Geographical and Socioeconomic Disparity Analysis – An Empirical Study of Hypertension and Its Comorbidities in China

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Abstract

As one of the most prevalent chronic diseases, hypertension is often a long-term economic burden to patients and public healthcare system. Although hypertension was well studied for its prevalence, comorbidities, and treatment, patient's geographical and socioeconomic disparity has rarely been considered. People from different regions are likely to have different diet and life styles which are important for developing hypertension.

We investigated the correlation of the prevalence of hypertension and three comorbidities with various geographical and socioeconomic factors. From 29 hospitals across China, we collected a large sample of electronic medical records. Patient's gender, age, income level, hospital class, and geographical zone were chosen as risk factors. A univariate analysis showed strong correlations between those risk factors and the disease prevalence. Policy makers can benefit from our findings to identify at-risk hypertensive patients with different socioeconomic characteristics in different geographical regions, and thus allocate medical resources more effectively.

1. Introduction

Hypertension has been proved a major threat to human being's health in lots of countries. China also experienced an increasing trend in the prevalence of hypertension in the past decade [6, 14]. As a chronic disease, the treatment of hypertension often leads to a long-time economic burden to patients, health insurance providers, and various levels of public healthcare systems. Therefore identifying patients at-risk as early as possible is critical to prevent the disease development and reduce the financial obligation for all stakeholders.

Lots of research effort has been explored in investigating possible risk factors of hypertension, i.e. patient's gender, age, education level, occupation, tobacco usage, and obesity, etc [5, 15, 17]. Besides the investigation in hypertension itself, recent studies showed that analyzing hypertension's comorbid diseases might also reveal some underlying patterns of the prevalence of hypertension [7]. In China, several researchers have analyzed the prevalence, etiology, treatment, and economic burden associated with hypertension and its comorbidities [6, 8, 10-13, 24, 25, 27-29]. The hazards, importance, and risk factors of the comorbidities of hypertension have also been studied [2-5, 9, 18-20, 29].

Despite informative results reported by the previous research, most studies on hypertension and its comorbidities were based on data from confined geographical regions [21]. However findings obtained from one region is hardly applicable to another due to the large population and vast geographical disparity in China. People in different regions tend to have quite different diet, socioeconomic characteristics, life styles, and work schedules because of China's imbalanced economic development. Since diet and life styles play an important role in the pathogenesis of hypertension, studying the geographical and socioeconomic disparity of Chinese population will be extremely helpful to understand the imbalanced disease prevalence in various geographical areas.

In this study, we adopted an empirical approach to analyze

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the correlation of the prevalence of hypertension and some of its comorbidities with several geographical and socioeconomic dimensions. Specifically we collected a large sample of electronic medical records from 29 hospitals in 29 different cities across China. Using the large data set, we focused on not only hypertension, but three highly prevalent comorbidities, namely diabetes mellitus [1, 30], hyperlipidemia [22, 23], and coronary heart disease [16, 22]. Those three comorbid diseases were chosen because they too are long-term economic burdens due to their chronic nature and high prevalence in hypertensive patients.

We then performed a Univariate Analysis to demonstrate that geographical and socioeconomic disparity was strongly correlated to the prevalence of hypertension and the three comorbidities. We also indicated important risk factors for patients with different socioeconomic nature and in different geographical areas in China. Our work can be leveraged by public health decision makers to identify at-risk patients with specific geographical and socioeconomic characteristics, and thus to allocate medical resources more wisely and effectively to improve hypertension prevention.

2. Method

2.1. Data collection

The Electronic Medical Records (EMR) being analyzed in this study were obtained from a national-level public health information system in China. We carefully selected 29 hospitals in 29 different cities from a variety of geographical zones in China. Those hospitals were chosen due to the quality of the EMRs and the representativeness of different regions.

To esteem patient's privacy, it is usually extremely hard to obtain EMR from medical service providers. In our study, the data provider is a national organization that stores and regulates patient data from hospitals across China. Patient's identification was masked before we can access the data set. We were only allowed to access the data set and perform all data analysis on a specific computer in an isolated and monitored room at the data provider's facility.

Another challenge of performing our study was to consolidate data from different hospitals. Since disease diagnosis was typed using free text, different physicians might choose to use slightly different terms to record his/her diagnosis. Before we could perform data analysis, we spent a great deal of time on data cleaning to standardize data records.

All records were collected from January 1, 2011, to December 31, 2013, while patients were seeing a doctor in hospital. Patient's personal and medical information was collected for diagnosis purpose at the time. Data was collected by onsite physicians, summarized by trained medical staff, and reviewed by several levels of authorization units before the data was submitted to the national public health information system. Thus the information included in the EMRs should be highly reliable and objective. However since the data set that we utilized in this study only contained 3-year time scope, longitudinal study is hardly feasible, especially for the study of chronic diseases.

In total, 2,122,703 hypertensive outpatients were found out of all the EMRs in the data set. In those hypertensive outpatients, patients who were also diagnosed with diabetes mellitus, hyperlipidemia, or coronary heart disease were particularly interesting to our study for computing the prevalence of comorbidities.

Each EMR contained patient's information, i.e. date of treatment, gender, age, and diagnosis, etc., as well as hospital's information such as hospital class and location, etc. Unfortunately the data set lacked some important dimensions such as patient's test results and symptoms. Thus we could not retrospectively monitor the details of diagnostic procedure and assure the standardization of data collection process. On the other hand, in China, all medical schools and almost all high-classed hospitals are public and are closely regulated by the central government. The diagnostic procedures for common diseases like hypertension and the three comorbidities in our study are highly standardized in reputable hospitals [26]. However, we did take into consideration of the variation in doctor's personal abilities. To assure the data quality, we purposely excluded data collected from Tier-1 hospitals which are usually small community hospitals.

2.2. Risk factors

In order to analyze the disparity of disease prevalence, we investigated the following geographical and socioeconomic dimensions as possible risk factors: patient's gender, age, income level, hospital class, and zone type.

WHO criteria (http://www.who.int/topics/ageing/en/) was adopted to categorize patient's age group. Specifically we defined people aged 0-44 as young group, 45-59 as middle-aged group, and ≥60 as elderly group.

Patient's income level was defined as the average income of the city where the patient resided. Both city average income and national average income were based on the published source, "Per Capita Disposable Income of Urban Households (Yuan)" 2011-2013 (http://www.stats.gov.cn/). A patient was categorized into one of two groups depending on whether his city average income was higher than the national average level or not.

Hospital class in China recognizes a hospital's quality and

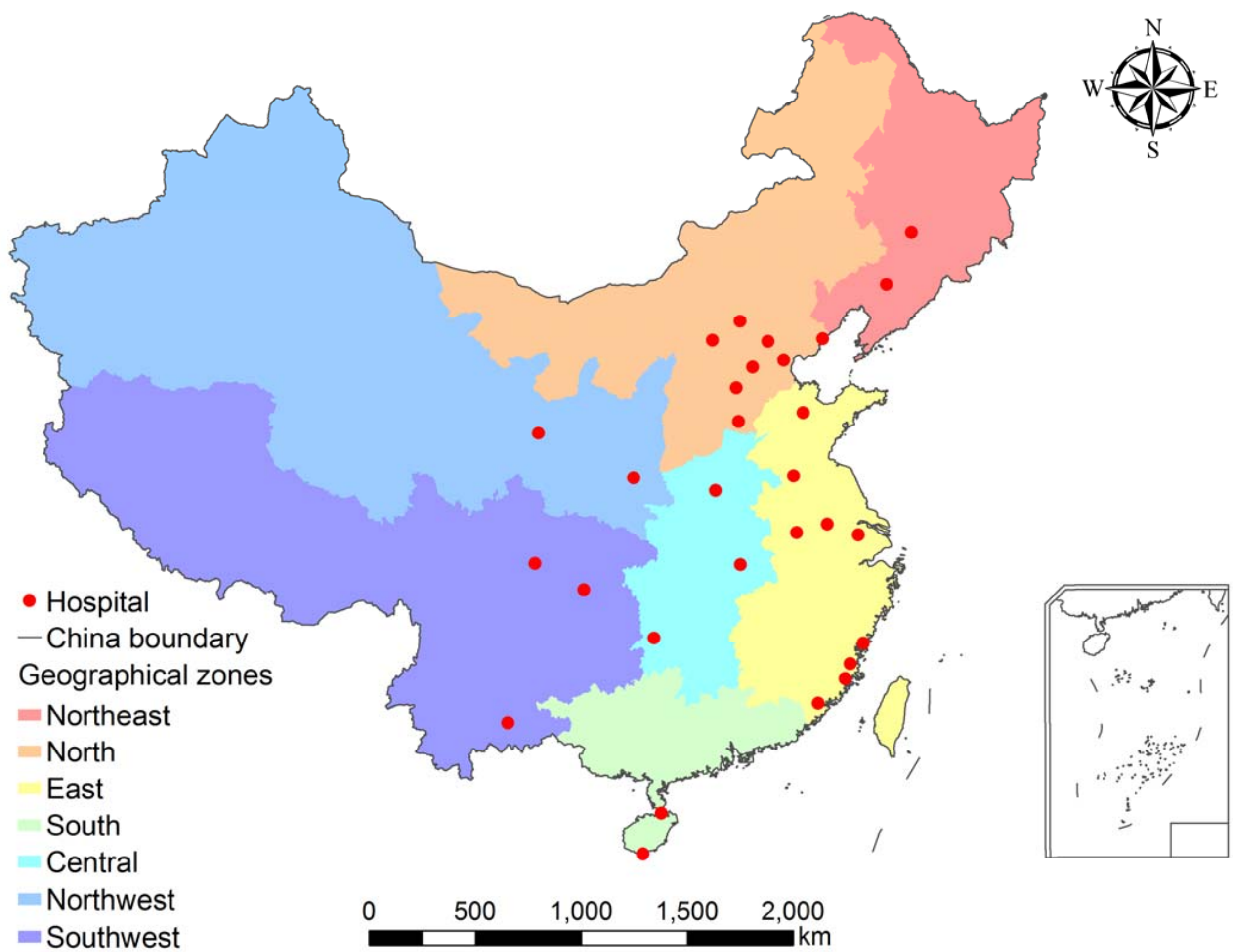

Figure 1. Geographical zones showing the cities where the 29 hospitals were located. Generated by ESRI ArcMap v10.1

capacity of medical services being provided. The current Chinese healthcare policy categorizes Chinese hospitals into 3 tiers depending the hospital's inpatient bed count. Tier 3 hospitals should have more than 500 inpatient beds, Tier 2 between 100 and 500, and Tier 1 less than 100. Furthermore, based on the quality of medical services, infrastructure, and management efficiency, hospitals in each tier are further categorized into 3 subsidiary levels, A, B, and C, with A being the highest and C the lowest. Thus 3A hospitals are generally considered the best hospitals in China and usually treat large number of patients. In our study, the 29 hospitals that we obtained data from involved five classes, namely 3A, 3B, 3C, 2A, and 2C.

The 29 hospitals are located in 29 different cities in China. Those hospitals are usually the best or one of the best hospitals in that city, which implies that they are the popular choices when the local population are seeking for medical services. However we do realize it may not be sufficiently persuasive with data of only one hospital from each city. In the future, we intend to include more hospitals from each city. At this stage, we will not claim any city-level patterns. Instead, based on the hospital location, we categorized those 29 hospitals into 7 geographical zones, namely Northeast, North, East, South, Central, Northwest, and Southwest of China. We will then study disease distribution in each geographical zone. Figure 1 showed the cities and the geographical zones that those hospitals are located.

2.3. Study design

Based on the risk factor definitions in the previous section, we considered five dimensions of risk factors, namely, gender, age, income level, hospital class, and hospital zone type. Within each dimension, several patient groups were defined. From the EMRs that we obtained, each hypertensive patient was categorized into one and exactly one group in each dimension. For example, when a 30-year old male hypertensive patient visited a 3A hospital in Beijing, that patient would be categorized into Male group, Young (0-44) group, Income higher than national average group, 3A group, and North group. Then the count of hypertension prevalence in each one of those five groups would have an increment of one. If that patient also happened to be diagnosed with hyperlipidemia, then the count of hypertension and its comorbidity hyperlipidemia would also have an increment of one in all those five groups. Using that design, we computed the occurrences of hypertension and the three comorbidities in all groups for all five dimensions. The results were exhibited in Table 1 which showed an overview of prevalence of each disease in each group of each risk factor dimension.

Within a specific group i of a specific risk factor dimension, the total number of hypertensive patients was denoted as H_i. In group i, the total number of hypertensive patients with a comorbid disease j was represented by C_{ij}. We then defined the Detection Rate of comorbidity j in group i, DR_{ij}, as follows.

$$DR_{ij} = C_{ij} / H_i$$

Comorbidity detection rate was useful to measure the likelihood of coexistence of hypertension and its comorbidity. Table 2 listed the detection rate values for the three previously mentioned comorbidities in all groups.

To further investigate the correlation of disease prevalence with the risk factors, we performed a Univariate Analysis using SPSS for WINDOWS (version 21.0). In every risk factor dimension, one group was selected as the reference with regard to other groups in that dimension. Specifically, the reference groups were Female, Young (0-44), Income lower than national average, 2C Hospital, and Northeast Zone.

All categorical variables used in the study were coded as dummy variables, namely, gender (male = 1, female = 0); age (45-59 = 1, 60+ = 2, 0-44 = 0); the city average of per capita disposable income of urban households during 2011-2013 (higher than national average = 1, lower than national average = 0); hospital class (3A = 1, 3B = 2, 3C = 3, 2A = 4, 2C = 0); zone type (North = 1, East = 2, South = 3, Central = 4, Northwest = 5, Southwest = 6, Northeast = 0). Odd ratios (OR) and 95% confidence intervals (CI) were calculated. P value < 0.05 was considered statistically significant. Table 3 concluded the Univariate Analysis result.

3. Result and discussion

3.1. Disease distribution

The overview of disease occurrence distribution of hypertension and three important comorbidities, namely diabetes mellitus, hyperlipidemia, and coronary heart disease,

Table 1. Disease distribution in each group of risk factor dimension.

Dimension (Number and %)	Hypertension	Hypertension and Diabetes mellitus	Hypertension and Hyperlipidemia	Hypertension and Coronary heart disease
Gender				
Male	1146218 (54.00)	209121 (54.44)	108929 (55.63)	163156 (54.44)
Female	976485 (46.00)	174984 (45.56)	86876 (44.37)	136538 (45.56)
Age				
0-44	265554 (12.51)	15222 (3.96)	20557 (10.50)	7444 (2.48)
45-59	653872 (30.80)	100263 (26.10)	62154 (31.74)	56712 (18.92)
60+	1203277 (56.69)	268620 (69.93)	113094 (57.76)	235538 (78.59)
Income				
higher than national average	1448506 (68.24)	266401 (69.36)	151541 (77.39)	171784 (57.32)
lower than national average	674197 (31.76)	117704 (30.64)	44264 (22.61)	127910 (42.68)
Hospital class				
3A	1771120 (83.44)	340968 (88.77)	154595 (78.95)	261746 (87.34)
3B	131428 (6.19)	23749 (6.18)	6790 (3.47)	17863 (5.96)
3C	12221 (0.58)	2063 (0.54)	570 (0.29)	1502 (0.50)
2A	197455 (9.30)	16119 (4.20)	33320 (17.02)	18180 (6.07)
2C	10479 (0.49)	1206 (0.31)	530 (0.27)	403 (0.13)
Zone type				
Northeast	54983 (2.59)	10521 (2.74)	681 (0.35)	4115 (1.37)
North	621662 (29.29)	129063 (33.60)	136712 (69.82)	120361 (40.16)
East	750531 (35.36)	135533 (35.29)	17864 (9.12)	72028 (24.03)
South	29300 (1.38)	3848 (1.00)	2761 (1.41)	4648 (1.55)
Central	179844 (8.47)	19477 (5.07)	7998 (4.08)	20445 (6.82)
Northwest	189209 (8.91)	20471 (5.33)	9433 (4.82)	17724 (5.91)
Southwest	297174 (14.00)	65192 (16.97)	20356 (10.40)	60373 (20.14)
Total	**2122703 (100)**	**384105 (100)**	**195805 (100)**	**299694 (100)**

Values in parentheses referred to the percentage of patients in the corresponding group. The three age groups were defined based on the WHO criteria. “0-44” group represents young people (patients aged 0-44 years), “45-59” middle-aged people and “60+” elderly people. The variable “Income” was based on the city average of “per capita disposable income of urban households (yuan)” during 2011-2013. Hospital class reflected hospital size and quality with 3A the highest and 2C the lowest in this table.

was presented in Table 1. Besides the number of patients in each group, the percentage values for each group of all dimensions were also reported in parentheses. In total, 2,122,703 hypertensive patients were found in our data set.

Our results regarding gender and age were mostly consistent with previously reported findings. We found that male patients had unanimous higher occurrences in all four columns compared with female patients. Our results in Table 1 also concurred with previous findings in that as patient's age increased, the occurrences of hypertension and the three comorbidities also increased.

In terms of patient's income level, patients from higher income regions accounted for the majority of hypertension cases (68.24%) and all three comorbidities (69.36% for diabetes mellitus, 77.39% for hyperlipidemia, and 57.32% for coronary heart disease). That observation might be due to the fact that hospitals and medical facilities were usually more accessible to people in higher income regions than to people in lower income

Table 2. Comorbidity detection rate in each group of risk factor dimension.

Dimension (Detection Rate %)	Hypertension and Diabetes mellitus	Hypertension and Hyperlipidemia	Hypertension and Coronary heart disease
Gender			
Male	18.24	9.50	14.23
Female	17.92	8.90	13.98
Age			
0-44	5.73	7.74	2.80
45-59	15.33	9.51	8.67
60+	22.32	9.40	19.57
Income			
higher than national average	18.39	10.46	11.86
lower than national average	17.46	6.57	18.97
Hospital class			
3A	19.25	8.73	14.78
3B	18.07	5.17	13.59
3C	16.88	4.66	12.29
2A	8.16	16.87	9.21
2C	11.51	5.06	3.85
Zone type			
Northeast	19.14	1.24	7.48
North	20.76	21.99	19.36
East	18.06	2.38	9.60
South	13.13	9.42	15.86
Central	10.83	4.45	11.37
Northwest	10.82	4.99	9.37
Southwest	21.94	6.85	20.32
Total	**18.10**	**9.22**	**14.12**

regions.

Hospital's zone type also showed some interesting patterns. East zone accounted for the largest portion of disease occurrences for hypertension (35.56%) and diabetes mellitus (35.29%), and north zone was by far the biggest contributor in hyperlipidemia (69.82%) and coronary heart disease (40.16%).

3.2. Detection rate of hypertension's comorbidities

While Table 1 indicated the overall distribution of different diseases, Table 2 focused on the likelihood of coexistence of hypertension and its comorbidities. The likelihood of comorbidities was normalized by the occurrence of hypertension in Table 1. The values in Table 2 were detection rate percentage of comorbidities in each group.

The gender pattern found in Table 2 was consistent with that in Table 1. Male patients tended to have higher detection rates of all three comorbidities than female patients did. On the other hand, in age dimension, we recognized that middle age group (45-59) had the highest detection rate of hyperlipidemia, 9.51%, compared to the other two age groups including the elder group (60+), 9.40%. That result indicated that although old patients (60+) had the highest identified hyperlipidemia as shown in Table 1, it was actually the middle-aged patients (45-59) who were most likely to develop hyperlipidemia if patients already had hypertension. A possible reason might be because the middle-aged population in China had to attend lots of business related dinner gatherings which usually involved high fat foods. The unhealthy diet led to a high detection rate of hyperlipidemia. However compared with the elder group, the middle-aged patient group was less motivated to go to hospital due to their busy working schedule which resulted in a relatively low prevalence of hyperlipidemia. Our finding implied that the most at-risk patient groups might not be the same as the most prevalent patient groups.

Another discrepancy between disease occurrence and detection rate was found in patient's income level dimension. Table 1 showed that patients from higher income regions had higher occurrences of all three comorbidities than patients from lower income regions did. However, in Table 2, a clear difference in detection rate was realized regarding the three comorbidities. For patients with comorbidity hyperlipidemia, higher income regions had higher detection rate (10.46% vs 6.57%) which was consistent with hyperlipidemia's prevalence pattern. But for patients with coronary heart disease, the detection rate clearly exhibited the converse pattern (higher income 11.86% vs lower income 18.97%). The result indicated that compared with hypertensive patients in higher income regions, those in lower income regions were more likely to develop coronary heart disease although those patients did not go to hospital often enough.

In terms of hospital class dimension, hypertensive patients with diabetes mellitus and coronary heart disease were more likely to be found in higher-classed hospitals, while those with hyperlipidemia might not. In our analysis, class 2A hospitals had the highest detection rate, 16.87%, for patients with both hypertension and hyperlipidemia. In China, most higher-classed hospitals, though had better medical resources, were usually crowded and requested longer waiting time for patients. As discussed before, the middle-aged patient group had the highest detection rate of hyperlipidemia. It was easy to understand that those patients were the least willing to spend much time waiting in hospital. Thus their best choice would be to go to a smaller-sized hospital to fulfill their medical needs.

The patterns shown in geographical zones revealed some interesting intuitions. For diabetes mellitus, patients from northeast of China showed very high detection rate, 19.14%, despite the fact that its occurrence percentage in all seven zones was as low as 2.74% as shown in Table 1. North zone showed high detection rates in all three comorbidities. Besides, detection rates in east and southwest zones were high for diabetes mellitus and coronary heart disease.

3.3. Risk factor analysis

In order to demonstrate statistically the correlative relations of risk factors with disease prevalence and detection rate, a Univariate Analysis was conducted. We calculated odd ratios

(OR) and 95% confidence intervals (CI). We defined statistical significance as *P* value less than 0.05. The results were presented in Table 3. Most patterns revealed by the univariate analysis were consistent with Table 2 which affirmed the patterns that we have discovered before.

Regarding the age impact, the middle-aged group (1.25) had higher OR than the elder group (1.24) which was consistent with Table 2. For patients from higher income regions, hyperlipidemia's OR (1.66) was larger than 1 while coronary heart disease's OR (0.57) was less than 1 and diabetes mellitus' OR (1.07) was close to 1. Similar patterns to Table 2 were found with regard to hospital class and zone type. Interestingly although north and east zones had about the same numbers of participating hospitals and similar numbers of hypertensive patients as shown in Table 1, Table 3 showed that north zone had a much higher - more than 10 times - hypertension and hyperlipidemia risk compared to east zone (OR 22.48 vs. 1.94). On the other hand, hypertension and coronary heart disease risks in those two zones did not show much difference (OR 2.97 vs. 1.31). While that finding might reveal some interesting and important regional differences between those two zones, we would also like to extend our research in the near future by carefully examining the diagnostic process of hyperlipidemia in those two zones.

Table 3. Univariate analysis of risk factors.

Dimension	Hypertension and Diabetes mellitus			Hypertension and Hyperlipidemia			Hypertension and Coronary heart disease		
	OR	95% CI	P	OR	95% CI	P	OR	95% CI	P
Gender	Female as reference								
Male	1.02	1.02, 1.03	0.00	1.08	1.07, 1.09	0.00	1.02	1.01, 1.03	0.00
Age	0-44 as reference								
45-59/0-44	2.98	2.93, 3.03	0.00	1.25	1.23, 1.27	0.00	3.29	3.21, 3.38	0.00
60+/0-44	4.73	4.65, 4.81	0.00	1.24	1.22, 1.26	0.00	8.44	8.24, 8.64	0.00
Income	Lower than national average as reference								
higher than national average	1.07	1.06, 1.07	0.00	1.66	1.64, 1.68	0.00	0.57	0.57, 0.58	0.00
Hospital class	2C as reference								
3A	1.83	1.73, 1.95	0.00	1.80	1.64, 1.96	0.00	4.34	3.92, 4.79	0.00
3B	1.70	1.60, 1.80	0.00	1.02	0.93, 1.12	0.63	3.93	3.56, 4.35	0.00
3C	1.56	1.45, 1.69	0.00	0.92	0.81, 1.04	0.17	3.50	3.13, 3.92	0.00
2A	0.68	0.64, 0.73	0.00	3.81	3.49, 4.16	0.00	2.54	2.29, 2.80	0.00
Zone type	Northeast as reference								
North	1.11	1.08, 1.13	0.00	22.48	20.8, 24.3	0.00	2.97	2.87, 3.07	0.00
East	0.93	0.91, 0.95	0.00	1.94	1.80, 2.10	0.00	1.31	1.27, 1.36	0.00
South	0.64	0.61, 0.67	0.00	8.30	7.62, 9.03	0.00	2.33	2.23, 2.44	0.00
Central	0.51	0.50, 0.53	0.00	3.71	3.43, 4.02	0.00	1.59	1.53, 1.64	0.00
Northwest	0.51	0.50, 0.53	0.00	4.18	3.87, 4.53	0.00	1.28	1.23, 1.32	0.00
Southwest	1.19	1.16, 1.22	0.00	5.86	5.43, 6.33	0.00	3.15	3.05, 3.26	0.00

OR: Odds Ratio. CI: Confidence Interval. P: P value. Female, age group 0–44, income lower than national average, 2C hospital class, and northeast zone were used as the baseline in calculation of OR, 95% CI, and P values.

4. Conclusion

This work aimed to analyze the prevalence and detection rate of hypertension and its three comorbidities, namely diabetes mellitus, hyperlipidemia, and coronary heart disease. We assessed the impact of several geographical and socioeconomic risk factors for disease distribution and comorbidity detection rate. Those risk factors included gender, age, income level, hospital class, and zone type. A univariate analysis demonstrated that those risk factors had significant impact which led to dramatic geographical and socioeconomic disparity in prevalence and detection rate. We indicated the at-risk patient groups with different socioeconomic characteristics in each risk factor dimension. The zone type dimension clearly demonstrated the significant geographical disparity of detection rate and prevalence for the three comorbid diseases.

Besides the many interesting findings that we reported, there are several limitations to our study. Firstly, each city that we investigated only had one hospital in our data set. It would be interesting if we could collect data from multiple hospitals within a city. Secondly, we were limited in our analyses to a set of comorbidities. But several other diseases may also have important associations to hypertension. Thirdly, each EMR that we analyzed only contained a limited set of clinical dimensions. More detailed information about the patient (e.g., occupation, residential address, height, weight, and blood pressure, etc.) may reveal more interesting patterns.

Despite those limitations, our study showed significant disparities in patients from different geographical regions and with different socioeconomic characteristics in China. Our results suggested public health decision makers that specific and differential attention be paid to specific population in a specific geographical region so that medical resources can be allocated rationally and effectively. Our analysis could also be leveraged by public health practitioners to better identify at-risk patients and thus offer customized disease prevention plans.

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