21.68	8.72	6.32
		2008–2011	26.28	8.62	-
	Shandong, Zhaoyuan[11]	2009–2013	48.83	19.51	13.47
	Shanghai[12]	2002–2006	42.53	19.19	13.75
	Zhejiang, Haining[13]	2003–2015	42.69	26.13	24.14
	Taiwan[14]	2002–2007	37.81	14.66	9.37
		2010–2014	57.39	29.55	17.34
Japan[15]		1993–1996	52.10	25.90	19.50
India	Chennai[16]	1990–1999			7.00
	Mumbai[17]	1992–1994	29.90	15.90	12.50
Denmark[22]		2000–2002	31.00	-	10.00
		2003–2005	34.00	-	10.00
		2006–2008	34.00	-	12.00
		2009–2011	37.00	-	13.00
Finland[23]		1990–1992	-	-	12.00
Germany[24]		2000–2004	-	-	13.00
Hungary[27]		2011–2016	42.33	-	14.75
Portugal[28]		2009–2011	41.40	18.90	13.60
Spain[25,29]		2000–2007	-	-	9.30
		2008–2013	-	-	12.10
UK	Scotland[26]	1995	23.40	8.30	-
		2002	29.10	10.50	-
Peru	Lima[18]	2004–2005	-	-	8.20
USA	Total[21]	2002–2008	-	-	18.30
	California[19]	1992–1997	-	-	19.10
		1998–2003	-	-	24.00
		2004–2009	-	-	31.10
	Florida[20]	1996–2007	39.90	18.20	12.10

Note: - No report or nonavailable in the original articles.

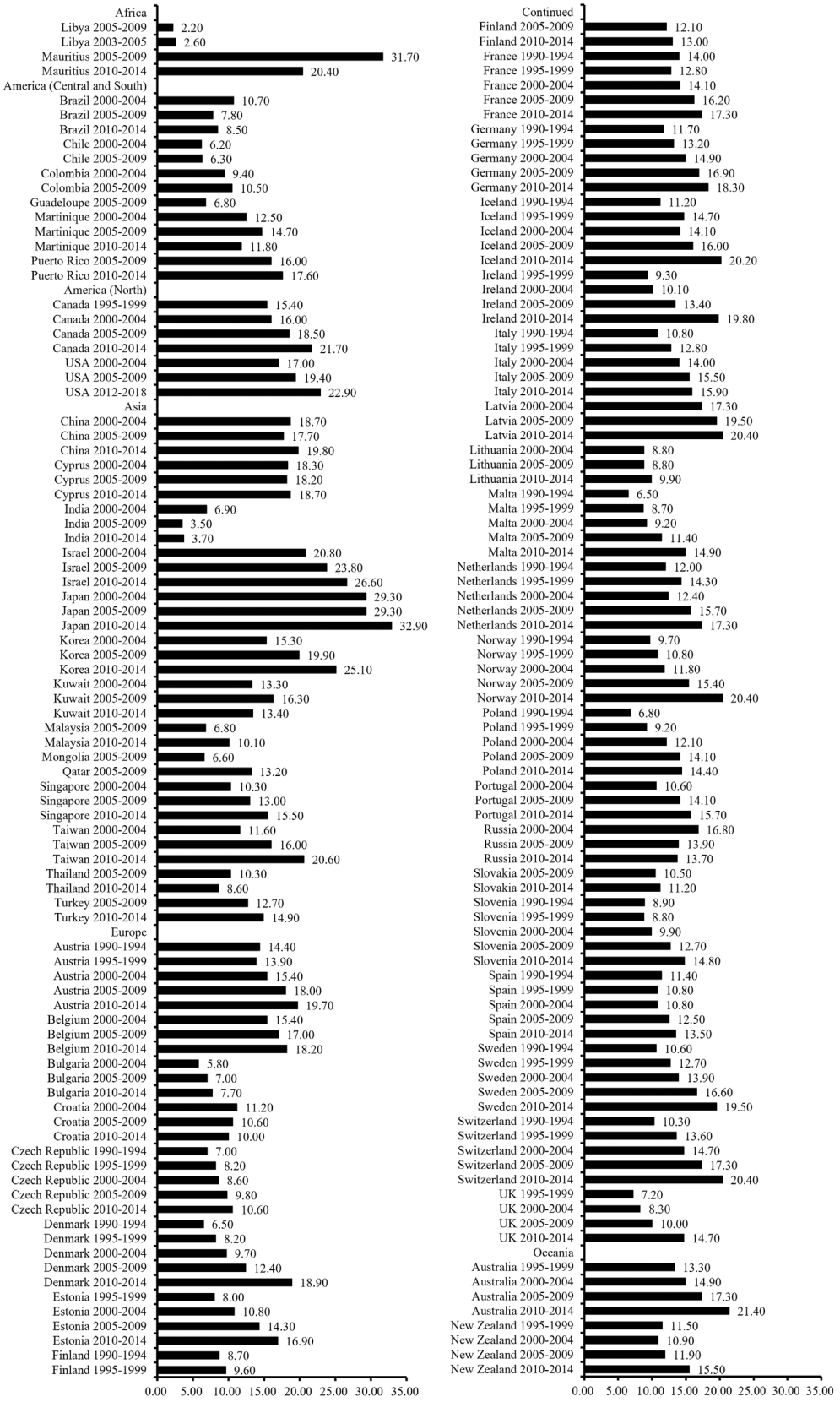

FIGURE 2 Age-standardized 5-year relative/net survival rates of lung cancer in selected regions during 1990–2018.

USA,[19–21] and the European countries.[16,22–29] The differences in 1, 3, and 5-year OSRs between different regions were distinctive. The highest 1-year OSR was in Taiwan (2010–2014, China) with 57.39%.[14] The highest 5-year OSRs were in California (2004–2009, USA)[19] with 31.10%, followed by Haining (2003–2015, China)[13] with 24.14%. However, in Denmark

TABLE 2 Sex-specific age-standardized 5-year relative/net survival rates of lung cancer in selected regions during 1990–2016.

Region		Period	Male	Female
China[36]		2003–2005	15.40	17.40
		2006–2008	14.50	18.30
		2009–2011	15.20	19.90
		2012–2015	16.80	25.10
Japan[37]		1993–1996	20.80	27.10
		2006–2008	27.00	43.30
Singapore[38]		1998–2002	9.70	11.60
		2003–2007	9.60	14.10
Austria[39,40]		1990–1994	13.40	16.00
		2000–2002	13.50	17.80
Belgium[39,41]		2000–2002	15.00	19.90
		2000–2004	14.00	18.00
Czech Republic[40]		1990–1994	6.30	8.20
Denmark[43,48]		1994–1998	7.00	7.00
		1999–2003	8.00	9.00
		2005–2009	13.00	16.00
		2000–2012	12.00	14.00
Estonia[40,42,47]		1990–1994	6.80	11.90
		1995–2000	7.00	13.00
		2001–2006	10.00	16.00
		2003–2009	12.00	17.00
		2010–2016	15.00	20.00
Finland[43]		1994–1998	8.00	12.00
		1999–2003	8.00	13.00
France[37,40,41,46]		1990–1994	13.10	15.90
		1995–1999	12.10	16.80
		2000–2004	13.00	17.00
		2005–2010	16.00	20.00
Germany[37,40,44]		1990–1994	10.80	10.50
		1995–1999	13.00	13.80
		2000–2007	14.50	18.50
		2007–2010	15.50	20.30
Iceland[43]		1994–1998	11.00	13.00
		1999–2003	11.00	15.00
Italy[37,40,41]		1990–1994	9.80	10.50
		1995–1999	12.00	15.40
		2000–2004	13.00	17.00
		2000–2007	13.20	17.30
Netherlands[40]		1990–1994	11.70	12.40
Norway[43]		1994–1998	9.00	12.00
		1999–2003	10.00	13.00
Poland[39,40]		1990–1994	6.10	6.80
		2000–2002	9.50	11.00
Portugal	Total[41]	2000–2004	9.00	17.00
	Azores[45]	1997–2000	5.60	7.00
		2001–2004	4.20	16.00
		2005–2009	8.10	10.90
		2010–2016	10.80	23.30
Slovakia[40]		1990–1994	6.90	12.00
Slovenia[39,40]		1990–1994	8.00	9.30
		2000–2002	9.30	12.00
Spain[25,29,40]		1990–1994	12.40	12.80
		1995–1999	10.20	13.40
		2008–2013	12.70	17.60
		2000–2007	10.10	14.70
Sweden[43]		1994–1998	11.00	15.00
		1999–2003	11.00	15.00
Switzerland[39–41]		1990–1994	9.70	16.20
		2000–2002	14.90	15.30
		2000–2007	15.00	17.00
Ireland[39]		2000–2002	10.00	12.30
UK	England[37,40]	1990–1994	7.40	7.70
		1995–1999	8.00	9.10
		2000–2007	8.00	9.90
	Northern Ireland[39]	2000–2002	9.60	12.00
	Scotland[39,40]	2000–2002	7.80	8.90
		1990–1994	7.00	6.80
	Wales[39,40]	1990–1994	8.00	7.50
		2000–2002	9.60	11.30
USA[37]		1997	13.50	16.60
		2004	15.00	19.00

(2006–2008),[22] Sihui (2007–2009, China),[8] and Taiwan (2002–2007, China),[14] the 5-year OSRs were poorer, at 12.00%, 10.35%, and 9.37%, respectively.

Figure 2 demonstrates the age-standardized 5-year relative or net survival rates in selected countries and regions from Africa,[30–32] America,[30,32,33] Asia,[30,32] Europe,[32–35] and Oceania.[33] Age-standardized 5-year relative or net survival rate of lung cancer was typically low, with 10%–20% for most regions, both in the developed and developing countries. The highest age-standardized 5-year relative or net survival rate was 32.9% in Japan (2010–2014), followed by 21.4% in Australia (2010–2014).[32] The lowest was only 3.7% in India (2010–2014).[32] The age-standardized 5-year relative or net survival rates of lung cancer increased with time in most countries, with the most pronounced increase in Denmark of more than 10% between 1990 and 2014.[33,34] However, in some countries, such as the Czech Republic and France, age-standardized 5-year relative or net survival rates increased by less than 5% between 1990 and 2014.[32,34]

Figure S1 also shows the time trends of the overall 5-year relative or net survival rate of lung cancer worldwide.

TABLE 3 Overall and age-standardized 5-year relative/net survival rates of lung cancer in some areas of China during 1992–2018.

Region		Period	Overall rates			Age-standardized rates		
			Total	Male	Female	Total	Male	Female
China[36,53]		2003–2005	-	-	-	16.10	15.40	17.40
		2006–2008	-	-	-	15.80	14.50	18.30
		2009–2011	-	-	-	16.80	15.20	19.90
		2012–2015	-	-	-	19.70	16.80	25.10
Fujian	Total[54]	2012–2014	15.33	13.44	19.94	14.98	13.36	19.33
	Xiamen[55]	2011–2014	11.98	9.44	18.86	11.32	9.00	18.07
		2015–2018	14.17	12.15	18.70	13.83	12.21	18.55
Guangdong	Zhongshan[57,58]	1995–1999	-	-	-	7.10	-	-
		2000–2004	-	-	-	10.40	-	-
		2005–2009	-	-	-	12.80	-	-
		2010–2013	-	-	-	16.80	-	-
	Sihui[8]	2007–2009	12.22	10.55	16.26	-	-	-
Hebei	Cixian[9]	2000–2002	7.23	6.96	7.73	-	-	-
Jiangsu	Qidong[49,60]	1992–1996	-	5.51	6.74	-	-	-
		1997–2000	-	8.87	13.95	-	-	-
		2001–2007	12.73	11.73	15.21	-	-	-
	Jiangyin[59]	2012–2013	27.51	27.90	31.62	-	-	-
Macao[56]		2003–2005	21.00	20.00	23.00			
Shandong	Linqu[49]	1993–1999	-	9.00	9.40	-	-	-
	Zhaoyuan[11]	2009–2013	15.46	14.57	18.01			
Shanghai[12]		2002–2006	20.23	20.27	22.11	-	-	-
Zhejiang	Haining and Jiashan[61]	2003–2006	14.20	14.10	14.60	14.80	-	-
		2007–2010	13.40	11.70	18.10	14.20	-	-
		2011–2014	18.10	15.20	25.00	16.40	-	-
Taiwan[32]		2000–2004	-	-	-	11.60	-	-
		2005–2009	-	-	-	16.00	-	-
		2010–2014	-	-	-	20.60	-	-

Note: - No report or nonavailable in the original articles.

Subgroup analysis of lung cancer survival

Table 2 presents the recent reports of the sex-specific age-standardized 5-year relative or net survival rates in selected regions including China,[36] Japan,[37] Singapore,[38] the USA,[37] and the European countries.[25,29,37,39–48] The 5-year relative or net survival rates were higher in females in many regions except Germany (1990–1994).[40] The dissimilarity of the sex-specific age-standardized 5-year relative or net survival rates in different areas was striking. For example, the highest 5-year survival rates were 27.00% and 43.30% in males and females in Japan (2006–2008),[37] while the poorer 5-year survival rates were 8.10% and 10.90% in the Azores (2005–2009, Portugal), and 8.00% and 9.90% in England (2000–2007, UK), for males and females, respectively.[37,45] In addition, we found that sex differences in lung cancer survival have become more significant, for example in China, as shown in Table S1.

Although few publications provided the survival data by stages, women also had a significant survival advantage over men irrespective of stages (Table S2). Localized lung cancer patients had a better prognosis than other groups. As for the histological types, patients with adenocarcinoma experienced better survival than other types both in men and women. The survival advantage among females was the most prominent in adenocarcinoma in selected countries. The lower 5-year RSRs were observed in the large cell, small cell, and unknown groups except for adenocarcinoma and squamous cell carcinoma (Table S3).

Table S4 compares the age-specific 5-year relative or net survival rates of lung cancer in China,[12,49] India,[17] Japan,[15] Europe,[50] Canada,[51] and the USA[52] between 1992 and 2016. The 5-year survival rates decreased with age. The rates of lung cancer patients aged 15–44, followed by those aged 45–54, were higher than other age groups, while the prognosis of patients aged 75 or older was the poorest. In the age group of 15–44, the rates in the USA (2010–2016) were markedly higher than those in other regions.[52] All available results are only shown because

some reports did not provide age-specific survival data or adopted different age groups.

Lung cancer survival in China

Table 3 shows the detailed figures of population-based overall and age-standardized 5-year relative or net survival rates of lung cancer in China. It mainly includes the survival data of lung cancer from the nation,[36,53] Fujian Province (Xiamen),[54,55] Macao,[56] Shanghai,[12] Taiwan,[32] Guangdong Province (Zhongshan and Sihui),[8,57,58] Hebei Province (Cixian),[9] Jiangsu Province (Qidong and Jiangyin),[59,60] Shandong Province (Linqu and Zhaoyuan),[11,49] and Zhejiang Province (Haining and Jiashan).[61]

As shown in Table 3, the overall 5-year relative or net survival rates of lung cancer gradually increased over time. The age-standardized 5-year relative or net survival rates in women were higher than those in men, especially in China during 2012–2015.[36] The highest overall 5-year overall relative or net survival rates were 27.90% and 31.62% in men and women in Jiangyin (Jiangsu Province) during 2012–2013.[59] Since 2000, the overall 5-year RSR in Cixian (Hebei Province) was the lowest, with only 7.23% in 2000–2002.[9]

DISCUSSION

In the current study, we systematically collected and evaluated the survival data of lung cancer from population-based cancer registration. Major indicators of survival were selected in our study, such as "observed survival rate, relative survival rate, net survival rate, age-standardized relative survival rate, and age-standardized net survival rate".[62] First, we presented the global pattern and trends of lung cancer survival and compared of survival rates of lung cancer by the characteristics of a diagnostic period, region, sex, stage, pathology, and age group. Meanwhile, international comparisons of the age-standardized and the overall survival rates were performed to have a better understanding of the global pattern and trends.[7] Furthermore, we detailed the survival rates of lung cancer in China.

Over the last decades, the improvements in lung cancer survival have probably been a direct consequence of major health reforms and technological advances, including changes in smoking habits, improvements in medical insurance, the promotion of screening, earlier diagnosis, treatment advances, creation of incentives for clinical research, and better patient management than in previous periods.[33,63,64] However, these factors varied greatly in different regions, leading to geographical differences in lung cancer survival. In addition, population-based survival studies may use different methods to collect survival data on cancer cases, which can affect the accuracy and comparability of the results.

Globally, the 5-year relative or net survival rates in Africa (such as Libya) and South America (such as Chile and Brazil) are much poorer than the countries in Europe and North America during the same period. Nevertheless, the 5-year survival rates of lung cancer are also diverse across regions in Europe. It has been consistently reported that poorer survival has been detected in cancer patients from socioeconomically disadvantaged groups than in advantaged groups.[65,66] Socioeconomic status (SES) is a broad term for the social standing or "class" of an individual or group of people. It is often measured based on the highest attained education, income, and occupation. A pooled analysis of 17 021 cases and 20 885 controls found that, after adjusting for smoking, low SES was associated with increased risk of lung cancer by 84% and 54% in men and women.[67] Cancer diagnosis and treatment practices can vary widely between different regions and healthcare systems, which can affect the survival rates of patients. People with high SES groups may have better access to advanced diagnostic tools or treatments, while others may have limited resources or expertise.

The presence of lung cancer screening and early detection by low-dose computed tomography (LDCT) and advanced treatments can decrease mortality rates and improve survival outcomes.[68] The National Lung Screening Trial found screening via LDCT is the most effective way to reduce mortality in lung cancer.[69] Some organized and opportunistic lung cancer screenings have been established in many countries and regions, such as China, the USA, and Europe.[68,70,71] In addition, surgery, radiotherapy, systemic therapy, and the concept of multidisciplinary treatment of lung cancer have improved the outcome of lung cancer patients.[71] Therefore, the survival rate of lung cancer has continuously improved in most countries and regions.

The disparities of sex and age in lung cancer survival were also reviewed in our study. The survival rates of lung cancer in women were higher than in men in most countries and regions, whereas the pattern of squamous cell carcinoma in Japan and South Korea appears contrary. The survival advantage among women was most pronounced in patients diagnosed with adenocarcinoma (Table S4). In 1990, the benefit for lung cancer survival in women over men, irrespective of histological type, was reported in the USA.[72] Since then, several studies of sex differences in lung cancer survival have been reported worldwide.[47,73–75] Previous studies indicated that women have a survival advantage within all histological subsets except squamous cell carcinoma.[47,73,75] Smoking is an independent factor affecting the prognosis of lung cancer, while the disparity in smoking between men and women leads to s disparity in lung survival.[74,76] Second, the different distribution of epidermal growth factor receptor (EGFR) mutations between sexes might have contributed to prognostic advantages in lung cancer survival for females. In addition, unequal clinical management between men and women might offer an alternative explanation. A study published on sex equality in health care suggested that superior health awareness and healthcare utilization in women might contribute to the less

advanced stage at diagnosis, which could directly manifest itself as improved survival.[77] Sex-specific distinctions in the survival rate of lung cancer subtypes require more population-based follow-up studies. For the age at cancer diagnosis, survival was highest among patients in the 35–44 age group, followed by the 45–54 age group, and lowest for the 75 or older age group. This may be partially due to elderly patients being treated less aggressively because of their vulnerability to comorbidities and various chronic diseases. No frameworks have been established in terms of new targeted therapies for older people, which require special treatment considerations.[78]

When comparing survival rates in different countries, periods, populations, and so on, the following points need to be considered. First, it is worth noting estimates used in each original study, such as observed, relative, and net survival rates used in this review. However, descriptive indicators of cancer survival also included cause-specific survival, and so on. The estimation methods and their interpretations may be completely different and cannot be substituted for each other. Next, close attention to additional comorbidities or variables (such as age, sex, ethnicity, etc.) used in survival estimation in the study is required. For example, as in this review, some studies excluded patients aged under 15[14,22,25,32,39,40,44,47,50,51,73,79–84] or 18.[20] Furthermore, a large number of studies excluded DCO (death certificate only) cases or autopsy cases,[10,17,25,26,30,32,41,46,47,49,51,53,56–58,60,61,73,74,79–81,85–88] which would affect outcomes. These might be cautious or particular needs when comparing cancer survival rates between different regions or populations.

In conclusion, in the present study, we summarized 1–5 years observed, relative, and net survival rates of lung cancer worldwide, markedly distinct between different countries or periods in the same regions. The implications of this data are that the region, period, sex, and age might affect the survival rate of lung cancer patients. Therefore, the highest priority to improve survival globally in lung cancer prevention remains the hope that all countries will advance initiatives to reduce smoking, encourage screening, conduct more translational research and application on new technological treatments, and so on.

AUTHOR CONTRIBUTIONS

Yong-Bing Xiang designed the research and obtained funding. Jing-Hao Bi and Yong-Bing Xiang conducted the study. Jing-Hao Bi and Jia-Yi Tuo collected publications and abstract data. Jing-Hao Bi and Yong-Bing Xiang prepared and wrote the first draft of the manuscript. Jing-Hao Bi, Jia-Yi Tuo, Yu-Xuan Xiao, Dan-Dan Tang, Xiao-Hui Zhou, Yu-Fei Jiang, Xiao-Wei Ji, Yu-Ting Tan, Hui-Yun Yuan, and Yong-Bing Xiang reviewed and approved the final version of the manuscript; and Yong-Bing Xiang has primary responsibility for final content.

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CONFLICT OF INTEREST STATEMENT

All authors declare there are no conflicts of interest.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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