Original Article

Comparison of cancer incidence and mortality in three GDP per capita levels in China, 2013

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Abstract

Objective: In this research, the patterns of cancer incidence and mortality in areas with different gross domestic product per capita (GDPPC) levels in China were explored, using data from population-based cancer registries in 2013, collected by the National Central Cancer Registry (NCCR).

Methods: Data from 255 cancer registries were qualified and included in this analysis. Based on the GDPPC data of 2014, cities/counties were divided into 3 levels: high-, middle- and low-GDPPC areas, with 40,000 and 80,000 RMB per year as cut points. We calculated cancer incidences and mortalities in these three levels, stratified by gender and age group. The national population of the Fifth Census in 2000 and Segi's population were applied for age-standardized rates.

Results: The crude incidence and mortality rates as well as age-standardized incidence rate (ASIR) showed positive associations with GDPPC level. The age-standardized mortality rate (ASMR) nevertheless showed a negative association with GDPPC level. The ASMR in high-, middle- and low-GDPPC areas was 103.12/100,000, 112.49/100,000 and 117.43/100,000, respectively. Lung cancer was by far the most common cancer in all three GDPPC levels. It was also the leading cause of cancer death, regardless of gender and GDPPC level. Negative associations with GDPPC level were found for the ASIRs of lung, stomach, esophageal and liver cancer, whereas colorectal and breast cancer showed positive associations. Except for breast cancer, the ASMRs of the other five cancers were always higher in middle- and low-GDPPC areas than in high-GDPPC areas.

Conclusions: The economic development is one of the main factors of the heavy cancer burden on Chinese population. It would be reasonable to implement cancer control strategies referring to the local GDPPC level.

Keywords: Cancer; incidence; mortality; epidemiology; GDP per capita; China

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Introduction

Cancer is a major public health problem in China and has been the leading cause of death since 2010 (1). The findings of International Agency for Research on Cancer (IARC) showed that in 2012, approximately 21.8% of the world's new cases and 26.9% of the world's deaths occurred in China (2), indicating therefore a heavy cancer burden in China (3). This burden could be even heavier. According to our recent researches, there were more than 10,000 new cancer cases diagnosed and about 6,100 cancer deaths every day in 2013 (4), whereas the numbers were predicted to increase to 12,000 and 7,500 respectively in 2015 (5). A rising temporal trend could also be found in incidence and mortality rates (6-9). The crude incidence and mortality rates of all cancers were 235.23/100,000 and 148.81/100,000 in 2010 (6), whereas they were 284.55/100,000 and 176.28/100,000 respectively in 2013 (9).

These rising trends of cancer burden can be attributed to the aging and growing population as well as the rapid economic development. Of all the influential factors on cancer epidemiology, economic factors, especially the economic development, have always played an important role. One of the most widely used measures for comparing economic development is gross domestic product per capita (GDPPC). On the international scale, the relation between cancer disparity and the economic development has already been well studied. Prostate cancer, which had the highest age-standardized incidence rate (ASIR) in all cancer types for men in more developed areas, was also the second most common cancer for men worldwide. It, together with breast cancer, the most common cancer and the leading cause of cancer death for women worldwide (10), was the two most studied cancer types. That the incidence rate of prostate cancer was greater in countries with higher GDPPC or more developed areas had been pointed out by many researchers (10-13). The mortality rate was comparatively low in these countries, yet still higher than less developed regions (10,12,13). As for breast cancer, wealthier countries tended to have higher incidence rate (14,15), with the ASIR in more developed countries two times as high as in less developed countries (10). In China, positive correlation between breast cancer mortality rate and GDPPC was found (16). Researches based on GLOBOCAN data showed that liver cancer incidence and mortality was negatively correlated with GDPPC (17), and cervical cancer incidence and mortality rates in developing countries were two-fold and three-fold higher respectively than women in developed countries (18). A study on women in the USA showed agreeable relation between poverty and cervical cancer incidence and mortality rates (19).

Along with the economic development, the distribution of risk factors for cancer in Chinese population changes. The influence of economic variations on cancer patterns in China has not been as well studied as that on the international scale. Furthermore, detailed research of this influence on especially all cancer types in China is yet to be published. In this article, using data on GDPPC, we provide an in-depth overview of cancer incidence and mortality in China in 2013, including a comparison of cancer patterns in three GDPPC levels.

Materials and methods

Data sources

Population-based cancer registry data of 2013 were used in this study, including 255 qualified cancer registries which are distributed in 31 provinces, covering 16.65% of the national population at the end of 2013 (4,9). GDPPC data were obtained from the publication of National Bureau of Statistics and Ministry of Public Security (20,21). The geographical distribution of these 255 cities/counties is shown in *Figure 1* stratified by GDPPC level.

Statistical analysis

All the 255 qualified registries were classified into high-, middle- and low-GDPPC areas with 40,000 RMB per year and 80,000 RMB per year as the cut points. Cancer incidence and mortality were calculated by gender and age group in different areas. The numbers of new cases, incidence rates and mortality rates of the top 10 cancers were reported in each GDPPC level. We used the Chinese population in 2000 and World Segi's population to calculate the age-standardized rates. The cumulative risk of developing or dying from cancer before 75 years old (in the absence of competing causes of death) was calculated and presented as percentage. All statistical analysis was conducted by SAS software (SAS Institute Inc., Cary, NC, USA).

Results

Brief description of GDPPC

The values of GDPPC were not normally distributed. In all 255 cities/counties in 2014, the median of GDPPC (RMB per year) was 42,485, while the maximum and minimum were 183,480 and 7,413 respectively. The 25th percentile was 28,773 and the 75th percentile was 66,777. The 255 registries (88 in cities and 167 in counties) were classified into 43 high-GDPPC areas (28 cities and 15 counties), 95 middle-GDPPC areas (29 cities and 66 counties) and 117 low-GDPPC areas (31 cities and 86 counties). The median value of GDPPC in high-, middle- and low-GDPPC areas were 98,305, 53,771 and 27,580, respectively.

Incidence of overall cancers

The result of cancer incidences in three GDPPC levels is displayed in *Table 1*. In 2013, about 644,500 new cases in

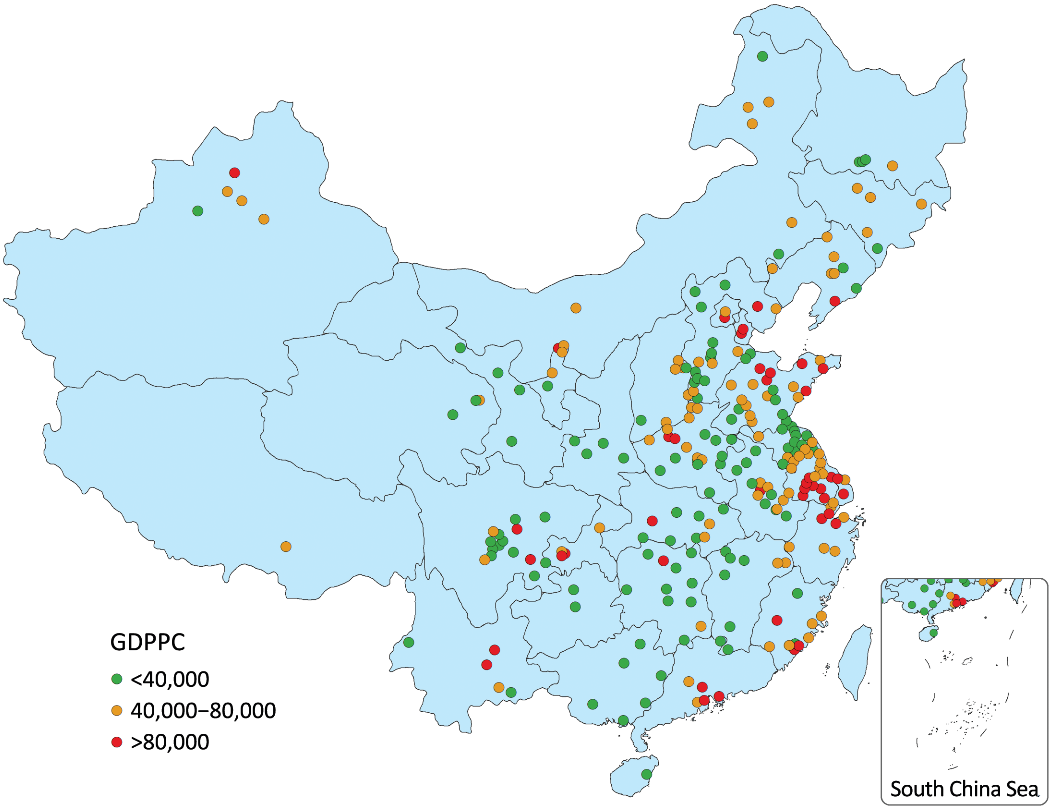

Figure 1 Map of distribution of 255 qualified cancer registries and corresponding gross domestic product per capita (GDPPC) levels in China, 2013.

the 255 cancer registries were diagnosed as cancer. The crude incidence rate in middle-GDPPC areas (284.09/100,000) was close to that in all areas (284.55/100,000), with high-GDPPC areas having a higher rate (327.06/100,000) and low-GDPPC areas having a lower rate (244.39/100,000). A similar association could be found in

Table 1 Cancer incidence by GDPPC level in China, 2013

Areas	Gender	Cases (thousand)	Crude incidence ($1/10^5$)	ASIRC ($1/10^5$)*	ASIRW ($1/10^5$)**	Cumulative rate 0–74 (%)
All areas	Both	644.5	284.55	190.10	186.24	21.60
	Male	360.7	314.06	213.09	211.56	25.10
	Female	283.8	254.19	169.54	163.30	18.22
High-GDPPC areas	Both	237.8	327.06	197.58	192.23	21.88
	Male	128.0	350.99	210.53	208.13	24.31
	Female	109.9	302.99	186.83	178.53	19.56
Middle-GDPPC areas	Both	220.7	284.09	187.53	184.13	21.54
	Male	124.5	316.45	213.56	212.54	25.40
	Female	96.2	250.90	164.45	158.67	17.87
Low-GDPPC areas	Both	186.0	244.39	185.20	182.46	21.47
	Male	108.2	277.17	215.75	214.77	25.77
	Female	77.7	209.81	156.49	151.87	17.18

GDPPC, gross domestic product per capita; *, age-standardized incidence rate (China population, 2000); **, age-standardized incidence rate (Segi's population).

ASIR. Sex-specific crude incidence rates showed a positive association with GDPPC levels like the whole population in each GDPPC level did, as well as the ASIR for females. However, after adjusted by age, the incidence rate for males contradicted the association above, with the rates of 210.53/100,000, 213.56/100,000 and 215.75/100,000 in the high-, middle- and low-GDPPC areas respectively. Furthermore, the ASIR for males in each GDPPC level was higher than that for females, although the difference was not substantial.

Mortality of overall cancers

The result of cancer mortalities in three GDPPC levels is displayed in *Table 2*. In 2013, there were about 399,300 cancer death cases in the 255 cancer registries. The crude mortality rate in middle-GDPPC areas (178.83/100,000) was close to that in all areas (176.28/100,000), with high-GDPPC areas having a higher rate (191.29/100,000) and low-GDPPC areas having a lower rate (159.34/100,000). A similar association could be found in sex-specific mortality rates. After adjusted by age, nevertheless, the mortality rates of not only the whole population, but also each gender, contradicted the association above and showed negative associations with GDPPC levels. The age-standardized mortality rate (ASMR) in high-, middle- and low-GDPPC areas were 103.12/100,000, 112.49/100,000 and 117.43/100,000 respectively. The ASMR for males in each level was higher than that for females, and the difference was substantial. Mostly the rate for males was two times as high as the rate for their female counterparts.

Age-specific incidence and mortality rates

The age-specific incidence rate stayed relatively low before 40 years old, while increased dramatically since then and peaked at the age of 80–84 years old. This pattern of age-specific incidence rate was similar in each GDPPC level (*Figure 2*). In high-GDPPC areas, women between 10 and 54 years old had a higher incidence rate compared with their male counterparts, while in middle- and low-GDPPC areas, 20 to 49 years old. To the age groups not mentioned above, the incidence rates for males were always higher than that for females.

The age-specific mortality rate stayed relatively low before 50 years old, while increased dramatically since then and peaked at 80–84 or more than 85 years old. This pattern of age-specific mortality rate was similar in each GDPPC level (*Figure 3*). To almost all the age groups in every GDPPC level, the mortality rates for males were always higher than that for females.

Top ten leading cancer types for new cancer cases

The top 10 cancer incidence rates in three GDPPC levels are displayed in *Table 3*. In 2013, about 46,200, 45,400 and 39,100 people were diagnosed as lung cancer in high-, middle- and low-GDPPC areas respectively, making lung cancer the most common cancer in every GDPPC level. Colorectal cancer, stomach cancer, breast cancer and liver

Table 2 Cancer mortality by GDPPC level in China, 2013

Areas	Gender	Cases (thousand)	Crude mortality ($1/10^5$)	ASMRC ($1/10^5$)*	ASMRW ($1/10^5$)**	Cumulative rate 0–74 (%)
All areas	Both	399.3	176.28	110.91	109.92	12.43
	Male	251.6	219.03	144.60	143.88	16.41
	Female	147.7	132.30	79.20	78.00	8.53
High-GDPPC areas	Both	139.1	191.29	103.12	102.31	11.25
	Male	85.9	235.61	132.84	132.33	14.71
	Female	53.2	146.72	75.27	74.22	7.86
Middle-GDPPC areas	Both	138.9	178.83	112.49	111.44	12.67
	Male	88.2	224.17	148.48	147.75	16.90
	Female	50.7	132.32	79.04	77.77	8.58
Low-GDPPC areas	Both	121.2	159.34	117.43	116.34	13.55
	Male	77.5	198.39	153.00	152.09	17.80
	Female	43.8	118.16	83.34	82.06	9.29

GDPPC, gross domestic product per capita; *, age-standardized mortality rate (China population, 2000); **, age-standardized mortality rate (Segi's population).

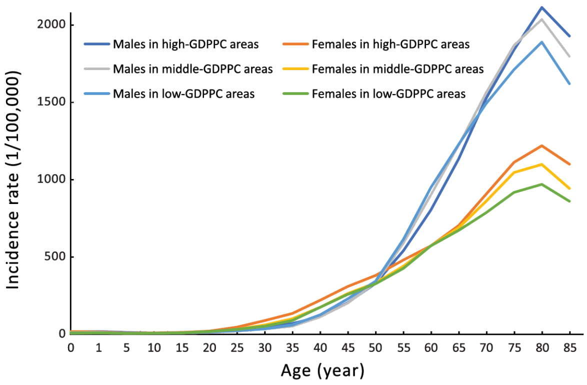

Figure 2 Age-specific incidence rates of overall cancers, 2013.

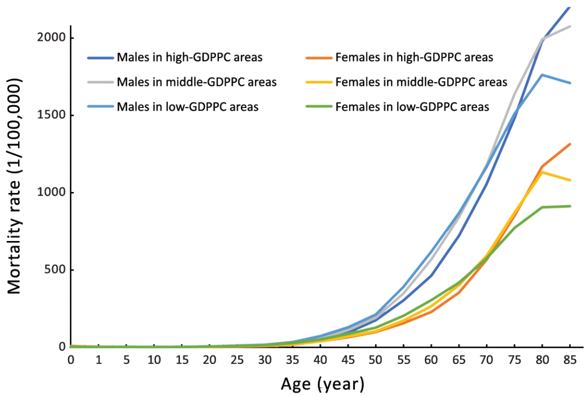

Figure 3 Age-specific mortality rates of overall cancers, 2013.

cancer were the other cancer types with leading incidence rate in high-GDPPC areas, while in middle- and low-GDPPC areas, stomach, liver, esophageal and colorectal cancers, with the same ranking. Lung cancer showed a negative association with GDPPC level. A similar association of ASIR could also be found in stomach, liver and esophageal cancers, with high-GDPPC areas having a lower rate and low-GDPPC areas having a higher rate. Colorectal cancer, nevertheless, showed a positive association, with high-GDPPC areas having the highest ASIR. Lung, stomach, colorectum, liver and esophagus were the top 5 cancer sites for males in each GDPPC level, only with different rankings. As for females, breast cancer had the top incidence rate in high- and middle-GDPPC areas but dropped to the second place in low-GDPPC areas. The ASIR of breast cancer and colorectal cancer showed a positive association with GDPPC level. Similar associations like their male counterparts could be found in stomach cancer, liver cancer and esophageal cancer.

Top ten leading cancer types for deaths

The top 10 cancer mortality rates in three GDPPC levels are displayed in *Table 4*. In 2013, about 38,600, 36,500 and 31,200 people died of lung cancer in high-, middle- and low-GDPPC areas respectively, making lung cancer the leading cause of death, regardless of gender or GDPPC level. Stomach cancer, liver cancer, colorectal cancer and esophageal cancer were the other top causes of cancer death both in the whole population and in males in each GDPPC level, only with different rankings. As for females, the top five leading causes of cancer death were lung, colorectal, stomach, liver and breast cancers in high-GDPPC areas, lung, stomach, liver, esophageal and colorectal cancers in middle-GDPPC areas, and lung, stomach, liver, esophageal and breast cancers in low-GDPPC areas. The ASMR of lung cancer was higher in middle- and low-GDPPC areas than in high-GDPPC areas. A similar association could also be found in stomach and liver cancers. Colorectal cancer, however, showed a positive association, with high-GDPPC areas having the highest ASMR.

Discussion

This study is, to our knowledge, the first in China to show the variation of all-sites cancer incidence and mortality in different GDPPC levels. Economic factors, of which GDPPC is a commonly quoted indicator, have always played an important role in cancer epidemiology. Internationally, there are already many articles on the difference of the incidence and mortality of a certain cancer type in countries or states with different economic developments, when it comes to all cancer types, nevertheless, the articles are not as many. With regard to China, there are only a handful of articles on the association between economic factors and the pattern of a certain cancer in certain cities (16,22).

High-GDPPC areas had both the highest crude incidence and mortality rates, followed by middle- and low-GDPPC areas. Agreeable results could be found in a research based on GLOBOCAN 2012 showing that all-sites cancer incidence rate in Western Europe was more than twice as high as that in Eastern Africa, whereas mortality rates were 8% to 15% higher in more developed countries (10). Colorectal cancer and breast cancer were two of the major contributors to the high incidence rate in high-GDPPC areas as *Table 3* showed. This echoed the

Table 3 Top 10 cancer incidence by GDPPC level in China, 2013

Rank	Gender	All areas				High-GDPPC areas				Middle-GDPPC areas				Low-GDPPC areas			
		Site	Cases (thousand)	Incidence ($1/10^5$)	ASR* ($1/10^5$)	Site	Cases (thousand)	Incidence ($1/10^5$)	ASR* ($1/10^5$)	Site	Cases (thousand)	Incidence ($1/10^5$)	ASR* ($1/10^5$)	Site	Cases (thousand)	Incidence ($1/10^5$)	ASR* ($1/10^5$)
1		Lung	130.7	57.70	36.23	Lung	46.2	63.47	34.66	Lung	45.4	58.43	36.58	Lung	39.1	51.44	37.61
2		Stomach	76.2	33.66	21.52	Colorectum	26.6	36.56	20.27	Stomach	28.1	36.16	23.00	Stomach	24.9	32.66	24.13
3		Liver	63.8	28.17	18.36	Stomach	23.3	32.04	17.93	Liver	22.1	28.41	18.25	Liver	22.9	30.13	22.41
4		Colorectum	60.9	26.90	17.06	Breast	19.2	53.04	33.18	Esophagus	21.6	27.78	17.59	Esophagus	18.8	24.74	18.22
5		Esophagus	50.2	22.16	14.09	Liver	18.8	25.85	15.01	Colorectum	19.5	25.09	15.90	Colorectum	14.9	19.52	14.38
6	Both	Breast	46.6	41.73	27.96	Thyroid	13.7	18.78	13.13	Breast	15.8	41.14	26.88	Breast	11.6	31.28	23.13
7		Thyroid	23.0	10.16	7.37	Esophagus	9.8	13.45	7.41	Thyroid	6.4	8.20	5.84	Cervix	5.7	15.40	11.39
8		Cervix	16.9	15.17	10.31	Pancreas	7.1	9.70	5.16	Cervix	6.0	15.75	10.35	Brain, CNS	4.9	6.40	5.11
9		Brain, CNS	16.6	7.31	5.32	Brain, CNS	6.4	8.79	5.94	Brain, CNS	5.3	6.83	4.92	Leukemia	3.9	5.07	4.57
10		Pancreas	15.7	6.95	4.31	Lymphoma	6.2	8.59	5.29	Pancreas	5.2	6.66	4.14	Pancreas	3.5	4.63	3.40
1		Lung	87.1	75.81	49.90	Lung	30.0	82.36	46.75	Lung	30.2	76.73	50.58	Lung	26.9	68.77	52.79
2		Stomach	53.3	46.43	30.94	Stomach	16.0	43.89	25.39	Stomach	19.8	50.45	33.58	Stomach	17.5	44.74	34.49
3		Liver	46.8	40.72	27.54	Colorectum	15.1	41.40	23.84	Liver	16.2	41.22	27.51	Liver	16.9	43.15	33.17
4		Esophagus	35.4	30.83	20.55	Liver	13.7	37.57	22.66	Esophagus	14.9	37.84	25.23	Esophagus	13.1	33.45	25.77
5		Colorectum	34.8	30.30	20.05	Esophagus	7.5	20.47	11.85	Colorectum	11.1	28.20	18.62	Colorectum	8.6	22.05	16.97
6	Male	Prostate	10.8	9.40	5.81	Prostate	6.1	16.82	8.88	Bladder	3.4	8.65	5.61	Brain, CNS	2.5	6.41	5.22
7		Bladder	10.4	9.01	5.81	Bladder	4.6	12.73	7.05	Prostate	3.0	7.54	4.71	Bladder	2.3	5.92	4.47
8		Pancreas	8.9	7.77	5.09	Pancreas	3.9	10.81	6.10	Pancreas	2.9	7.49	4.90	Leukemia	2.2	5.66	5.17
9		Lymphoma	8.1	7.08	5.00	Kidney	3.8	10.33	6.32	Brain, CNS	2.6	6.58	4.91	Pancreas	2.0	5.21	4.01
10		Brain, CNS	8.0	6.96	5.23	Lymphoma	3.6	9.79	6.20	Lymphoma	2.6	6.50	4.59	Lymphoma	2.0	5.14	4.12
1		Breast	46.6	41.73	27.96	Breast	19.2	53.04	33.18	Breast	15.8	41.14	26.88	Lung	12.3	33.16	22.94
2		Lung	43.6	39.07	23.26	Lung	16.1	44.47	23.24	Lung	15.2	39.66	23.50	Breast	11.6	31.28	23.13
3		Colorectum	26.1	23.41	14.22	Colorectum	11.5	31.69	16.87	Colorectum	8.4	21.90	13.35	Stomach	7.4	19.93	13.94
4		Stomach	22.9	20.53	12.46	Thyroid	10.2	28.25	19.66	Stomach	8.2	21.50	12.95	Colorectum	6.2	16.86	11.88
5		Thyroid	17.4	15.60	11.24	Stomach	7.3	20.12	10.82	Esophagus	6.7	17.47	10.27	Liver	6.1	16.40	11.57
6	Female	Liver	17.0	15.25	9.28	Cervix	5.2	14.31	9.43	Cervix	6.0	15.75	10.35	Esophagus	5.8	15.57	10.80
7		Cervix	16.9	15.17	10.31	Liver	5.1	14.06	7.48	Liver	5.9	15.27	9.17	Cervix	5.7	15.40	11.39
8		Esophagus	14.8	13.24	7.84	Uterus	4.2	11.67	7.17	Thyroid	4.9	12.82	9.08	Uterus	3.1	8.31	6.16
9		Uterus	10.6	9.50	6.32	Brain, CNS	3.5	9.63	6.22	Uterus	3.3	8.60	5.58	Brain, CNS	2.4	6.38	5.00
10		Brain, CNS	8.6	7.68	5.41	Ovary	3.3	9.05	5.87	Ovary	2.9	7.64	5.16	Ovary	2.3	6.22	4.77

GDPPC, gross domestic product per capita; *, age-standardized incidence rate (China population, 2000); CNS, central nervous system.

Table 4 Top 10 cancer mortality by GDPPC level in China, 2013

Rank	Gender	All areas				High-GDPPC areas				Middle-GDPPC areas				Low-GDPPC areas			
		Site	Cases (thousand)	Mortality ($1/10^5$)	ASR* ($1/10^5$)	Site	Cases (thousand)	Mortality ($1/10^5$)	ASR* ($1/10^5$)	Site	Cases (thousand)	Mortality ($1/10^5$)	ASR* ($1/10^5$)	Site	Cases (thousand)	Mortality ($1/10^5$)	ASR* ($1/10^5$)
1	Both	Lung	106.3	46.92	28.59	Lung	38.6	53.04	27.63	Lung	36.5	46.98	28.71	Lung	31.2	41.00	29.45
2		Liver	56.0	24.70	15.86	Stomach	16.9	23.27	12.13	Stomach	19.9	25.66	15.75	Liver	19.6	25.73	19.00
3		Stomach	54.6	24.11	14.77	Liver	16.6	22.80	12.85	Liver	19.8	25.48	16.16	Stomach	17.8	23.34	16.83
4		Esophagus	37.7	16.64	10.18	Colorectum	13.0	17.92	8.99	Esophagus	16.4	21.12	12.90	Esophagus	13.5	17.70	12.68
5		Colorectum	29.5	13.03	7.78	Esophagus	7.8	10.75	5.64	Colorectum	9.0	11.64	7.04	Colorectum	7.4	9.77	6.95
6		Pancreas	14.2	6.28	3.83	Pancreas	6.7	9.14	4.76	Pancreas	4.6	5.92	3.63	Breast	3.3	8.89	6.46
7		Breast	11.3	10.08	6.35	Breast	4.4	12.00	6.59	Breast	3.6	9.40	5.86	Brain, CNS	3.2	4.16	3.28
8		Brain, CNS	9.7	4.29	3.05	Leukemia	3.6	4.91	3.36	Brain, CNS	3.3	4.25	3.00	Pancreas	3.0	3.90	2.83
9		Leukemia	9.1	4.04	3.13	Lymphoma	3.4	4.67	2.59	Leukemia	2.9	3.69	2.83	Leukemia	2.7	3.55	3.12
10		Lymphoma	7.7	3.40	2.20	Brain, CNS	3.2	4.46	2.93	Lymphoma	2.4	3.09	2.01	Lymphoma	1.9	2.51	1.91
1	Male	Lung	72.2	62.85	40.60	Lung	25.9	70.98	39.03	Lung	24.7	62.80	40.85	Lung	21.6	55.32	42.00
2		Liver	41.1	35.82	24.02	Liver	12.1	33.23	19.65	Liver	14.5	36.96	24.51	Liver	14.5	37.08	28.45
3		Stomach	37.7	32.86	21.34	Stomach	11.5	31.64	17.39	Stomach	13.9	35.25	23.05	Stomach	12.3	31.59	24.07
4		Esophagus	26.5	23.03	15.02	Colorectum	7.3	20.06	10.79	Esophagus	11.3	28.83	18.87	Esophagus	9.3	23.81	18.16
5		Colorectum	16.8	14.62	9.35	Esophagus	5.8	15.94	8.94	Colorectum	5.2	13.20	8.54	Colorectum	4.3	10.97	8.31
6		Pancreas	8.0	6.99	4.54	Pancreas	3.7	10.02	5.57	Pancreas	2.6	6.67	4.34	Brain, CNS	1.8	4.53	3.69
7		Brain, CNS	5.4	4.69	3.46	Prostate	2.5	6.73	3.21	Brain, CNS	1.9	4.73	3.46	Pancreas	1.7	4.48	3.44
8		Leukemia	5.3	4.58	3.61	Leukemia	2.0	5.58	3.84	Leukemia	1.7	4.20	3.28	Leukemia	1.6	4.03	3.60
9		Lymphoma	4.6	4.03	2.73	Lymphoma	2.0	5.45	3.16	Lymphoma	1.5	3.72	2.54	Lymphoma	1.2	3.03	2.39
10		Prostate	4.6	4.02	2.42	Brain, CNS	1.8	4.81	3.31	Bladder	1.4	3.43	2.18	Bladder	1.0	2.66	1.97
1	Female	Lung	34.1	30.52	17.34	Lung	12.7	35.01	16.96	Lung	11.8	30.74	17.51	Lung	9.6	25.91	17.46
2		Stomach	16.9	15.11	8.59	Colorectum	5.7	15.76	7.34	Stomach	6.1	15.83	8.96	Stomach	5.4	14.64	9.84
3		Liver	14.8	13.27	7.83	Stomach	5.4	14.84	7.25	Liver	5.2	13.69	8.05	Liver	5.1	13.76	9.52
4		Colorectum	12.7	11.39	6.33	Liver	4.5	12.32	6.20	Esophagus	5.1	13.20	7.28	Esophagus	4.2	11.26	7.40
5		Breast	11.3	10.08	6.35	Breast	4.4	12.00	6.59	Colorectum	3.9	10.05	5.68	Breast	3.3	8.89	6.46
6		Esophagus	11.2	10.06	5.55	Pancreas	3.0	8.26	3.96	Breast	3.6	9.40	5.86	Colorectum	3.1	8.49	5.68
7		Pancreas	6.2	5.55	3.13	Esophagus	2.0	5.52	2.48	Pancreas	2.0	5.16	2.96	Cervix	1.8	4.76	3.48
8		Cervix	4.6	4.12	2.65	Gallbladder	1.7	4.74	2.20	Cervix	1.6	4.30	2.66	Brain, CNS	1.4	3.76	2.87
9		Brain, CNS	4.3	3.87	2.64	Ovary	1.6	4.32	2.45	Brain, CNS	1.4	3.76	2.54	Pancreas	1.2	3.30	2.24
10		Leukemia	3.9	3.48	2.67	Leukemia	1.5	4.24	2.90	Leukemia	1.2	3.17	2.40	Uterus	1.1	3.09	2.22

GDPPC, gross domestic product per capita; *, age-standardized mortality rate (China population, 2000); CNS, central nervous system.

result of our recent research on the relation between cancer incidence and mortality with urbanization level in China (9). In 2013, breast cancer accounted for 17.07% of all new cancer cases in Chinese females (4). A study in Europe showed that incidence rates of breast cancer were much higher in developed Western European countries like France and the UK than in developing Eastern European countries like Ukraine and Moldova (23). Therefore, it was reasonable to find a high incidence rate of breast cancer in high-GDPPC areas in China. This variation in incidence may reflect the differences in the availability of early detection and risk factors in three GDPPC levels. Reproductive factors and the use of oral contraceptives are the main risk factors of breast cancer (24), and they vary significantly across China owing to the contradiction between traditional concept and westernized concept alongside with the economic development. Colorectal cancer is also well-known for its relation with a westernized lifestyle, obesity and other factors that are easy to find in an affluent society (25). The high incidence of breast cancer and colorectal cancer in high-GDPPC areas agreed with the researches in developed countries (14,15,26,27), which further proved our result.

The ASIRs showed similar associations with GDPPC levels like crude rates. The association between ASMR and GDPPC level nevertheless was exactly opposite to that of crude rate, with high-GDPPC areas having the lowest ASMR and low-GDPPC areas having the highest. This disparity can be attributed to the younger age structure, immaturity of the tobacco epidemic and competing causes of death in less developed areas with lower GDPPC (10), while the growing and aging population in high-GDPPC areas contributed to the overall high crude mortality rate (5,9), since the incidence and mortality rates for most cancers increase rapidly with age. In terms of the low ASMR in high-GDPPC areas, a study in major developed countries pointed out that countries with the greatest proportional increase in GDP expenditure on health had the biggest reduction in cancer deaths and vice versa (28). Affluent cities/counties are more likely to spend a larger proportion of GDP on health, which may lead to easier access to better medical sources for the citizens, while people in poor cities/counties cannot have. As a result, a better prognosis and a lower ASMR were achieved.

Lung cancer, accounting for about 23.86% of all new cancer cases in Chinese males in 2013 (4), was the most common cancer in all GDPPC levels and both genders except females in high- and middle-GDPPC areas, where it was replaced by breast cancer. Same ranking of it for females in differently developed countries was reported by other researchers (10). Lung cancer was also the leading cause of cancer death throughout the population covered by this research, regardless of gender or GDPPC level. The burden of lung cancer was similar in Korea, since it was the third common cancer in incidence and the most common cancer resulting in death (29). Despite the low prevalence of smoking, incidence of lung cancer in Chinese women was higher than their counterparts in Europe (10). This may be owing to the indoor air pollution from unventilated coal-fueled stoves and cooking fumes (30), especially in less developed areas with lower GDPPC. In 2012, lung cancer was the most fatal cancer for males in all European countries except Sweden, and was one of the top three fatal cancers for females in most European countries (23). Tobacco smoking is an undisputed carcinogen of lung cancer. Recent study also found its relation with cancers in other organs including esophagus, pancreas, stomach, liver, kidney and even uterine cervix (31). Although the burden of lung cancer is heavy worldwide, it is one of the most preventable cancers. A study carried out in the USA showed that tobacco control was effective and could reduce significantly the number of lung cancer death (32). Therefore, it is urgent to continue the implemented tobacco control policy in China.

Stomach cancer, esophageal cancer and liver cancer had higher incidence and mortality rates in middle and low-GDPPC areas than in high-GDPPC areas. On the global scale, many researches agreed with our finding, pointing out that countries with higher levels of GDPPC reported low incidence and mortality rates of these cancers (17,26). Prevalence of stomach and liver cancers has always been high in East Asian countries compared with not only other continents but also other Asian countries (17,33). Furthermore, the age-standardized five-year net survival from liver cancer was generally low both in the developed and developing world (34). And the mortality rate of liver cancer ranked higher than its incidence rate in our study, regardless of GDPPC level. As for esophageal cancer, it is even more popular in China because it occurred in China at a rate of 20 to 30 times higher than in the USA and far above average level in the world (35). However, significantly declining trends in incidence and mortality were observed for these three cancers, to which the control of hepatitis B virus (HBV) and hepatitis C virus (HCV) for liver cancer and *Helicobacter pylori* for stomach cancer may contribute (5).

Understanding cancer pattern is important in the monitoring of cancer control and in the evaluation of changes in cancer risks and the effectiveness of health care. Therefore, enlarging cancer registration areas and enhancing cancer registration qualification should be the priority. With the continuous economic development, the burden of cancer in China will keep rising and differentiating in the near future. As a consequence, targeted prevention, early detection and treatment programs should be carried out accordingly.

Conclusions

The crude incidence and mortality rates showed positive associations with GDPPC levels, with high-GDPPC areas having the highest crude rates followed by middle- and low-GDPPC areas. The ASIR was highest in high-GDPPC areas and lowest in low-GDPPC areas, whereas the ASMR was highest in low-GDPPC areas and lowest in high-GDPPC areas. Other than lung cancer, which was the most common cancer as well as the leading cause of cancer death in all areas, the incidence and mortality patterns for the major cancers varied in each GDPPC level. Middle- and low-GDPPC areas had higher ASIR and ASMR for stomach, liver and esophageal cancers than high-GDPPC areas. As for colorectal cancer, the ASIR and ASMR were positively associated with GDPPC levels. Therefore, economic factors can influence the epidemiology of cancers and the economic development is one of the main factors of the heavy cancer burden on Chinese population. It would be reasonable to implement cancer control strategies referring to the local GDPPC level.

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Footnote

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