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Full length article

Assessing variation among the drug-lists of 16 cities and impact on cardiovascular disease mortality: Evidence from Anhui

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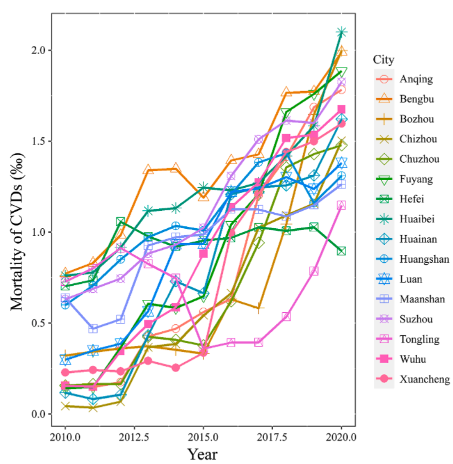
HIGHLIGHTS

- This article compared the differences in city-level drug-lists of CVD medicines.
- The relationship between city-level CVD drug-lists and CVD mortality rate was examined.
- The risk factors that impact of CVD mortality rate was analyzed.

GRAPHICAL ABSTRACT



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ABSTRACT

Background: This study compares the differences in city-level cardiovascular disease (CVD) drug-lists and investigates their relationship with CVD mortality rate across 16 cities in Anhui province, China.
Methods: Data on the usage of CVD medicines from 2016 to 2020 in hospitals across various levels in 16 cities and China's 2018 national list of essential medicines (EMs) were collected and mortality, demographic, environmental data related to CVD were analyzed. The negative binomial mixed-effects model was adopted to compare the differences. A generalized estimating equation was applied to evaluate associations between Anhui city-level drug-lists and mortality over the five years.
Results: The drug-lists across cities in Anhui province were short. Analysis revealed that the drug-lists of ten cities were shorter than that of the capital city, Hefei. Healthcare expenditure appeared to impact the length of drug-lists. After controlling for per capita GDP, population, widowhood rate, and beds per 1000 people, it was found that differences in drug-lists were associated with the CVD mortality rate in Anhui Province.

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Conclusion: A shorter city-level CVD drug-list correlates with a higher CVD mortality rate, suggesting the crucial need for local health authorities to revise and establish their own list of essential CVD medicines to meet patient needs.

Abbreviations

EMs	Essential Medicines
WHO	World Health Organization
US	United States of America
CVD	Cardiovascular disease

1. Introduction

Since the World Health Organization (WHO) initially released the Essential Medicines (EMs) list in 1977, more than 156 countries, covering a population exceeding five billion people, have developed and implemented their individual Essential Medicines Lists (EMLs).[1,2] The essential medicine list is a key tool for improving drug accessibility. Current research suggests that enhancing drug accessibility contributes to better health outcomes. The PURE study[3] indicated that in low-income countries, the prevalence rate of cardiovascular drugs, such as statins and anti-hypertensive drugs, was significantly associated with the all-cause mortality rate. The mortality rate in communities with high drug accessibility (5.84 %) was significantly lower than that in communities with limited drug accessibility (12.64 %). Additionally, the review published in *Circulation* indicated that drug accessibility, encompassing five dimensions including availability and affordability, was a key driving factor for the high mortality rate of cardiovascular disease (CVD) in low- and middle-income countries. It suggested that enhancing drug accessibility could narrow the treatment gap and decrease the mortality rate.[4] The collective evidence supports the hypothesis that the coverage of drug lists directly affects clinical accessibility, which in turn influences the mortality rate through the standardization of treatment, adherence to treatment, and treatment effectiveness.

The coverage of the drug lists is influenced by various factors. Taglione MS et al conducted an assessment of the national EMLs of 21 high-income countries, revealing significant variations among these nations concerning population size, infant mortality rate, gross domestic product, and per capita health expenditures.[5] Steiner's study identified differences in the national EMLs between countries in the Americas with high and low healthcare expenditure.[6] CVDs, specifically ischemic heart disease (IHD), stroke, and hypertensive heart disease, account for approximately 29 % of global deaths, leading to significant loss of national productivity and catastrophic healthcare expenditure. The differences were also observed in the EMLs related to CVDs, as indicated by the findings of Steiner's study.[7] This might be attributed to the influence of specific local social determinants of health, encompassing economic, social, environmental, and psychosocial factors. These factors played a substantial role in the development of CVD risk factors, as well as the morbidity and mortality associated with CVD. In this study, we hypothesize that local social determinants of health are associated with the composition of EMLs for CVDs. Specifically, we postulate that regions in China with less favorable social determinants may include fewer essential CVD medications in their EMLs, thereby limiting the affordability and accessibility of these medicines.[8]

To improve access to EMs for CVDs, the Global Heart Initiative was launched in 2016 by the WHO and the Centers for Disease Control and Prevention (CDC), in collaboration with the World Heart Federation (WHF).[9] Bazargani YT et al conducted a study on the availability of EMs for cardiovascular conditions, revealing that the median accessibility of EMs for CVDs (at 50 %) was lower in both the primary and supplementary EMLs provided by the WHO, especially in comparison to the accessibility of acute medications.[10] In their comprehensive analysis of national EMLs related to cardiovascular management, researchers covered six distinct regions, comprising 34 low- and middle-income countries. Successfully validating their hypothesis, they revealed variations in the determination of the number of EMs for preventing and treating CVDs across different income levels, geographical regions, and disease burdens. For instance, countries with a higher prevalence of CVDs tended to have a more extensive list of EMs.[11] The study highlighted that these influencing factors collectively contribute to variations in EMLs. Mehrtash H et al investigated the disproportionately high burdens of CVDs in Mediterranean countries, including Yemen, Somalia, Afghanistan, and Djibouti, where certain types of CVDs were not covered by the available EMs. Furthermore, in several nations like Tunisia and Saudi Arabia, the percentage of EMs for CVDs, including their formulations and dosages, was relatively low compared to the WHO's EML. These findings underscored potential challenges in accessing EMs for CVDs in specific populations.[12] Consequently, we assert that each country should not only formulate its national list based on the WHO's exemplary list but also consider social determinants, such as the political, social, financial, economic, and epidemiological context of that country.

CVD medicines rank as second largest category, in China's 2018 EML, following antimicrobial drugs.[13] A large-scale survey conducted in 2020 by Li *X* et al and published in *The Lancet Public Health*l encompassed 31 provinces and 980,000 individuals, documenting the CVD regional disparities across China due to its vast territory, with primary risk factors varying across different regions.[14] Zhang *M* et al showed that the availability of EMs in China was lower than the WHO standards from 2009 to 2019, with significant disparities observed across regions.[15] Neglecting these factors when implementing the EMLs for CVDs in various regions could substantially impact the affordability and accessibility of CVD medicines. In a study comparing the 2009 national EMLs and the EMLs of 29 provinces in China, researchers proposed the establishment of a two-tiered system composed of national and provincial levels, covering medicines of different price ranges. They emphasized that each province and city should, according to its own economic development level and disease spectrum, adhere to the principles of rational medicine use. However, the goal of achieving rational and consistent provincial EMLs has not been realized.[16] Some CVD medicines listed have been discontinued, and clinicians in primary, secondary, and tertiary healthcare hospitals have ceased prescribing medicines on the EM list due to insufficient profit following the zero-markup policy.

Local health authorities have also raised concerns about the inadequacy of China's EMLs, citing a lack of consideration for local characteristics, including sub-regional epidemiological characteristics of CVD. These challenges may hinder the realization of rational and consistent provincial EMLs. For instance, research has shown that refined particulate matter concentration and composition in regions with severe air pollution could affect CVD-related incidence and mortality. In addition, the literature suggested that exposure to greenspace was significantly correlated with health outcomes, and an increase in such exposure aids in reducing the incidence of CVD.[17,18] The research findings of Wenning Fu et al showed that noise exposure was also an independent risk factor for the incidence and mortality of stroke.[19] Economic development, coupled with its interactions with other CVD risk factors, may contribute to the prevalence of CVD due to associated risks linked to growth.[20] With GDP growth, there often comes an increase in air pollution and changes in lifestyle. Furthermore, social factors, such as the divorce rate, have been reported to be associated with the all-cause mortality rate among the elderly.[21] Dhindsa DS et al found that in multiple US and international cohort studies, divorced patients had a higher probability of experiencing adverse cardiovascular events.[22] Kozo Tanno K et al analyzed the cardiovascular disease mortality rate of Japanese hemodialysis patients, and the results indicated that divorced patients had a higher risk of CVD mortality compared to married patients.[23] Although the mechanism through which social factors influence the CVD mortality rate has not been fully elucidated, considering their potential effects, we also included them in the study.

In this study, we used Anhui province as an example to explore how societal health determinants, including health policy, environmental factors, and social behavior, influenced the provincial CVD mortality rate and impacted the development of provincial EMLs. In this study, we first compare the differences among CVD drug-lists of 16 cities in Anhui province. Then, we analyze upstream risk factors that impact the CVD mortality rate, helping to elucidate the characteristics of the regional debase burden (DB) of CVD and establish more effective local CVD EM lists to increase access to quality healthcare.

2. Materials and methods

2.1. Data collection

The drug list mentioned in the article referred to national EMLs, a government-approved catalog that all healthcare institutions at various levels are required to follow. The 2018 CVD list of China was collected from the National Health Commission of the People's Republic of China. The lists of CVD medicines used in primary, secondary, and tertiary healthcare hospitals across 16 cities from 2016 to 2020 in Anhui Province were extracted from the National Drug Use Monitoring data of Anhui. CVD medicines from two lists include antianginal, antiarrhythmic, anti-heart failure, antihypertensive, antishock, and anti-atherosclerotic medicines, along with others. We extracted the generic names of essential cardiovascular drugs reported by tertiary, secondary, and primary medical institutions in 16 cities in Anhui province and on China's 2018 list of EMs from 2016 to 2020. The dosage forms were classified as oral, injection, topical, and others.

The CVD mortality data from January 1, 2014 to December 31, 2020 was sourced from the Anhui Provincial Center for Disease Control and Prevention. Demographic and environmental data related to CVD from 2014 to 2020 in 16 cities were extracted from the Statistical Yearbook of Anhui Province. This included per capita GDP, population density, urbanization, educational level, rate of widowed, rate of divorce, proportion of elderly population, average noise, air quality, and per capita medical expenditure. In addition, each CVD cause and related health states were identified with standard case definitions. Furthermore, the morbidity and mortality data were estimated through vital registration data coded to the International Classification of Disease (ICD) system (tenth revision (ICD-10), 2007 version).

2.2. Data description

In this study, several time series data, including the drug-list data from 2016 to 2020, city-level mortality data relating to CVD, demographic data, environmental data, and economic data from 2014 to 2020 were depicted using line charts. The spatial distribution of drug-lists was determined by ArcGis (version 10.7). ArcGis is geospatial software designed to do geomorphometric analysis of Digital Elevation Models (DEMs) within a Geographic information system.

2.3. The differences in CVD city-level drug-lists in Anhui province

In this study, drug-list variation denoted differences in the length (number of medicines) of city-level CVD drug lists across 16 cities in Anhui Province. The Boruta algorithm, an all-relevant variable selection method, was applied to select important variables with higher importance than randomized variables.[24] In our study, the importance of the drug-list effective factors was used to choose which were selected for further analysis by the Boruta algorithm. Goodness-of-Fit testing was applied to check whether the size of a drug-list followed the Poisson distribution because the number of drugs on the list is count data.[25] Subsequently, the Poisson mixed-effects model[26] or negative binomial mixed-effects model was adopted to analyze the differences of CVD drug-lists across 16 cities over time in Anhui province based on the results of the Goodness-of-Fit and Boruta tests. After that, the over-dispersion of the model was checked because the count data or frequency data often display overdispersion. We assessed multicollinearity using variance inflation factors (VIF) to ensure multivariable models were not overfitted. Finally, a diagnosis model was implemented for residual diagnostics by DHARMa.[27]

2.4. Evaluating the influence of the upstream risk factors on city-level CVD mortality

The city-level CVD mortality rate in Anhui was introduced as a representative indicator of the disease burden (DB) of CVD. The Shapiro–Wilk method was applied to test whether the data follows the normal distribution. The homogeneity of variance test was carried out simultaneously. Subsequently, a generalized estimating equation (GEE)[28] was applied to investigate the influence of the upstream risk factors, including drug coverage, per capita GDP, population, rate of widowed, rate of divorce, average noise, greenspace per capita, air quality (number of days meeting national level standards), per capita medical expenditure, and beds per 1000 people, on the city-level CVD mortality rate across 16 cities. Drug coverage referred to the number of CVD medicines included in the drug lists of healthcare institutions within each city. A *P*-value <0.05 was considered statistically significant in all analyses. All the statistical analyses were carried out using *r* (version 4.2.0).

2.5. Ethical approval

Since this study did not involve any human or animal subjects, ethical review was not necessary. Consequently, ethical approval for this type of study is not required in this research.

3. Results

3.1. Data description

Results showed that the CVD drug-lists across 16 cities in Anhui province grew over the study years. From 2016 to 2020, the longest drug-list was for Luan and the shortest for Huaibei (Fig. 1A and Supplementary Table 1). As depicted in Fig. 1B, despite the overall increase in drug-list lengths over the years, the total number of CVD drug-list in Anhui province remained low compared to the CVD medicines (48) in the China's 2018 EM list. Quite a few cities had drug-lists that included less than 60 % of the total number of CVD medicines in China's 2018 EM list. The results of data description of socioeconomic data and air pollution data were detailed in Supplementary Table 2.

Although the total CVD mortality rate in Anhui Province increased over five years, the rate of increase was rapid before 2018 and slowed down after that (Fig. 2). From a regional perspective, Huaibei (from 1.23 ‰ to 2.10 ‰) and Bengbu (from 1.39 ‰ to 1.99 ‰) have suffered a high level of CVD mortality over the past five years, while the CVD mortality in Hefei (from 0.97 ‰ to 0.89 ‰) has remained relatively low (Supplementary Fig. 1, Supplementary Table 3).

3.2. Differences in city-level CVD drug-lists in Anhui province

Since the Boruta analysis identified region, drug-type, and per-capita medical expense as essential factors associated with drug-lists, these

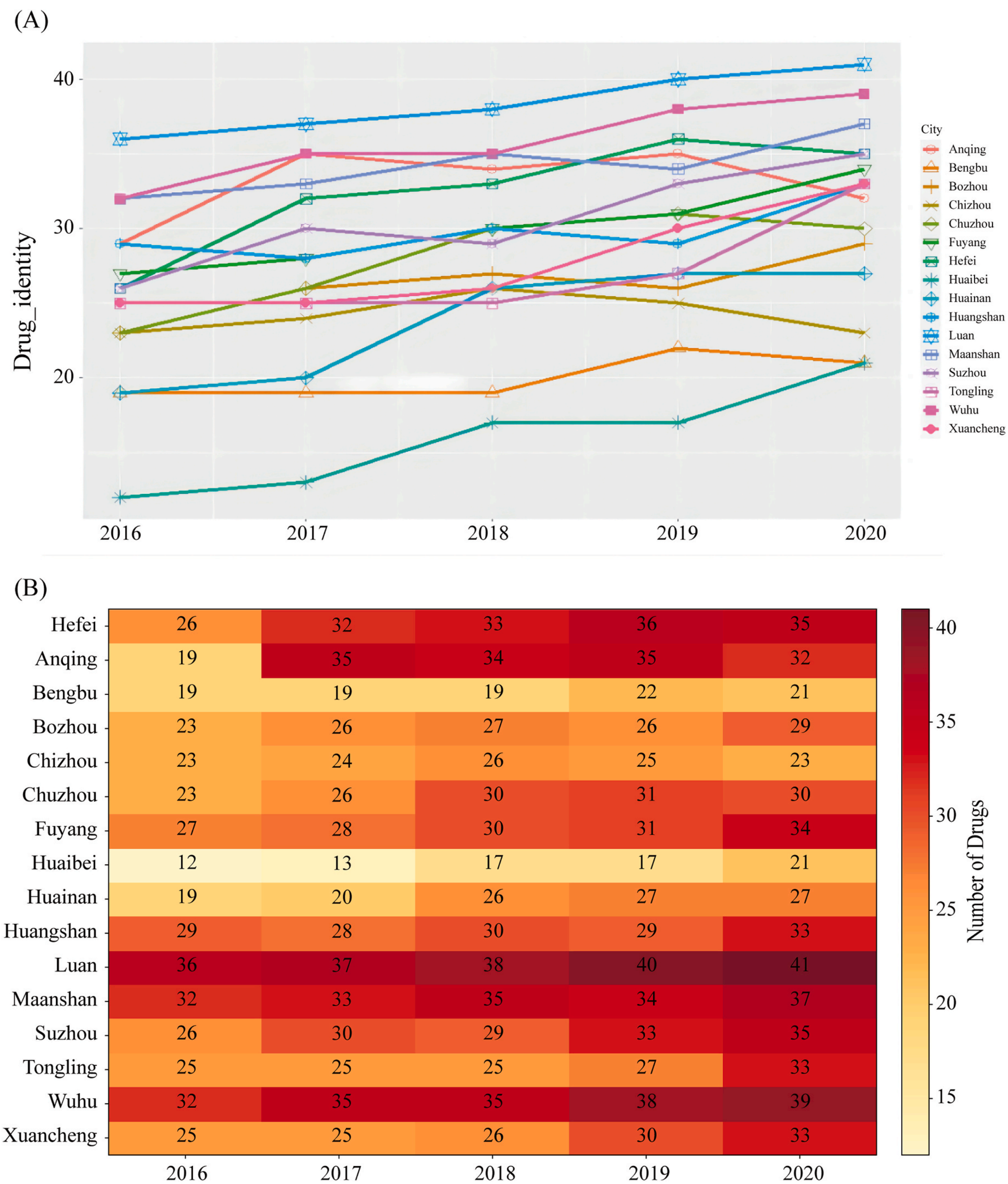

Fig. 1. Differences in CVD drug-lists across 16 cities in Anhui province. (A) Variation of the length of drug-lists between 16 cities in Anhui Province over five years. (B) Heatmap of drug-lists.

three variables were utilized as the explanatory variables in the following analysis model fitting. A negative binomial mixed-effects model was adopted because the drug coverage did not follow a Poisson distribution due to good fit results (P-value <0.001). The ANOVA results confirmed that Region and Per-capita-medical expense significantly impact the drug-list lengths based on the mixed-effect intercept-only baseline models (Table 1). The VIF results suggested that no multicollinearity problem exists (VIF <2). According to the results of the negative binomial mixed-effects model, ten cities' drug-lists were shorter than that of Hefei, and Per-capita-medical expense could explain some additional variance (Table 2). The results of overdispersion implied that no over-dispersion existed (overdispersion measure=0.362). In addition, two figures in Fig. 3 demonstrated that the negative binominal mixed-effects model was suitable, as there was no significant deviation in the KS test or the outlier test, as seen in Fig. 3A, and the dark lines in Fig. 3B matched the light lines better.

3.3. Evaluating the impact on city-level CVD mortality and increasing access to EMs

The Shapiro–Wilk results indicated that CVD mortality followed the normal distribution ($W = 0.975$, P-value $= 0.486$). Moreover, the homogeneity of variance test revealed no significant difference in variance among variables (P-value $= 0.251$). As presented in Table 3, significant

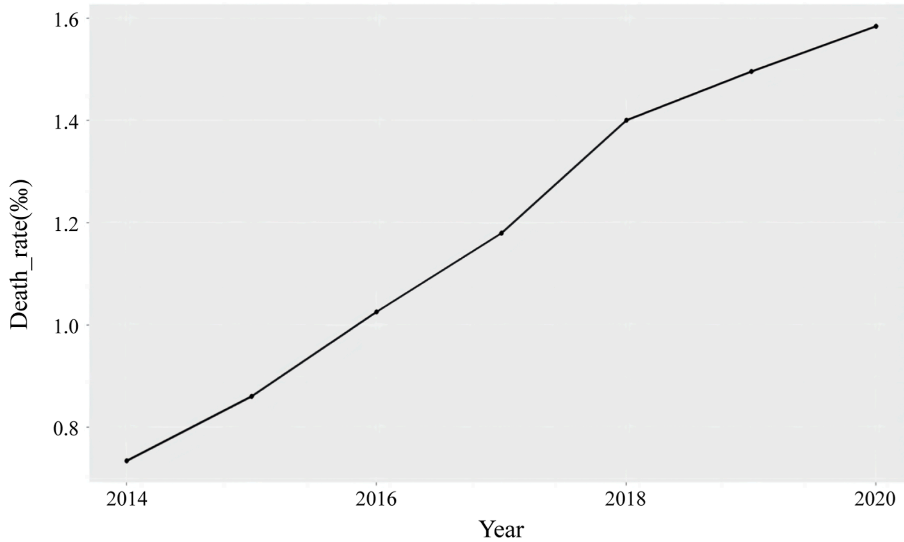

Fig. 2. Total CVD mortality rate in Anhui Province.

associations were observed in Anhui province (*P*-value <0.05 for each) between the following factors: (1) drug-list length and CVD mortality, (2) per capita GDP and CVD mortality, (3) widowed rate and CVD mortality, and (4) beds per 1000 people and CVD mortality. Specifically, we found a 0.38 % decrease (±0.1646) in CVD mortality for every 1 % increase in Drug-coverage, a 0.68 % decrease (±0.1592) in CVD mortality for every 1 % increase in per capita GDP, a 0.26 % increase (±0.2611) in CVD mortality for every 1 % increase in the Widowed rate, and a 0.88 % increase (±0.1737) in CVD mortality for every 1 % increase in Beds per 1000 people.

4. Discussion

The results of the comparative analysis on the length of EMLs for CVDs between 16 cities in Anhui province and the national level indicated that the number of CVD EMLs in the 16 cities was lower than that specified in the national EMLs for CVDs. An analysis of the risk factors influencing the mortality rate associated with CVDs across these 16 cities revealed that the number of drugs listed in the city-level EMLs and per capita GDP were significant factors. This suggested that using essential drugs might indeed impact population health outcomes.[29] The preceding analysis highlighted the importance of devising cardiovascular drug inventories with local variations in accordance with the guidance provided by the national essential drug list, both at the provincial and city levels.[30]

Several factors contributed to the lower inclusion of essential medicines for CVDs in the EMLs across 16 cities in medical practice compared to the national EMLs for CVDs. Firstly, certain clinical CVD medicines commonly recommended by local hospital doctors were not featured in the national EMLs.[16,31] Secondly, regional and lifestyle differences gave rise to variations in the types, incidence, and mortality rate of CVDs in different areas.[32] Consequently, the selection of cardiovascular medications should be tailored to these regional variations. Lastly, specific region-level characteristics, including economic, social, and environmental conditions, also played a role in influencing the inclusion of CVD medicines in such lists.[33]

Regional analysis at the city level is crucial for formulating an appropriate list of EMs with urban characteristics.[15] The results of the differences in Anhui's city-level CVD EMLs over time showed that these EMLs in ten cities were shorter than the provincial capital Hefei's EML, with a 49.77 % increase in the length of city-level EMLs for every unit of healthcare expenditure increase. This aligns with a previous study by Persaud *n* et al which suggested more than 200 differences exist in the EM lists of 137 countries when compared to the WHO EM list.[32] The differences can be partially attributed to countries' characteristics, such as WHO region and healthcare expenditure. This supports the idea that higher per-capita healthcare expenditure enhances the availability of EMs, extends the city-level EMLs for CVDs, and results in better health outcomes. Jia Y et al found that the incidence of medical impoverishment (4.5 %) in Anhui was higher than that of Shanghai (0.03 %), and the catastrophic health expenditure in Anhui was relatively low in the GDP per capita middle group.[34] In addition, Hefei, the capital of Anhui province, has become one of China's fastest-growing cities. According to

Table 1
Results of model selection.

	AIC	logLik	deviance	Chisq	Pr (>Chisq)
model 1 (intercept-only baseline)	1881.8	−937.92	1875.8		
model 2 (model1 + Region)	1819.2	−891.6	1783.2	92.6469	<0.001
model 3 (model2 + Medical expenses)	1810.5	−886.28	1772.5	10.6485	0.001
model 4 (model3 + Drug-type)	1812.5	−886.25	1772.5	0.0594	0.807436

Table 2
Results of Negative binomial mixed-effects model.

Predictors	Drug-list			
	Estimates	Std.err	Z value	Pr (>|z|)
Hefei (Intercept)	1.43931	0.20303	7.089	<0.001
Anqing	−0.06173	0.10337	−0.597	0.550
Bengbu	−0.49633	0.12092	−4.105	<0.001
Bozhou	−0.22982	0.11037	−2.082	0.037
Chizhou	−0.40675	0.11548	−3.522	<0.001
Chuzhou	−0.25653	0.11022	−2.327	0.020
Fuyang	−0.09334	0.10409	−0.897	0.370
Huaibei	−0.66755	0.12794	−5.218	<0.001
Huainan	−0.31757	0.11187	−2.839	0.005
Huangshan	−0.22473	0.11168	−2.012	0.044
Luan	0.08251	0.10016	0.824	0.410
Maanshan	0.01045	0.10158	0.103	0.918
Suzhou	−0.06901	0.10408	−0.663	0.507
Tongling	−0.24985	0.10983	−2.275	0.023
Wuhu	0.01741	0.10139	0.172	0.864
Xuancheng	−0.31662	0.11727	−2.7	0.007
Medical expenses	0.40391	0.11846	3.41	0.001

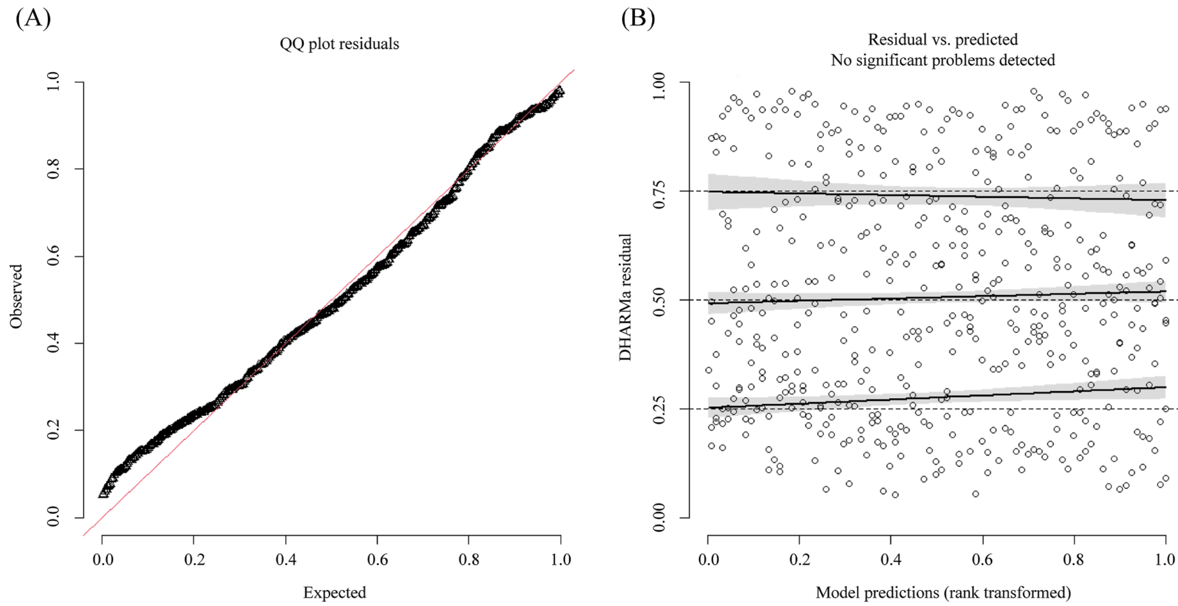

Fig. 3. Residual plots for negative binomial model by using DHARMa. (A) QQ plot for residual. (B) Residuals vs predicted plot.

Table 3
GEE model results.

Predictors	Estimates	Std.err	Wald	Pr (>|W|)
(Intercept)	0.2041	0.169	1.46	0.227
Drug-coverage	−0.3827	0.1646	5.41	0.02
Per capita GDP	−0.6838	0.1592	18.46	<0.001
Population	0.5697	0.2477	5.29	0.021
Divorce rate	0.0306	0.0453	0.46	0.5
Widowed rate	0.2611	0.1211	4.65	0.031
Greenspace per capita	0.1556	0.1376	1.28	0.258
Average noise	−0.3365	0.1917	3.08	0.079
Air quality	−0.0217	0.1273	0.03	0.865
Beds per 1000 people	0.8752	0.1737	25.39	<0.001
Medical expenses	0.2705	0.1719	2.48	0.11

survey data from CEIC (www.ceicdata.com/), healthcare expenditure in Hefei is almost the highest among the 16 cities and far exceeds that of ten other cities over the years. These factors may partly account for the differences in quantity between the other cities and Hefei. Hence, some scholars have suggested that for countries with diverse territories, such as China, it is advisable to develop EMLs at the national, provincial, or state level, taking into account factors such as regional needs, characteristics, and health conditions.[16]

The analysis of our study supported the assertion that healthcare expenditure was associated with the magnitude of drug coverage, as evidenced by the impact of city-level drug coverage and per capita GDP on CVD mortality. This result aligns with the study of Steiner *L* et al which suggested that having more medicines on the national EM list reduced mortality from CVD and improved healthcare access and quality scores.[7] Aside from the immense health burden of CVD, there is an enormous financial burden related to its prevention, treatment, and CVD mortality rate.[33] Since the Chinese government initiated a new phase of health system reforms to address healthcare inequity in 2009, the health expenditure from governments has risen dramatically over the years, and several policies have been established. For example, the "zero-mark-up" policy caps the bidding price for drugs in the list of EMs and makes medicines on the list of China's EMs reimbursable by health insurance schemes.[35] These policies reduce drug expenses, resulting in lower charges for patients and increasing the number of patient visits and inpatient admissions to the hospitals, while also decreasing the CVD mortality rate. However, implementing these policies significantly depends on the health expenditure from local governments. Our study showed that the affordability and availability of EMs in Anhui province were at a low level, and the issue of regional inequity persisted. Unlike some provincial-level entities with higher GDP, such as Beijing and Shanghai, Anhui province faced these challenges. Consequently, it was speculated that government healthcare expenditure was positively correlated with the magnitude of drug coverage, and it was also inferred to be negatively associated with the CVD mortality rate.

Research indicates that population, widowed rate, and number of hospital beds are factors that contribute to CVD mortality. Researchers previously found that population growth contributed to a 25 % increase in CVD deaths globally.[7] Furthermore, the perception of social isolation, such as loneliness, unmarried state, widowed state was correlated with the activation of the hypothalamic–pituitary–adrenocortical axis and the sympathetic nervous system, which in turn elevated the risk of CVD-related mortality.[36–39] A higher number of hospital beds per 1000 people correlates with a larger number of patients in that region. However, CVD is the leading cause of patient hospitalization, resulting in a scarcity of CVD hospital beds. This shortage persists because the number of CVD hospital beds has remained unchanged for years. Consequently, this leads to higher mortality rate for certain CVDs, such as ischemic heart disease, aortic aneurysm, hypertensive heart disease, and endocarditis, due to the shorter length of hospital stays and unequal medical resource allocation for each patient with CVD.

The current study has several limitations beyond the common issues faced by qualitative research. Firstly, it only encompassed five years of data across 16 cities in Anhui province. During this timeframe, local health authorities might not have had enough time to build their own appropriate list of EMs. Secondly, due to data limitations, variables such as regional healthcare quality and physician density were not included in the study. It was worth noting that regional healthcare quality could influence outcomes by affecting baseline population health status and per capita healthcare expenditure. This aspect warrants further investigation in future studies. Thirdly, data on some other related social, economic, environmental, and demographic risk factors for CVD mortality were not collected. Lastly, the present findings should not be considered representative of the entire country, therefore, expanding the study to include other provinces would be informative.

5. Conclusion

China's official health-sector reform documents encourage local health authorities to consider the country's EM list and to make city-level adaptations to it. This approach may help identify opportunities to enhance the availability and affordability of EMs and promote the appropriate use of medicines, thereby reducing the local government's economic, social, and medical burden.

CRediT authorship contribution statement

Anping Guo: Writing – original draft, Validation, Software, Resources, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Zhenzhen Pan:** Writing – review & editing, Funding acquisition. **Haizhu Tan:** Supervision, Project administration.

In brief

Shorter city CVD drug lists correlate with higher CVD mortality rates.

Data availability statement

The data supporting the finding of this study are available within the article and its supplementary materials. Additionally, further reasonable request can be directed to the corresponding author.

Declaration of competing interest

The authors declare no competing interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ipha.2025.05.002.

References

1. World HO. *World Health Organization Model List of Essential Medicines: 22nd List (2021)*. 2021.
2. Executive Board. *WHO Medicines Strategy: Revised Procedure for Updating WHO's Model List of Essential Drugs: Report by the Secretariat*. 2002.
3. Chow CK, Nguyen TN, Marschner S, et al. Availability and affordability of medicines and cardiovascular outcomes in 21 high-income, middle-income and low-income countries. *BMJ Glob Health*. 2020;5(11):e002640.
4. Wirtz VJ, Kaplan WA, Kwan GF, Laing RO. Access to medications for cardiovascular diseases in low- and middle-income countries. *Circulation*. 2016;133(21):2076–2085.
5. Taglione MS, Persaud N. Assessing variation among the national essential medicines lists of 21 high-income countries: a cross-sectional study. *BMJ Open*. 2021;11(8):e045262.
6. Steiner L, Maraj D, Woods H, et al. A comparison of national essential medicines lists in the Americas. *Rev Panam Salud Públic*. 2020;44:e5.
7. Steiner L, Fraser S, Maraj D, Persaud N. Associations between essential medicines and health outcomes for cardiovascular disease. *BMC Cardiovasc Disord*. 2021;21(1):151.
8. Kinge JM, Modalsli JH, Overland S, et al. Association of household income with life expectancy and cause-specific mortality in Norway, 2005-2015. *JAMA*. 2019;321(19):1916–1925.
9. World HO. *Working Together to Promote Cardiovascular Health*. 2016.
10. Bazargani YT, Ewen M, de Boer A, Leufkens HGM, Mantel-Teeuwisse AK. Essential medicines are more available than other medicines around the globe. *PLoS One*. 2014;9(2):e87576.
11. Kishore SP, Blank E, Heller DJ, et al. Modernizing the world health organization list of essential medicines for preventing and controlling cardiovascular diseases. *J Am Coll Cardiol*. 2018;71(5):564–574.
12. Mehrtash H, Laing R, Wirtz VJ. Comparative analysis of essential medicines for cardiovascular diseases in countries of the WHO Eastern Mediterranean Region. *East Mediterr Health J*. 2018;24(5):427–434.
13. Bazargani YT, Ugurlu M, de Boer A, Leufkens HGM, Mantel-Teeuwisse AK. Selection of essential medicines for the prevention and treatment of cardiovascular diseases in low and middle income countries. *BMC Cardiovasc Disord*. 2018;18(1):126.
14. Li X, Wu C, Lu J, et al. Cardiovascular risk factors in China: a nationwide population-based cohort study. *Lancet Public Health*. 2020;5(12):e672–e681.
15. Zhang M, Zou K, Liu Z, et al. Availability of essential medicines, progress and regional distribution in China: a systematic review and meta-analysis. *Front Public Health*. 2023;11:1149838.
16. Tian X, Song Y, Zhang X. National Essential Medicines List and policy practice: a case study of China's health care reform. *BMC Health Serv Res*. 2012;12:401.
17. Twohig-Bennett C, Jones A. The health benefits of the great outdoors: a systematic review and meta-analysis of greenspace exposure and health outcomes. *Environ Res*. 2018;166:628–637.
18. Zare Sakhvidi MJ, Yang J, Mehrparvar AH, et al. Exposure to greenspace and cancer incidence, prevalence, and mortality: a systematic review and meta-analyses. *Sci Total Environ*. 2022;838(Pt 2):156180.
19. Fu W, Liu Y, Yan S, et al. The association of noise exposure with stroke incidence and mortality: a systematic review and dose-response meta-analysis of cohort studies. *Environ Res*. 2022;215(Pt 1):114249.
20. Baptista EA, Queiroz BL. Spatial analysis of cardiovascular mortality and associated factors around the world. *BMC Public Health*. 2022;22(1):1556.
21. Wang L, Yi Z. Marital status and all-cause mortality rate in older adults: a population-based prospective cohort study. *BMC Geriatr*. 2023;23(1):214.
22. Dhindsa DS, Khambhati J, Schultz WM, Tahhan AS, Quyyumi AA. Marital status and outcomes in patients with cardiovascular disease. *Trends Cardiovasc Med*. 2020;30(4):215–220.
23. Tanno K, Ohsawa M, Itai K, et al. Associations of marital status with mortality from all causes and mortality from cardiovascular disease in Japanese haemodialysis patients. *Nephrol Dial Transplant*. 2013;28(4):1013–1020.
24. Kursa MB, Rudnicki WR. Feature selection with Boruta package. *J Stat Software*. 2010;36(11):1–13.
25. Friendly M. *Visualizing Categorical Data*. SAS Institute; 2000.
26. Chen C. Generalized additive mixed models. *Commun Stat Theor Methods*. 2000;29:1257–1271.
27. Gelman A, Hill J. *Data Analysis Using Regression and Multilevel/Hierarchical Models: Simulation of Probability Models and Statistical Inferences*. 2006.
28. Bu R, Ková P, Lumley T. Longitudinal data analysis for generalized linear models with follow-up dependent on outcome-related variables. *Can J Stat*. 2007;35(4):485–500.
29. World HO. *Equitable Access to Essential Medicines : A Framework for Collective Action*. 2004.
30. Mahmic-Kaknjo M, Jelicic-Kadic A, Utrobicic A, et al. Essential medicines availability is still suboptimal in many countries: a scoping review. *J Clin Epidemiol*. 2018;98:41–52.
31. Cheng L, Li C, Zhang X, Chen Y, Yan J. The consistency between the Chinese essential medicines list and treatment guidelines-taking oncology medicines as an example. *Front Public Health*. 2022;10:943994.
32. Persaud N, Jiang M, Shaikh R, et al. Comparison of essential medicines lists in 137 countries. *Bull World Health Organ*. 2019;97(6):394–404C.
33. Gaziano TA. Economic burden and the cost-effectiveness of treatment of cardiovascular diseases in Africa. *Heart*. 2008;94(2):140–144.
34. Jia Y, Hu M, Fu H, Yip W. Provincial variations in catastrophic health expenditure and medical impoverishment in China: a nationwide population-based study. *Lancet Reg Health West Pac*. 2023;31:100633.
35. Li Y, Ying C, Sufang G, et al. Evaluation, in three provinces, of the introduction and impact of China's National Essential Medicines Scheme. *Bull World Health Organ*. 2013;91(3):184–194.
36. Dhindsa DS, Khambhati J, Schultz WM, Tahhan AS, Quyyumi AA. Marital status and outcomes in patients with cardiovascular disease. *Trends cardiovas Med*. 2020;30(4):215–220.
37. Long RM, Terracciano A, Sutin AR, et al. Loneliness, social isolation, and living alone associations with mortality risk in individuals living with cardiovascular disease: a systematic review, meta-analysis, and meta-regression. *Psychosom Med*. 2023;85(1):8–17.
38. Steptoe A, Shankar A, Demakakos P, Wardle J. Social isolation, loneliness, and all-cause mortality in older men and women. *Proc Natl Acad Sci U S A*. 2013;110(15):5797–5801.
39. Hassanin A, Hassanein M, Bendary A, Maksoud MA. Demographics, clinical characteristics, and outcomes among hospitalized heart failure patients across different regions of Egypt. *Egypt Heart J*. 2020;72(1):49.