

Age-Specific Patterns and Dual Economic Burden of Dyadic Chronic Disease Combinations Among Older Inpatients in Inner Mongolia, China

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Abstract

With global aging and rising multimorbidity, China's large older population strains its healthcare system. This study analyzes age-specific patterns and dual economic burden (medical and out-of-pocket expenses) of common dyadic chronic disease combinations among older inpatients in Inner Mongolia. Using multistage random sampling, we analyzed data from six hospitals (four secondary, two tertiary) in 2022. Patients aged ≥ 50 years with a diagnosis of a chronic disease were included. The ten most frequent dyadic combinations were extracted from the first five diagnoses. Descriptive statistics, chi-square tests, and one-way ANOVA were used ($p < .05$). Among 106,202 older inpatients, 73.8% had multimorbidity, and 27.7% presented dyadic combinations. The ten most common combinations ($n = 5,190$) showed age-clustering ($p < .001$). Hypertension appeared in six of the top ten patterns, highlighting its pivotal role. "Hypertension + Joint arthrosis" was the costliest, with mean expenses 3.0 and 3.2 times the overall averages for medical and out-of-pocket expenses. Three distinct cost patterns emerged: increasing, declining in the oldest-old, and stable. High-cost combinations showed financial-risk heterogeneity, especially for cancer patients aged ≥ 80 years. Dyadic combinations are pivotal in multimorbidity progression, and age interacts with disease patterns to shape economic burden. Therefore, tiered, age-specific interventions are essential to mitigate risk and optimize resource use.

Keywords

Age-specific patterns; China; dyadic multimorbidity; economic burden; medical expenses; older inpatients; out-of-pocket expenses

Introduction

Amidst profound global demographic shifts and changing disease patterns, population aging has emerged as a universal societal challenge. Within this context, the high prevalence and co-occurrence of chronic non-communicable diseases, known as multimorbidity, are increasingly becoming a pressing public health issue. The World Health Organization (2016) defines it as the coexistence of two or more chronic health conditions in the same individual. This phenomenon represents far more than a simple summation of multiple diseases. It entails more complex clinical management needs, poorer health-related quality-of-life expectations, and a significantly increased socioeconomic burden. Globally, the prevalence of multimorbidity rises sharply with age, imposing substantial pressure on healthcare systems (Busija et al., 2019; Fortin et al., 2012; Uijen et al., 2008).

As the country with the world's largest older population, China is undergoing an unprecedented scale of population aging. In this process, multimorbidity has become a core feature affecting the health of the older population. Research indicates that over 78% of older adults in China are affected by multimorbidity, with its prevalence showing a significant and consistent increasing trend with advancing age (Marengoni et al., 2011; State Council of China, 2022; Zhang et al., 2020). For instance, various studies report that the prevalence of multimorbidity among individuals aged 60 and above in China ranges from 28.6% to 64.8%, with rates in specific older age groups (e.g., those aged 75 and above) reaching as high as 76.4% (Chen & Liu, 2022; Jing et al., 2021; La et al., 2022; Li et al., 2022). This severe epidemiological reality foreshadows enormous demands for healthcare services and associated costs.

Within China's vast territorial landscape, significant heterogeneity exists across regions in aging patterns, disease profiles, and levels of healthcare security. The Inner Mongolia Autonomous Region, an important border region in northern China, possesses distinct characteristics in its demographic structure, socioeconomic development, and healthcare resource distribution. According to the 2020 Seventh National Population Census, the proportion of the population aged 60 and above in Inner Mongolia reached 19.78%, exceeding the national average of 18.70%. In 2022, the region's GDP per capita was approximately 96,500 Chinese yuan (CNY), above the national average of 85,700 CNY, while its urbanization rate stood at 68.6%, higher than the national level of 65.2%. However, large disparities persist between urban, pastoral, and rural areas.

With a total population of approximately 24.01 million and a land area of 1.183 million square kilometers, Inner Mongolia has a population density of about 20 persons per square kilometer, which contrasts sharply with the national average of 150 persons per square kilometer. Healthcare resources are relatively modest. The number of hospital beds per 1,000 population is 6.98, and the number of physicians per 1,000 population is 3.58, yet the spatial distribution of these resources is highly uneven. These features, namely a vast territory with low population density, a multi-ethnic composition, a high aging rate, and unevenly distributed medical resources, may contribute to regional specificities in the health status of the older population, patterns of chronic disease prevalence, and the resulting economic burden.

Nevertheless, systematic research focusing on the patterns of multimorbidity and the associated economic burden among older inpatients in Inner Mongolia remains relatively scarce. The choice of this region is therefore motivated by its representativeness of a high-

aging, resource-constrained border area, where generating local evidence is urgently needed. The findings from this region can serve as a baseline for future comparative studies involving other border provinces in China.

To better understand the mechanisms linking age, multimorbidity patterns, and healthcare expenditure, this study draws on two complementary theoretical frameworks. The first theoretical framework is Grossman's (1972) health capital model, which conceptualizes health as a durable capital stock that depreciates with age. As individuals grow older, the rate of health depreciation accelerates, particularly in the presence of chronic conditions. This depreciation can be partially offset through investments in medical care, such as hospitalization. The model yields two key predictions relevant to this study. First, medical care demand increases as health depreciation accelerates; second, when health capital falls below a certain threshold, as often occurs in the oldest old population, individuals may choose less intensive treatment options because the marginal return on further health investment diminishes. These predictions help explain the non-linear age-cost patterns observed in the data, specifically, the rise in costs up to age 70–79 and the subsequent decline among those aged 80 and above.

The second theoretical framework is Andersen's (1995) behavioral model of health services use, providing a complementary lens by classifying factors that influence healthcare utilization into three categories: predisposing characteristics (e.g., age, sex), enabling resources (e.g., income, insurance, hospital accessibility), and need factors (e.g., disease severity, multimorbidity burden). In this study, dyadic chronic disease combinations serve as critical need factors that drive variation in both total medical expenses and out-of-pocket payments. At the same time, age acts as a predisposing factor, and health insurance status as an enabling resource. Together, these frameworks guide an empirical analysis of how age interacts with specific disease patterns to shape the dual economic burden of multimorbidity in a resource-constrained border region.

This study advances conceptual understanding in several ways that go beyond merely filling a regional gap. First, beyond disease counts, previous research on multimorbidity costs has largely relied on the simple number of chronic conditions, treating each additional disease as equally additive. By focusing on specific dyadic combinations, the analysis demonstrates that different disease pairs carry vastly different economic burdens, a finding that a simple count variable cannot capture. Second, through age-stratified analysis of non-linear age trajectories, three distinct cost patterns (increasing, declining in the oldest-old, and stable) are uncovered, which challenge the linear age-cost assumption implicit in many health economics models. Third, the dyadic stage as a policy window suggests that dyadic multimorbidity is a critical, identifiable stage for early intervention, offering a novel policy target before progression to more complex multimorbidity. Fourth, regional comparison, compared to national-level studies, provides region-specific evidence from a high-aging, resource-constrained border area that serves as a baseline for future comparative research in similar settings (e.g., Xinjiang). Together, these elements clearly distinguish our conceptual contribution from a purely descriptive case study.

Of particular concern is the “dual burden” imposed by multimorbidity: on one hand, the detriment to patient health and quality of life, and on the other, the substantial direct medical costs, especially the out-of-pocket expenses (OOPE). Existing research generally indicates that the OOPE for outpatient, inpatient, and medication for individuals with multimorbidity is significantly higher than for those without, and the cost level is strongly positively correlated with the number of comorbid conditions (Barnett et al., 2012; Larkin et al., 2022; Zhao et al.,

2020). However, evidence regarding the specific relationship between age and OOEPE remains inconsistent. First, studies vary considerably in their data sources: some rely on claims data that capture all reimbursed services, whereas others use household surveys that rely on patient recall, leading to different estimates of OOEPE. Second, health insurance policies differ across regions and over time. That is, a finding from one insurance context may not hold in another. Third, and most critically for this study, existing research has largely treated multimorbidity as a simple count of chronic conditions, implicitly assuming that each additional disease contributes equally to the economic burden (Barnett et al., 2012; Zhao et al., 2020). This count-based approach, while convenient, overlooks that different disease combinations, such as hypertension with joint arthrosis versus hypertension with diabetes, may require vastly different clinical management and, consequently, different levels of OOEPE.

Recent systematic reviews on multimorbidity costs have explicitly called for moving beyond disease counts toward disease-pattern analyses (Skou et al., 2022; Watson et al., 2025). For instance, a systematic review of multimorbidity costs found that the healthcare costs associated with many disease combinations exceed the sum of the costs of each disease, indicating that specific combinations have synergistic economic effects that a simple count cannot capture (Skou et al., 2022). Moreover, emerging evidence from China suggests that specific multimorbidity patterns, rather than the number of conditions alone, are strongly associated with catastrophic health expenditure among older adults, with cardiovascular and multisystem disease clusters posing the highest financial risk (Wang & Zeng, 2023; Zhai et al., 2023).

These findings underscore the need for a more refined analytical approach that moves beyond disease counts to examine how specific dyadic disease combinations interact with age to shape the dual economic burden of multimorbidity, particularly in under-studied, resource-constrained border regions such as Inner Mongolia. Notably, while most studies support the conclusion that costs increase with age (Goodman et al., 2013; Park et al., 2014), some have found that cost increases may plateau or even decline in specific older age groups (Chen & Liu, 2022; Mukherjee & Kamal, 2017).

Therefore, analyzing older inpatients in China, a population that consumes a highly concentrated share of medical resources, to identify age-specific patterns of multimorbidity and accurately quantify the associated healthcare costs (particularly OOEPE) is of significant theoretical and practical importance. This endeavor will not only enrich research at the intersection of healthy aging and health economics but also provide crucial scientific evidence to optimize the allocation of medical resources for older patients with multimorbidity in China, alleviate the economic burden on their families, and inform the design of more targeted and equitable health insurance policies.

This study focuses on older inpatients in the Inner Mongolia Autonomous Region. Specifically, it aims to identify age-specific patterns of common dyadic chronic disease combinations among older patients in this region, and accurately quantify the associated dual economic burden, encompassing both total medical expenses and out-of-pocket payments. By doing so, the study provides critical region-specific evidence to inform the optimization of healthcare resource allocation for older patients with multimorbidity in similar border areas, alleviate family economic burdens, and support the design of more targeted and equitable healthcare security policies.

Research methods

Data source

The data for this study were derived from a hospital cost dataset of inpatients from six general hospitals in a city in the Inner Mongolia Autonomous Region of China in 2022. Hospitals were selected using a multi-stage random sampling method: first, six counties/banners were randomly selected from all counties/banners within the city; subsequently, if a county/banner had more than one general hospital, one hospital was randomly selected from that county/banner. Ultimately, data from six general hospitals, including four secondary general hospitals and two tertiary general hospitals, were included. This sampling strategy aimed to enhance the representativeness of the sample for similar urban healthcare environments in the Inner Mongolia region, while selecting data from within a single administrative jurisdiction helped control for variations in healthcare policies and pricing, thereby improving the internal homogeneity and comparability of the study.

In China's healthcare system, general hospitals serve not only as primary providers of medical services but also as providers of a range of other services and functions. In addition to offering emergency care, diagnosis, and treatment, general hospitals function as major centers for critical care, serve as bases for medical education and scientific research, and provide public health services. They also undertake responsibilities such as supporting primary healthcare, responding to medical emergencies, and coordinating the allocation of medical resources. Furthermore, general hospitals actively engage in social services and charitable initiatives and participate in the formulation and reform of healthcare policies. Overall, general hospitals play an indispensable role in China's healthcare system, making significant contributions to safeguarding public health and advancing the development of healthcare services.

This study focused on inpatients aged 50 years or older with a primary diagnosis of a chronic disease. To reveal differences in financial burden across age groups, individuals aged 50–59 were also included. This age range may represent a critical phase for preventing chronic diseases or health issues. Understanding the economic burden in this age group can aid in developing more effective preventive measures, as interventions targeting this population may prevent or mitigate the development of multimorbidity and more severe chronic conditions when they enter older age. Chronic diseases were identified based on ICD-10 codes, with reference to an established list of 46 chronic conditions (Koller et al., 2014).

The study specifically examined dyadic combinations of chronic diseases. Cases were included if at least two chronic diseases from the aforementioned list were recorded among the first five diagnoses. The analysis focused on the ten most common dyadic chronic disease combinations. This design is grounded in clinical practice, as the first five diagnoses typically drive clinical decision-making and resource utilization during hospitalization.

Variables and outcome measures

To comprehensively assess the economic burden of disease, this study defined two outcome variables:

Medical Expenses: This refers to the total of all direct medical costs incurred during a single hospitalization, including medications, diagnostic tests and laboratory examinations, surgical procedures, bed occupancy, and other related expenditures. This metric reflects the overall consumption of healthcare resources from the health system's perspective.

Out-of-Pocket Expenses (OOPE): This refers to the portion of total medical expenses that the patient must pay out of pocket in cash. This indicator directly measures the economic risk and financial pressure faced by the patient's household from their perspective. The two variables are complementary: total medical expenses reveal the scale of costs generated by comorbidity, while out-of-pocket expenses reflect the extent to which these costs are transferred to the patient. By analyzing both variables simultaneously, a comprehensive understanding can be achieved regarding whether high patient burden stems primarily from high medical costs, insufficient insurance coverage, or a combination of both.

The use of this pair of variables also enhances alignment with the study objectives. From a total medical expenses perspective, the study aims to identify how factors such as age and dyadic comorbidity patterns drive hospitalization costs. Policy recommendations arising from this analysis may include improving cost-control mechanisms, optimizing clinical pathways, and strengthening resource allocation for comorbidity management. From an out-of-pocket expense perspective, the study evaluates how insurance schemes and patient characteristics influence the actual economic burden. The findings can provide a basis for policies to refine insurance benefit design, reduce coverage disparities across insured groups, and establish targeted financial protection mechanisms for vulnerable populations. Together, these two variables form a balanced foundation for evidence-based policy recommendations that address both systemic operational efficiency and patient-level affordability.

The core independent variables included:

Age Group: This independent variable was categorized into four 10-year-interval groups (50–59, 60–69, 70–79, ≥80 years) and treated as an ordinal categorical variable.

Dyadic Chronic Disease Combinations: These are defined as the 10 most frequent specific combinations of two chronic diseases (e.g., “Cerebral infarction + Hypertension”). These were treated as nominal categorical variables to analyze the impact of different disease patterns on economic burden.

Data analysis

All statistical analyses were conducted using SPSS software (version 29.0). Descriptive statistics were employed to summarize the characteristics of the study population. Categorical variables, such as age groups and specific dyadic chronic disease combinations, were presented as frequencies and percentages. Continuous variables, including total medical costs and out-of-pocket expenses, were summarized using means and standard deviations (SDs), and 95% confidence intervals (CIs) for the mean were calculated where applicable.

The association between age groups and the distribution of chronic disease count categories was assessed using the Chi-square (χ^2) test. Similarly, the Chi-square test was used to analyze the distribution of the most frequent dyadic chronic disease combinations across different age groups. To compare the means of total medical and out-of-pocket expenses across dyadic disease combinations, a one-way analysis of variance (ANOVA) was performed. For all

inferential statistical tests, a two-sided p value of less than .05 was considered indicative of statistical significance.

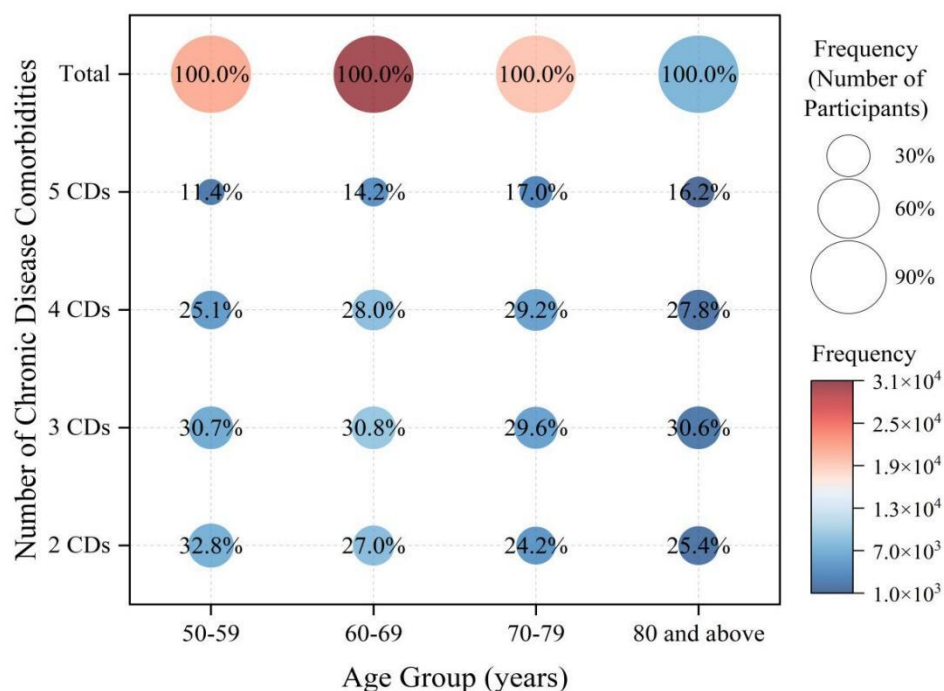
Results

Characteristics of the study population and prevalence of dyadic chronic diseases

In 2022, a total of 106,202 inpatients aged 50 years and older from six hospitals in the city were included in this study. Among them, 78,393 patients met the criteria for multimorbidity (having ≥ 2 chronic diseases), representing an overall prevalence of 73.8%. Within the entire multimorbid population, this study specifically focused on the 21,733 patients with dyadic chronic disease combinations (i.e., those with exactly two chronic diseases), accounting for 27.7% of all multimorbid patients. The average total hospitalization cost for this group was 9,271.29 CNY, with an average out-of-pocket expense of 4,190.10 CNY (all monetary values are reported in Chinese yuan [CNY], based on an approximate 2022 exchange rate of 1 USD $\approx$ 6.7 CNY).

Figure 1 illustrates the age-specific distribution of chronic disease counts among all multimorbid patients ($\chi^2 = 622.77$, $p < .001$). It is noteworthy that, even against the general trend of an increasing number of chronic diseases with age, dyadic combinations represented a substantial proportion across all age groups (ranging from 24.2% to 32.8%), being most prevalent among younger multimorbid patients (aged 50–69 years). This finding justifies an in-depth analysis of the economic burden associated with this fundamental and prevalent form of multimorbidity.

Figure 1: Distribution of Study Population by Number of Chronic Diseases (CDs) Across Age Groups

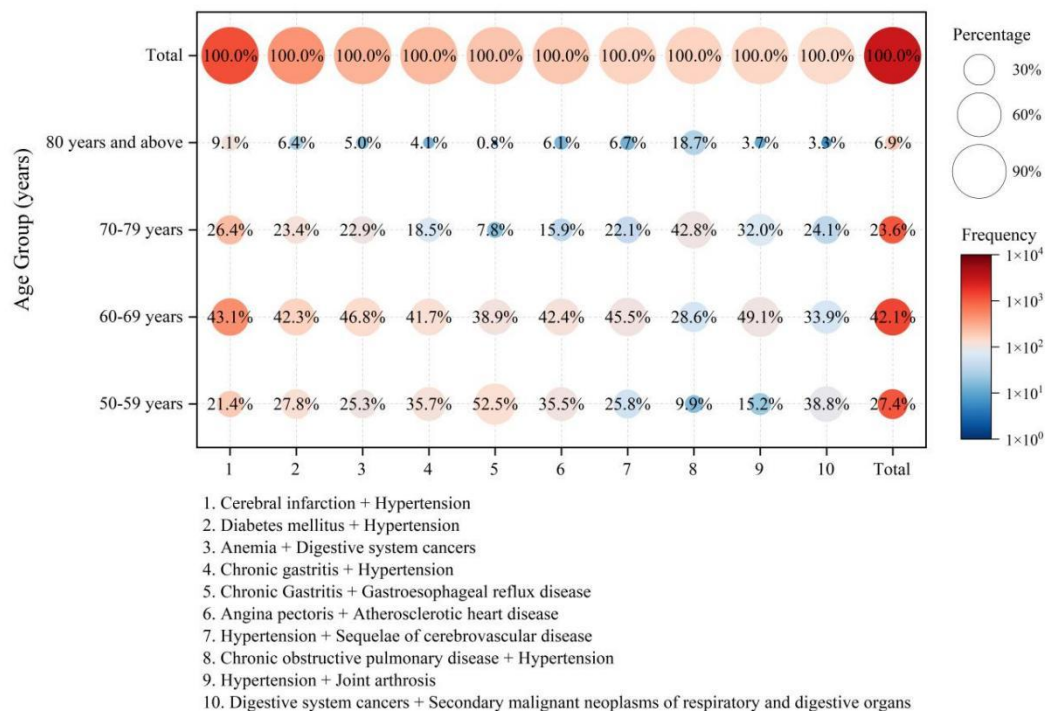


Age distribution characteristics of the top 10 dyadic chronic disease combinations

This study identified a total of 5,190 older inpatients affected by the 10 most common dyadic chronic disease combinations. The age distribution within this population showed statistically significant variation ($\chi^2 = 483.823$, $p < .001$). As illustrated in Figure 2, patients were predominantly concentrated in the 60–69 age group (2,184 individuals, 42.1%), followed by the 50–59 group (1,423 individuals, 27.4%).

Distinct age-clustering patterns were observed for different disease combinations. Combinations represented by “Chronic gastritis + Gastroesophageal reflux disease” showed the highest proportion (52.5%) among patients aged 50–59, characterizing a younger-age-dominant pattern. In contrast, the combination “Chronic obstructive pulmonary disease + Hypertension” had a significantly higher distribution proportion (18.7%) among patients aged 80 and above than other combinations, indicating an advanced-age-associated feature. Hypertension was a component in six of the top ten patterns, highlighting its pivotal role in disease clustering. Cerebral infarction also appeared frequently, indicating it is a key component constituting these prevalent multimorbidity patterns.

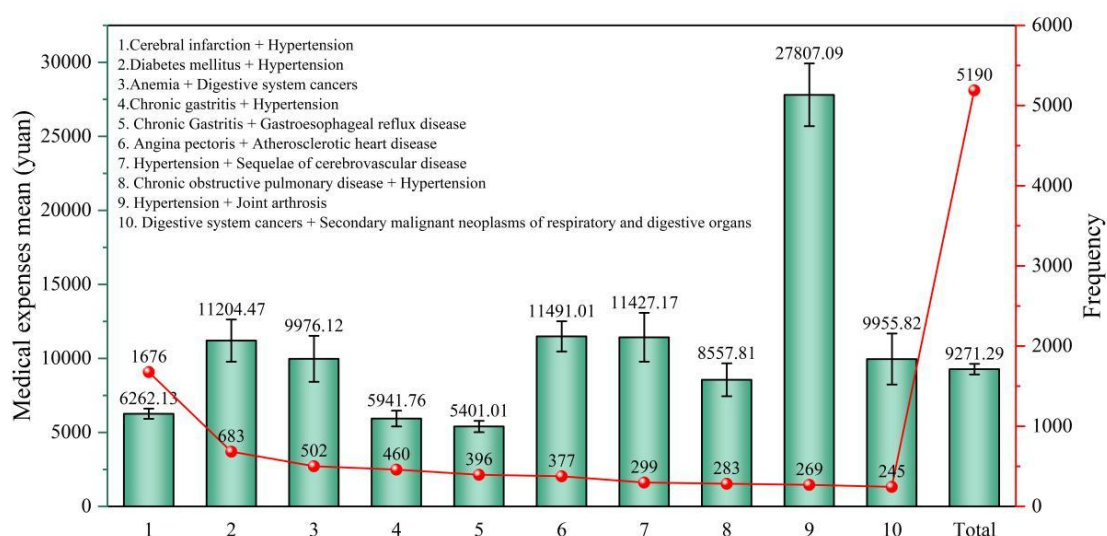
Figure 2: Age Distribution of the Top 10 Dyadic Chronic Disease Combinations Among Older Inpatients (%)



Relationship between dyadic chronic disease combinations and medical expenses

Analysis of medical expenses among the 5,190 older inpatients with the top 10 dyadic chronic disease combinations revealed significant differences in the corresponding total medical costs across combinations ($F = 93.824, p < .001$). The “Hypertension + Joint arthrosis” combination had the highest mean cost at 27,807.09 CNY, approximately three times the overall mean cost (9,271.29 CNY), making it the disease cluster with the heaviest economic burden. In contrast, the “Chronic gastritis + Gastroesophageal reflux disease” combination had the lowest mean cost at 5,401.01 CNY. Furthermore, the degree of cost dispersion varied across combinations. For instance, the “Diabetes mellitus + Hypertension” combination showed the largest standard deviation (18,907.59 CNY), suggesting substantial heterogeneity in disease complexity or treatment regimens within this patient group, leading to significant cost variability. Illustrated in Figure 3, the 95% confidence intervals for the mean cost of all combinations did not include zero, indicating stable and reliable estimates.

Figure 3: Mean Medical Expenses Associated with the Top 10 Dyadic Chronic Disease Combinations Among Older Inpatients

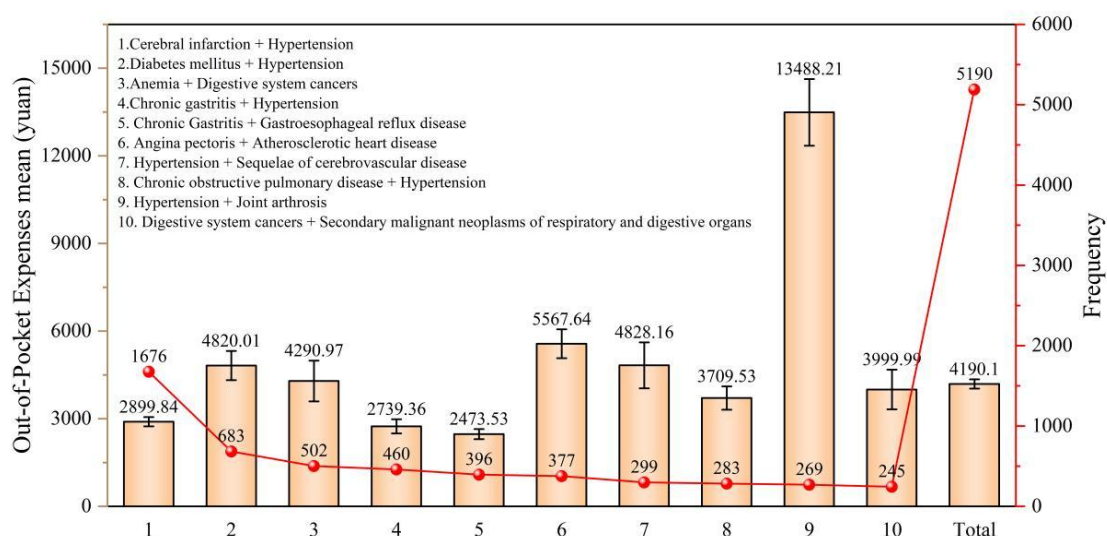


Note: Values are reported in Chinese yuan (CNY); 1 USD $\approx$ 6.7 CNY (2022)

Relationship between dyadic chronic disease combinations and OOPE

The impact of different dyadic chronic disease combinations on patients' OOPE varied significantly ($F = 118.628$, $p < .001$). The "Hypertension + Joint arthrosis" combination imposed the heaviest personal financial burden, with a mean OOPE of 13,488.21 CNY, approximately 3.2 times the overall average (4,190.10 CNY), and exhibited the greatest cost fluctuation (standard deviation 9,517.73 CNY). In stark contrast, the "Chronic gastritis + Gastroesophageal reflux disease" combination was associated with the lowest mean OOPE (2,473.53 CNY) and the most stable costs (standard deviation 1,751.56 CNY). These results indicate that specific disease combinations are a key factor driving substantial divergence in personal financial risk among older inpatients, as illustrated in Figure 4.

Figure 4: Mean Out-of-Pocket Expenses for the Top 10 Dyadic Chronic Disease Combinations Among Older Inpatients



Note: Values are reported in Chinese yuan (CNY); 1 USD $\approx$ 6.7 CNY (2022)

Age-specific patterns of medical expenses for dyadic chronic disease combinations

Medical expenses for different dyadic chronic disease combinations exhibited significant age-specific patterns, as shown in Table 1. Overall, the average cost for all combinations increased from 8,329.08 CNY in the 50–59 age group to 10,259.98 CNY in the 70–79 age group, but decreased to 9,095.97 CNY in the 80 years and above group. This suggests a potential shift in the trend of healthcare resource utilization among the oldest-old population.

Analysis of age patterns of medical expenses across dyadic combinations revealed three typical patterns. In a consistently increasing pattern, combinations such as “Diabetes mellitus + Hypertension” and “Anemia + Digestive system cancers” showed a continuous rise in costs with advancing age, peaking in the 80-year-and-above group. A decline-in-oldest-age pattern was represented by “Hypertension + Joint arthrosis,” costs remained high (above 27,000 CNY) across the 50–79 age groups, but decreased significantly to 18,853.37 CNY in the 80 years and above group. In a relatively stable pattern, the combinations such as “Cerebral infarction + Hypertension” showed minimal fluctuation across age groups.

The study found that cancer-related and clinically complex combinations exhibited extremely large standard deviations in the 80-year-and-above group (e.g., 44,882.11 CNY for “Anemia + Digestive system cancers”), indicating a high degree of individual heterogeneity in treatment intensity and costs within this population.

Table 1: Medical Expenses for the Top 10 Multimorbidity Patterns of Dyadic Chronic Diseases Among Older Inpatients by Age Group (Mean $\pm$ SD, CNY).

Top 10 Dyadic Chronic Disease Combination	50–59 Years	60–69 Years	70–79 Years	80 Years and Above
1. Cerebral infarction + Hypertension	6,839.12 $\pm$ 7,496.17	6,021.55 $\pm$ 7,426.12	6,247.91 $\pm$ 7,446.24	6,084.61 $\pm$ 4,850.55
2. Diabetes mellitus + Hypertension	9,407.33 $\pm$ 11,295.03	10,806.90 $\pm$ 12,645.14	13,299.51 $\pm$ 31,649.25	13,957.77 $\pm$ 17,177.67
3. Anemia + Digestive system cancers	7,615.37 $\pm$ 12,215.35	9,536.48 $\pm$ 16,053.50	12,237.43 $\pm$ 15,545.05	15,699.26 $\pm$ 44,882.11
4. Chronic gastritis + Hypertension	5,736.25 $\pm$ 4,510.77	5,400.21 $\pm$ 2,865.54	7,467.25 $\pm$ 10,749.47	6,363.59 $\pm$ 6,139.03
5. Chronic gastritis + Gastroesophageal reflux disease	5,201.58 $\pm$ 4,106.61	5,357.21 $\pm$ 2,322.04	6,927.24 $\pm$ 7,261.15	5,706.15 $\pm$ 1,981.35
6. Angina pectoris + Atherosclerotic heart disease	11,203.61 $\pm$ 8,767.56	12,009.50 $\pm$ 11,555.84	10,901.59 $\pm$ 8,328.41	11,096.17 $\pm$ 11,122.62
7. Hypertension + Sequelae of cerebrovascular disease	10,812.20 $\pm$ 12,638.88	12,543.93 $\pm$ 17,644.39	9,958.49 $\pm$ 9,510.17	11,047.55 $\pm$ 10,511.41

Top 10 Dyadic Chronic Disease Combination	50–59 Years	60–69 Years	70–79 Years	80 Years and Above
8. Chronic obstructive pulmonary disease + Hypertension	8,488.50 ± 10,692.55	7,358.61 ± 7,010.85	10,012.19 ± 11,729.80	7,106.77 ± 5,169.76
9. Hypertension + Joint arthrosis	26,967.46 ± 19,954.66	29,015.27 ± 19,497.49	27,394.09 ± 13,474.82	18,853.37 ± 13,143.06
10. Digestive system cancers + Secondary malignant neoplasms of respiratory and digestive organs	9,922.61 ± 11,851.79	9,802.75 ± 11,333.38	9,211.76 ± 17,382.91	17,425.87 ± 24,227.49
Average for all listed patterns	8,329.08 ± 10,087.74	9,359.37 ± 12,553.36	10,259.98 ± 16,103.11	9,095.97 ± 15,224.69

Note: Values are reported in Chinese yuan (CNY); 1 USD ≈ 6.7 CNY (2022).

Age-Specific patterns of out-of-pocket expenses for dyadic chronic disease combinations

The age distribution pattern of OOPE largely mirrored that of total medical costs, showing an overall “rise-then-fall” trend, increasing from 3,874.07 CNY in the 50–59 age group to 4,388.48 CNY in the 70–79 age group before declining to 3,957.30 CNY in the 80 years and above group, as presented in Table 2.

Analysis revealed three typical age-related patterns of OOPE, which varied by disease combination. In a consistently increasing pattern, the combinations such as “Diabetes mellitus + Hypertension” and “Anemia + Digestive system cancers” showed a progressive increase in personal financial burden with age. The latter reached a high of 6,511.49 CNY in the 80-and-above age group, with substantial inter-individual variation (SD = 21,570.86 CNY). The decline-in-oldest-age pattern was exemplified by the highest-burden combination, “Hypertension + Joint arthrosis,” where OOPE exceeded 13,000 CNY across the 50–79 age groups but decreased significantly to 9,897.66 CNY in the oldest age group. The relatively stable pattern included cardiovascular-related patterns such as “Angina pectoris + Atherosclerotic heart disease” (costs stable at approximately 5,500 CNY across age groups) and benign digestive system patterns such as “Chronic gastritis + Gastroesophageal reflux disease” (costs consistently remained at a lower level of around 2,000–3,000 CNY).

The study confirmed that “Hypertension + Joint arthrosis” was the combination associated with the highest level of personal financial risk. Furthermore, combinations involving cancer and complex clinical conditions exhibited extreme heterogeneity in personal financial burden among the oldest patients.

Table 2: Out-of-pocket Expenses for the Top 10 Multimorbidity Patterns of Dyadic Chronic Diseases Among Older Inpatients by Age Group (Mean $\pm$ SD, CNY).

Top 10 Dyadic Chronic Disease Combination	50–59 Years	60–69 Years	70–79 Years	80 Years and Above
1. Cerebral infarction + Hypertension	3,215.56 $\pm$ 3,472.06	2,850.99 $\pm$ 3,523.62	2,783.70 $\pm$ 3,114.35	2,725.00 $\pm$ 2,274.88
2. Diabetes mellitus + Hypertension	4,291.29 $\pm$ 5,615.12	5,114.55 $\pm$ 6,554.23	4,759.77 $\pm$ 7,203.54	5,387.61 $\pm$ 8,768.86
3. Anemia + Digestive system cancers	3,538.53 $\pm$ 5,781.88	4,107.99 $\pm$ 7,246.20	5,013.11 $\pm$ 5,781.92	6,511.49 $\pm$ 21,570.86
4. Chronic gastritis + Hypertension	2,722.41 $\pm$ 2,459.21	2,525.90 $\pm$ 1,409.49	3,195.75 $\pm$ 4,554.66	3,000.92 $\pm$ 2,555.25
5. Chronic gastritis + Gastroesophageal reflux disease	2,451.25 $\pm$ 1,844.89	2,416.51 $\pm$ 1,219.22	2,967.88 $\pm$ 2,994.12	1,837.24 $\pm$ 873.14
6. Angina pectoris + Atherosclerotic heart disease	5,524.66 $\pm$ 4,150.24	5,739.16 $\pm$ 5,571.21	5,257.43 $\pm$ 4,166.10	5,434.11 $\pm$ 5,810.64
7. Hypertension + Sequelae of cerebrovascular disease	4,201.64 $\pm$ 5,180.34	5,300.44 $\pm$ 8,737.63	4,463.29 $\pm$ 4,558.00	5,232.85 $\pm$ 5,119.30
8. Chronic obstructive pulmonary disease + Hypertension	4,227.78 $\pm$ 5,474.51	3,430.61 $\pm$ 3,123.96	3,980.25 $\pm$ 3,511.78	3,243.97 $\pm$ 1,819.79
9. Hypertension + Joint arthrosis	13,537.32 $\pm$ 10,210.32	13,965.34 $\pm$ 10,723.47	13,149.96 $\pm$ 7,297.05	9,897.66 $\pm$ 6,221.60
10. Digestive system cancers + Secondary malignant neoplasms of respiratory and digestive organs	4,211.53 $\pm$ 5,193.05	3,876.92 $\pm$ 4,512.89	3,750.03 $\pm$ 6,907.30	4,608.37 $\pm$ 4,077.80
Average for all listed patterns	3,874.07 $\pm$ 4,823.16	4,322.91 $\pm$ 6,155.52	4,388.48 $\pm$ 5,540.88	3,957.30 $\pm$ 7,147.75

Note: Values are reported in Chinese yuan (CNY); 1 USD $\approx$ 6.7 CNY (2022)

Discussion

By analyzing inpatient data, this study reveals the high prevalence of dyadic chronic diseases among the older population. It highlights their significance as a critical starting point in the progression towards more complex multimorbidity. In the study sample, a substantial 27.7% of multimorbid patients were in a dyadic chronic disease state, representing a considerable proportion across all age groups. This underscores the importance of considering this pattern as a fundamental unit for investigating the economic burden of multimorbidity. This approach aligns with the emerging consensus that dyadic multimorbidity represents a critical and identifiable stage for intervention before progression to greater complexity (Whitty et al., 2020).

Age emerged as a core factor shaping disease patterns. On one hand, the data confirm the overall trend of cumulative chronic diseases with increasing age, with dyadic chronic diseases being particularly common among younger multimorbid individuals (aged 50–69). This finding suggests that this age range represents a critical window of opportunity for preventing the progression to more complex multimorbidity. Early, proactive interventions for this population should prioritize delaying the transition from dyadic multimorbidity to a higher-burden state of multiple comorbidities (Salive, 2013). On the other hand, the slight shift in the disease spectrum observed in the oldest-old group (≥ 80 years) suggests the influence of complex mechanisms, such as the survivor effect (Marengoni et al., 2011), necessitating more targeted and comprehensive intervention strategies for this age group.

This study further contextualizes the findings within the background of the Inner Mongolia region. The region's aging rate is higher than the national average, and its characteristics, a vast territory with a sparse population and a distinct distribution of healthcare resources, may contribute to regional specificities in the composition of dyadic multimorbidity and the patterns of its associated economic burden. For instance, the central role of hypertension across the most common combinations is particularly pronounced in the local data, which may be related to regional dietary habits, lifestyles, and access to disease management. Future regional prevention and control strategies must fully account for such localized characteristics.

The research further identified key disease nodes that form the multimorbidity network. Hypertension was present in the majority (6 out of 10) of common multimorbidity patterns, highlighting its central role, while cerebral infarction also appeared repeatedly as a significant comorbid component. Together, they constitute the core pathological basis of multimorbidity in the older population. This finding confirms, at the level of disease combinations, that managing cardiovascular and cerebrovascular diseases is of paramount importance in addressing the burden of multimorbidity among older adults. Consequently, tackling the challenge of multimorbidity among the older requires a tiered, precise strategy. Understanding and addressing its burden must systematically encompass multiple dimensions: disease complexity, intensity of healthcare needs, and socioeconomic pressures (Calderón-Larrañaga et al., 2012; Chen et al., 2017; McPhail, 2016). For middle-aged and younger-old populations, the focus should be on early prevention centered on the management of core diseases such as hypertension.

This study confirms that specific dyadic chronic disease combinations are a central factor driving significant differences in both total medical costs and patient out-of-pocket expenses ($F = 93.824, p < .001$; $F = 118.628, p < .001$) (Lehnert et al., 2011; van den Akker et al., 1998). "Hypertension + Joint arthrosis" carried the heaviest economic burden among all combinations, with its total medical costs and out-of-pocket expenses approximately 3.0 and 3.2 times the overall averages, respectively. This exceptionally high burden may be related to costly treatment needs such as joint replacement surgery, long-term rehabilitation, and medication (Starfield, 2011). In contrast, costs for benign digestive system combinations, such as "Chronic gastritis + Gastroesophageal reflux disease," remained consistently low and stable, reflecting cost controllability under standardized treatment protocols (Marengoni & Onder, 2015).

The cost patterns reveal substantial heterogeneity in individual financial risk. High-cost combinations (e.g., "Hypertension + Joint arthrosis," "Diabetes mellitus + Hypertension") not only exhibited high means but also large standard deviations, indicating considerable variation in the actual burden borne by patients. This suggests that within high-cost disease clusters such as "Hypertension + Joint arthrosis," differences in treatment pathways, disease

severity, and insurance reimbursement rates may be reflected in unequal financial risk among patients (Muka et al., 2015).

This study found that the economic burden of dyadic chronic disease combinations exhibits three typical patterns across age groups, revealing its complexity. These patterns can be further understood through the lens of health economics and behavioral models. The three age-specific cost patterns we identified-consistently increasing, decline in the oldest-old, and stable-can be interpreted through the lens of Grossman's (1972) health capital model. For combinations characterized by a consistently increasing pattern (e.g., Diabetes mellitus + Hypertension, Anemia + Digestive system cancers), health depreciation appears to accelerate continuously with age, with no observable shift toward conservative treatment even in the oldest age group. This suggests that the marginal return on medical investment remains sufficiently high to justify intensive treatment, possibly because these conditions involve progressive pathology that demands ongoing intervention.

Conversely, the decline-in-oldest-age pattern, exemplified by "Hypertension + Joint arthrosis," aligns with Grossman's (1972) prediction that when health capital falls below a critical threshold, individuals (or their physicians) may opt for less aggressive management. The sharp reduction in both total medical expenses and out-of-pocket payments among patients aged ≥ 80 years is likely attributable to a lower proportion of major surgical interventions (e.g., joint replacements) in this age group, consistent with a shift toward conservative or palliative care. The relatively stable pattern observed for certain combinations (e.g., "Cerebral infarction + hypertension," "Chronic gastritis + GERD") suggests that these conditions follow standardized treatment pathways that are less sensitive to age variation, possibly because their management protocols are well-established and do not escalate with age. Andersen's (1995) behavioral model further illuminates why specific dyadic combinations carry vastly different economic burdens. In this framework, dyadic disease combinations function as need factors-the strongest drivers of healthcare utilization.

Combinations involving high-severity conditions (e.g., joint arthrosis requiring surgery, cancer requiring chemotherapy or targeted therapy) generate greater need and consequently higher medical expenses and out-of-pocket payments. Age, as a predisposing factor, interacts with need by influencing both disease progression and treatment decisions. Meanwhile, enabling resources-notably health insurance coverage and spatial accessibility to hospitals-mediate the translation of need into actual expenditure and financial risk. The extreme heterogeneity in out-of-pocket expenses among cancer patients aged ≥ 80 years (standard deviation 21,570.86 CNY for the combination "Anemia + Digestive system cancers") can be understood as variation in enabling resources. That is, some patients have comprehensive insurance that covers high-cost therapies, while others face catastrophic expenses due to insufficient coverage or the need to seek care across regions.

Overall, both total medical costs and out-of-pocket expenses peaked in the 70–79 age group before declining in the ≥ 80 age group. This "rise-then-fall" pattern with advancing age has also been observed in other national studies of multimorbidity in China, likely reflecting a combination of changing clinical needs and healthcare utilization (Zhao et al., 2020). This shift in trend may be associated with more conservative treatment strategies, reduced invasive interventions like surgery, and evolving treatment preferences among patients and their families in the oldest-old population (Puts et al., 2017). These findings align with previous studies that have reported similar age-related cost trajectories for specific disease clusters (Jiang et al., 2013; Lehnert et al., 2011; Ma et al., 2021).

A key finding was the extreme individual heterogeneity in costs (indicated by very large standard deviations) for cancer-related combinations among the oldest patients. This heterogeneity may be partly explained by the fact that multimorbidity patterns involving cancer are consistently associated with highly variable and intensive treatment pathways, leading to greater financial risk (Moriarty et al., 2015). This suggests that even with the same diagnosis, a subset of these patients face catastrophic personal financial risk associated with receiving high-intensity treatments (e.g., surgery, targeted therapy) (Schoen et al., 2013). This warns that focusing solely on average costs may obscure the severe burden borne by the most vulnerable subgroups. Within the context of Inner Mongolia's healthcare resources, this heterogeneity may be especially pronounced.

For cancer patients with comorbidities who require high-cost, high-technology treatments, factors such as their ability to access specialized services at regional medical centers conveniently and the policies for cross-regional treatment reimbursement under the health insurance scheme can substantially impact their actual economic burden. Therefore, management strategies for geriatric multimorbidity must reflect dual specificity for both age and disease combination. For consistently increasing patterns, early prevention and standardized management in middle age should be strengthened, and protection policies for such patients should be further refined (Watson et al., 2025). For the oldest-old patients, clinical decision-making requires careful balancing of treatment intensity, quality of life, and economic affordability, supported by more precise health insurance payment designs to prevent catastrophic health expenditure, with particular attention to patients with complex conditions such as cancer.

The findings, particularly the identification of high-burden dyadic combinations (e.g., "Hypertension + Joint arthrosis") and the three age-specific cost patterns, may serve as a useful reference for other aging, resource-constrained border areas in China, such as parts of Xinjiang and other western provinces. However, direct application of these results requires careful adjustment for local differences in disease spectrum, health insurance policies, and healthcare infrastructure.

Policy implications

The three age-specific cost patterns have distinct implications for policy and practice. Health insurance payment systems and clinical management frameworks may be shifted from a single-disease mindset toward a multimorbidity-combination-oriented approach, which requires integrated care pathways tailored to common disease clusters and payment models that appropriately finance the complexity of care (Skou et al., 2022).

For consistently increasing patterns (e.g., "Diabetes mellitus + Hypertension"), early prevention and standardized management in middle age should be strengthened. In addition, health insurance systems may consider diagnosis-related group (DRG) payments with quality bonuses to encourage efficient care. For the decline-in-oldest-old pattern (e.g., Hypertension + Joint arthrosis), geriatric-specific clinical guidelines are needed, along with bundled payments that appropriately reimburse both surgical and conservative management options. For stable patterns (e.g., Chronic gastritis + GERD), current standardized treatment pathways should be maintained, with a focus on primary care. For high-risk cancer combinations, out-of-pocket caps and targeted medical assistance programs for border and remote areas are urgently needed to prevent catastrophic health expenditure (Barnett et al., 2012).

Specifically within Inner Mongolia, local health insurance policies, such as reimbursement rates, benefit package design, and the effectiveness of the tiered healthcare delivery system, significantly influence patients' out-of-pocket expenses. Regional authorities could pilot payment models based on combinations of diseases or strengthen medical assistance for patients in pastoral and remote areas. These measures would directly address the heterogeneity in individual financial risk revealed by this study, particularly the extreme economic risk faced by the oldest cancer patients.

Strengths and limitations

This study has several strengths. First, it is based on inpatient data from six general hospitals in a city in the Inner Mongolia Autonomous Region in 2022, with a substantial sample size ($N = 106,202$). This dataset authentically reflects the real-world scenario of older inpatients with multimorbidity in this typical border region, providing important local evidence for an area characterized by a high degree of aging yet relatively insufficient related research. Second, unlike many studies that broadly discuss multimorbidity, this research focuses specifically on the distinct and prevalent stage of dyadic chronic disease combinations. Conducting an in-depth analysis of the ten most common combinations helps identify key disease clusters that drive the economic burden, making the findings more targeted for policy and practice. Third, the study examines both total and out-of-pocket medical expenses, offering a comprehensive assessment of the economic burden from the perspectives of the healthcare system and individual households. Furthermore, stratifying the analysis by age reveals three heterogeneous patterns in the evolution of the economic burden with age (consistently increasing, decline in the oldest age, and relatively stable), thereby deepening the understanding of the dynamic economic impact of multimorbidity.

This study also has several limitations. First, the data originate from a single city within the Inner Mongolia Autonomous Region. While this ensures strong internal comparability, caution is warranted when generalizing the findings to other regions in China, especially those with significant differences in healthcare policies and levels of economic development. The results provide valuable references for understanding issues related to aging and the economic burden of multimorbidity in other similar cities within Inner Mongolia or in other border regions across the country (e.g., Xinjiang); however, their generalizability still requires verification through more regional studies. Second, the data cover only inpatient costs and exclude outpatient, rehabilitation, long-term care, and indirect non-medical costs, which may lead to an underestimation of the full economic burden of multimorbidity. Third, as a retrospective study, it can reveal significant associations between variables but cannot establish causality.

Fourth, the identification of chronic diseases and their combinations relied solely on the first five diagnoses recorded during hospitalization, which may not fully capture all relevant chronic health conditions. Fifth, although focusing on dyadic combinations is representative, the analysis does not encompass more complex multimorbidity patterns (involving three or more diseases) and their potentially unique economic impacts. Sixth, regarding statistical methods, although our large sample size supports the validity of chi-square tests and one-way ANOVA for group comparisons, the medical expense and out-of-pocket expense data exhibited right-skewed distributions. Skew-adjusted statistical models, more suitable for cost data, were not used, nor was multivariable modeling performed to adjust for potential confounders such as sex, hospital level, health insurance type, and disease severity. Skewness

and extreme values, if left untreated, may increase within-group variance. These limitations may affect the inferential robustness of the findings. Future studies should adopt more appropriate statistical methods for skewed healthcare cost data and incorporate multivariable regression to adjust for confounders, thereby enhancing the reliability and depth of cost analyses.

Conclusion

By focusing on dyadic combinations of chronic diseases, this study reveals their epidemiological significance and serves as a critical starting point for understanding the progression of multimorbidity complexity. It clarifies how age and specific disease patterns jointly shape the complex landscape of economic burden among older inpatients in Inner Mongolia, a representative aging region in northern China. Key findings indicate that specific combinations, such as “Hypertension + Joint arthrosis,” constitute high-burden focal points of resource consumption, while cancer-related conditions exhibit extreme individual heterogeneity in financial risk among the oldest-old patients. The evolution of economic burden with age does not follow a simple linear trajectory but rather exhibits three distinct patterns: a consistent increase, a decline in the oldest age group, and relative stability.

Based on these findings, addressing the challenge of geriatric multimorbidity in regions with similar demographic and healthcare contexts requires establishing a tiered and precise intervention system. Concurrently, health insurance policies should be designed to prioritize high economic-risk disease clusters, aiming to optimize resource allocation and effectively prevent catastrophic health expenditure. The findings and implications provide a regional evidence base for tailoring strategies to the specific needs of aging populations in border and underserved areas.

Ethical approval

The study protocol was reviewed and approved by the Research Ethics Committee (Social Sciences) of Mahidol University, Thailand (Approval No. 2024/056.1806). As this study used a fully anonymized hospital cost dataset containing no personally identifiable information (such as names, contact details, or patient identification numbers), the ethics committee waived the requirement to obtain individual patient informed consent.

Statement on AI tool usage

During the preparation of this manuscript, the authors used DeepSeek for language polishing, grammar checking, and improving readability. All research design, data analysis, interpretation, and academic reasoning are entirely the authors’ own work, based on original data and a thorough literature review. After using the tool, the authors carefully reviewed and revised the content to ensure it accurately reflects the research and adheres to academic standards. The authors take full responsibility for the entire content of this manuscript.

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References

- Andersen, R. M. (1995). Revisiting the behavioral model and access to medical care: Does it matter? *Journal of Health and Social Behavior*, 36(1), 1–10. <https://doi.org/10.2307/2137284>
- Barnett, K., Mercer, S. W., Norbury, M., Watt, G., Wyke, S., & Guthrie, B. (2012). Epidemiology of multimorbidity and implications for health care, research, and medical education: A cross-sectional study. *Lancet*, 380(9836), 37–43. [https://doi.org/10.1016/S0140-6736\(12\)60240-2](https://doi.org/10.1016/S0140-6736(12)60240-2)
- Busija, L., Lim, K., Szoek, C., Sanders, K. M., & McCabe, M. P. (2019). Do replicable profiles of multimorbidity exist? Systematic review and synthesis. *European Journal of Epidemiology*, 34(11), 1025–1053. <https://doi.org/10.1007/s10654-019-00568-5>
- Calderón-Larrañaga, A., Poblador-Plou, B., González-Rubio, F., Gimeno-Feliu, L. A., Abad-Díez, J. M., & Prados-Torres, A. (2012). Multimorbidity, polypharmacy, referrals, and adverse drug events: Are we doing things well? *British Journal of General Practice*, 62(605), e821–e826. <https://doi.org/10.3399/bjgp12X659295>
- Chen, W., Zhang, Q., Renzaho, A. M. N., Zhou, F., Zhang, H., & Ling, L. (2017). Social health insurance coverage and financial protection among rural-to-urban internal migrants in China: Evidence from a nationally representative cross-sectional study. *BMJ Global Health*, 2(4), Article e000477. <https://doi.org/10.1136/bmjgh-2017-000477>
- Chen, Y., & Liu, W. (2022). Utilization and out-of-pocket expenses of primary care among the multimorbid elderly in China: A two-part model with nationally representative data. *Frontiers in Public Health*, 10, Article 1057595. <https://doi.org/10.3389/fpubh.2022.1057595>
- Fortin, M., Stewart, M., Poitras, M. E., Almirall, J., & Maddocks, H. (2012). A systematic review of prevalence studies on multimorbidity: Toward a more uniform methodology. *Annals of Family Medicine*, 10(2), 142–151. <https://doi.org/10.1370/afm.1337>
- Goodman, R. A., Posner, S. F., Huang, E. S., Parekh, A. K., & Koh, H. K. (2013). Defining and measuring chronic conditions: Imperatives for research, policy, program, and practice. *Preventing Chronic Disease*, 10, Article 120239. <https://doi.org/10.5888/pcd10.120239>
- Grossman, M. (1972). On the concept of health capital and the demand for health. *Journal of Political Economy*, 80(2), 223–255. <https://doi.org/10.1086/259880>
- Jiang, Y., Wang, Y., Zhang, L., Li, Y., Wang, X., & Ma, S. (2013). Access to healthcare and medical expenditure for the middle-aged and elderly: Observations from China. *PLOS ONE*, 8(5), Article e64589. <https://doi.org/10.1371/journal.pone.0064589>
- Jing, Z., Li, J., Fu, P. P., Wang, Y., Yuan, Y., Zhao, D., Hao, W., Yu, C., & Zhou, C. (2021). Catastrophic health expenditure among single empty-nest elderly with multimorbidity in rural Shandong, China: The effect of co-occurrence of frailty. *International Journal for Equity in Health*, 20(1), Article 23. <https://doi.org/10.1186/s12939-020-01362-6>
- Koller, D., Schön, G., Schäfer, I., Glaeske, G., van den Bussche, H., & Hansen, H. (2014). Multimorbidity and long-term care dependency--A five-year follow-up. *BMC Geriatrics*, 14, Article 70. <https://doi.org/10.1186/1471-2318-14-70>

- La, D. T. V., Zhao, Y., Arokiasamy, P., Atun, R., Mercer, S., Marthias, T., McPake, B., Pati, S., Palladino, R., & Lee, J. T. (2022). Multimorbidity and out-of-pocket expenditure for medicines in China and India. *BMJ Global Health*, 7(11), Article e007724. <https://doi.org/10.1136/bmjgh-2021-007724>
- Larkin, J., Walsh, B., Moriarty, F., Clyne, B., Harrington, P., & Smith, S. M. (2022). What is the impact of multimorbidity on out-of-pocket healthcare expenditure among community-dwelling older adults in Ireland? A cross-sectional study. *BMJ Open*, 12(9), Article e060502. <https://doi.org/10.1136/bmjopen-2021-060502>
- Lehnert, T., Heider, D., Leicht, H., Heinrich, S., Corrieri, S., Lupp, M., Riedel-Heller, S., & König, H. H. (2011). Review: Health care utilization and costs of elderly persons with multiple chronic conditions. *Medical Care Research and Review*, 68(4), 387–420. <https://doi.org/10.1177/1077558711399580>
- Li, H., Chang, E., Zheng, W., Liu, B., Xu, J., Gu, W., Zhou, L., Li, J., Liu, C., Yu, H., & Huang, W. (2022). Multimorbidity and catastrophic health expenditure: Evidence from the China Health and Retirement Longitudinal Study. *Frontiers in Public Health*, 10, Article 1043189. <https://doi.org/10.3389/fpubh.2022.1043189>
- Ma, M., Tian, W., Kang, J., Li, Y., Xia, Q., Wang, N., Miao, W., Zhang, X., Zhang, Y., Shi, B., Gao, H., Sun, T., Fu, X., Hao, Y., Li, H., Shan, L., Wu, Q., & Li, Y. (2021). Does the medical insurance system play a real role in reducing catastrophic economic burden in elderly patients with cardiovascular disease in China? Implication for accurately targeting vulnerable characteristics. *Globalization and Health*, 17(1), Article 36. <https://doi.org/10.1186/s12992-021-00683-7>
- Marengoni, A., Angleman, S., Melis, R., Mangialasche, F., Karp, A., Garmen, A., Meinow, B., & Fratiglioni, L. (2011). Aging with multimorbidity: A systematic review of the literature. *Ageing Research Reviews*, 10(4), 430–439. <https://doi.org/10.1016/j.arr.2011.03.003>
- Marengoni, A., & Onder, G. (2015). Guidelines, polypharmacy, and drug-drug interactions in patients with multimorbidity. *BMJ*, 350, Article h1059. <https://doi.org/10.1136/bmj.h1059>
- McPhail S. M. (2016). Multimorbidity in chronic disease: Impact on health care resources and costs. *Risk Management and Healthcare Policy*, 9, 143–156. <https://doi.org/10.2147/RMHP.S97248>
- Moriarty, F., Hardy, C., Bennett, K., Smith, S. M., & Fahey, T. (2015). Trends and interaction of polypharmacy and potentially inappropriate prescribing in primary care over 15 years in Ireland: A repeated cross-sectional study. *BMJ Open*, 5(9), Article e008656. <https://doi.org/10.1136/bmjopen-2015-008656>
- Muka, T., Imo, D., Jaspers, L., Colpani, V., Chaker, L., van der Lee, S. J., Mendis, S., Chowdhury, R., Bramer, W. M., Falla, A., Pazoki, R., & Franco, O. H. (2015). The global impact of non-communicable diseases on healthcare spending and national income: A systematic review. *European Journal of Epidemiology*, 30(4), 251–277. <https://doi.org/10.1007/s10654-014-9984-2>
- Mukherjee, K., & Kamal, K. M. (2017). Sociodemographic determinants of out-of-pocket expenditures for patients using prescription drugs for rheumatoid arthritis. *American Health & Drug Benefits*, 10(1), 7–15. <https://www.ahdbonline.com/issues/2017/february-2017-vol-10-no-1/sociodemographic-determinants-of-out-of-pocket-expenditures-for-patients-using-prescription-drugs-for-rheumatoid-arthritis>
- Park, E. J., Sohn, H. S., Lee, E. K., & Kwon, J. W. (2014). Living arrangements, chronic diseases, and prescription drug expenditures among Korean elderly: Vulnerability to potential medication underuse. *BMC Public Health*, 14, Article 1284. <https://doi.org/10.1186/1471-2458-14-1284>
- Puts, M. T. E., Toubasi, S., Andrew, M. K., Ashe, M. C., Ploeg, J., Atkinson, E., Ayala, A. P., Roy, A., Rodríguez Monforte, M., Bergman, H., & McGilton, K. (2017). Interventions to prevent or reduce the level of frailty in community-dwelling older adults: A scoping review of the literature and international policies. *Age and Ageing*, 46(3), 383–392. <https://doi.org/10.1093/ageing/afw247>
- Salive M. E. (2013). Multimorbidity in older adults. *Epidemiologic Reviews*, 35(1), 75–83. <https://doi.org/10.1093/epirev/mxs009>
- Schoen, C., Osborn, R., Squires, D., & Doty, M. M. (2013). Access, affordability, and insurance complexity are often worse in the United States compared to ten other countries. *Health Affairs*, 32(12), 2205–2215. <https://doi.org/10.1377/hlthaff.2013.0879>

- Skou, S. T., Mair, F. S., Fortin, M., Guthrie, B., Nunes, B. P., Miranda, J. J., Boyd, C. M., Pati, S., Mtenga, S., & Smith, S. M. (2022). Multimorbidity. *Nature Reviews Disease Primers*, 8, Article 48. <https://doi.org/10.1038/s41572-022-00376-4>
- Starfield, B. (2011). Challenges to primary care from co- and multi-morbidity. *Primary Health Care Research & Development*, 12(1), 1–2. <https://doi.org/10.1017/S1463423610000484>
- State Council of the People's Republic of China. (2019, July 15). *Guowuyuan guanyu shishi jiankang Zhongguo xingdong de yijian* [State Council's opinions on implementing the Healthy China Action] (Document No. Guo Fa [2019] No. 13). Central People's Government of the People's Republic of China. https://www.gov.cn/zhengce/content/2019-07/15/content_5409492.htm
- Uijen, A. A., & van de Lisdonk, E. H. (2008). Multimorbidity in primary care: Prevalence and trend over the last 20 years. *European Journal of General Practice*, 14 (Suppl 1), 28–32. <https://doi.org/10.1080/13814780802436093>
- van den Akker, M., Buntinx, F., Metsemakers, J. F., Roos, S., & Knottnerus, J. A. (1998). Multimorbidity in general practice: Prevalence, incidence, and determinants of co-occurring chronic and recurrent diseases. *Journal of Clinical Epidemiology*, 51(5), 367–375. [https://doi.org/10.1016/s0895-4356\(97\)00306-5](https://doi.org/10.1016/s0895-4356(97)00306-5)
- Wang, Z., & Zeng, Z. (2023). Effects of multimorbidity patterns and socioeconomic status on catastrophic health expenditure of widowed older adults in China. *Frontiers in Public Health*, 11, Article 1188248. <https://doi.org/10.3389/fpubh.2023.1188248>
- Watson, K. B., Wiltz, J. L., Nhim, K., Kaufmann, R. B., Thomas, C. W., & Greenlund, K. J. (2025). Trends in multiple chronic conditions among US adults by Life stage, Behavioral Risk Factor Surveillance System, 2013–2023. *Preventing Chronic Disease*, 22, Article 240539. <https://doi.org/10.5888/pcd22.240539>
- Whitty, C. J. M., MacEwen, C., Goddard, A., Alderson, D., Marshall, M., Calderwood, C., Atherton, F., McBride, M., Atherton, J., Stokes-Lampard, H., Reid, W., Powis, S., & Marx, C. (2020). Rising to the challenge of multimorbidity. *BMJ*, 368, Article l6964. <https://doi.org/10.1136/bmj.l6964>
- World Health Organization. (2016). *Multimorbidity: Technical series on safer primary care*. <https://apps.who.int/iris/handle/10665/252275>
- Zhai, X., Zhang, Q., Li, X., & Zhao, X. (2023). Association between multimorbidity patterns and catastrophic health expenditure among Chinese older adults living alone. *Archives of Gerontology and Geriatrics*, 106, Article 104892. <https://doi.org/10.1016/j.archger.2022.104892>
- Zhang, Y., Zhou, L., Liu, S., Qiao, Y., Wu, Y., Ke, C., & Shen, Y. (2020). Prevalence, correlates and outcomes of multimorbidity among the middle-aged and elderly: Findings from the China Health and Retirement Longitudinal Study. *Archives of Gerontology and Geriatrics*, 90, Article 104135. <https://doi.org/10.1016/j.archger.2020.104135>
- Zhao, Y., Atun, R., Oldenburg, B., McPake, B., Tang, S., Mercer, S. W., Cowling, T. E., Sum, G., Qin, V. M., & Lee, J. T. (2020). Physical multimorbidity, health service use, and catastrophic health expenditure by socioeconomic groups in China: An analysis of population-based panel data. *Lancet Global Health*, 8(6), e840–e849. [https://doi.org/10.1016/S2214-109X\(20\)30127-3](https://doi.org/10.1016/S2214-109X(20)30127-3)