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RESEARCH

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Effect of a health management model based on the three-tier prevention and control system for cardiovascular and cerebrovascular diseases: a prospective cohort study in rural Central China (CENTRAL-HMM)

Yongxia Wang[1†], Jingjing Wei[1†], Rui Yu[1†], Xinlu Wang[1], Xingyuan Li[1], Guangcao Peng[1], Hongjie Ren[1], Jianru Wang[1], Qifei Zhao[1], Yanbo Zhang[2], Bin Li[1,3], Hongxin Guo[1], Yang Sun[1], Lijie Qiao[1], Jiabao Lei[1], Mingjun Zhu[1,5*] and Duolao Wang[4,6*]

Abstract

Background Cardiovascular and cerebrovascular diseases (CVDs) present a significant challenge in the realm of chronic disease management in China. The objective of this study is to assess the efficacy of a health management model rooted in a three-tier prevention and control system for CVDs.

Methods From August 2020 to September 2020, this study enrolled 2033 CVDs patients from 105 villages across three townships in central China. All participants underwent a 12-month health management involving monitoring, risk assessment, health education, and interventions. The primary endpoint focused on recurrence and exacerbation, while secondary outcomes encompassed health economic indicators, awareness of prevention and control knowledge, risk factor, lifestyle behavior. Data analysis was conducted using generalized estimating equation models.

Results After 1 year of follow-up, the odds of recurrence and exacerbation decreased significantly compared to the baseline [odds ratio (OR) 0.30, 95% confidence interval (CI): 0.26, 0.35], accompanied by reduced hospitalization frequency [mean difference (MD) -0.61, 95% CI: -0.66, -0.56] and a monthly average reduction in medication costs (MD, -69.80, 95% CI: -104.55, -35.05). Moreover, patients' awareness of CVDs prevention and treatment knowledge markedly improved ($P < 0.01$). Diastolic blood pressure, blood lipid and plasma glucose levels, anxiety and depression, lifestyle

†Yongxia Wang, Jingjing Wei and Rui Yu contributed equally to this work.

*Correspondence:
Mingjun Zhu
zhumingjun317@163.com
Duolao Wang
Duolao.Wang@lstmed.ac.uk
Full list of author information is available at the end of the article

behavior all demonstrated significant enhancements from baseline levels ($P < 0.01$). Crucially, health management did not result in an increased abnormality rate of safety indicators.

Conclusions The health management model, grounded in a three-level prevention and control system, showed potential applicability in reducing recurrence and exacerbation, easing healthcare economic burden, boosting awareness of prevention and treatment, and positively influencing risk factors. Additional multicenter and long-term studies are necessary to validate these findings and support broader implementation of this model.

Trial registration Chinese Clinical Trial Registry (ChiCTR) ChiCTR2000032243 (24/04/2020) (https://www.chictr.org.cn/showproj.html?proj=52395).

Keywords Health management model, Cardiovascular and cerebrovascular diseases, Rural area, Village doctor, Three-tiered prevention and control

Introduction

Cardiovascular and cerebrovascular diseases (CVDs) such as angina pectoris, myocardial infarction, heart failure, cerebral infarction, and intracerebral hemorrhage, rank notably high in terms of disability and mortality rates globally [1]. Data sourced from the World Health Organization indicates that CVDs contribute to one-third of worldwide fatalities, significantly straining healthcare systems globally [2, 3]. Particularly in China, CVDs have risen as a primary challenge in domestic health management, impacting the quality of life and socioeconomic progress of millions. As per the "2022 Report on Cardiovascular Health and Diseases in China" [4], the prevalence of CVDs in China has steadily increased, affecting an estimated 330 million individuals presently. Rural areas exhibit a disturbingly high mortality rate for CVDs at 48%, while urban areas also show a substantial rate of 45.86%. This not only poses a substantial threat to the health of residents but also amplifies the socioeconomic burden. Notably, the annual escalation in total hospitalization costs for CVDs significantly surpasses the growth rate of the national economy, imposing immense strain on the healthcare system.

Implementation of chronic disease health management models has led to a turning point in the prevalence and mortality rates of CVDs in developed countries. During the 1960s, North Karelia, Finland, exhibited high prevalence rates of cardiovascular diseases. From 1969 to 2006, the persistent implementation of community-based interventions for chronic diseases resulted in an 85% decrease in mortality rates for coronary heart disease among men and a 90% decrease among women aged 35 to 64 [5]. In the 21st century, developed countries have achieved significant progress in preventing and controlling CVDs by continuously improving chronic disease health management models [6, 7]. Currently, China has achieved initial advancements in community-based prevention and control of CVDs risk factors, such as hypertension and diabetes [8, 9]. However, in rural county areas, the management of chronic diseases continues to face pervasive challenges. Currently, there is a dearth of clinical data on the application of health management models for chronic diseases in rural areas, and it remains uncertain whether implementing such models can mitigate the recurrence and exacerbation of CVDs in rural regions. Hence, it is crucial to furnish evidence regarding the efficacy of health management models in reducing the recurrence and exacerbation of CVDs.

To tackle these challenges, our research team, on the basis of medical alliances and medical consortia, relying on multidisciplinary research and development team, integrated the core technologies of monitoring, early warning, health promotion, follow-up management and data governance, and constructed the "real-time monitoring, proactive alerting, intelligent analysis, and visual presentation as an integrated intelligent platform for the health management of chronic diseases (http://cd.ttdoc.cn); Furthermore, adhering to international guidelines, we developed health management guidelines for CVDs, which include angina pectoris, myocardial infarction, heart failure, cerebral infarction, and intracerebral hemorrhage. These guidelines were officially unveiled by the China Association of Chinese Medicine in April 2022 [10]. After assessing the service capabilities of rural healthcare institutions, we established the "Standards for three-level prevention and control services of Chinese medicine health management for CVDs" [11]. The aim of our study was to evaluate the effectiveness of the health management model in the application to CVDs patients in rural areas, and further to investigate whether the health management model can effectively mitigate the recurrence and exacerbation of CVDs. Our approach operated on a three-tier prevention and control system that prioritized the patient, with village doctors as the executing agents and specialized physicians from tertiary hospitals leading the effort. This " patients- village doctors - specialized physicians" model provided new insights and methods for the management of CVDs.

Methods

Design and participants

The CENTRAL-HMM (Health Management Model for Cardiovascular and Cerebrovascular Diseases in Rural Central China) study was an investigator-initiated, prospective cohort study. It adhered to the principles outlined in the Declaration of Helsinki and was duly registered in China Clinical Trials under the registration number ChiCTR2000032243 (http://www.chictr.org.cn). The research protocol was approved by the Ethics Committee of the First Affiliated Hospital of Henan University of Chinese Medicine (2020HL-019). Written informed consent was obtained from all patients before enrollment. The study recruited participants from August 2020 to September 2020, involving 140,000 individuals from 105 administrative villages in Dongdian Township, Jiangang Township, and Liaodi Township, Sui County, Shangqiu City, Henan Province, in which patients diagnosed with angina pectoris, myocardial infarction, heart failure, cerebral infarction, and intracerebral hemorrhage were enrolled. Participants were enrolled on a village-by-village basis, and were initially screened by village health office doctors before enrollment, and re-screened by associate physician fellows from tertiary care hospitals according to inclusion and exclusion criteria.

Inclusion and exclusion criteria

Patients were required to meet al.l of the following criteria for study inclusion: (1) age 18 or above, regardless of gender or race, (2) meeting the national guidelines for the diagnosis and treatment of stable angina pectoris, myocardial infarction, chronic heart failure, cerebral infarction, and intracerebral hemorrhage [12–16], (3) being in the non-acute stage, (4) being aware of the content of the study and voluntarily participating and signing a written informed consent. The main exclusion criteria for this study were as follows: (1) severe psychiatric or psychological disorders, (2) cognitive dysfunction, communication disorders, or unwillingness to cooperate with health management, (3) participation in other clinical trials within the last 3 months.

Procedures

In this study, we rigorously implemented the management protocol that adheres to the management measures outlined in the "Guidelines for Chinese Medicine Health Management of Stable Angina Pectoris," "Guidelines for Chinese Medicine Health Management of Myocardial Infarction," "Guidelines for Chinese Medicine Health Management of Heart Failure," "Guidelines for Chinese Medicine Health Management of Cerebral Infarction," and "Guidelines for Chinese Medicine Health Management of Intracerebral Hemorrhage" published by the Chinese Association of Chinese Medicine [10], along with the regulations of the "Standards for three-level prevention and control services of Chinese medicine health management for CVDs" [11]. Under the overall management of our research team, we established various groups, including a health education and promotion group, intervention technique training group, chronic disease management group, online information group, and quality control group. This structure forms a three-tier prevention and control management system with a patient-centric approach, where rural doctors are the specific managers and tertiary hospitals play a leading role, creating the "home-community-hospital" framework. In the supplementary document, we have meticulously outlined the responsibilities of different personnel within the three-tier prevention and control system (Supplemental Table 1). The main emphasis of this system revolves around four key management activities: health monitoring, risk assessment, health education, and health intervention.

Personal health record

Eligible participants, who met the criteria, signed informed consent upon completing their enrollment. Following this, family contract management was implemented, and a contract informed consent was signed to establish individual health records.

Health monitoring

Following patients' enrollment, their basic information (including gender, age, marital status, education level, occupation, economic status, and family background), medical history (including disease history, treatment history, past medical conditions, allergies, personal history, marital and reproductive history, menstrual history, and family history), and examination results (including physical examinations, laboratory tests, and additional tests) were collected and dynamically monitored, serving as the foundation for patient risk assessment.

Risk assessment

Following the completion of medical data collection, a risk assessment was conducted based on patient information, considering long-term risks, lifestyle, risk factors, and medication usage. For myocardial infarction patients, long-term risk assessment primarily followed the requirements of the "Guidelines for Chinese Medicine Health Management of Myocardial Infarction" and categorized patients as low-risk, medium-risk, or high-risk for classification management. Lifestyle assessment focused on factors such as patients' dietary habits, exercise habits, psychological state, and smoking and alcohol consumption. Risk factors for diseases primarily included patients' blood pressure, lipid profile, blood sugar levels, and the presence of depression or anxiety. Medication usage assessment primarily examined whether patients were using medication interventions in a reasonable and standardized manner. For other types of patients, risk assessments were conducted according to the relevant content in the "Guidelines for Chinese Medicine Health Management of Stable Angina Pectoris," "Guidelines for Chinese Medicine Health Management of Heart Failure," "Guidelines for Chinese Medicine Health Management of Cerebral Infarction," and "Guidelines for Chinese Medicine Health Management of Intracerebral Hemorrhage" [10]. The risk assessment identified the weaknesses in the current patient management and served as the basis for developing specific intervention plans.

Health education

The personnel from village doctors and the chronic disease management teams of tertiary hospitals conducted regular health education activities in compliance with the requirements specified in the "Standards for three-level prevention and control services of Chinese medicine health management for CVDs." This entailed distributing the handbook on preventing and controlling CVDs to patients, installing boards with information on the prevention and control of CVDs in village health centers, and organizing monthly health knowledge lectures, public health consultation events, and personalized health education.

Health intervention

Following patient assessments, individualized intervention management was applied to address patients' lifestyles (diet, exercise, and smoking, etc.), risk factors (blood pressure, blood lipids, blood sugar, emotional well-being, and sleep, etc.), and treatment measures for their conditions. Specific management guidelines are outlined in the relevant disease health management references [10].

Primary and secondary outcomes

The primary endpoint was recurrence and exacerbation, where refers to the reoccurrence of a patient's major symptoms, a decrease in triggering threshold, prolonged symptom duration, symptom exacerbation, or seeking medical care for CVDs. The rate of recurrence and exacerbation was calculated by recording whether such events occurred within the 12 months preceding each observation point. The secondary outcomes include the following contents. Health economics indicators included hospitalization frequency and the average monthly medication expenses. The awareness rate regarding CVDs prevention and treatment included hypertension, diabetes, disease risk factors, adverse lifestyle behaviors, principles of regular monitoring and principles of medication adherence principles. Additionally, we examined alterations in risk factors, encompassing systolic blood pressure (SBP), diastolic blood pressure (DBP), total cholesterol (TC), triglycerides (TG), low-density lipoprotein cholesterol (LDL-C), HDL-C, fasting plasma glucose (FPG), patient health questionnaire-9 (PHQ-9), generalized anxiety disorder-7 (GAD-7), Hamilton anxiety rating Scale (HAMA), and Hamilton depression scale (HAMD). We also observed changes in lifestyle behavior indicators, including the rates of smoking, greasy diet, sweet diet, salty diet, and moderate physical activity [17]. Safety indicators, including blood tests, liver function, kidney function, urine analysis, and coagulation function. The aforementioned endpoints were observed and recorded at months 0 and 12 during the management period.

Statistical analysis

The statistical analysis was designed and executed by the statistician at the Department of Clinical Sciences at the Liverpool School of Tropical Medicine in the United Kingdom. All statistical analyses were performed using R statistical software (version 4.1.2, R Foundation for Statistical Computing, Vienna, Austria). All statistical analysis tests were conducted using two-sided hypothesis tests, and the hypothesis test level was $\alpha=0.05$. $P\leq0.05$ was considered to be statistically significant for the differences tested.

In the context of descriptive analysis, continuous variables were presented as mean ± standard deviation ($\overline{x}\pm s$), and categorical variables were reported with their frequencies and corresponding percentages. The generalized estimating equation (GEE) model was employed to evaluate the difference between baseline and follow-up in primary and secondary outcomes related to health management before (baseline) and after 12 months. Logistic regression model was used to ascertain risk factors for recurrence and exacerbation. The analysis was conducted in two steps. Firstly, univariate logistic regression models were fitted for each variable based on completed cases. All variables used in the univariate regression analysis were also included in the second stage of multivariate logistic regression. In the logistic regression analysis, odds ratios (ORs) and their 95% confidence intervals (CIs) were computed for each variable in relation to the recurrence and exacerbation.

Results

Subjects enrollment and baseline characteristics

From August 2020 to September 2020, this study enrolled 2,033 CVD patients meeting the inclusion and exclusion criteria from three townships in Sui County, Henan Province. These patients comprised 658 cases of angina, 277 of myocardial infarction, 72 of heart failure, 888 of cerebral infarction, and 138 of intracerebral hemorrhage. Throughout the study, 84 participants voluntarily withdrew due to personal reasons. These individuals included 24 angina patients, 16 myocardial infarction patients, 7 heart failure patients, 30 cerebral infarction patients, and 7 intracerebral hemorrhage patients. There were 39 recorded fatalities, consisting of 15 angina patients, 16 myocardial infarction patients, 15 cerebral infarction patients, and 3 intracerebral hemorrhage patients. Figure 1 illustrates the study's flow chart.

Overall, our study included a total of 2,033 patients, with males accounting for 48.7% and females for 51.3%. Patients had an average age of 67.1±8.54 years. Baseline assessments showed relatively elevated SBP levels (146.92±22.81), with 61.98% of patients having a history of hypertension, and 34.78% experiencing hyperlipidemia. Educational attainment was relatively low, with the majority having completed primary school or lower education (71.57%). Approximately 95.97% of participants reported a family annual income below ¥30,000. The majority of patients (65.47%) commonly sought medical care at the district or secondary hospital. A total

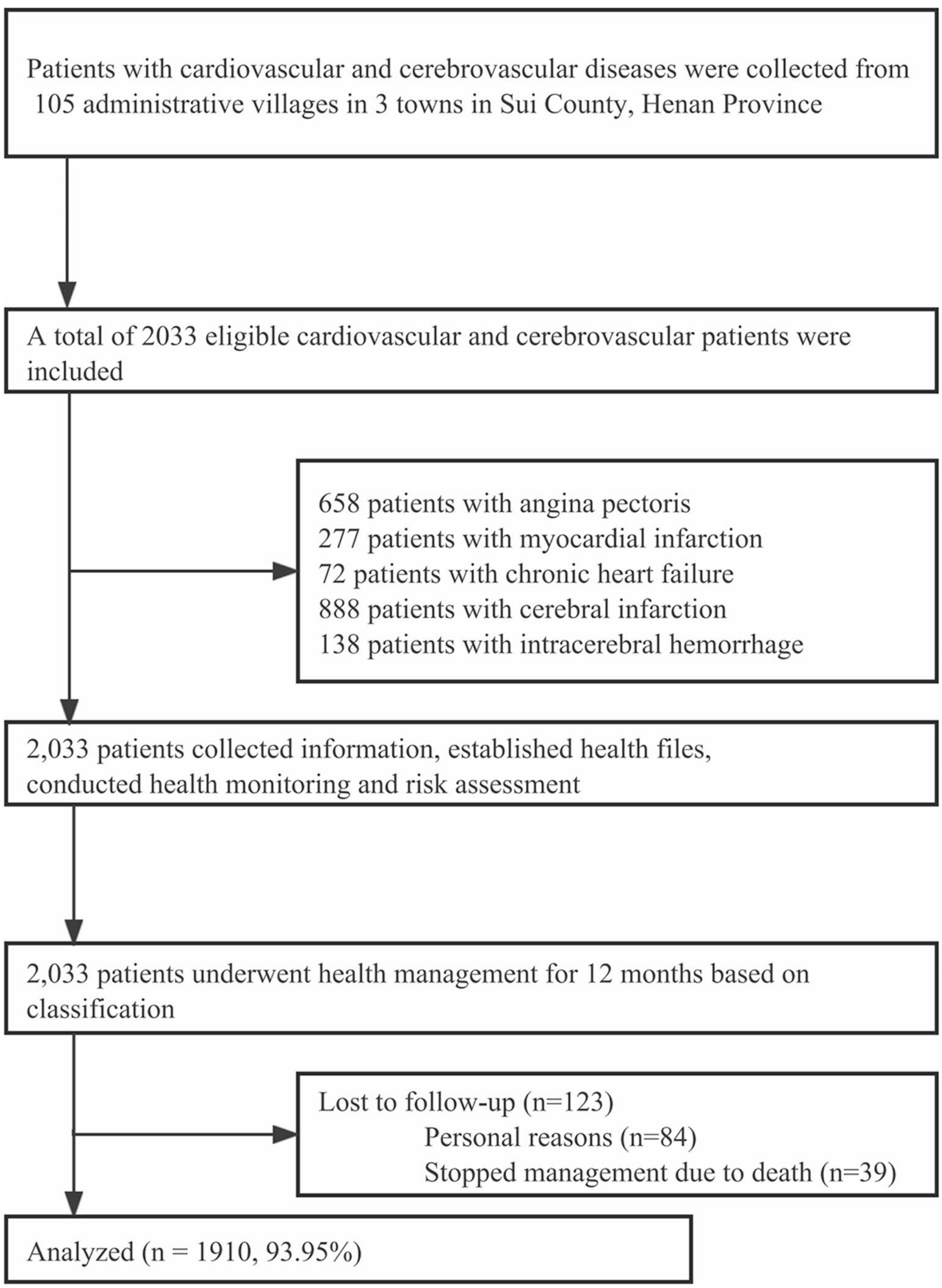

Fig. 1 Flow chart of the study design

of 102 village doctors took part in the study, with a predominantly male composition (63.73%). Age distribution predominantly skewed towards an aging demographic, with around 70.59% falling within the 41 to 60 age group. Most village doctors had received some form of medical training, having completed a 3-year medical education at vocational medical schools or specialized medical colleges. Additionally, most village doctors had accumulated over 20 years of experience in delivering fundamental primary healthcare and public health services. Table 1 provides a comprehensive overview of the baseline characteristics of both study participants and village doctors.

Effect of the health management model on the recurrence and exacerbation

After 12 months of health management, the number of recurrent and exacerbated cases among CVDs patients decreased from 728 at baseline to 298. Findings obtained using GEE demonstrated a substantial 70% reduction in the odds of recurrence and exacerbation following the 12-month management period (OR 0.30, 95% CI: 0.26, 0.35; $P<0.001$) (Table 2).

Logistic regression analysis of recurrence and exacerbation in patients with CVDs

To investigate the factors influencing recurrence and exacerbation following health management, regression analysis was performed, considering a wide range of variables, such as patient age, gender, baseline blood pressure, LDL-C, smoking history, dietary habits, and moderate exercise. The results of both univariate and multivariate binary logistic regression analyses can be found in Table 3. Factors independently related to the occurrence of recurrence and exacerbation after management included LDL-C≥1.80 mmol/L (OR 1.86, 95%CI: 1.20, 2.89) and a history of smoking (OR 1.83, 95%CI: 1.19, 2.83). The multivariate regression analysis, adjusting for multiple variables and based on complete data cases without missing values, continued to show statistically significant associations for these factors ($P<0.01$).

Effect of the health management model on the health economics indicators

In our GEE results, there has been encouraging improvement in hospitalization frequency and average monthly medication expenses for CVDs patients over the course of health management. After applying the health management model for 12 months, significant reductions were observed in hospitalization frequency [mean difference (MD) -0.61, 95% CI: -0.66, -0.56; $P<0.001$] and average monthly medication expenses (MD -69.80, 95% CI: -104.55, -35.05; $P<0.001$) compared to baseline values (see Table 4).

Table 1 Baseline characteristics of study participants and village doctors

Characteristics of participants	
Number of participants	2033
Sex, n (%)	
Male	991 (48.7%)
Female	1042 (51.3%)
Age (years)	67.1 ± 8.54
Blood pressure (mmHg)	
SBP	146.92 ± 22.81
DBP	81.21 ± 12.45
BMI (kg/cm^2)	25.03 ± 3.48
Education, n (%)	
Primary school or lower	1450 (71.57%)
Junior high school	452 (22.23%)
High school	114 (5.48)
College or higher	10 (0.49)
Medical history, n (%)	
History of hypertension	1260 (61.98%)
History of diabetes	381 (18.74%)
History of hyperlipidemia	707 (34.78%)
Treatment, n (%)	
Antiplatelet	1059 (52.09%)
Lipid-lowering drug	865 (42.55%)
Anticoagulant drug	143(7.03%)
Beta-blockers	510 (25.14%)
ACEI/ARB	275 (13.53%)
Calcium antagonists	272 (13.38%)
Place of Residence, n (%)	
City	21 (1.03%)
Rural Area	2012 (98.97%)
Frequent hospital visits, n (%)	
Village clinic	256 (12.59%)
Township health center	385 (18.94%)
District hospital/secondary hospital	1331 (65.47%)
Municipal hospital/tertiary hospital	61 (3.00%)
Household Income Range (USD), n (%):	
≤$4200	1951 (96.0%)
$4200 ~ 11,200	76 (3.7%)
≥$11,200	6 (0.3%)
Characteristics of village doctors	
Number of village doctors	102
Age (years), n (%)	
≤ 40	19 (18.62%)
41 ~ 50	42 (41.17%)
51 ~ 60	30 (29.41%)
61 ~ 70	7 (6.86%)
≥ 70	4 (3.92%)
Sex, n (%)	
Male	65 (63.73%)
Female	37 (36.27%)
Experience (years), n (%)	
≤ 10	35 (34.31)
11 ~ 20	11 (10.78)
≥ 20	56 (54.91)

Table 1 (continued)

Characteristics of participants	
Education, n (%)	
Junior high school	3 (2.94)
High school	4 (3.92)
Vocational medical school	51 (50)
Junior medical college and above	44 (43.14)

Abbreviations SBP, systolic blood pressure; DBP, diastolic blood pressure; BMI, body mass index; ACEI, angiotensin converting enzyme inhibitors; ARB, angiotensin receptor blocker; USD, United States dollar

Effect of the health management model on the awareness rate regarding CVDs prevention and treatment

Table 2 provided an overview of the changes in awareness of CVDs prevention and treatment knowledge before and after the management period. Following 12 months of health management, patients showed remarkable enhancements in their awareness levels. Specifically, in contrast to baseline levels, patients exhibited significantly increased awareness regarding hypertension, diabetes, CVD risk factors, unhealthy lifestyle behaviors, regular monitoring, and adherence to medication principles ($P<0.001$). These enhancements were evident with increments of 3.16 times in odds (95%CI: 2.79, 3.58), 2.52 times (95%CI: 2.16, 2.94), 3.32 times (95% CI: 2.97, 3.72), 2.79 times (95% CI: 2.48, 3.13), 3.18 times (95%CI: 2.82, 3.59), and 1.92 times (95%CI: 1.70, 2.17), respectively.

Effect of the health management model on the risk factors associated with CVDs

As depicted in Table 4, CVDs patients experienced significant reductions in DBP, TC, LDL-C, HDL-C, TG, and FPG levels after 12 months compared to the pre-management period ($P<0.001$). It is noteworthy that, following 12 months of health management, there was a significant increase in SBP among patients with CVDs (MD 4.29, 95%CI: 3.24, 5.34; $P<0.001$). Moreover, our analysis encompassed GAD-7 and PHQ-9 for cardiovascular patients (angina, myocardial infarction, and heart failure), and HAMA and HAMD for cerebrovascular patients. Results highlighted significant decreases in GAD-7 (MD -1.80, 95% CI: -2.12, -1.47; $P<0.001$), PHQ-9 (MD -3.68, 95%CI: -4.07, -3.28; $P<0.001$), HAMA (MD -3.32, 95% CI: -3.83, -2.81; $P<0.001$), and HAMD scores (MD -1.44, 95% CI: -1.80, -1.09; $P<0.001$) compared to baseline, indicating alleviation in anxiety and depression among patients.

Effect of the health management model on the lifestyle behavioral indicators

In evaluating the impact of health management on lifestyle behaviors among CVDs patients, noteworthy changes were observed. Following 12 months of health management, a significant decrease was noted in the proportion of patients favoring a salty diet (22.09% versus 34.35%, OR 0.54, 95% CI: 0.48, 0.61; $P<0.001$). Similarly, preferences for sweet and greasy diets notably decreased (OR 0.34, 95% CI: 0.28, 0.41; $P<0.001$) (OR 0.30, 95% CI: 0.24, 0.38; $P<0.001$) compared to baseline. Simultaneously, there was an observed increase in patients engaging in moderate physical activity after 12 months (OR 1.64, 95% CI: 1.45, 1.84; $P<0.001$). Concerning the number of individuals currently smoking among CVDs patients, there was a notable decrease after 12 months of health management (13.25% versus 11.62%, OR 0.85, 95% CI: 0.75, 0.96; $P=0.008$) (Table 2).

Safety evaluation

All patients underwent safety indicator observations, including blood routine, liver function, kidney function, urine analysis, and coagulation function, both before and after health management. Our results indicated that following the application of chronic disease management, apart from a decrease in the abnormal rates of urinary protein, urinary white blood cell count, alanine transaminase, glutamic oxalacetic transaminase, and blood urea nitrogen, there were no significant differences in other laboratory indicators ($P>0.05$) (Supplemental Table 2). Importantly, during the study, 34 patients passed away, all due to the deterioration of their diseases. We have diligently documented and reported these cases.

Discussion

Health management encompasses a comprehensive process of monitoring, assessing, and implementing effective interventions for the health risk factors of individuals or populations. Its primary aim is to achieve the maximum health improvement with limited resources by enhancing or modifying health service approaches and fostering effective public health behaviors. This concept was initially introduced by Dr. Edington DW [17]. In China, research on health management models started later compared to developed countries. Rural areas face vulnerability in chronic disease management due to economic disparities between urban and rural regions [18]. Substantial healthcare resources are primarily concentrated in urban centers. Despite the lower incidence of cardiovascular diseases in rural areas compared to urban regions, the mortality rate has remained consistently higher in recent years [4]. An urgent need exists to establish a standardized and effective health management model for CVDs in rural areas.

In this study, we aimed to assess the effectiveness and feasibility of a health management model for CVDs based on a three-tier prevention and control system. Our research focused on rural areas in Central China and emphasized a patient-centric approach with village doctors as the implementing agents and specialized physicians from tertiary hospitals leading the effort. The

Table 2 Results from GEE Model analyses of primary outcome, the awareness rate, and lifestyle behavioral indicators after 12 months of health management

	Before management	12 months after management	GEE model	
			OR (95%CI)	*P*-value [a]
Recurrence and exacerbation rate	728 (38.12%)	298 (15.60%)	0.30 (0.26, 0.35)	< 0.001
Awareness rate of hypertension	377 (19.74%)	982(51.41%)	3.16 (2.79, 3.58)	< 0.001
Awareness rate of diabetes	194(10.16%)	481(25.18%)	2.52 (2.16, 2.94)	< 0.001
Awareness rate of risk factors	541(28.32%)	1268(66.39%)	3.32 (2.97, 3.72)	< 0.001
Awareness rate of adverse lifestyle behaviors	682(35.71%)	1365(71.47%)	2.79 (2.48, 3.13)	< 0.001
Awareness rate of principles of regular monitoring	788(41.26%)	1338(70.05%)	3.18 (2.82, 3.59)	< 0.001
Awareness rate of medication adherence principles	781(40.89%)	1242(65.03%)	1.92 (1.70, 2.17)	< 0.001
Current smoker	253(13.25%)	222(11.62%)	0.85 (0.75, 0.96)	0.008
Salty diet	656(34.35%)	422(22.09%)	0.54 (0.48, 0.61)	< 0.001
Sweet diet	377(19.74%)	148(7.75%)	0.34 (0.28, 0.41)	< 0.001
Greasy diet	286(14.97%)	95(4.97%)	0.30 (0.24, 0.38)	< 0.001
Moderate physical activity	1004(52.57%)	1234(64.61%)	1.64 (1.45, 1.84)	< 0.001

[a] GEE model was used to evaluate the differences between baseline and follow-up for each outcome related to health management

Abbreviations GEE, generalized estimating equation; OR, odds ratio; CI, confidence interval

Table 3 Factors related to recurrence and exacerbation of cardiovascular and cerebrovascular patients: results from logistic regression analysis

	Univariate analysis		Multivariate analysis	
	OR (95%CI)	*P*-value [a]	OR (95%CI)	*P*-value [b]
Age ≥ 65years	0.80(0.62, 1.04)	0.100	1.04(0.74, 1.47)	0.822
Sex	0.77(0.60, 0.99)	0.043	0.81(0.52, 1.27)	0.364
SDP ≥ 140mmHg	0.97(0.76, 1.25)	0.829	1.09(0.77, 1.54)	0.641
DBP ≥ 90mmHg	1.29(0.97, 1.71)	0.076	1.04(0.72, 1.49)	0.840
LDL-C ≥ 1.80mmol/L	1.60(1.12, 2.29)	0.009	1.86(1.20, 2.89)	0.006
History of smoking	1.69(1.22, 2.35)	0.002	1.83(1.19, 2.83)	0.006
Salty diet	1.16(0.90, 1.50)	0.248	1.28(0.90, 1.81)	0.165
Sweet diet	0.93(0.69, 1.26)	0.647	1.07(0.69, 1.66)	0.752
Greasy diet	1.22(0.85, 1.76)	0.275	1.09(0.69, 1.73)	0.716
Moderate physical activity	1.11(0.86, 1.42)	0.425	0.99(0.71, 1.38)	0.941

[a] Univariate logistic regression models were fitted for each variable based on complete cases to calculate unadjusted odds ratios

[b] Multivariate logistic regression analysis was performed using a stepwise entry method, adjusting for age, sex, blood pressure, blood lipids, smoking status, and dietary and exercise habits

Abbreviations OR, odds ratio; CI, confidence interval; SBP, systolic blood pressure; DBP, diastolic blood pressure; LDL-C, low-density lipoprotein cholesterol

"patient-village doctors-specialized physicians" model demonstrated potential applicability in reducing recurrence and exacerbation, easing healthcare economic burden, enhancing patient awareness regarding prevention and treatment, and positively impacting risk factors and lifestyle behaviors.

The rate of recurrence and exacerbation is a crucial indicator for evaluating disease stability and intervention effectiveness. This study observed a substantial 70% reduction in the odds of the recurrence and exacerbation among CVDs patients after one year of health management compared to pre-management levels. This indicates that the adopted three-tier prevention and control system has yielded promising results in improving disease control. Data on the prevalence and disease burden of CVDs in China from 1990 to 2019 indicated that the 1-year recurrence and exacerbation rates for angina, myocardial infarction, and heart failure were 10%, 10.6%, and 16.9%, respectively. For cerebral infarction and intracerebral hemorrhage, the 1-year recurrence and exacerbation rates were 17.7% and 32.5%, respectively [4]. In our study, following one year of health management, the recurrence and exacerbation rate for CVDs patients decreased from 38.12 to 15.60%. This result represented a reduced occurrence of acute events and reduced demand for urgent medical care, consequently relieving the strain on healthcare resources, which included a reduction in hospitalization frequency and a monthly decrease in medication expenses. Subsequent observations confirmed this trend, demonstrating a 0.61 reduction in annual hospitalizations and a 69.80 reduction in monthly medication costs after health management. This positive outcome may be attributed to the fact that in this study, the village doctors providing health intervention and education

Table 4 Results from GEE Model analyses of health economics indicators, risk factors after 12 months of health management

	Before management	12 months after management	GEE model	
			MD (95%CI)	*p*-value
Hospitalization frequency	0.79 ± 1.07	0.23 ± 0.65	-0.61 (-0.66, -0.56)	< 0.001
Average monthly medication expenses	212.04 ± 332.96	159.61 ± 219.54	-69.80 (-104.55, -35.05)	< 0.001
SBP (mmHg)	146.92 ± 22.81	151.29 ± 22.05	4.29 (3.24, 5.34)	< 0.001
DBP (mmHg)	81.21 ± 12.45	80.27 ± 12.32	-0.88 (-1.44, -0.31)	0.002
TC (mmol/L)	4.51 ± 1.07	3.84 ± 0.96	-1.89 (-6.79, 3.00)	0.01
LDL-C (mmol/L)	2.92 ± 0.96	2.42 ± 0.79	-0.29 (-0.67, -0.10)	< 0.001
HDL-C (mmol/L)	1.35 ± 0.42	1.12 ± 0.29	-0.17 (-0.39, 0.06)	< 0.001
TG (mmol/L)	1.84 ± 1.16	1.58 ± 1.33	-0.45 (-1.76, -0.86)	0.001
FPG (mmol/L)	6.19 ± 2.30	5.96 ± 2.37	-0.93 (-1.93, 0.06)	< 0.001
Cardiovascular disease				
GAD-7	6.88 ± 5.59	4.26 ± 4.60	-1.80 (-2.12, -1.47)	< 0.001
PHQ-9	3.13 ± 4.44	2.23 ± 3.58	-3.68 (-4.07, -3.28)	< 0.001
Cerebrovascular disease				
HAMA	8.83 ± 7.15	5.51 ± 6.03	-3.32 (3.83, -2.81)	< 0.001
HAMD	4.13 ± 4.86	2.68 ± 4.49	-1.44 (-1.80, -1.09)	< 0.001

[a] GEE model was used to evaluate the differences between baseline and follow-up for each outcome related to health management

Abbreviations GEE, generalized estimating equation; MD, mean difference CI confidence interval; SBP, systolic blood pressure; DBP, diastolic blood pressure; TC, total cholesterol; LDL-C, low-density lipoprotein cholesterol; TG, triglycerides; FPG, fasting plasma glucose; GAD-7, Generalized Anxiety Disorder-7; PHQ-9, Patient Health Questionnaire-9; HAMA, Hamilton Anxiety Rating Scale; HAMD Hamilton Depression Scale

had fixed contracts with their patients, allowing them to have a thorough understanding of their patients' health and medication information, which likely contributed to patient satisfaction. A diabetes management study conducted in Germany integrated a supplier-based disease management approach with CCM, primarily grounded in nursing practice and overseen by physicians [19]. After a 4-year follow-up, it was evident that the overall prognosis and medication costs for patients involved in the study were notably lower than those of patients who were not part of the study. Our results were in line with the findings of the aforementioned study, highlighting the positive impact of health management in improving patient outcomes and alleviating the burden on healthcare resources.

To gain deeper insights into the factors influencing recurrence and exacerbation after health management, regression analysis was performed, considering a range of variables, including patient characteristics and baseline risk factors. The analysis, post multiple adjustments, revealed that patients with LDL-C ≥ 1.80 mmol/L exhibited a 1.86 times higher recurrence and exacerbation odds compared to those with LDL-C < 1.8 mmol/L. Similarly, patients with a history of smoking displayed a 1.83 times higher recurrence and exacerbation odds than those without a smoking history. Elevated levels of LDL-C are widely acknowledged as a primary risk factor for CVDs. The findings of this study further substantiated the strong link between LDL-C levels and the recurrence and exacerbation of CVDs. Recent lipid management guidelines advocated more stringent LDL-C control, setting the target at < 1.4 mmol/L for extremely high-risk CVD patients [20]. This underscored the importance of prioritizing the reduction of LDL-C levels in the health management process, particularly for patients with elevated LDL-C levels. Smoking is undeniably associated with the development and progression of cardiovascular diseases. Data from the China Kadoorie Biobank prospective study [21], tracking 461,047 adults aged 30–79 over 11.2 years, revealed that in individuals without cardiovascular metabolic diseases at baseline, smokers had a 23% higher risk of first-time ischemic heart disease and a 14% elevated risk of ischemic stroke compared to non-smokers. Therefore, in health management, particular emphasis should be placed on smoking cessation and anti-smoking measures, especially for patients with a history of smoking.

When it comes to patient awareness regarding prevention and treatment, patients in this region had awareness rates of 19.74% for hypertension and 10.16% for diabetes, which were significantly lower than the national awareness rates of 44.7% and 43.3% [22, 23]. Additionally, the average baseline SBP was 146.92 mmHg, and FPG was 6.19 mmol/l, indicating relatively poor control of hypertension and diabetes in this region. Patients had low awareness rates of risk factors, unhealthy lifestyle choices, and medication usage principles, which were 28.32%, 35.71%, and 40.89%, respectively. This might be due to the higher baseline blood pressure and lipid levels of the patients. About 61.98% and 34.78% of patients in this region had a history of hypertension and hyperlipidemia, respectively. However, there was insufficient use of antihypertensive medications, with usage rates of beta-blockers, ACEI/ARB, and calcium antagonists at only 25.14%, 13.53%, and 13.38%, much lower than the national average [24]. This might contribute to the poor blood pressure control in this region. These findings indicated a relatively low level of the awareness rate regarding CVDs prevention and treatment in China, particularly in rural areas. Our study demonstrated a significant improvement in patient awareness of CVDs prevention and treatment. Patients exhibited increased understanding of hypertension, diabetes, risk factors, unhealthy lifestyle choices, regular monitoring, and medication adherence. This aligned with a previous chronic disease management study from Australia, highlighting the significance of patient education in chronic disease management [25]. The improvement in awareness of prevention and treatment knowledge is also evident in the positive changes to daily lifestyle behaviors. Following 12 months of management, patients exhibited a notable improvement in the rates of a greasy, sweet, and salty diet, as well as engaging in moderate physical activity compared to baseline, signifying a further refinement of patients' dietary and exercise habits. Unhealthy dietary and exercise habits lay the foundation for various CVDs risk factors, and optimizing these habits further contributes to the control of these risk factors [26]. Smoking, as both an unhealthy lifestyle habit and a significant cardiovascular risk factor, showed a noticeable decline in the current smoking rate among patients after management. It's noteworthy that during the management phase, we observed a number of ex-smokers who had quit at the baseline but later experienced relapses. This emphasizes the need to enhance smoking management for those who have quit smoking.

The core of the intelligent health management model is to assist patients in managing and improving their health through dynamic monitoring, risk assessment, and personalized intervention plans to help control the levels of risk factors. Following management in this study, patients exhibited a significant reduction in DBP, TC, LDL-C, HDL-C, TG, and FPG compared to baseline, signifying the effectiveness of the health management model in controlling risk factors. However, the SBP level of CVDs patients slightly increased after management compared to baseline, indicating suboptimal control of systolic blood pressure. This might be attributed to the longer history of hypertension and severe inadequacy in antihypertensive drug use among patients included at baseline. Notably, following health management, the patients included in the study did not experience an increase in the abnormality rate of laboratory indicators, and no serious adverse events related to the health management model were found. We tentatively assume that the health management model is relatively safe.

Despite the positive findings in our study, there were some limitations that need to be addressed. Firstly, our research was conducted in a specific rural area in China, which may limit the generalizability of the study results to other rural areas. Secondly, this study was a single-arm clinical study without a control group. Using predominantly paired analysis for most indicators introduced limitations as the effectiveness differences were influenced by various factors such as different village doctors, the natural course of the disease, personalized intervention plans, and others, thereby reducing the persuasiveness of the results. Additionally, the relatively short 12-month study period may not capture long-term effects and the sustainability of the health management model. Furthermore, the final analysis was conducted on patient data that complied with the protocol, which may increase the risk of selection bias. The open-label design suggested that the interpretation of the results of this study should be cautious. In future research, efforts should be made to actively seek suitable randomized double-blind trial designs. This involves stratifying CVDs with different disease courses and risk levels upon enrollment, conducting multicenter, large-sample, long-term dynamic follow-up randomized double-blind controlled studies, focusing on endpoint events. This will provide higher-level evidence for the effectiveness of health management models for CVDs.

Conclusions

In summary, the health management model for CVDs, based on the three-tier prevention and control system, displays promising effects in curtailing recurrence and exacerbation, mitigating healthcare economic burdens, enhancing patient awareness regarding prevention and treatment, and fostering positive changes in risk factors and lifestyle behaviors. Moreover, this health management model is generally considered safe. Despite limitations in this study, including its specific regional focus and a relatively short intervention period, it offers valuable insights into the potential of health management models to alleviate the burden of CVDs in rural China. Additional multicenter and long-term studies are required to validate these findings and endorse the wider application of this model.

Abbreviations

CENTRAL	HMM Health Management Model for Cardiovascular and Cerebrovascular Diseases in Rural Central China
CVDs	Cardiovascular and cerebrovascular diseases
CI	Confidence interval
OR	Odd ratio
MD	Mean difference
GEE	Generalized estimating equation

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12872-024-04431-8.

Supplementary Material 1: Table S1. Responsibilities of Different Personnel in the Three-Tier Prevention and Control System for Cardiovascular and

Cerebrovascular Diseases. Table S2. Changes in the incidence of abnormal laboratory indicators after 12 months of health management.

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Author contributions
M.Z., and D.W. contributed to the conception and design of this work. Y.W., J.W., and R.Y. drafted the manuscript and analyzed the data. X.W., X.L., G.P., and Y.Z. contributed to data collection. H.R., J.W., and Q.Z. were responsible for coordinating the study. B.L., and D.W. contributed to the interpretation of the data. H.G., Y.S., L.Q., and J.L. conducted the data cleaning and analysis. All authors read and approved the final manuscript.

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Data availability
Data is provided within the manuscript or supplementary information files.

Declarations

Ethics approval and consent to participate
All participants provided written informed consent and the Ethics Committee of the First Affiliated Hospital of Henan University of Chinese Medicine approved this study 2020HL-019), which conforms to the ethical principles of the Declaration of Helsinki.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]Heart Center, The First Affiliated Hospital of Henan University of Chinese Medicine, Zhengzhou, China
[2]Department of Neurological Intensive Care, The First Affiliated Hospital of Henan University of Chinese Medicine, Zhengzhou, China
[3]Henan Evidence-Based Medicine Center of Chinese Medicine, The First Affiliated Hospital of Henan University of Chinese Medicine, Zhengzhou, China
[4]Department of Clinical Sciences, Liverpool School of Tropical Medicine, Liverpool, UK
[5]Heart Center, The First Affiliated Hospital of Henan University of CM, Renmin Road 19, Zhengzhou 450000, China
[6]Department of Clinical Sciences, Liverpool School of Tropical Medicine, Pembroke Place, Liverpool L3 5QA, UK

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