An Analysis of Economic Burden of Hypertensive Patients Based on “System of Health Accounts 2011” and Multiple Layer Perceptron Neural Network

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1 **Title page**

2 **Article title**

3 An analysis of economic burden of hypertensive patients based on “System of Health
4 Accounts 2011” and multiple layer perceptron neural network

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1 Abstract

2 **Background:** Hypertension requires long-term treatment and medication, which not
3 only affects people's health, but also brings heavy economic burden for families and
4 society. Therefore, it is meaningful to reveal the actual personal and socio-economic
5 burdens of hypertension based on a tool recognized internationally to improve
6 management of hypertensive patients and provide more information for policy makers,
7 analysts, and international comparisons.

8 **Methods:** We collected expense records of 180441 hypertensive outpatients and
9 14763 inpatients in Shanxi Province of China in 2017. Curative care expenditure for
10 hypertension(CCE_{ht}) were analyzed based on System of Health Accounts 2011, and
11 influencing factors were analyzed by multiple layer perceptron (MLP) neural network.

12 **Results:** In 2017, CCE_{ht} was US\$ 307.71 million, accounted for 3.63% of the total
13 CCE and 0.14% of GDP in Shanxi Province of China. CCE of hypertensive
14 outpatients (CCE_{ht-out}) and inpatients (CCE_{ht-in}) accounted for 44.49% and 55.51% of
15 the CCE_{ht} , drug fee accounted for 81.55% of CCE_{ht-out} and 22.50% of CCE_{ht-in} ,
16 respectively. CCE_{ht} increased from the age of 30, and the highest occurred in age 60-
17 69. The patients with the age of 40-79 accounted for 86.49% of total CCE_{ht} . CCE_{ht} of
18 male patients were generally higher than that of female, and there is a significant
19 difference between CCE_{ht} for male and female in terms of age. The diagnosis and
20 treatment capacity of primary health care system had been enhanced. New rural
21 cooperation medical insurance and urban employee basic medical insurance had the
22 trend of overusing, and burden of family healthcare expenditure was still very heavy.
23 In the MLP neural network, the top three influencing factors were drug fee, surgical

1 fee and hospitalization days for inpatients, drug fee, examination fee and test fee for
2 outpatients.

3 **Conclusions:** To ease the economic burden of hypertensive patients and improve the
4 utilization efficiency of social resources , the policy makers should pay more attention
5 to the hypertensive patients aging 40-79, strengthen prevention and outpatient
6 treatment for young men and the inpatient treatment for women at older ages, further
7 increase support for primary health care system, standardize the treatment and
8 reimbursement of hypertension, and incline the reimbursement policy to outpatient
9 service.

10 **Keywords**

11 Hypertension, Economic burden, Curative care expenditure, System of Health
12 Accounts 2011, Multiple layer perceptron neural network

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1 **Background**

2 Along with the rapid development of society and economy, China has a high prevalence of
3 hypertension and it has risen from 18.8% in 2002 [1] to 29.6% in 2014 [2], ranking first in the
4 prevalence of major chronic diseases. Hypertension is a non-independent disease, which is
5 often accompanied by cardiovascular and cerebrovascular diseases. Hypertension requires
6 long-term treatment and medication, which not only affects people's health, but also bring
7 heavy economic burden for families and society [3]. Therefore, accurately estimating the
8 economic burden caused by hypertension is of great practical significance to develop an
9 intervention strategy and to achieve "global action plan for the prevention and control of
10 noncommunicable diseases 2013-2020" [4].

11 In our study, we collected expense records of 180441 hypertensive outpatients and
12 14763 hypertensive inpatients from 1088 medical institutions in Shanxi Province in
13 2017, and calculated curative care expenditure(CCE) for hypertension(CCE_{ht}) in the
14 frame of System of Health Accounts 2011(SHA2011) [5]. SHA 2011 is an
15 internationally recognized health policy analysis and evaluation tool for the
16 systematic description of the financial flows related to health care. According to the
17 situation of China, researchers from the China National Health Development
18 Research Center proposed a detailed system for the systematic description of the
19 financial flows in 2014 [6, 7]. In SHA 2011, CCE contains expenditure of curative
20 care, rehabilitative care and long-term health care, not include preventive care. Based
21 on the SHA 2011and combined with the actual situation of China's health system, the
22 CCE for hypertension in Shanxi Province can reveal the actual personal and socio-
23 economic burdens of hypertension.

24 Multiple layer perceptron(MLP) neural network is an important one of Artificial
25 Neural Networks, which can model complex functions and ignore irrelevant inputs

1 and noise [8]. Due to the skewness and nonlinearity of medical expense data, we
2 select MLP neural network to analyze the influence factors of CCE_{ht} . All the
3 calculation and analysis will improve management of hypertensive patients and
4 provide more information for policy makers, analysts, and international comparisons.

5 **Methods**

6 **Data sources**

7 Data in different health institutions was collected from Shanxi Health Financial
8 Yearbook 2017, Shanxi Health Statistical Yearbook 2017, China National Health
9 Accounts Report 2017, Shanxi Health Accounts Report 2017, etc. Demographic data
10 was obtained from medical institutions, Shanxi statistical yearbook 2017, and public
11 health institutions.

12 **Study samples**

13 Multistage stratified cluster random sampling was applied in this study. First, we
14 chose four sample cities (Taiyuan, Changzhi, Yuncheng and Xizhou) from Shanxi
15 Province on the basis of the sufficient consideration of the level of health information
16 management system and economic development. Next, we chose one county and one
17 district in every city, and selected six township hospitals and community health
18 service organization in every country and district. At last, we chose medical
19 institutions and public health institutions on the basis of the type of institutions or
20 administration structure. The final valid sample included 180441 hypertensive
21 outpatients and 14763 inpatients from 1088 medical institutions. The basic
22 information of sample included gender, age, disease coded by International
23 Classification of Diseases Tenth Revision(ICD-10) and Global Burden of Disease

(GBD), total expense, drug fee, examination fee, level of health institutions, financing schemes, etc.

Calculation of CCE in the frame of SHA 2011

CCE consists of curative income and allowance, which come from statistical yearbook and financial yearbook. All the calculations were performed by the software STATA 12.0. $E_{t-income}$ is total income in different health institutions of Shanxi Province, includes curative and partial preventive expenditure, can be queried from 2017 Shanxi Health Statistical Yearbook. e_i , e_{pre} and e are curative income of per patient, total preventive expenditure and total income in the sample. Through formula (1), we can remove preventive expenditure and get curative income $E_{c-income}$ of outpatient or inpatient in deferent health institutions of Shanxi Province. E_{income} represents curative income in various dimensions, such as age, gender, region, etc.

$\frac{e_i}{e-e_{pre}}$ is a sharing coefficient of per patient. Through formula (2), we can work out the curative income of patient in various dimensions, such as gender, age, health institutions and financing schemes.

$$E_{c-income} = E_{t-income} \left(1 - \frac{e_{pre}}{e} \right) \quad (1)$$

$$E_{income} = \sum_{k=1}^n (E_{c-income} \times \frac{e_i}{e-e_{pre}})_k \quad (2)$$

$E_{t-subsidy}$ represents total government subsidy in deferent health institutions of Shanxi Province, including curative and partial preventive expenditure in outpatient and inpatient, can be queried from 2017 Shanxi Health Financial Yearbook. $E_{p-subsidy}$ is government subsidy in preventive service, collected from Yearbook as well. We can

1 get curative government subsidy from formula (3). $N_{b-subsidy}$ is the number of hospital's
2 bed, $N_{o-subsidy}$ is number of curative outpatient, and $\frac{N_{b-subsidy}}{N_{b-subsidy} - N_{o-subsidy} \times 0.1}$ is a sharing
3 coefficient of inpatient. We can calculate government subsidy of inpatient ($E_{i-subsidy}$)
4 and outpatient ($E_{o-subsidy}$) through formula (4) and (5) separately. Then times the
5 sharing coefficient of per patient, we can get the government subsidy of patient
6 ($E_{subsidy}$) in various dimensions through formula (6). In formula (7), Curative care
7 expenditure (E_{CCE}) is the sum of E_{income} and $E_{subsidy}$ in various dimensions.

$$8 \quad E_{c-subsidy} = E_{t-subsidy} - E_{p-subsidy} \quad (3)$$

$$9 \quad E_{i-subsidy} = E_{c-subsidy} \times \frac{N_{b-subsidy}}{N_{b-subsidy} - N_{o-subsidy} \times 0.1} \quad (4)$$

$$10 \quad E_{o-subsidy} = E_{c-subsidy} \times (1 - \frac{N_{b-subsidy}}{N_{b-subsidy} - N_{o-subsidy} \times 0.1}) \quad (5)$$

$$11 \quad E_{subsidy} = \sum_{k=1}^n [E_{i-subsidy} \text{ (or } E_{o-subsidy}) \times \frac{e_i}{e - e_{pre}}]_k \quad (6)$$

$$12 \quad E_{CCE} = E_{income} + E_{subsidy} \quad (7)$$

13 **MLP neural network**

14 MLP neural network consists of an input layer, one or more multiple hidden layers
15 and an output layer. According to the principles of input layer variables, we choose
16 gender, age, surgical fee, drug fee, test fee, treatment fee, bed fee, consultation fee,
17 examination fee, nursing fee, diagnosis fee, hospitalization days, type of health
18 financing schemes, type of medical institutions and level of medical institutions as
19 input layer variables for inpatients. We choose gender, age, drug fee,
20 test fee, treatment fee, consultation fee, examination fee, registration fee, type of

1 health financing schemes, type of medical institutions and level of medical institutions
2 as input layer variables for outpatients. We choose one hidden layer and curative
3 income from hypertensive patients as neuron in the output layer. The samples are
4 divided into training set and testing set randomly. According to the relative error, we
5 can get the cost model and variables importance rank. MLP neural network were
6 established by IBM SPSS Statistics 20.

7 **Results**

8 **Basic result of CCE for hypertensive patients**

9 As shown in table 1, in 2017, the CCE_{ht} was US\$ 307.71 million (RMB 2061.64
10 million yuan, average US\$1= RMB ¥ 6.7, in 2017), accounted for 3.63% of the gross
11 CCE of Shanxi Province(CCE_{sx}), and 0.14% of GDP. CCE_{ht} accounted for 15.98% of
12 CCE for circulatory system diseases (CCE_{cd}), which has the highest CCE in the ICD-
13 10 disease classification. CCE_{ht} accounted for 4.93% of CCE for non-communicable
14 diseases (CCE_{ncd}) in the GBD disease classification. CCE of hypertensive outpatients
15 (CCE_{ht-out}) and inpatients (CCE_{ht-in}) accounted for 44.49% and 55.51% of the CCE_{ht} ,
16 drug fee accounted for 81.55% of CCE_{ht-out} and 22.50% of CCE_{ht-in} , respectively.
17

18 **Allocation of CCE_{ht} in terms of age and gender**

19 The whole samples were divided into 10-year age groups: 0-9, 10-19, etc., 80-89 and
20 90+. The allocation in Fig.1 shows that CCE_{ht} increased with age from the age of 30,
21 and the highest occurred in the age group of 60-69. The patients aging from 40 to 79
22 accounted for 86.49% of total CCE_{ht} . Outpatient spending is 2.80 times of inpatient
23 spending in the groups under 50 years old, while the inpatient spending is 1.64 times
24 of inpatient spending in the groups over 50 years old.

1 CCE_{ht} of male patients was generally higher than that of women, accounted for 51.27%
2 and 48.73% of CCE_{ht}, respectively. There is a significant difference between CCE_{ht}
3 for male and female in terms of age. As shown in Fig.2, the CCE_{ht} for male
4 outpatients was significantly higher than that of female, especially in the group of 20-
5 49, the CCE_{ht} for male outpatients was about 1.76 times that of female. CCE_{ht} for
6 female inpatients increased significantly from the age of 50, in the group of 50-89, the
7 CCE_{ht} for female inpatients was about 1.31 times that of male.

8 **Allocation of CCE_{ht} in medical institutions and institution levels**

9 Medical institutions in this study included hospital (general hospital, traditional
10 Chinese medicine hospital and special hospital), basic medical institution and public
11 health institution. As data in Table 2 shows, 34.41% and 65.51% of outpatients chose
12 general hospital and basic medical institution, accounted for 76.56% and 23.43% of
13 total CCE_{ht-out}, respectively. 45.99% and 53.98% of inpatients chose general hospital
14 and basic medical institution, accounted for 36.19% and 63.80% of total CCE_{ht-in},
15 respectively.

16 Medical institution levels included provincial, municipal, district and county level.
17 Data shows, 71.07% of outpatients and 74.75% of inpatients chose medical institution
18 with county level, accounted for 45.33% of CCE_{ht-out} and 71.96% of CCE_{ht-in},
19 respectively.

20

21 **Allocation of CCE_{ht} in health financing schemes**

22 Financing schemes involve government subsidy, social medical insurance, voluntary
23 medical insurance (commercial insurance, CI), other insurances (civil servant
24 insurance, employment injury insurance, assistance, etc.) and family health care
25 expenditure (out-of-pocket, OOP). Social medical insurance involves urban employee

1 basic medical insurance (UEBMI), urban resident basic medical insurance (URBMI)
2 and new rural cooperation medical insurance (NRCMI). As data shows in Table 3,
3 72.44% of outpatients and 88.78% of inpatients have social medical insurance, of
4 which 64.13% of outpatients and 71.48% of inpatients had NRCMI, respectively. The
5 patients with UEBMI of has the highest per capita reimbursement ratio. OOP
6 accounted for 47.85% of total CCE_{ht-out} and 14.48% of total CCE_{ht-in} , respectively.

7

8 **Analysis of influencing factors of CCE_{ht} by MLP neural network**

9 In the MLP neural network, 9 and 8 hidden neurons are found out from hyperbolic
10 tangent function for inpatients and outpatients, respectively. Neural network structure
11 and result shows in Table 4. After continuous learning, testing relative error of MLP
12 model are 6.3% for inpatients and 3.1% for outpatients. The top three influencing
13 factors for inpatients are drug fee, surgical fee and hospitalization days. The top three
14 influencing factors for outpatients are drug fee, examination fee and test fee.

15

16 **Discussion**

17 In China, high prevalence of hypertension mainly concentrates in the northeast and
18 north China [9]. Shanxi Province is located in Northern China with a resident
19 population of 37 million [10] and the prevalence of hypertension was about 33.2% [11]
20 in 2014, that is, about 12.3 million residents of Shanxi Province suffer from
21 hypertension. Study shows CCE_{ht} of Shanxi Province in 2017 accounted for 0.14% of
22 GDP [9]. Compared with 0.03% of GDP in the Latin American region in 2015[12],
23 hypertensive patients consumed a large number of health resources, which implies the
24 prevention and control system of hypertension should be strengthened.

1 Study shows CCE_{ht} increased with age, and the patients with the age of 40-79
2 accounted for majority of total CCE_{ht} . The aging population is an important factor that
3 increases the CCE_{ht} . As we know, China has entered the “aging society” [13], which
4 means that the economic burden caused by hypertension diseases will become heavier
5 and heavier.

6 Study shows that the CCE_{ht} has increased significantly since the age of 30 in both
7 sexes. Consistent with literatures [14,15], more and more young people suffer from
8 hypertension, and it has been a major public health problem in developing countries,
9 which is mainly attributable to unhealthy lifestyles of young people, such as
10 insufficient exercise, long-term use of smartphone and computers, lack of sleep, etc.

11 Once established, hypertension will systematically promote abnormal development
12 and progression of heart, blood vessel and kidney [16]. Therefore, in our study, the
13 outpatient spending accounted for majority of CCE_{ht} before age 40, while the
14 inpatient spending replaced it after age 50.

15 Study shows the prevalence and economic burden of hypertension for male is
16 generally higher than that for female. Literature [17] shows that the prevalence of
17 hypertension was higher in men than women at younger ages, but higher in women
18 than men at older ages. This study also shows the economic burden of hypertension
19 for male outpatients were significantly higher than that of females in 20-49 age, which
20 is mainly caused by the fact that men of this age smoke, drink, have more work and
21 life stress [18,19], etc. While the economic burden of hypertension for female
22 inpatients increased significantly from age 50, and it likely due to dramatic changes in
23 estrogen level which can influence the vascular system [20,21]. Therefore, we should
24 pay more attention to the prevention and outpatient treatment for young men, and the
25 inpatient treatment for women at older ages.

1 For a long time, Chinese patients tend to go to provincial and municipal general
2 hospitals rather than primary health care system, mainly due to insufficient medical
3 resources, imperfect medical system, limited level of general practitioner in primary
4 health care system, and patient distrust of community doctors [22]. Studies show that
5 basic medical institution is an effective way to control hypertension [23,24]. As a
6 result, the standardized prevention and treatment of hypertension has been included in
7 the national basic public health service program in 2009 [25]: patients with
8 hypertension can receive regular physical examination and standardized management
9 provided by basic medical institution free of charge, and basic medical institution
10 should give full play in the role of prevention and treatment of hypertension. In our
11 study, data shows (Table 2), 65.51% of outpatients and 53.98% of inpatients chose
12 basic medical institution, which effectively reduced CCE_{ht} , especially CCE_{ht-out} , which
13 only accounted for 23.43% of total CCE_{ht-out} . Although 34.41% of outpatients and
14 45.99% of inpatients still chose general hospitals, more than 70% of hypertensive
15 patients chose medical institutions with county level. This suggests that the diagnosis
16 and treatment capacity of primary health care system has been enhanced. To better
17 prevent and control hypertension, the government should continue to increase support
18 for primary health care system, improve the standardization construction of primary
19 health care system, strengthen the training of community doctors, encourage the
20 exploration of a new mode of cooperation between primary health care system and
21 provincial(or municipal) hospital, guide more chronic patients to primary health care
22 system, reasonably divert patients with mild hypertension, effectively ease the
23 economic burden of families, and improve the utilization efficiency of social
24 resources.

25 Literature [26] shows that different types of medical insurance will have a great

1 impact on patients' medical behavior and expenses. This study shows the majority of
2 hypertension outpatients and inpatients used social medical insurance. According to
3 the population characteristics report of Shanxi provincial government in 2017[10],
4 rural and urban population accounted for 42.66% and 57.34% of the total population,
5 respectively. However, in this study, the number of rural hypertension patients in
6 outpatient department was nearly 8 times that of urban patients, and the number of
7 hospitalized rural hypertension patients was 4 times that of urban patients. This shows
8 that NRCMI not only has been widely used in rural areas, but also has the trend of
9 overuse. Consistent with the literatures [27], in this study, UEBMI has the highest per
10 capita reimbursement ratio, which implies that patients with UEBMI are more likely
11 to over-pursue certain unnecessary high-tech materials, technologies, and high-cost
12 treatment programs. This suggests that the government should strengthen the
13 standardization of disease treatment, restrict unnecessary medical behavior, and ease
14 the burden of medical insurance. At the same time, the research also shows that the
15 government subsidy in the inpatient is 23 times that of the outpatient, and nearly half
16 of CCE_{ht-out} was paid by OOP, which indicates that burden of family health
17 expenditure is still very heavy in the outpatient treatment of hypertension. Therefore,
18 the government should incline the policy to outpatient service and increase the
19 reimbursement limit of outpatient expenses in basic medical insurance, which is
20 conducive to reducing the direct medical expenses of patients with hypertension.
21 Analysis of influencing Factors by MLP neural network shows that drug fee is the
22 most important influencing factor of CCE_{ht} . This is mainly due to long-term
23 medication, irrational use of medications by medical staff, blind and excessive
24 consumption of new special drugs and imported drugs, etc. In addition, in outpatient
25 treatment, the impact of examination fee and test fee on CCE_{ht-out} follows drug fee,

1 which shows that the phenomenon of "relying on medicine, examination and test to
2 support doctors" still exists. Therefore, the government should further strengthen the
3 standardization and supervision of drugs and inspection items, improve the usage of
4 general medication and inspection efficiency. In inpatient, the impact of surgical fee
5 and hospitalization days on CCE_{ht-out} follows drug fee. The high surgical fee is mainly
6 caused by the expensive imported medical materials. Research [28] shows some high-
7 value consumable medical equipments made by domestic manufacturers are fully
8 complies with international standards, and partially or completely replace imported
9 products. It is suggested that medical personnel use domestic supplies as much as
10 possible, which is feasible in terms of social and economic benefits. Hospitalization
11 days can also significantly increase CCE_{ht-in} , study [29] has shown that 18.10% of the
12 hospitalization days are actually unnecessary, which not only increases the economic
13 burden of patients, but also reduces the reasonable allocation of medical resources.
14 The hospital should shorten hospitalization time to reduce CCE_{ht-in} on the premise of
15 ensuring medical quality.

16 Our study has some limitations. First, this study samples reflect the economic burdens
17 of hypertension from medical institutions. As we all know, hypertensive patients need
18 long-term medication, and some patients may go directly to buy medicine in drugstore
19 instead of medical institutions. Therefore, the true financial expenditure of
20 hypertensive patients may be underestimated. Second, in the commercial insurance,
21 generally, the reimbursement of medical expenses is paid in advance by the patient,
22 and then reimbursed by the insurance company after treatment. So this study is biased
23 in allocation of CCE_{ht} in commercial insurance.

24 **Conclusion**

1 From the calculation of curative care expenditure for hypertension in the frame of
2 SHA2011, we found: economic burden caused by hypertension diseases is still heavy,
3 NRCMI and UEBMI has the trend of overusing, and burden of family expenditure on
4 healthcare is still very heavy, and drug fee, check fee, test fee and hospitalization time
5 are important influencing factors of CCE_{ht} . Therefore, to ease the economic burden of
6 hypertensive patients and improve the utilization efficiency of social resources, the
7 policy makers should pay more attention to the hypertensive patients with 40-79 age,
8 strengthen prevention and outpatient treatment for young men and the inpatient
9 treatment for women at older ages, further increase support for primary health care
10 system, standardize the treatment and reimbursement of hypertension, and incline the
11 reimbursement policy to outpatient service.

12 **Abbreviations**

13 SHA2011: System of Health Account 2011; CCE: curative care expenditure;
14 MLP: multi-layer perceptron; ICD-10: International Classification of Diseases Tenth
15 Revision; GBD: Global Burden of Disease; CCE_{ht} : curative care expenditure for
16 hypertension; CCE_{sx} : gross CCE of Shanxi Province; CCE_{ht-out} : CCE of hypertensive
17 outpatients; CCE_{ht-in} : CCE of hypertensive inpatients; CI: commercial insurance; OOP:
18 family health expenditure; UEBMI: urban employee basic medical insurance; URBMI:
19 urban resident basic medical insurance; NRCMI: new rural cooperation medical
20 insurance; OECD: Organization for Economic Cooperation and Development; CCE_{cd} :
21 CCE for circulatory system diseases; CCE_{ncd} : CCE for non-communicable diseases.

22

1 **Declarations**

2 *Ethics approval and consent to participate*

3 Not applicable

4 *Consent for publication*

5 Not applicable

6 *Availability of data and materials*

7 All data generated or analyzed during this study are included in this published article.

8 *Competing interests*

9 The authors declare that they have no competing interests.

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13 *Authors' contributions*

14 GJL and XW designed the whole process and did the pre-research. GJL, XYJ, JOY,
15 and YLZ did the pre-research and statistical analysis. GJL was the main drafter of the
16 manuscript. YLZ and LYW contributed the coordination and manuscript editing. XW
17 was the director for the fund and designed ideas of research. All authors reviewed and
18 contributed to the subsequent drafts and approved the final version for publication.

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- 1 Fig.1 Allocation of CCE_{ht} of outpatient and inpatient in terms of age
- 2 Fig.2 Allocation of CCE_{ht} in terms of age and gender

Figures

Figure 1

Allocation of CCEht of outpatient and inpatient in terms of age

Figure 1

Allocation of CCEht of outpatient and inpatient in terms of age

Figure 2

Allocation of CCEht in terms of age and gender

Figure 2

Allocation of CCEht in terms of age and gender

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