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Identifying the patterns of non-communicable diseases (NCDs) in developed eastern coastal China: inspiration for NCDs prevention and cure in developing regions

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Identifying the patterns of non-communicable diseases (NCDs) in developed eastern coastal China: inspiration for NCDs prevention and cure in developing regions

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ABSTRACT

Objectives: Few studies have examined the spectrum and trends of inpatients' non-communicable diseases (NCDs) in eastern coastal China, which is transforming from an industrial economy to a service-oriented economy and is the most economically developed region in the country. The aim of this study was to dynamically elucidate the spectrum and characteristics of the severe NCDs in eastern coastal China by analysing patients' longitudinal electronic health records.

Setting: To monitor the spectrum of NCDs dynamically, we extracted data of electronic health records from 12 general tertiary hospitals in Shanghai from 2003 to 2014. The rankings of and trends in the proportions of different NCDs presented by inpatients in different gender and age groups were calculated and analysed.

Participants: We obtained a total sample of 1,907,484 inpatients with NCDs from 2003 to 2014, among whom 50.05% were male and most were aged 50 years or older (81.53%).

Results: From 2003 to 2014, the prevalence of diabetes, blood and endocrine diseases among inpatients increased approximately four-fold (from 1.36% to 6.74%, P<0.001) in eastern coastal China. Compared with men, women displayed relatively higher and more stable proportions of digestive diseases (P=0.394) and neurological disorders (P=0.173) over time. Moreover, the proportion of 21-50-year-old inpatients with diabetes or blood diseases and endocrine diseases skyrocketed over this period (P<0.001).

Conclusions: The burden of inpatients' NCDs increased rapidly, particularly among women and younger people. The NCD spectrum observed in eastern coastal China is a good source of evidence for developing prevention guides for regions experiencing transition.

Keywords: Non-communicable diseases; Electronic Health Record; Eastern coastal China; Health policy

Strength and limitations

- Previous research in China has primarily focused on the nationwide spectrum, or has studied the major patterns of NCDs in specific regional areas cross-sectionally.
- This study aimed at exploring the epidemiological patterns of NCDs in eastern

coastal China across 12 consecutive years.

- It is a good source of evidence for similar developing regions who are or will go through transformation to develop NCDs prevention guides or policies.

INTRODUCTION

In recent years, an epidemiological shift in morbidity and mortality from infectious diseases and malnutrition to non-communicable diseases (NCDs) has occurred in many countries, including China[1-3]. NCDs have become the major causes of death in China and globally. According to the 2012 WHO data repository, 87% of deaths in China were associated with NCDs[1]. The Global Burden of Disease Study (GBD) revealed that of the 8.3 million deaths in China in 2010, 7.0 million resulted from NCDs[3]. Stroke, ischaemic heart disease, cancers, and chronic obstructive pulmonary disease are now the leading causes of premature death in China, and the burden of these diseases is substantial[4].

Previous research on the epidemiological patterns of NCDs in China has primarily focused on the entire nation or cross-sectional studies of specific regions [1-6]. However, both the WHO and the GBD have acknowledged that a national analysis for a country as large and diverse as China can mask substantial variations in key outcomes[3,5]. Also, few have examined the inpatients' NCD spectrum, which can reflect the more severe condition of NCDs. In this study, we conducted a longitudinal study of NCD patterns in five provinces in eastern coastal China: Shandong, Jiangsu, Zhejiang, Shanghai and Guangdong provinces. Geographically speaking, these provinces are located in the three most productive and dynamic regions of China: the

Bohai Sea, the Yangtze River Delta and the Pearl River Delta. The gross regional domestic product in these five provinces accounts for approximately half that of the 32 provinces/autonomous regions/municipalities in China. These provinces' gross domestic product (GDP) per capita far exceeded the average value in China from 2005 to 2014[7] and was similar to the GDP of other developed countries in Asia. Moreover, since 2000s, this region experienced dramatic changes in both the economic and health sectors[8]. According to the Health Statistics Yearbook, in 2015, the average life expectancy in eastern coastal China was around 78 years old, which is greater than the national average of approximately 76 years old[7]. Due to the rapid urbanisation, economic development and population ageing in eastern coastal China, NCDs and disabilities are becoming more prevalent[1,3], and the spectrum of inpatients' diseases in this area is speculated to largely differ from that in other regions of China. More specific guidelines for preventing and curing NCDs that are tailored to the disease patterns observed in eastern coastal China must be developed.

In exploring disease patterns, particularly in longitudinal studies based on a large sample, second-hand data may be regarded as a good source. In particular, data from hospitals' electronic health record (EHR) systems have unique advantages. For instance, Upshur et al. applied time series methods to a population-based retrospective cohort for the 52 most common causes of hospital admissions in the province of Ontario from 1988 to 2001 and showed that hospital admissions displayed systematic patterns that are understandable, predictable, and reasonably accurate[9]. Using data from the admission and discharge/death register, Sani et al.[10] conducted a

three-year review of mortality patterns. Their result supported the emerging trend of a combined burden of communicable diseases and NCDs. In China, disease surveillance is conducted by the National Disease Surveillance Points System, which was founded in 1978; however, this system reports primarily on communicable diseases and reports on only a small subset of NCDs, such as cancer[11,12]. Given these factors, the current study used the hospital-based EHR system as a data source. This relatively new database compiles clinical information from a large number of patients in a computationally accessible form. The EHR system provides us with a unique opportunity to elucidate the relatively severe NCD epidemiology and includes a diverse array of NCDs[13].

The aim of this study was to dynamically elucidate the spectrum and characteristics of the severe NCDs in eastern coastal China by analysing hospitals' longitudinal EHR data. The results can provide insight into the aetiology of NCDs and aid in the development of evidence-based clinical guidelines for preventing and curing NCDs. In addition, the distribution of NCDs in eastern coastal China can inform the development of clinical guidelines for NCDs in other regions or countries in transition.

METHODS

Study design and data collection

Longitudinal data (2003-2014) on NCDs were extracted from the EHR systems of 12 general tertiary hospitals in Shandong (2 hospitals), Jiangsu (2 hospitals), Zhejiang (2

hospitals), Shanghai (3 hospitals) and Guangdong Provinces (3 hospitals).

A multistage sample was obtained. To obtain a representative sample, when choosing the sites, we first selected 3 cities that represented high, middle, and low socioeconomic statuses, as defined by GDP level, in each of the 5 provinces. Second, in each city, we selected the largest general tertiary hospital, resulting in 15 sampled hospitals. However, we did not obtain consent from three tertiary hospitals in some cities in Shandong, Jiangsu and Zhejiang Provinces due to political reasons regarding EHR data collection. In China, EHR data are not openly available but can be obtained from consenting hospitals with the help of health authorities. However, for several reasons, the health authorities cannot support us in the future. Thus, 12 general tertiary hospitals were included in the study.

We selected tertiary hospitals for this study. In China, hospitals are classified into three categories according to their major functions. Although community hospitals are intended to serve as gatekeepers, a patient's freedom to select medical facilities and doctors is not restricted by policies or health insurance coverage. Consequently, patients with acute or chronic diseases frequently visit the higher-tier, more sophisticated or specialised, and more expensive hospitals rather than community health centres, and many of the community health centres do not have hospital beds, and their EHR systems are defective and incomplete, limiting the use of the information contained in them [14]. Typically, the largest tertiary hospitals see most of the patients discharged in their cities.

Study subjects

In this study, information on inpatients with NCDs was extracted from the 2003-2014 hospital EHR data of each hospital, and only individuals who had been admitted to these hospitals during this period were included. We chose 2003 as the starting point because the first EHR system was formally launched in these hospitals in that year. In our study, the EHR systems of the tertiary hospitals include the admission information of patients who received their first diagnosis of an NCD between 2003 and 2014. As these hospitals may also attract patients from other districts or provinces, the inclusion criteria stipulated that participants must have a fixed address in the relevant region, regardless of whether they were registered or nonregistered residents. After excluding non-residents, NCD information for a total of 1,907,484 inpatients was stripped of identifying information and extracted from the hospitals' EHR systems. These patients were admitted to a variety of hospital divisions, and according to the ICD-9 and GBD NCD classification, we classified them into various disease groups based on their first-list diagnosis. The final data set included the residents' basic demographic information(gender and age)and the presence of chronic diseases (disease system/category, disorder and year of admission). We did not include region as a factor because all the hospitals were located in an urban region and it is difficult to determine the inpatients' status from the EHR.

Statistical analysis

All data were analysed by using SAS Software 9.20. Basic descriptive statistics were

used to analyse the inpatients' personal characteristics (gender, age, and year of admission). The NCD systems and the most common disorders within each disease system were ranked according to their relative proportions. The Cochran-Armitage Chi-square test was then used to examine significant increases or decreases in the proportions of NCDs in disease systems across different gender and age groups between 2003 and 2014.

Ethics statement

All research activities were conducted with integrity according to generally accepted ethical principles and were approved by the Ethics Committees of Tongji University (ref: LL-2016-ZRKX-017). This study presented minimal risk of harm to its subjects, and the data were collected anonymously. None of the inpatients' personal information included in the database was available to individuals outside of the research team.

RESULTS

Description of the personal characteristics of inpatients with NCDs

The personal characteristics of the studied population are summarised in Table 1. This population included 1,907,484 inpatients with NCDs, 50.05% of whom were male. Most of these patients were aged 50 years or older (81.53%). Furthermore, the number of inpatients with NCDs increased from 2003 to 2014.

Ranking of the disorders in all NCDs categories within gender and age groups

The ranks and proportions of all NCDs for each gender group are presented in Table 2. Among males, each of the five most common disorders represented more than 4.0% of the total NCDs from 2003 to 2014. The three most frequently occurring disorders among men were cerebral infarction (12.61%), coronary heart disease (6.94%) and hypertension (6.05%). Similar to the results for men, those for women showed that cerebral infarction (9.63%) occurred most frequently. However, hypertension (6.84%) and uterine fibroids (4.15%) were the second and third most frequently occurring NCDs among women.

Table 2 also shows the ranks of the most frequently occurring disorders across age groups. There were relatively few inpatients with NCDs in the 0-10-year-old group, but chronic tonsillitis occurred most frequently in this age group (26.19%). In the 11-30-year-old group, redundant prepuce and benign neoplasm of the breast occurred frequently in men and women, respectively. Among 31-50-year-old patients, the most common disorders were endocrine diseases, including uterine fibroids, ovarian cysts, endometrial polyps, ureteral calculi and hyperplasia of the mammary glands. Among 51-80-year-old inpatients, the most common conditions were cerebral infarction (ranking first), coronary heart disease and hypertension. Among patients aged 80 or older, the three most common disorders were cerebral infarction, hypertension and coronary heart disease. Vertebrobasilar insufficiency, diabetes, and chronic obstructive pulmonary disease were more common among the elderly than among individuals in the other age groups.

Distribution of NCDs across different groups from 2003 to 2014

Table 3 shows the changes in the proportions of the 12 NCD categories from 2013 to 2014. A significant decrease in the occurrence of cancer (Z=-20.525, P<0.001), other neoplasms (Z=-20.525, P<0.001), chronic respiratory diseases (Z=-18.290, P<0.001), urogenital diseases (Z=-5.329, P<0.001) and sensory organ diseases (Z=-2.403, P=0.008) was found. In contrast, the proportions of other NCDs increased to various extents over the 12-year period. Notably, the proportion of patients with diabetes and blood and endocrine diseases increased approximately four-fold (from 1.36% to 6.74%).

As shown in Figure 1, the 12-year NCD percentages recorded in the hospitals varied widely by gender. The percentage of men who were diagnosed with cancer (from 13.62% to 5.91%, P<0.001) and chronic respiratory diseases (from 18.80% to 12.42%, P<0.001) decreased substantially, whereas the percentage of men with diabetes or blood and endocrine diseases (from 0.94% to 6.58%, P<0.001) and that of men with neurological disorders(from 2.16% to 4.29%, P<0.001) increased substantially. The percentage of women who were diagnosed with digestive diseases (Z=-0.270, P=0.394), neurological disorders (Z=0.943, P=0.173), and sensory organ diseases (Z=0.056, P=0.478) did not change significantly from 2003 to 2014; this result is in strong contrast to the pattern found in the male inpatients. Furthermore, a substantial increase in the percentage of female patients with diabetes or blood and endocrine diseases (from 1.77% to 6.91%, P<0.001) was found. Although the proportion of cancer and other neoplasms decreased in women, the decrease was less pronounced than that found in men.

Changes in NCD proportions across age groups were also examined (Figure 2). NCDs were relatively rare among patients aged 10 years or younger, but chronic respiratory diseases occurred most frequently in this group. For11-20-year-old subjects, sensory organ diseases (Z=3.304, P<0.001) and cardiovascular and circulatory diseases (Z=2.090, P=0.018) occurred more frequently over time. We noted dramatic decreases in the percentages of patients with cancer and chronic respiratory diseases in the 31-50-year-oldgroup: all decreased nearly 50% from 2003 to 2014. However, the proportions of patients with diabetes or blood and endocrine diseases increased in these two groups and in the 21-30-year-old group. For the 41-50-year-oldgroup, the number of patients diagnosed with cancer decreased significantly but the proportions of patients with cardiovascular, circulatory (Z=7.918, P<0.001) and digestive diseases (Z=3.086, P<0.01) increased to a greater extent than in the younger population. In the ≥50-year-old group, the proportion of patients with diabetes, blood, and endocrine diseases increased substantially (P<0.001). The proportion of patients with cancer decreased to a greater extent in this age group than in any other age group (P<0.001).

DISCUSSION

By analysing the EHR information of inpatients with NCDs at 12 hospitals in eastern coastal China, our research team was able to elucidate the severe NCD patterns in a relatively unbiased fashion and to confirm that NCDs displayed regional heterogeneity to some extent. In order of frequency, cardiovascular and circulatory diseases, urogenital diseases, chronic respiratory diseases, and digestive diseases were the most common NCDs. When comparing these data with inpatient data in other

regions, we found different patterns. For instance, a study using a sample from a hospital in central China found that cardiovascular and circulatory diseases, diabetes, and chronic respiratory diseases occurred most frequently[15]. However, since most studies on inpatients' NCDs were based on only one hospital's EHR data, the comparison may have defects. In eastern coastal China, the severe cardiovascular and circulatory diseases may be the most frequently occurring because of the greater degree of urbanisation and greater proportion of ageing population in the region[2,3]. In addition, urogenital diseases (second) and digestive diseases (fourth) were common in this region, potentially because of the more rapid pace of modern life, more sedentary lifestyle and longer working hours. In our search of existing studies on inpatients with NCDs, we rarely found this spectrum at the top of the list[16].

Concerning the longitudinal trends in inpatients' NCDs, the results showed a significant increase in the proportions of many NCDs, including diabetes, blood and endocrine diseases, and cardiovascular and circulatory diseases, from 2003 to 2014. However, interestingly, the proportion of chronic respiratory diseases and cancer inpatients decreased over the 12-year period, in stark contrast to the changes in the incidence observed throughout China[17,18]. Often, previous studies have concluded that the incidence of respiratory diseases is increasing, likely due to ambient air pollution and tobacco use, resulting in tremendous threats to respiratory health[3,19]. The difference may be caused by the data since the incidence also includes mild respiratory diseases, however, the opposite trend of inpatients found in eastern coastal China may have also resulted from this region’s transition from a heavy industrial

district to a technologically focused area, which has been associated with a substantial reduction in environmental pollution. Moreover, regional public health media campaigns focused on cancer prevention and the regional government have promoted early screening and the treatment of major cancers since the 2000s[20], which likely explains the reduced proportion of cancer patients. However, PM 2.5 air pollution, household pollution, tobacco use, residents' insufficient knowledge of NCD prevention, etc. remain persistent risk factors in eastern coastal China and deserve considerable attention[21, 22].

Demographic factors may result in physiological and psychological differences across different populations, which may then give rise to distinct behaviours and ultimately to a heterogeneous distribution of NCDs. For instance, the Framingham Heart Study (FHS) conducted in the USA showed that women were significantly older than men at their first stroke, had a higher stroke rate than men at ages above 85 years, lower rates than men at all other ages, and a higher life time risk of stroke than men at all ages[23]. Our study found a significant increase in the proportion of male and female inpatients with diabetes, blood and endocrine diseases, cardiovascular and circulatory diseases, and congenital anomalies in eastern coastal China. However, we identified demographic differences in the patterns of NCDs. The proportion of male inpatients with digestive diseases decreased, but that of female inpatients remained relatively high. The proportion of female patients with mental and behavioural disorders increased. Currently, women in China are employed in the same fast-paced jobs or roles as men, which is likely one important cause of this phenomenon[24].

Furthermore, women are expected to devote more effort to balancing family and work[25,26], which is undoubtedly challenging. On the other hand, we found an increasing trend in the number of men diagnosed with neurological diseases, which may be associated with the complex aetiology of dystrophia, immune damage, endocrine disorders, etc. Diet and stress may also influence the incidence of these diseases among men to a certain extent and should be closely examined.

In our study, we found that, on the one hand, a greater proportion of older inpatients (>50 years) suffered from NCDs such as diabetes or blood and endocrine diseases as they aged. This proportion increased nearly four-fold from 2003 to 2014. On the other hand, the proportion of inpatients between the ages of 30 and 50 with these diseases increased significantly. In addition, the proportion of young patients with NCDs, such as cardiovascular and circulatory diseases, increased over the 12-year period. As shown in Figure 2, cancer was not among the most common NCDs in any age group, and surprisingly, the proportion of patients with cancer decreased in all age groups but decreased more quickly in older age groups. This phenomenon is likely highly correlated with improvements to the environment and the effects of cancer prevention media campaigns[27-29]. However, this result does not imply that cancer prevention can be abated in the future.

The public's awareness of NCD prevention is insufficient due to complex cultural and social factors[27,30,31]. The specific risk factors for frequently occurring NCDs in different gender and age groups should be monitored every year. Other interventions, such as reform of China's medical system, should aim to improve the function of

community hospitals such that these hospitals focus on NCD prevention. Meanwhile, education or training should be promoted in communities and among health practitioners. Knowledge of and information on NCDs should be disseminated via the media to increase awareness. The distributions of NCDs in eastern coastal China suggest future directions for NCD prevention in this region and may provide similar developing regions with strategies for better managing NCDs.

Limitations

In this study, there were several limitations. First, the sampled hospitals were the largest hospitals in eastern coastal cities. These cities were selected to increase the sample's representativeness of eastern coastal China. However, the generalisability and reliability of the findings are a concern. However, because the EHR included a large number of inpatients with NCDs, it was a precise data source for determining the status of and trends in the occurrence of different diseases. To reduce selection bias, more representative hospitals from each of the cities must be investigated. Second, because few longitudinal studies examining the spectrum of NCDs among many hospitals' inpatients have been conducted in other areas of China, it was difficult to compare the current findings regarding inpatients' NCDs with those in other parts of China.

CONCLUSIONS

In summary, the spectrum of NCDs inpatients from 12 hospitals exhibits the severe NCDs condition and spectrum in eastern coastal China to a certain extent. Specific

NCDs rapidly increased in women and the younger population over the studied 12-year period, underscoring the importance of healthcare policies or guidelines for developing countries or regions such as China. Public awareness campaigns should be targeted at the regional level and should consider differences in demographic factors across regions. However, due to the limited generalisability and reliability of this study, stronger support must be obtained through future studies on the spectrum of inpatients' NCDs in eastern coastal China and other regions.

Abbreviations

Non-communicable diseases: NCDs

GDP: Gross domestic product

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Availability of data and materials

All relevant data are available in the Figshare database under the DOI:

https://figshare.com/s/f79b2b4e686d1d477527

Authors' contributions

Conceived and designed the experiments: DHY, JWS and ZXW. Analysed the data: JWS, HZZ and YL. Contributed reagents/materials/analysis tools: YL, BZ, YP, BW and PFS. Wrote the paper: DHY and JWS.

Competing interests

The authors have declared that they have no competing interests.

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Table 1 Demographic Characteristics of Inpatients with NCDs

Variable	Classification	N	%
Gender	Male	954612	50.05
	Female	952872	49.95
Age	0-10	1008	0.05
(years)	11-20	14688	0.77
	21-30	47484	2.49
	31-40	70164	3.68
	41-50	219060	11.48
	51-60	320172	16.79
	61-70	268176	14.06
	71-80	523452	27.44
	>80	443280	23.24
Year of admission	2003	110796	5.81
	2004	126744	6.64
	2005	127704	6.69
	2006	135972	7.13
	2007	141780	7.43
	2008	145728	7.64
	2009	155220	8.14
	2010	157500	8.26
	2011	171060	8.97
	2012	191004	10.01
	2013	209100	10.96
	2014	234876	12.31
	Total	1907484	100.00

Table 2 Ranking of the Most Common NCDs by Group

Variable	First		Second		Third		Fourth		Fifth	
	Disease	N(%)	Disease	N(%)	Disease	N(%)	Disease	N(%)	Disease	N(%)
Gender										
Male	Cerebral infarction	120396(12.61)	Coronary heart disease	66216(6.94)	Hypertension	57708(6.05)	Chronic obstructive pulmonary disease	53904(5.65)	Chronic bronchitis	45252(4.74)
Female	Cerebral infarction	91776(9.63)	Hypertension	65136(6.84)	Uterine fibroid	39564(4.15)	Coronary heart disease	31188(3.27)	Chronic bronchitis	25776(2.71)
Age(years)										
0-10	Chronic tonsillitis	264(16.19)	Redundant prepuce	144(14.29)	Adenoid vegetation	72(7.14)	Adenoidal hypertrophy	48(4.76)	Tonsil hypertrophy	24(2.38)
11-20	Redundant prepuce	2064(14.05)	Benign neoplasm of breast	996(6.78)	Spontaneous pneumothorax	648(4.41)	Chronic tonsillitis	552(3.76)	Respiratory failure	444(3.02)
21-30	Redundant prepuce	4704(9.91)	Benign neoplasm of breast	2448(7.51)	Ovarian cyst	3564(5.16)	Ureteral calculi	1632(3.44)	Chronic tonsillitis	1032(2.17)
31-40	Uterine fibroid	5484(7.82)	Ovarian cyst	3156(4.50)	Endometrial polyp	2844(4.05)	Ureteral calculi	2556(3.64)	Hyperplasia of mammary glands	2268(3.23)
41-50	Uterine fibroid	25644(11.71)	Endometrial hyperplasia	9408(4.29)	Hyperplasia of mammary glands	8052(3.68)	Endometrial polyp	7404(3.38)	Ureteral calculi	5640(2.57)
51-60	Cerebral infarction	23124(7.22)	Coronary heart disease	14016(4.38)	Hypertension	12144(3.79)	Ureteral calculi	8364(2.61)	Cerebral haemorrhage	6636(2.07)
61-70	Cerebral infarction	29508(11.00)	Coronary heart disease	14016(6.30)	Hypertension	13668(5.10)	Vertebrobasilar insufficiency	6480(2.42)	Diabetes	5640(2.10)
71-80	Cerebral infarction	75972(14.51)	Hypertension	45612(8.71)	Coronary heart disease	38808(7.41)	Chronic bronchitis	30720(5.87)	Chronic obstructive pulmonary disease	25536(4.88)
>80	Cerebral infarction	46560(17.58)	Hypertension	31488(10.50)	Coronary heart disease	77928(8.51)	Chronic obstructive pulmonary disease	36216(8.17)	Chronic bronchitis	37728(7.10)

Table 3 Distribution of Non-communicable Diseases from 2003 to 2014 in the Total Sample (%)

Disorder	2003 N =110796	2004 N =126744	2005 N =127704	2006 N =135972	2007 N =141780	2008 N =145728	2009 N =155220	2010 N =157500	2011 N =171060	2012 N =191004	2013 N =209100	2014 N =234876	Z	P-value	Trend
Cancer	11.57	10.16	8.15	9.33	8.37	8.28	7.24	7.18	7.19	7.80	6.12	5.78	-20.525	<0.001	↓↓↓
Other neoplasms	6.63	8.05	7.43	7.41	5.58	4.55	5.54	4.45	4.67	4.55	4.36	4.01	-20.527	<0.001	↓↓↓
Cardiovascular and circulatory diseases	28.30	29.38	29.18	29.52	31.43	33.33	34.68	36.21	35.64	35.65	34.87	34.60	19.861	<0.001	↑↑↑
Chronic respiratory diseases	13.43	13.46	13.85	12.98	13.50	12.85	12.52	12.45	11.27	10.89	9.37	9.40	-18.290	<0.001	↓↓↓
Diabetes and blood and endocrine diseases	1.36	1.43	1.25	1.26	1.44	1.46	1.35	1.75	1.55	3.67	6.47	6.74	41.268	<0.001	↑↑↑
Digestive diseases	10.54	11.57	10.98	11.24	9.58	10.56	10.00	10.81	10.12	9.67	10.00	10.98	-2.757	0.003	↓↓
Mental and behavioural disorders	0.17	0.08	0.23	0.19	0.19	0.13	0.26	0.25	0.16	0.12	0.36	0.25	3.130	0.001	↑↑
Musculoskeletal disorders	5.44	4.74	4.85	4.64	5.18	4.48	4.58	3.86	4.67	4.54	5.80	6.23	4.668	<0.001	↑↑↑
Urogenital diseases	14.97	13.24	15.95	14.93	15.68	14.65	13.29	13.12	15.34	14.81	13.83	12.72	-5.329	<0.001	↓↓↓
Neurological disorders	2.25	3.78	4.35	3.96	4.58	5.34	5.33	4.97	4.83	3.49	4.13	4.36	3.915	<0.001	↑↑↑
Sensory organ diseases	4.14	3.20	2.69	3.15	3.50	2.97	3.64	3.18	2.84	3.26	3.02	3.15	-2.403	0.008	↓↓
Congenital anomalies	0.40	0.44	0.28	0.38	0.37	0.26	0.49	0.41	0.32	0.28	0.60	0.63	3.750	<0.001	↑↑↑
Skin and subcutaneous disease	0.80	0.47	0.82	0.99	0.59	1.14	1.06	1.35	1.38	1.26	1.08	1.15	7.294	<0.001	↑↑↑

↓↓: P<0.01, negative trend; ↓↓↓: P<0.001, negative trend;↑↑: P<0.01, positive trend;↑↑↑: P<0.001, positive trend.

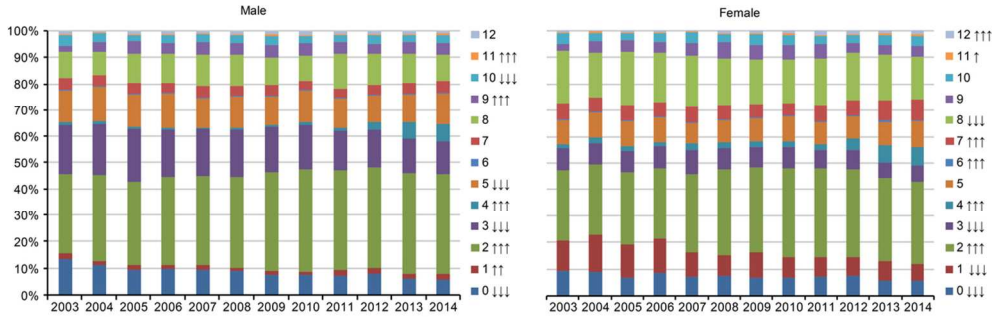

Fig.1 Distribution of non-communicable diseases by gender
0: cancer, 1: other neoplasms, 2: cardiovascular and circulatory diseases, 3: chronic respiratory diseases, 4: diabetes and blood and endocrine diseases, 5: digestive diseases, 6: mental and behavioural disorders, 7: musculoskeletal disorders, 8: urogenital diseases, 9: neurological disorders, 10: sensory organ diseases, 11: congenital anomalies, 12: skin and subcutaneous diseases
↓: P<0.05, negative trend; ↓↓: P<0.01, negative trend; ↓↓↓: P<0.001, negative trend;
↑: P<0.05,positive trend; ↑↑: P<0.01,positive trend;↑↑↑: P<0.001,positive trend.

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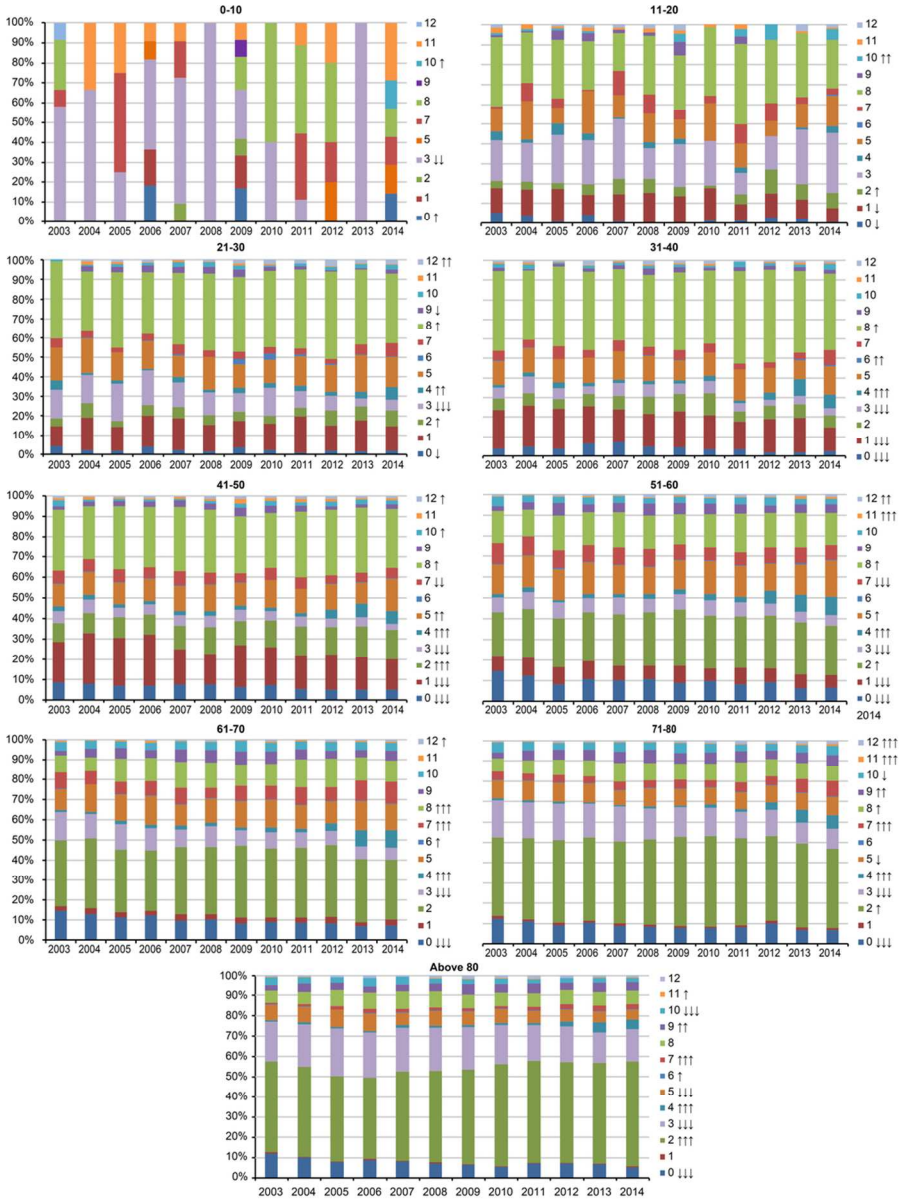

Fig. 2 Distribution of non-communicable diseases by age
0: cancer, 1: other neoplasms, 2: cardiovascular and circulatory diseases, 3: chronic respiratory diseases, 4: diabetes and blood and endocrine diseases, 5: digestive diseases, 6: mental and behavioural disorders, 7: musculoskeletal disorders, 8: urogenital diseases, 9: neurological disorders, 10: sensory organ diseases, 11: congenital anomalies, 12: skin and subcutaneous diseases
↓: P<0.05,negative trend;↓↓: P<0.01, negative trend;↓↓↓: P<0.001,negative trend;
↑: P<0.05,positive trend; ↑↑: P<0.01,positive trend;↑↑↑: P<0.001,positive trend.

48x64mm (600 x 600 DPI)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5-6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7-8
Bias	9	Describe any efforts to address potential sources of bias	7
Study size	10	Explain how the study size was arrived at	5-6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7-8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7-8
		(*b*) Describe any methods used to examine subgroups and interactions	7-8
		(*c*) Explain how missing data were addressed	7-8
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	7-8
		(*e*) Describe any sensitivity analyses	7-8
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	N/A
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8
		(b) Indicate number of participants with missing data for each variable of interest	N/A
Outcome data	15*	Report numbers of outcome events or summary measures	8-11
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	N/A
		(*b*) Report category boundaries when continuous variables were categorized	N/A
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
Discussion			
Key results	18	Summarise key results with reference to study objectives	11-12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	15
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12-15
Generalisability	21	Discuss the generalisability (external validity) of the study results	15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	16

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Identifying the patterns of non-communicable diseases in developed eastern coastal China: A longitudinal study on the electronic health records in 12 public hospitals

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Identifying the patterns of non-communicable diseases in developed eastern coastal China: A longitudinal study on the electronic health records in 12 public hospitals

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ABSTRACT

Objective: Few studies have examined the spectrum and trends of non-communicable diseases (NCDs) in inpatients in eastern coastal China, which is transforming from an industrial economy to a service-oriented economy and is the most economically developed region in the country. The aim of this study was to dynamically elucidate the spectrum and characteristics of severe NCDs in eastern coastal China by analysing patients' longitudinal electronic health records (EHRs).

Setting: To monitor the spectrum of NCDs dynamically, we extracted the EHR data from 12 general tertiary hospitals in eastern coastal China from 2003 to 2014. The rankings of and trends in the proportions of different NCDs presented by inpatients in different gender and age groups were calculated and analysed.

Participants: We obtained a total sample of 1,907,484 inpatients with NCDs from 2003 to 2014, 50.05% of whom were male and the majority of whom were aged 50 years or older (81.53%).

Results: There is an increase in the number of total NCD inpatients in eastern coastal China from 2003 to 2014. However, the proportion of chronic respiratory diseases and cancer inpatients decreased over the 12-year period. Compared with men, women displayed higher proportions of digestive diseases (P=0.394) and neurological disorders (P=0.173) over time. The older group accounted for a larger and growing proportion of the NCD inpatients, and the most common conditions in this group were cerebral infarctions, coronary heart disease and hypertension. In addition, the proportion of 21- to 50-year-old inpatients with diabetes, blood diseases or endocrine diseases skyrocketed from 2003 to 2014 (P<0.001).

Conclusions: The burden of inpatients' NCDs increased rapidly, particularly among women and younger people. The NCD spectrum observed in eastern coastal China is a good source of evidence for developing prevention guides for regions experiencing transition.

Keywords: Non-communicable diseases; Electronic Health Record; Eastern coastal China; Health policy

Strengths and limitations

- The concept of using longitudinal EHRs to document the proportion of NCD admissions in eastern coastal China hospitals can provide a reasonably simple and

precise method of examining NCD trends over time.

- The evidence is a good source to develop NCD prevention guides or policies for similar developing regions that are undergoing or will undergo an economic transformation.
- The generalisability and reliability of the findings of this study are a concern, and more hospitals from other parts of China should be included in future studies to make a persuasive comparison.

INTRODUCTION

In recent years, an epidemiological shift in morbidity and mortality from infectious diseases and malnutrition to non-communicable diseases(NCDs) has occurred in many countries, including China[1-3]. NCDs have become the major causes of death in China and globally. According to the 2012 WHO data repository, 87% of deaths in China were associated with NCDs[1]. The Global Burden of Disease Study(GBD) revealed that of the 8.3 million deaths in China in 2010, 7.0 million resulted from NCDs[3]. Stroke, ischaemic heart disease, cancers, and chronic obstructive pulmonary disease are now the leading causes of premature death in China, and the burden of these diseases is substantial[4].

Previous research on the epidemiological patterns of NCDs in China has primarily focused on the entire nation or cross-sectional studies of specific regions[1-6]. However, both the WHO and the GBD have acknowledged that a national analysis conducted in a country as large and diverse as China can mask substantial variations

in key outcomes[3,5]. In addition, few studies have examined the NCD spectrum in inpatients, which can reflect the severe state of NCDs. In this study, we conducted a longitudinal study of NCD patterns in five provinces in eastern coastal China: Shandong, Jiangsu, Zhejiang, Shanghai and Guangdong provinces. Geographically speaking, these provinces are located in the three most productive and dynamic regions of China: the Bohai Sea, the Yangtze River Delta and the Pearl River Delta. The gross regional domestic product in these five provinces accounts for approximately half that of the 32 provinces/autonomous regions/municipalities in China. These provinces' gross domestic product(GDP) per capita far exceeded the average value in China from 2005 to 2014[7] and was similar to the GDP of other developed countries in Asia. Moreover, since the 2000s, this region has experienced dramatic changes in both the economic and health sectors[8]. According to the Health Statistics Yearbook, in 2015, the average life expectancy in eastern coastal China was around 78 years old, which is greater than the national average of approximately 76 years old[7]. Due to the rapid urbanisation, economic development and population ageing in eastern coastal China, NCDs and disabilities are becoming more prevalent[1,3], and the spectrum of inpatients' diseases in this area is speculated to largely differ from that in other regions of China. More specific guidelines for preventing and curing NCDs that are tailored to the disease patterns observed in eastern coastal China must be developed.

In exploring disease patterns, particularly in longitudinal studies based on a large sample, second-hand data may be regarded as a good source. In particular, data from

hospitals' electronic health record(EHR) systems have unique advantages. For instance, Upshur et al. applied time series methods to a population-based retrospective cohort for the 52 most common causes of hospital admissions in the province of Ontario from 1988 to 2001 and showed that hospital admissions displayed systematic patterns that are understandable, predictable, and reasonably accurate[9]. Using data from the admission and discharge/death register, Sani et al.[10] conducted a three-year review of mortality patterns. Their result supported the emerging trend of a combined burden of communicable diseases and NCDs. In China, disease surveillance is conducted by the National Disease Surveillance Points System, which was founded in 1978; however, this system reports primarily on communicable diseases and reports on only a small subset of NCDs, such as cancer[11,12]. Given these factors, the current study used the hospital-based EHR system as a data source. This relatively new database compiles clinical information from a large number of patients in a computationally accessible form. The EHR system provides us with a unique opportunity to elucidate the relatively severe NCD epidemiology and includes a diverse array of NCDs[13].

The aim of this study was to dynamically elucidate the spectrum and characteristics of severe NCDs in eastern coastal China by analysing hospitals' longitudinal EHR data. The results can provide insight into the aetiology of NCDs and aid in the development of evidence-based clinical guidelines for preventing and curing NCDs. In addition, the distribution of NCDs in eastern coastal China can inform the development of clinical guidelines for NCDs in other regions or countries in transition.

METHODS

Study design and data collection

Longitudinal data(2003-2014) on NCDs were extracted from the EHR systems of 12 general tertiary hospitals in Shandong(2 hospitals), Jiangsu(2 hospitals), Zhejiang(2 hospitals), Shanghai(3 hospitals) and Guangdong Provinces(3 hospitals).

A multistage sample was obtained. To obtain a representative sample, when choosing the sites, we first selected 3 cities that represented high, middle, and low socioeconomic statuses, as defined by GDP level, in each of the 5 provinces. Second, in each city, we selected the largest general tertiary hospital, resulting in 15 sampled hospitals. However, we did not obtain consent from three tertiary hospitals in some cities in Shandong, Jiangsu and Zhejiang Provinces due to political reasons regarding EHR data collection. In China, EHR data are not openly available but can be obtained from consenting hospitals with the help of health authorities. However, for several reasons, the health authorities cannot support us in the future. Thus, 12 general tertiary hospitals were included in the study. In this study, one hospital in Shandong Province in the low socioeconomic group, one hospital in Jiangsu Province in the middle socioeconomic group, and one hospital in Zhejiang Province in the high group were missing from the dataset. However, due to the distribution of the missing hospitals, it was thought that lack of participation of these hospitals would not influence the final results. In China, EHRs have used a uniform version since 2001 in most large cities and comprised two parts. The first part contains the patients' personal

information, including their gender, age, identification card number, profession, address, etc. This information is usually provided by the patients or their family. The second part contains the inpatients' hospitalisation information, including their diagnosis code, discharge status, pathologic diagnosis (if possible), operation code (if possible), etc. This information is provided by the patient's physician, which ensures its reliability. In terms of the diagnosis code, each inpatient is coded with an ICD-9 disease code by their physician. In addition, the GBD has well defined categories for NCDs. Therefore, we extracted the inpatients' NCDs using their ICD-9 codes and classified them into different categories.

We selected tertiary hospitals for this study. In China, hospitals are classified into three categories according to their major functions. Although community institutions are intended to serve as gatekeepers, a patient's freedom to select medical facilities and doctors is not restricted by policies or health insurance coverage. Consequently, patients with acute or chronic diseases frequently visit the higher-tier, more sophisticated or specialised, and more expensive hospitals rather than community health centres, and many of the community health centres do not have hospital beds. In addition, their EHR systems are defective and incomplete, limiting the use of the information they contain[14]. Typically, the largest tertiary hospitals see most of the patients discharged in their cities.

Study subjects

In this study, information on inpatients with NCDs was extracted from the 2003-2014

hospital EHR data of each hospital, and only individuals who had been admitted to these hospitals during this period were included. We chose 2003 as the starting point because the first EHR system was formally launched in these hospitals in that year. In our study, the EHR systems of the tertiary hospitals include the admission information of patients who received their first diagnosis of an NCD between 2003 and 2014. We excluded any duplicated patients by searching and analysing their Identification Card number in the EHRs. In addition, because these hospitals may also attract patients from other districts or provinces, the inclusion criteria stipulated that participants must have a fixed address in the relevant region, regardless of whether they were registered or nonregistered residents. After excluding non-residents, NCD information for a total of 1,907,484 inpatients was stripped of identifying information and extracted from the hospitals' EHR systems. These patients were admitted to a variety of hospital divisions, and according to the ICD-9 and GBD NCD classification, we extracted the NCD patients from all of the inpatients and classified them into various disease groups based on their first-list diagnosis. The final data set included the residents' basic demographic information(gender and age) and the presence of chronic diseases(disease system/category, disorder and year of admission). We did not include region and socioeconomic status as factors because all of the hospitals were located in an urban region and because it is difficult to determine the inpatients' socioeconomic status from the EHR.

Statistical analysis

All data were analysed by using SAS Software 9.20. Basic descriptive statistics were

used to analyse the inpatients' personal characteristics(gender, age, and year of admission). The NCD systems and the most common disorders within each disease system were ranked according to their relative proportions. The Cochran-Armitage Chi-square test was then used to examine significant increases or decreases in the proportions of NCDs in disease systems across different gender and age groups between 2003 and 2014.

Ethics statement

All research activities were conducted with integrity according to generally accepted ethical principles and were approved by the Ethics Committees of Tongji University(ref: LL-2016-ZRKX-017). This study presented minimal risk of harm to its subjects, and the data were collected anonymously. None of the inpatients' personal information included in the database was available to individuals outside of the research team.

RESULTS

Description of the personal characteristics of inpatients with NCDs

The personal characteristics of the studied population are summarised in Table 1. This population included 1,907,484 inpatients with NCDs, 50.05% of whom were male. Most of these patients were aged 50 years or older(81.53%). Furthermore, the number of inpatients with NCDs increased from 2003 to 2014.

Ranking of the disorders in all NCDs categories within gender and age groups

The ranks and proportions of all NCDs for each gender group are presented in Table 2. Among males, each of the five most common disorders represented more than 4.0% of the total NCDs from 2003 to 2014. The three most frequently occurring disorders among men inpatients were cerebral infarction(12.61%), coronary heart disease(6.94%) and hypertension(6.05%). Similarly, those for women showed that cerebral infarction(9.63%) occurred most frequently. However, hypertension(6.84%) and uterine fibroids(4.15%) were the second and third most frequently occurring NCDs among women, respectively.

Table 2 also shows the ranks of the most frequently occurring disorders across age groups. The older group(>41 years of age) accounted for a larger proportion of NCD inpatients, and the most common conditions in this group were cerebral infarction, coronary heart disease and hypertension. In the 11- to 50-year-old group, urogenital diseases, endocrine diseases and neoplasms including redundant prepuce, benign neoplasm of the breast and endometrial hyperplasia occurred frequently in men and women. In addition, hypertension, chronic obstructive pulmonary disease and diabetes were more common among the elderly than among individuals in the other age groups.

Distribution of NCDs across the different groups from 2003 to 2014

Table 3 shows the changes in the proportions of the 12 NCD categories from 2003 to 2014. A significant decrease in the occurrence of cancer($Z=-20.525$, $P<0.001$), other neoplasms($Z=-20.525$, $P<0.001$), chronic respiratory diseases($Z=-18.290$, $P<0.001$),

urogenital diseases(Z=-5.329, P<0.001) and sensory organ diseases(Z=-2.403, P=0.008) was found. In contrast, the proportions of other NCDs increased to various extents over the 12-year period. Notably, the proportion of patients with diabetes and blood and endocrine diseases increased approximately four-fold(from 1.36% to 6.74%).

As shown in Figure 1, the 12-year NCD percentages recorded in the hospitals varied widely by gender. The percentage of both men and women who were diagnosed with diabetes or blood and endocrine diseases increased substantially. It is worth noting that the percentage of women who were diagnosed with digestive diseases(Z=-0.270, P=0.394), neurological disorders(Z=0.943, P=0.173), and sensory organ diseases (Z=0.056, P=0.478) was higher and found in more stable proportions from 2003 to 2014; this result is in strong contrast to the pattern found in the male inpatients. In addition, although the proportion of cancer and other neoplasms decreased in women, this decrease was less pronounced than that found in men.

Changes in NCDs proportions across age groups were also examined(Figure 2). NCDs were relatively rare among patients aged 10 years or younger, but chronic respiratory diseases occurred most frequently in this group. For 11-20-year-old subjects, sensory organ diseases(Z=3.304, P<0.001) and cardiovascular and circulatory diseases(Z=2.090, P=0.018) occurred more frequently over time. We noted the proportions of patients with diabetes or blood and endocrine diseases increased in these two groups and in the below 30-year-old group. For the 41- to 50-year-old group, the number of patients diagnosed with cancer decreased

significantly but the proportions of patients with cardiovascular, circulatory(Z=7.918, P<0.001) and digestive diseases (Z=3.086, P<0.01) increased to a greater extent than in the younger population. In the ≥50-year-old group, the proportion of patients with diabetes or blood and endocrine diseases increased substantially(P<0.001).

DISCUSSION

By analysing the EHR information of inpatients with NCDs at 12 hospitals in eastern coastal China, our research team was able to elucidate the severe NCD patterns in a relatively unbiased fashion and to confirm that NCDs displayed regional heterogeneity to some extent. The increase in the number of NCD inpatients in eastern coastal China from 2003 to 2014 may be due to several reasons. First, owning to improvements in economics, health insurance and convenient transportation in China, even people with minor diseases may go to larger hospitals because they are equipped with better devices and doctors and do not adhere to strict referral policies. Second, the increase in the number of severe NCD patients may mainly result from higher pressure, a lack of exercise, and air pollution, among other factors in rapidly developed cities[14,15], which is consistent with the findings of Allen et al.(2017) who, in a systematic review, showed that NCD behavioural risk factors is well established in high-income countries. For example, high socioeconomic groups were found to be less physically active and to consume more fats, salt, and processed food than low socioeconomic status individuals[16].

In order of ranks, cardiovascular and circulatory diseases, urogenital diseases, chronic

respiratory diseases, and digestive diseases were the most common NCDs in this region. In eastern coastal China, severe cardiovascular and circulatory diseases may occur more frequently because of the greater degree of urbanisation and greater proportion of ageing population in the region[2,3]. Goryakin et al.(2017) studied the contribution of urbanisation to NCDs in 173 countries and found that when shifting from rural to urban areas, the average body mass index (BMI), total cholesterol level and systolic blood pressure, increased[17], demonstrating that high urbanisation increases the occurrence of cardiovascular and circulatory diseases, which is in consistent with this study. In addition, the frequency of urogenital diseases (second) and digestive diseases (fourth) in this region is potentially because of the more rapid pace of modern life, more sedentary lifestyle and longer working hours. In our search of existing studies on inpatients with NCDs, we rarely found this spectrum at the top of the list in other regions[18]. However, interestingly, this study revealed that the proportion of chronic respiratory diseases and cancer inpatients decreased over the 12-year period, in stark contrast to the changes in the incidence observed throughout China[19,20]. Often, previous studies have concluded that the incidence of respiratory diseases is increasing, likely due to ambient air pollution and tobacco use, resulting in tremendous threats to respiratory health[3,21]. This difference may be a result of the data because the reported incidence also includes mild respiratory diseases. However, the opposite trend found in inpatients in eastern coastal China may have also resulted from this region's transition from a heavy industrial district to a technologically focused area, which has been associated with a substantial reduction in environmental

pollution. Moreover, the regional public health media campaigns have focused on cancer prevention and the regional government has promoted early screening and the treatment of major cancers since the 2000s, particularly in these developed areas in China where the government can invest more money into public health activities[22], which likely explains the reduced proportion of cancer patients. However, PM 2.5 air pollution, household pollution, tobacco use, residents' insufficient knowledge of NCD prevention, etc. remain persistent risk factors in eastern coastal China and deserve considerable attention[23,24].

Concerning the NCD distribution in the different age groups, we found that the older age group accounted for the largest proportion of individuals with NCDs, with cerebral infarction, coronary heart disease and hypertension being the most common conditions, which is consistent with the epidemiological features of NCDs[25,26] and indicates these NCDs represent a significant burden for the Chinese government. Interestingly, it is also found that not only did the proportion of older patients suffering from NCDs such as diabetes or blood and endocrine diseases increase nearly four-fold from 2003 to 2014, but also, the proportion of younger individuals between the ages of 30 and 50 with these diseases increased significantly. However, this may be the result of unhealthy nutrient intake and great psychological pressure on the younger population in this fast-paced area and should be given great attention.

Additionally, the identified demographic differences in which women exhibit a higher proportion of severe digestive diseases and neurological disorders may indicate that currently, women in China are employed in the same fast-paced jobs or roles as

men[27]. Furthermore, women are expected to devote more effort to balancing family and work[28,29] in developed areas or cities, which is undoubtedly challenging for them and may induce the onset of these diseases. These factors imply that specific risk factors for frequently occurring NCDs in different gender groups should be monitored in addition to the diseases or groups that are currently monitored and screened for due to their significant burden. Other frequently occurring NCD diseases and a wider population should also be targeted, such as the prevention and screening of digestive diseases in females or increased preventative measures for diabetes and blood, endocrine, cardiovascular and circulatory diseases among the younger and population. In addition, all these call for the improvement and more invest in prevention and control of NCDs by community health institutions, which is lagged even in the economic-developed eastern coastal or averagely the whole China compared with the western countries[30]. For instance, usually community health institutions are competing with hospitals to attract more patients, and only the public health physicians(different from general physicians) mainly take the responsibilities of health education and follow-up visit for NCD patients. According to a survey on a representative community health institution in Shanghai, the public health physicians accounted for 7.94% of the total health personnel, which are in great shortage. Undoubted, this is a significant political and public issue for China currently to better reduce the NCDs and improve the national health[31].

Limitations

In this study, there were several limitations. First, the sampled hospitals were the

largest hospitals in eastern coastal cities. These cities were selected to increase the sample's representativeness of eastern coastal China. However, the generalisability and reliability of the findings are a concern. Because the EHR included a large number of inpatients with NCDs, it was a precise data source for determining the status of and trends in the occurrence of different diseases. To reduce selection bias, more representative hospitals from each of the cities must be investigated. Second, because socioeconomic data was absent in the EHRs, we were unable to compare the differences in socioeconomic groups in this study. Third, because few longitudinal studies examining the spectrum of NCDs among many hospitals' inpatients have been conducted in other areas of China, it was difficult to compare the current findings regarding inpatients' NCDs with those in other parts of China.

CONCLUSIONS

In summary, the spectrum of NCD inpatients from 12 hospitals exhibits the severe NCDs condition and spectrum in eastern coastal China to a certain extent. Specific NCDs rapidly increased in women and the younger population over the studied 12-year period, underscoring the importance of healthcare policies or guidelines for developing countries or regions such as China. However, due to the limited generalisability and reliability of this study, stronger support must be obtained through future studies on the spectrum of inpatients' NCDs in eastern coastal China and other regions.

Abbreviations

Non-communicable diseases: NCDs

GDP: Gross domestic product

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Availability of data and materials

All relevant data are available in the Figshare database under the DOI:

https://figshare.com/s/f79b2b4e686d1d477527

Authors' contributions

Conceived and designed the experiments: DHY, JWS and ZXW. Analysed the data: JWS, HZZ and YL. Contributed reagents/materials/analysis tools: YL, BZ, YP, BW and PFS. Wrote the paper: DHY and JWS.

Competing interests

The authors have declared that they have no competing interests.

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Table 1Demographic Characteristics of Inpatients with NCDs

Variable	Classification	N	%
Gender	Male	954612	50.05
	Female	952872	49.95
Age	0-10	1008	0.05
(years)	11-20	14688	0.77
	21-30	47484	2.49
	31-40	70164	3.68
	41-50	219060	11.48
	51-60	320172	16.79
	61-70	268176	14.06
	71-80	523452	27.44
	>80	443280	23.24
Year of admission	2003	110796	5.81
	2004	126744	6.64
	2005	127704	6.69
	2006	135972	7.13
	2007	141780	7.43
	2008	145728	7.64
	2009	155220	8.14
	2010	157500	8.26
	2011	171060	8.97
	2012	191004	10.01
	2013	209100	10.96
	2014	234876	12.31
	Total	1907484	100.00

Table 2 Ranking of the Most Common NCDs by Group

Variable	First		Second		Third		Fourth		Fifth	
	Disease	N(%)	Disease	N(%)	Disease	N(%)	Disease	N(%)	Disease	N(%)
Gender										
Male	Cerebral infarction	120396(12.61)	Coronary heart disease	66216(6.94)	Hypertension	57708(6.05)	Chronic obstructive pulmonary disease	53904(5.65)	Chronic bronchitis	45252(4.74)
Female	Cerebral infarction	91776(9.63)	Hypertension	65136(6.84)	Uterine fibroid	39564(4.15)	Coronary heart disease	31188(3.27)	Chronic bronchitis	25776(2.71)
Age(years)										
0-10	Chronic tonsillitis	264(16.19)	Redundant prepuce	144(14.29)	Adenoid vegetation	72(7.14)	Adenoidal hypertrophy	48(4.76)	Tonsil hypertrophy	24(2.38)
11-20	Redundant prepuce	2064(14.05)	Benign neoplasm of breast	996(6.78)	Spontaneous pneumothorax	648(4.41)	Chronic tonsillitis	552(3.76)	Respiratory failure	444(3.02)
21-30	Redundant prepuce	4704(9.91)	Benign neoplasm of breast	2448(7.51)	Ovarian cyst	3564(5.16)	Ureteral calculi	1632(3.44)	Chronic tonsillitis	1032(2.17)
31-40	Uterine fibroid	5484(7.82)	Ovarian cyst	3156(4.50)	Endometrial polyp	2844(4.05)	Ureteral calculi	2556(3.64)	Hyperplasia of mammary glands	2268(3.23)
41-50	Uterine fibroid	25644(11.71)	Endometrial hyperplasia	9408(4.29)	Hyperplasia of mammary glands	8052(3.68)	Endometrial polyp	7404(3.38)	Ureteral calculi	5640(2.57)
51-60	Cerebral infarction	23124(7.22)	Coronary heart disease	14016(4.38)	Hypertension	12144(3.79)	Ureteral calculi	8364(2.61)	Cerebral haemorrhage	6636(2.07)
61-70	Cerebral infarction	29508(11.00)	Coronary heart disease	14016(6.30)	Hypertension	13668(5.10)	Vertebrobasilar insufficiency	6480(2.42)	Diabetes	5640(2.10)
71-80	Cerebral infarction	75972(14.51)	Hypertension	45612(8.71)	Coronary heart disease	38808(7.41)	Chronic bronchitis	30720(5.87)	Chronic obstructive pulmonary disease	25536(4.88)
>80	Cerebral infarction	46560(17.58)	Hypertension	31488(10.50)	Coronary heart disease	77928(8.51)	Chronic obstructive pulmonary disease	36216(8.17)	Chronic bronchitis	37728(7.10)

Table 3 Distribution of Non-communicable Diseases from 2003 to 2014 in the Total Sample (%)

Disorder	2003 N =110796	2004 N =126744	2005 N =127704	2006 N =135972	2007 N =141780	2008 N =145728	2009 N =155220	2010 N =157500	2011 N =171060	2012 N =191004	2013 N =209100	2014 N =234876	Z	P-value	Trend
Cancer	11.57	10.16	8.15	9.33	8.37	8.28	7.24	7.18	7.19	7.80	6.12	5.78	-20.525	<0.001	↓↓↓
Other neoplasms	6.63	8.05	7.43	7.41	5.58	4.55	5.54	4.45	4.67	4.55	4.36	4.01	-20.527	<0.001	↓↓↓
Cardiovascular and circulatory diseases	28.30	29.38	29.18	29.52	31.43	33.33	34.68	36.21	35.64	35.65	34.87	34.60	19.861	<0.001	↑↑↑
Chronic respiratory diseases	13.43	13.46	13.85	12.98	13.50	12.85	12.52	12.45	11.27	10.89	9.37	9.40	-18.290	<0.001	↓↓↓
Diabetes and blood and endocrine diseases	1.36	1.43	1.25	1.26	1.44	1.46	1.35	1.75	1.55	3.67	6.47	6.74	41.268	<0.001	↑↑↑
Digestive diseases	10.54	11.57	10.98	11.24	9.58	10.56	10.00	10.81	10.12	9.67	10.00	10.98	-2.757	0.003	↓↓
Mental and behavioural disorders	0.17	0.08	0.23	0.19	0.19	0.13	0.26	0.25	0.16	0.12	0.36	0.25	3.130	0.001	↑↑
Musculoskeletal disorders	5.44	4.74	4.85	4.64	5.18	4.48	4.58	3.86	4.67	4.54	5.80	6.23	4.668	<0.001	↑↑↑
Urogenital diseases	14.97	13.24	15.95	14.93	15.68	14.65	13.29	13.12	15.34	14.81	13.83	12.72	-5.329	<0.001	↓↓↓
Neurological disorders	2.25	3.78	4.35	3.96	4.58	5.34	5.33	4.97	4.83	3.49	4.13	4.36	3.915	<0.001	↑↑↑
Sensory organ diseases	4.14	3.20	2.69	3.15	3.50	2.97	3.64	3.18	2.84	3.26	3.02	3.15	-2.403	0.008	↓↓
Congenital anomalies	0.40	0.44	0.28	0.38	0.37	0.26	0.49	0.41	0.32	0.28	0.60	0.63	3.750	<0.001	↑↑↑
Skin and subcutaneous disease	0.80	0.47	0.82	0.99	0.59	1.14	1.06	1.35	1.38	1.26	1.08	1.15	7.294	<0.001	↑↑↑

↓↓: P<0.01, negative trend; ↓↓↓: P<0.001, negative trend;↑↑: P<0.01, positive trend;↑↑↑: P<0.001, positive trend.

Fig.1 Distribution of non-communicable diseases by gender

0: cancer, 1: other neoplasms, 2: cardiovascular and circulatory diseases, 3: chronic respiratory diseases, 4: diabetes and blood and endocrine diseases, 5: digestive diseases, 6: mental and behavioural disorders, 7: musculoskeletal disorders, 8: urogenital diseases, 9: neurological disorders, 10: sensory organ diseases, 11: congenital anomalies, 12: skin and subcutaneous diseases

↓: P<0.05, negative trend; ↓↓: P<0.01, negative trend; ↓↓↓: P<0.001, negative trend;

↑: P<0.05,positive trend; ↑↑: P<0.01,positive trend;↑↑↑: P<0.001,positive trend.

Fig. 2 Distribution of non-communicable diseases by age

0: cancer, 1: other neoplasms, 2: cardiovascular and circulatory diseases, 3: chronic respiratory diseases, 4: diabetes and blood and endocrine diseases, 5: digestive diseases, 6: mental and behavioural disorders, 7: musculoskeletal disorders, 8: urogenital diseases, 9: neurological disorders, 10: sensory organ diseases, 11: congenital anomalies, 12: skin and subcutaneous diseases

↓: P<0.05,negative trend; ↓↓: P<0.01, negative trend; ↓↓↓: P<0.001,negative trend;

↑: P<0.05,positive trend; ↑↑: P<0.01,positive trend;↑↑↑: P<0.001,positive trend.

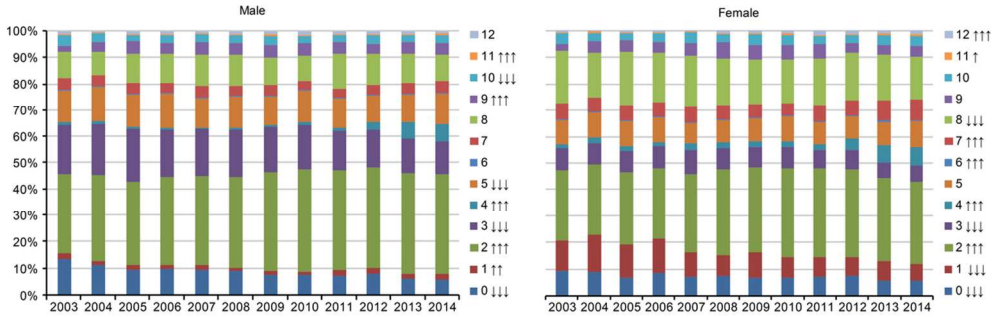

Fig.1 Distribution of non-communicable diseases by gender
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↓: P<0.05, negative trend; ↓↓: P<0.01, negative trend; ↓↓↓: P<0.001, negative trend;
↑: P<0.05,positive trend; ↑↑: P<0.01,positive trend;↑↑↑: P<0.001,positive trend.

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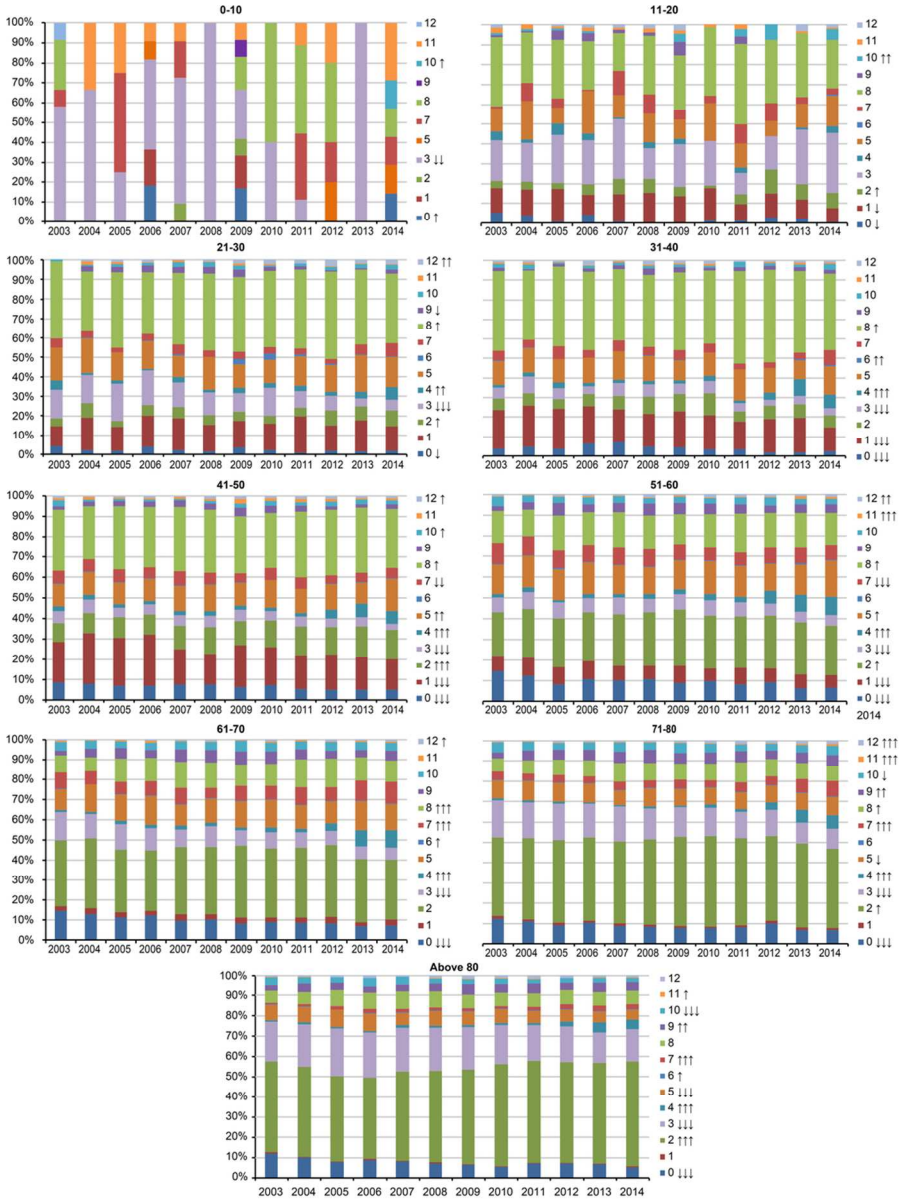

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↓: P<0.05,negative trend;↓↓: P<0.01, negative trend;↓↓↓: P<0.001,negative trend;
↑: P<0.05,positive trend; ↑↑: P<0.01,positive trend;↑↑↑: P<0.001,positive trend.

48x64mm (600 x 600 DPI)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5-6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7-8
Bias	9	Describe any efforts to address potential sources of bias	7
Study size	10	Explain how the study size was arrived at	5-6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7-8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7-8
		(*b*) Describe any methods used to examine subgroups and interactions	7-8
		(*c*) Explain how missing data were addressed	7-8
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	7-8
		(*e*) Describe any sensitivity analyses	7-8
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	N/A
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8
		(b) Indicate number of participants with missing data for each variable of interest	N/A
Outcome data	15*	Report numbers of outcome events or summary measures	8-11
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	N/A
		(*b*) Report category boundaries when continuous variables were categorized	N/A
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
Discussion			
Key results	18	Summarise key results with reference to study objectives	11-12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	15
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12-15
Generalisability	21	Discuss the generalisability (external validity) of the study results	15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	16

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Identifying patterns of non-communicable diseases in developed eastern coastal China: A longitudinal study of electronic health records from 12 public hospitals

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Identifying patterns of non-communicable diseases in developed eastern coastal China: A longitudinal study of electronic health records from 12 public hospitals

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Identifying patterns of non-communicable diseases in developed eastern coastal China: A longitudinal study of electronic health records from12 public hospitals

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ABSTRACT

Objective: Few studies have examined the spectrum and trends of non-communicable diseases (NCDs) in inpatients in eastern coastal China, which is transforming from an industrial economy to a service-oriented economy and is the most economically developed region in the country. This study aimed to dynamically elucidate the spectrum and characteristics of severe NCDs in eastern coastal China by analysing patients' longitudinal electronic health records (EHRs).

Setting: To monitor the spectrum of NCDs dynamically, we extracted the EHR data from 12 general tertiary hospitals in eastern coastal China from 2003 to 2014. The rankings of and trends in the proportions of different NCDs presented by inpatients in different gender and age groups were calculated and analysed.

Participants: We obtained a total sample of 1,907,484 inpatients with NCDs from

2003 to 2014, 50.05% of whom were male and 81.53% were aged 50 years or older.

Results: There was an increase in the number of total NCD inpatients in eastern coastal China from 2003 to 2014. However, the proportion of chronic respiratory diseases and cancer inpatients decreased over the 12-year period. Compared with men, women displayed a significant increase in the proportion of mental and behavioural disorders (P<0.001) over time. Additionally, digestive diseases and sensory organ diseases significantly decreased among men, but not women. The older group accounted for a larger and growing proportion of the NCD inpatients, and the most common conditions in this group were cerebral infarctions, coronary heart disease and hypertension. In addition, the proportion of 21- to 50-year-old inpatients with diabetes, blood diseases or endocrine diseases skyrocketed from 2003 to 2014 (P<0.001).

Conclusions: The burden of inpatients' NCDs increased rapidly, particularly among women and younger people. The NCD spectrum observed in eastern coastal China is a good source of evidence for developing prevention guides for regions experiencing transition.

Keywords: Non-communicable diseases; Electronic Health Record; Eastern coastal China; Health policy

Strengths and limitations

- The concept of using longitudinal EHRs to document the proportion of NCD admissions in eastern coastal China hospitals can provide a reasonably simple and precise method of examining NCD trends over time.

- This evidence provides a good foundation for the development of NCD prevention guides or policies for similar developing regions that are undergoing or will undergo an economic transformation.
- The generalisability and reliability of the findings of this study are a concern, and more hospitals from other parts of China should be included in future studies to make a persuasive comparison.

INTRODUCTION

In recent years, an epidemiological shift in morbidity and mortality from infectious diseases and malnutrition to non-communicable diseases(NCDs) has occurred in many countries, including China[1-3]. NCDs have become the major causes of death in China and globally. According to the 2012 WHO data repository, 87% of deaths in China were associated with NCDs[1]. The Global Burden of Disease Study(GBD) revealed that of the 8.3 million deaths in China in 2010, 7.0 million resulted from NCDs[3]. Stroke, ischaemic heart disease, cancers, and chronic obstructive pulmonary disease are now the leading causes of premature death in China, and the burden of these diseases is substantial[4].

Previous research on the epidemiological patterns of NCDs in China has primarily focused on the entire nation or cross-sectional studies of specific regions[1-6]. However, both the WHO and the GBD have acknowledged that a national analysis conducted in a country as large and diverse as China can mask substantial variations

in key outcomes[3,5]. In addition, few studies have examined the NCD spectrum in inpatients, which can reflect the severe state of NCDs. In this study, we conducted a longitudinal study of NCD patterns in five provinces in eastern coastal China: Shandong, Jiangsu, Zhejiang, Shanghai and Guangdong provinces. Geographically speaking, these provinces are located in the three most productive and dynamic regions of China: the Bohai Sea, the Yangtze River Delta and the Pearl River Delta. The gross regional domestic product in these five provinces accounts for approximately half that of the 32 provinces/autonomous regions/municipalities in China. These provinces' gross domestic product(GDP) per capita far exceeded the average value in China from 2005 to 2014[7] and was similar to the GDP of other developed countries in Asia. Moreover, since the 2000s, this region has experienced dramatic changes in both the economic and health sectors[8]. According to the Health Statistics Yearbook, in 2015, the average life expectancy in eastern coastal China was around 78 years old, which is greater than the national average of approximately 76 years old[7]. Due to the rapid urbanisation, economic development and population ageing in eastern coastal China, NCDs and disabilities are becoming more prevalent[1,3], and the spectrum of inpatients' diseases in this area is speculated to largely differ from that in other regions of China. More specific guidelines for preventing and curing NCDs that are tailored to the disease patterns observed in eastern coastal China must be developed.

In exploring disease patterns, particularly in longitudinal studies based on a large sample, second-hand data may be regarded as a good source. In particular, data from

hospitals' electronic health record(EHR) systems have unique advantages. For instance, Upshur et al. applied time series methods to a population-based retrospective cohort for the 52 most common causes of hospital admissions in the province of Ontario from 1988 to 2001 and showed that hospital admissions displayed systematic patterns that are understandable, predictable, and reasonably accurate[9]. Using data from the admission and discharge/death register, Sani et al.[10] conducted a three-year review of mortality patterns. Their result supported the emerging trend of a combined burden of communicable diseases and NCDs. In China, disease surveillance is conducted by the National Disease Surveillance Points System, which was founded in 1978; however, this system reports primarily on communicable diseases and reports on only a small subset of NCDs, such as cancer[11,12]. Given these factors, the current study used the hospital-based EHR system as a data source. This relatively new database compiles clinical information from a large number of patients in a computationally accessible form. The EHR system provides us with a unique opportunity to elucidate the relatively severe NCD epidemiology and includes a diverse array of NCDs[13].

The aim of this study was to dynamically elucidate the spectrum and characteristics of severe NCDs in eastern coastal China by analysing hospitals' longitudinal EHR data. The results can provide insight into the aetiology of NCDs and aid in the development of evidence-based clinical guidelines for preventing and curing NCDs. In addition, the distribution of NCDs in eastern coastal China can inform the development of clinical guidelines for NCDs in other regions or countries in transition.

METHODS

Study design and data collection

Longitudinal data(2003-2014) on NCDs were extracted from the EHR systems of 12 general tertiary hospitals in Shandong(2 hospitals), Jiangsu(2 hospitals), Zhejiang(2 hospitals), Shanghai(3 hospitals) and Guangdong Provinces(3 hospitals).

A multistage sample was obtained. To obtain a representative sample, when choosing the sites, we first selected 3 cities that represented high, middle, and low socioeconomic statuses, as defined by GDP level, in each of the 5 provinces. Second, in each city, we selected the largest general tertiary hospital, resulting in 15 sampled hospitals. However, we did not obtain consent from three tertiary hospitals in some cities in Shandong, Jiangsu and Zhejiang Provinces due to political reasons regarding EHR data collection. In China, EHR data are not openly available but can be obtained from consenting hospitals with the help of health authorities. However, for several reasons, the health authorities cannot support us in the future. Thus, 12 general tertiary hospitals were included in the study. In this study, one hospital in Shandong Province in the low socioeconomic group, one hospital in Jiangsu Province in the middle socioeconomic group, and one hospital in Zhejiang Province in the high group were missing from the dataset. However, due to the distribution of the missing hospitals, it was thought that lack of participation of these hospitals would not influence the final results. In most large cities in China, EHRs have used a uniform version composed of two parts since 2001. The first part contains the patients'

personal information, including their gender, age, identification card number, profession, address, etc. This information is usually provided by the patients or their family. The second part contains the inpatients' hospitalisation information, including their diagnosis code, discharge status, pathologic diagnosis (if possible), operation code (if possible), etc. This information is provided by the patient's physician, which ensures its reliability. In terms of the diagnosis code, each inpatient is coded with an ICD-9 disease code by their physician. In addition, the GBD has well defined categories for NCDs. Therefore, we extracted the inpatients' NCDs using their ICD-9 codes and classified them into different categories.

We selected tertiary hospitals for this study. In China, hospitals are classified into three categories according to their major functions. Although community institutions are intended to serve as gatekeepers, a patient's freedom to select medical facilities and doctors is not restricted by policies or health insurance coverage. Consequently, patients with acute or chronic diseases frequently visit the higher-tier, more sophisticated or specialised, and more expensive hospitals rather than community health centres, and many of the community health centres do not have hospital beds. In addition, their EHR systems are defective and incomplete, limiting the use of the information they contain[14]. Typically, the largest tertiary hospitals see most of the patients discharged in their cities.

Study subjects

In this study, information on inpatients with NCDs was extracted from the 2003-2014

hospital EHR data of each hospital, and only individuals who had been admitted to these hospitals during this period were included. We chose 2003 as the starting point because the first EHR system was formally launched in these hospitals in that year. In our study, the EHR systems of the tertiary hospitals include the admission information of patients who received their first diagnosis of an NCD between 2003 and 2014. We excluded any duplicated patients by searching and analysing their Identification Card number in the EHRs. In addition, because these hospitals may also attract patients from other districts or provinces, the inclusion criteria stipulated that participants must have a fixed address in the relevant region, regardless of whether they were registered or nonregistered residents. After excluding non-residents, NCD information for a total of 1,907,484 inpatients was stripped of identifying information and extracted from the hospitals' EHR systems. These patients were admitted to a variety of hospital divisions, and according to the ICD-9 and GBD NCD classification, we extracted the NCD patients from all of the inpatients and classified them into various disease groups based on their first-list diagnosis. The final data set included the residents' basic demographic information(gender and age) and the presence of chronic diseases(disease system/category, disorder and year of admission). Because there was no significant difference in disease spectrum between regions with high, middle and low socioeconomic status within eastern coastal China, we did not include region as a factor.

Statistical analysis

All data were analysed by using SAS Software 9.20. Basic descriptive statistics were

used to analyse the inpatients' personal characteristics(gender, age, and year of admission). The NCD systems and the most common disorders within each disease system were ranked according to their relative proportions. The Cochran-Armitage Chi-square test was then used to examine significant increases or decreases in the proportions of NCDs in disease systems across different gender and age groups between 2003 and 2014.

Ethics statement

All research activities were conducted with integrity according to generally accepted ethical principles and were approved by the Ethics Committees of Tongji University(ref: LL-2016-ZRKX-017). This study presented minimal risk of harm to its subjects, and the data were collected anonymously. None of the inpatients' personal information included in the database was available to individuals outside of the research team.

RESULTS

Description of the personal characteristics of inpatients with NCDs

The personal characteristics of the studied population are summarised in Table 1. This population included 1,907,484 inpatients with NCDs, 50.05% of whom were male. Most of these patients were aged 50 years or older(81.53%). Furthermore, the number of inpatients with NCDs increased from 2003 to 2014.

Ranking of the disorders in all NCDs categories within gender and age groups

The ranks and proportions of all NCDs for each gender group are presented in Table 2. Among males, each of the five most common disorders represented more than 4.0% of the total NCDs from 2003 to 2014. The three most frequently occurring disorders among male inpatients were cerebral infarction(12.61%), coronary heart disease(6.94%) and hypertension(6.05%). Similarly, those for women showed that cerebral infarction(9.63%) occurred most frequently. However, hypertension(6.84%) and uterine fibroids(4.15%) were the second and third most frequently occurring NCDs among women, respectively.

Table 2 also shows the ranks of the most frequently occurring disorders across age groups. The older group(>41 years of age) accounted for a larger proportion of NCD inpatients, and the most common conditions in this group were cerebral infarction, coronary heart disease and hypertension. In the 11- to 50-year-old group, urogenital diseases, endocrine diseases and neoplasms including redundant prepuce, benign neoplasm of the breast and endometrial hyperplasia occurred frequently in men and women. In addition, hypertension, chronic obstructive pulmonary disease and diabetes were more common among the elderly than among individuals in the other age groups.

Distribution of NCDs across the different groups from 2003 to 2014

Table 3 shows the changes in the proportions of the 12 NCD categories from 2003 to 2014. A significant decrease in the occurrence of cancer(Z=-20.525, P<0.001), other neoplasms(Z=-20.525, P<0.001), chronic respiratory diseases(Z=-18.290, P<0.001),

urogenital diseases(Z=-5.329, P<0.001) and sensory organ diseases(Z=-2.403, P=0.008) was found. In contrast, the proportions of other NCDs increased to various extents over the 12-year period. Notably, the proportion of patients with diabetes and blood and endocrine diseases increased approximately four-fold(from 1.36% to 6.74%).

As shown in Figure 1, the 12-year NCD percentages recorded in the hospitals varied widely by gender. The percentage of both men and women who were diagnosed with diabetes or blood and endocrine diseases increased substantially. We found a significant increase in mental and behavioural disorders(Z=5.130, P<0.001), and musculoskeletal disorders(Z=6.896, P<0.001) among women but no significant changes among men. Also, it is worth noting that the percentage of men who were diagnosed with digestive diseases(Z=-4.284, P<0.001) and sensory organ diseases(Z=-3.342, P<0.001) reduced significantly from 2003 to 2014, but there was no significant change for women. In addition, although the proportion of cancer and other neoplasms decreased in women, this decrease was less pronounced than that found in men.

Changes in NCDs proportions across age groups were also examined(Figure 2). NCDs were relatively rare among patients aged 10 years or younger, but chronic respiratory diseases occurred most frequently in this group. For 11-20-year-old subjects, sensory organ diseases(Z=3.304, P<0.001) and cardiovascular and circulatory diseases(Z=2.090, P=0.018) occurred more frequently over time. We

noted the proportions of patients with diabetes or blood and endocrine diseases increased in these two groups and in the below 30-year-old group. For the 41- to 50-year-old group, the number of patients diagnosed with cancer decreased significantly but the proportions of patients with cardiovascular, circulatory($Z=7.918$, $P<0.001$) and digestive diseases($Z=3.086$, $P<0.01$) increased to a greater extent than in the younger population. In the ≥50-year-old group, the proportion of patients with diabetes or blood and endocrine diseases increased substantially($P<0.001$).

DISCUSSION

By analysing the EHR information of inpatients with NCDs at 12 hospitals in eastern coastal China, our research team was able to elucidate the severe NCD patterns in a relatively unbiased fashion and to confirm that NCDs displayed regional heterogeneity to some extent. The increase in the number of NCD inpatients in eastern coastal China from 2003 to 2014 may be due to several reasons. First, owning to improvements in economics, health insurance and convenient transportation in China, even people with minor diseases may go to larger hospitals because they are equipped with better devices and doctors and do not adhere to strict referral policies. Second, the increase in the number of severe NCD patients appears to mainly result from the higher pressure, lack of exercise, and increased air pollution, among other factors in rapidly developed cities[14,15], which is consistent with the findings of Allen et al.(2017) who, in a systematic review, showed that NCD behavioural risk factors is well established in high-income countries. For example, high socioeconomic groups were found to be less physically active and to consume more fats, salt, and processed

food than low socioeconomic status individuals[16].

In order of ranks, cardiovascular and circulatory diseases, urogenital diseases, chronic respiratory diseases, and digestive diseases were the most common NCDs in this region. In eastern coastal China, severe cardiovascular and circulatory diseases may occur more frequently because of the greater degree of urbanisation and greater proportion of ageing population in the region[2,3]. Goryakin et al.(2017) studied the contribution of urbanisation to NCDs in 173 countries and found that when shifting from rural to urban areas, the average body mass index (BMI), total cholesterol level and systolic blood pressure, increased[17], demonstrating that high urbanisation increases the occurrence of cardiovascular and circulatory diseases, which is in consistent with this study. In addition, the frequency of urogenital diseases (second) and digestive diseases (fourth) in this region is potentially because of the more rapid pace of modern life, more sedentary lifestyle and longer working hours. In our search of existing studies on inpatients with NCDs, we rarely found this spectrum at the top of the list in other regions[18]. However, interestingly, this study revealed that the proportion of chronic respiratory diseases and cancer inpatients decreased over the 12-year period, in stark contrast to the changes in the incidence observed throughout China[19,20]. Often, previous studies have concluded that the incidence of respiratory diseases is increasing, likely due to ambient air pollution and tobacco use, resulting in tremendous threats to respiratory health[3,21]. This difference may be a result of the data because the reported incidence also includes mild respiratory diseases. However, the opposite trend found in inpatients in eastern coastal China may have also resulted

from this region's transition from a heavy industrial district to a technologically focused area, which has been associated with a substantial reduction in environmental pollution. Moreover, regional public health media campaigns have focused on cancer prevention and the regional government has promoted early screening and the treatment of major cancers since the 2000s, particularly in these developed areas in China where the government can invest more money into public health activities[22], which likely explains the reduced proportion of cancer patients. However, PM 2.5 air pollution, household pollution, tobacco use, residents' insufficient knowledge of NCD prevention, etc. remain persistent risk factors in eastern coastal China and deserve considerable attention[23,24].

Concerning the distribution of NCDs among the different age groups, we found that the older age group accounted for the largest proportion of individuals with NCDs, with cerebral infarction, coronary heart disease and hypertension being the most common conditions. This result is consistent with the epidemiological features of NCDs[25,26] and indicates that these NCDs represent a significant burden on the Chinese government. Interestingly, in addition to the nearly fourfold increase in the proportion of older patients suffering from NCDs such as diabetes or blood and endocrine diseases between 2003 and 2014, the proportion of individuals with these diseases between the ages of 30 and 50 also increased significantly. However, this result could have been due to suboptimal nutrient intake and the high level of psychological pressure on the young population in this fast-paced area, a relationship that warrants further attention.

Additionally, the observation that an increasing proportion of women exhibit severe mental and behavioural disorders may indicate that, currently, women in China are employed in the same fast-paced jobs or roles as men[27]. Furthermore, women are expected to devote more effort to balancing family and work[28,29] in developed areas or cities, which is undoubtedly challenging for them and may induce the onset of these diseases. These factors imply that specific risk factors for frequently occurring NCDs in different gender groups should be monitored in addition to the diseases or groups that are currently monitored and screened for due to their significant burden. Other frequently occurring NCD diseases and a wider population should also be targeted, such as the prevention and screening of digestive diseases in females or increased preventative measures for diabetes and blood, endocrine, cardiovascular and circulatory diseases among the younger and population. In addition, these observations call for an improvement and greater investment in the prevention and control of NCDs by community health institutions, which has lagged even in the economically well-developed eastern coastal regions of China as well as in China as a whole compared with western countries[30]. For instance, community health institutions typically compete with hospitals to attract patients, and only public health physicians (different from general physicians) take the responsibility of providing health education and follow-up visits for NCD patients. According to a survey conducted at a representative community health institution in Shanghai, public health physicians accounted for only 7.94% of total health personnel, and are therefore in great shortage. Undoubtedly, reducing the incidence of NCDs and

improving national health are significant political and public issues for China[31].

Limitations

In this study, there were several limitations. First, the sampled hospitals were the largest hospitals in eastern coastal cities. These cities were selected to increase the sample's representativeness of eastern coastal China. However, the generalisability and reliability of the findings are a concern. Because the EHR included a large number of inpatients with NCDs, it was a precise data source for determining the status of and trends in the occurrence of different diseases. To reduce selection bias, more representative hospitals from each of the cities must be investigated. Second, because socioeconomic data was absent in the EHRs, we were unable to compare the differences in socioeconomic groups in this study. Third, because the period of data collection spanned a long time, there may be some bias related to disease diagnosis caused by changes in policy, as well as changes in the availability of new treatments or therapies. Such changes could have resulted in patients with a given condition in the past becoming more or less likely to be inpatients in the present day. Fourth, because few longitudinal studies examining the spectrum of NCDs among many hospitals' inpatients have been conducted in other areas of China, it was difficult to compare the current findings regarding inpatients' NCDs with those in other parts of China.

CONCLUSIONS

In summary, the spectrum of NCD inpatients from 12 hospitals exhibits the severe

NCDs condition and spectrum in eastern coastal China to a certain extent. Specific NCDs rapidly increased in women and the younger population over the studied 12-year period, underscoring the importance of healthcare policies or guidelines for developing countries or regions such as China. However, due to the limited generalisability and reliability of this study, stronger support must be obtained through future studies on the spectrum of inpatients' NCDs in eastern coastal China and other regions.

Abbreviations

Non-communicable diseases: NCDs

GDP: Gross domestic product

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Availability of data and materials

All relevant data are available in the Figshare database under the DOI: https://figshare.com/s/f79b2b4e686d1d477527

Authors' contributions

Conceived and designed the experiments: DHY, JWS and ZXW. Analysed the data: JWS, HZZ and YL. Contributed reagents/materials/analysis tools: YL, BZ, YP, BW and PFS. Wrote the paper: DHY and JWS.

Competing interests

The authors have declared that they have no competing interests.

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Table 1 Demographic Characteristics of Inpatients with NCDs

Variable	Classification	N	%
Gender	Male	954612	50.05
	Female	952872	49.95
Age	0-10	1008	0.05
(years)	11-20	14688	0.77
	21-30	47484	2.49
	31-40	70164	3.68
	41-50	219060	11.48
	51-60	320172	16.79
	61-70	268176	14.06
	71-80	523452	27.44
	>80	443280	23.24
Year of admission	2003	110796	5.81
	2004	126744	6.64
	2005	127704	6.69
	2006	135972	7.13
	2007	141780	7.43
	2008	145728	7.64
	2009	155220	8.14
	2010	157500	8.26
	2011	171060	8.97
	2012	191004	10.01
	2013	209100	10.96
	2014	234876	12.31
	Total	1907484	100.00

Table 2 Ranking of the Most Common NCDs by Group

Variable	First		Second		Third		Fourth		Fifth	
	Disease	N(%)	Disease	N(%)	Disease	N(%)	Disease	N(%)	Disease	N(%)
Gender										
Male	Cerebral infarction	120396(12.61)	Coronary heart disease	66216(6.94)	Hypertension	57708(6.05)	Chronic obstructive pulmonary disease	53904(5.65)	Chronic bronchitis	45252(4.74)
Female	Cerebral infarction	91776(9.63)	Hypertension	65136(6.84)	Uterine fibroid	39564(4.15)	Coronary heart disease	31188(3.27)	Chronic bronchitis	25776(2.71)
Age(years)										
0-10	Chronic tonsillitis	264(16.19)	Redundant prepuce	144(14.29)	Adenoid vegetation	72(7.14)	Adenoidal hypertrophy	48(4.76)	Tonsil hypertrophy	24(2.38)
11-20	Redundant prepuce	2064(14.05)	Benign neoplasm of breast	996(6.78)	Spontaneous pneumothorax	648(4.41)	Chronic tonsillitis	552(3.76)	Respiratory failure	444(3.02)
21-30	Redundant prepuce	4704(9.91)	Benign neoplasm of breast	2448(7.51)	Ovarian cyst	3564(5.16)	Ureteral calculi	1632(3.44)	Chronic tonsillitis	1032(2.17)
31-40	Uterine fibroid	5484(7.82)	Ovarian cyst	3156(4.50)	Endometrial polyp	2844(4.05)	Ureteral calculi	2556(3.64)	Hyperplasia of mammary glands	2268(3.23)
41-50	Uterine fibroid	25644(11.71)	Endometrial hyperplasia	9408(4.29)	Hyperplasia of mammary glands	8052(3.68)	Endometrial polyp	7404(3.38)	Ureteral calculi	5640(2.57)
51-60	Cerebral infarction	23124(7.22)	Coronary heart disease	14016(4.38)	Hypertension	12144(3.79)	Ureteral calculi	8364(2.61)	Cerebral haemorrhage	6636(2.07)
61-70	Cerebral infarction	29508(11.00)	Coronary heart disease	14016(6.30)	Hypertension	13668(5.10)	Vertebrobasilar insufficiency	6480(2.42)	Diabetes	5640(2.10)
71-80	Cerebral infarction	75972(14.51)	Hypertension	45612(8.71)	Coronary heart disease	38808(7.41)	Chronic bronchitis	30720(5.87)	Chronic obstructive pulmonary disease	25536(4.88)
>80	Cerebral infarction	46560(17.58)	Hypertension	31488(10.50)	Coronary heart disease	77928(8.51)	Chronic obstructive pulmonary disease	36216(8.17)	Chronic bronchitis	37728(7.10)

Table 3 Distribution of Non-communicable Diseases from 2003 to 2014 in the Total Sample (%)

Disorder	2003 N =110796	2004 N =126744	2005 N =127704	2006 N =135972	2007 N =141780	2008 N =145728	2009 N =155220	2010 N =157500	2011 N =171060	2012 N =191004	2013 N =209100	2014 N =234876	Z	P-value	Trend
Cancer	11.57	10.16	8.15	9.33	8.37	8.28	7.24	7.18	7.19	7.80	6.12	5.78	-20.525	<0.001	↓↓↓
Other neoplasms	6.63	8.05	7.43	7.41	5.58	4.55	5.54	4.45	4.67	4.55	4.36	4.01	-20.527	<0.001	↓↓↓
Cardiovascular and circulatory diseases	28.30	29.38	29.18	29.52	31.43	33.33	34.68	36.21	35.64	35.65	34.87	34.60	19.861	<0.001	↑↑↑
Chronic respiratory diseases	13.43	13.46	13.85	12.98	13.50	12.85	12.52	12.45	11.27	10.89	9.37	9.40	-18.290	<0.001	↓↓↓
Diabetes and blood and endocrine diseases	1.36	1.43	1.25	1.26	1.44	1.46	1.35	1.75	1.55	3.67	6.47	6.74	41.268	<0.001	↑↑↑
Digestive diseases	10.54	11.57	10.98	11.24	9.58	10.56	10.00	10.81	10.12	9.67	10.00	10.98	-2.757	0.003	↓↓
Mental and behavioural disorders	0.17	0.08	0.23	0.19	0.19	0.13	0.26	0.25	0.16	0.12	0.36	0.25	3.130	0.001	↑↑
Musculoskeletal disorders	5.44	4.74	4.85	4.64	5.18	4.48	4.58	3.86	4.67	4.54	5.80	6.23	4.668	<0.001	↑↑↑
Urogenital diseases	14.97	13.24	15.95	14.93	15.68	14.65	13.29	13.12	15.34	14.81	13.83	12.72	-5.329	<0.001	↓↓↓
Neurological disorders	2.25	3.78	4.35	3.96	4.58	5.34	5.33	4.97	4.83	3.49	4.13	4.36	3.915	<0.001	↑↑↑
Sensory organ diseases	4.14	3.20	2.69	3.15	3.50	2.97	3.64	3.18	2.84	3.26	3.02	3.15	-2.403	0.008	↓↓
Congenital anomalies	0.40	0.44	0.28	0.38	0.37	0.26	0.49	0.41	0.32	0.28	0.60	0.63	3.750	<0.001	↑↑↑
Skin and subcutaneous disease	0.80	0.47	0.82	0.99	0.59	1.14	1.06	1.35	1.38	1.26	1.08	1.15	7.294	<0.001	↑↑↑

↓↓: P<0.01, negative trend; ↓↓↓: P<0.001, negative trend;↑↑: P<0.01, positive trend;↑↑↑: P<0.001, positive trend.

Fig.1 Distribution of non-communicable diseases by gender

0: cancer, 1: other neoplasms, 2: cardiovascular and circulatory diseases, 3: chronic respiratory diseases, 4: diabetes and blood and endocrine diseases, 5: digestive diseases, 6: mental and behavioural disorders, 7: musculoskeletal disorders, 8: urogenital diseases, 9: neurological disorders, 10: sensory organ diseases, 11: congenital anomalies, 12: skin and subcutaneous diseases

↓: P<0.05, negative trend; ↓↓: P<0.01, negative trend; ↓↓↓: P<0.001, negative trend;

↑: P<0.05, positive trend; ↑↑: P<0.01, positive trend; ↑↑↑: P<0.001, positive trend.

Fig. 2 Distribution of non-communicable diseases by age

0: cancer, 1: other neoplasms, 2: cardiovascular and circulatory diseases, 3: chronic respiratory diseases, 4: diabetes and blood and endocrine diseases, 5: digestive diseases, 6: mental and behavioural disorders, 7: musculoskeletal disorders, 8: urogenital diseases, 9: neurological disorders, 10: sensory organ diseases, 11: congenital anomalies, 12: skin and subcutaneous diseases

↓: P<0.05, negative trend; ↓↓: P<0.01, negative trend; ↓↓↓: P<0.001, negative trend;

↑: P<0.05, positive trend; ↑↑: P<0.01, positive trend; ↑↑↑: P<0.001, positive trend.

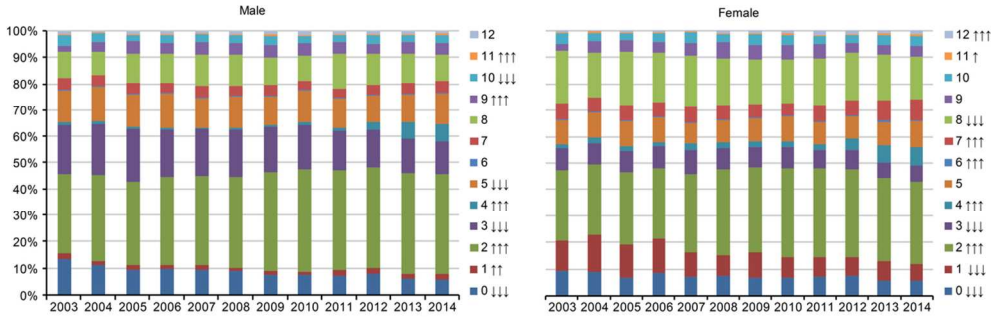

Fig.1 Distribution of non-communicable diseases by gender
0: cancer, 1: other neoplasms, 2: cardiovascular and circulatory diseases, 3: chronic respiratory diseases, 4: diabetes and blood and endocrine diseases, 5: digestive diseases, 6: mental and behavioural disorders, 7: musculoskeletal disorders, 8: urogenital diseases, 9: neurological disorders, 10: sensory organ diseases, 11: congenital anomalies, 12: skin and subcutaneous diseases
↓: P<0.05, negative trend; ↓↓: P<0.01, negative trend; ↓↓↓: P<0.001, negative trend;
↑: P<0.05,positive trend; ↑↑: P<0.01,positive trend;↑↑↑: P<0.001,positive trend.

55x17mm (600 x 600 DPI)

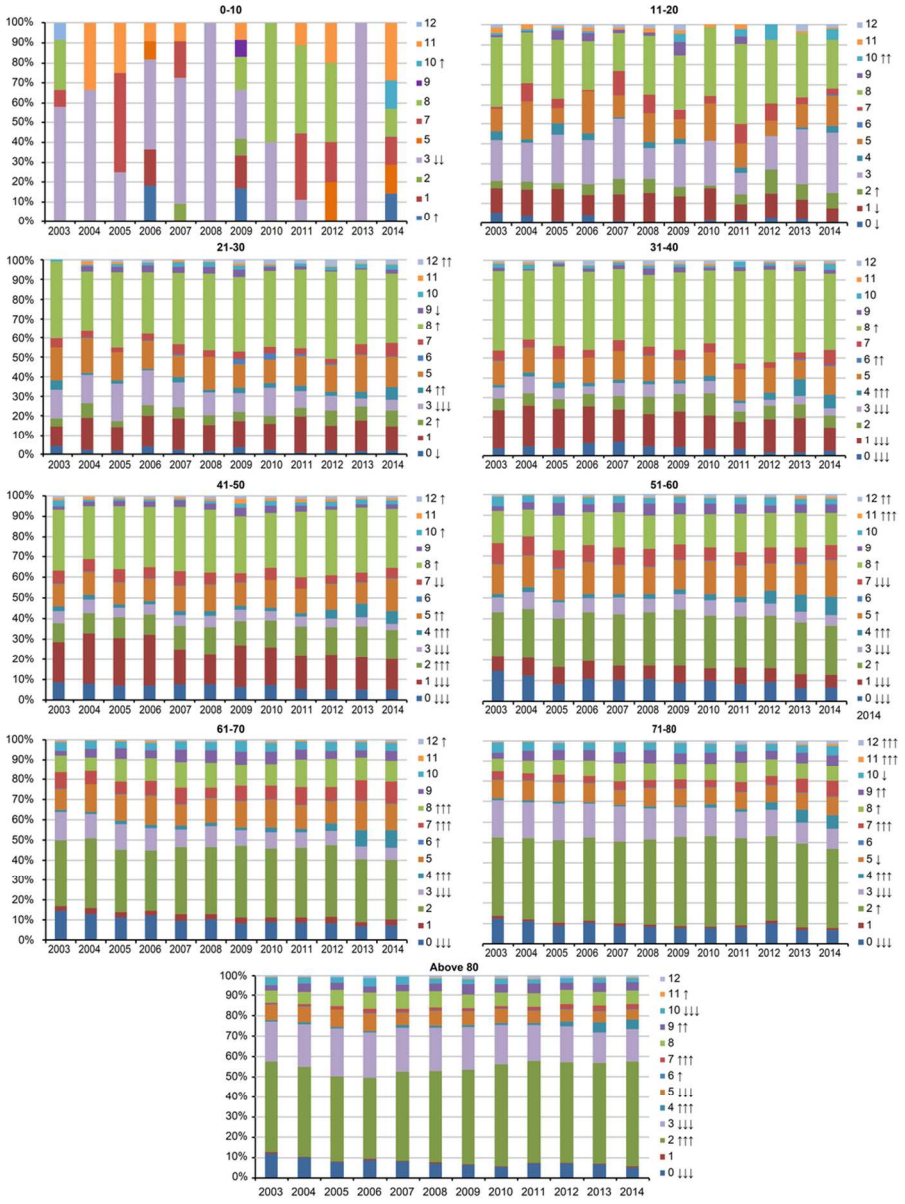

Fig. 2 Distribution of non-communicable diseases by age
0: cancer, 1: other neoplasms, 2: cardiovascular and circulatory diseases, 3: chronic respiratory diseases, 4: diabetes and blood and endocrine diseases, 5: digestive diseases, 6: mental and behavioural disorders, 7: musculoskeletal disorders, 8: urogenital diseases, 9: neurological disorders, 10: sensory organ diseases, 11: congenital anomalies, 12: skin and subcutaneous diseases
↓: P<0.05,negative trend;↓↓: P<0.01, negative trend;↓↓↓: P<0.001,negative trend;
↑: P<0.05,positive trend; ↑↑: P<0.01,positive trend;↑↑↑: P<0.001,positive trend.

48x64mm (600 x 600 DPI)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5-6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7-8
Bias	9	Describe any efforts to address potential sources of bias	7
Study size	10	Explain how the study size was arrived at	5-6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7-8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7-8
		(*b*) Describe any methods used to examine subgroups and interactions	7-8
		(*c*) Explain how missing data were addressed	7-8
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	7-8
		(*e*) Describe any sensitivity analyses	7-8
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	N/A
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8
		(b) Indicate number of participants with missing data for each variable of interest	N/A
Outcome data	15*	Report numbers of outcome events or summary measures	8-11
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	N/A
		(*b*) Report category boundaries when continuous variables were categorized	N/A
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
Discussion			
Key results	18	Summarise key results with reference to study objectives	11-12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	15
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12-15
Generalisability	21	Discuss the generalisability (external validity) of the study results	15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	16

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.