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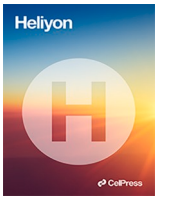

Effectiveness of health management among individuals at high risk of stroke: An intervention study based on the health ecology model and self-determination theory (HEM-SDT)

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ABSTRACT

Background: Stroke is the second leading cause of death in adults worldwide. However, up to 80% of strokes can be prevented by modifying risk factors.
Objective: The study aims to assess the effectiveness of the Health Ecology Model and Self-Determination Theory (HEM-SDT) based health management intervention among individuals at high risk of stroke.
Methods: A randomized controlled trial was conducted in Zhengzhou from May 1st, 2020, to December 31st, 2020. A total of 229 participants were recruited for the study, with 116 individuals at high risk of stroke being randomly assigned to the HEM-SDT health management group, while 113 participants were enrolled in the control group, following their current routine practices. The Generalized Estimating Equation model (GEE) was used to analyze the differences in health knowledge, belief and, behavior between the two groups at the beginning of the intervention, and at 6-month intervals after the intervention. The chi-square test was utilized to assess the control rate of risk factors.
Results: After 6 months of intervention, there were significant improvements in health knowledge, behavior, and belief among the participants. The study found significant differences in the interaction effects between time and group for health knowledge (Mean, SD = 25.62 ± 3.88, 95% *CI*: 7.944–9.604, $P < 0.001$), health belief (Mean, SD = 87.18 ± 14.21, 95%*CI*: 23.999–29.887, $P < 0.001$), and health behavior (Mean, SD = 173.28 ± 24.22, 95%*CI*: 22.332–36.904, $P < 0.001$). Additionally, the rates of hypertension, hyperglycemia, dyslipidemia, high or medium risk condition of stroke, obesity, hyperhomocysteinemia, smoking, alcohol consumption, and lack of exercise also showed statistical significance ($P < 0.05$) after the intervention.
Conclusion: The HEM-SDT health management model improves the health knowledge, behavior, and beliefs in people at high risk of stroke and remarkably it shows improvement in modifiable

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risk factors. It can be recommended for systematic health management in people at high-risk of stroke.

1. Introduction

Stroke is a significant global health concern, ranking as the second leading cause of death and disease worldwide [1]. Shockingly, approximately 795,000 people experience a stroke each year, with one occurrence happening every 40 s [2]. Moreover, the cumulative recurrence rates of stroke within 3 months, 6 months, and 1 year are reported at 10.9 %, 13.4 %, and 14.7 %, respectively [3]. Compounding the issue, up to 90% of strokes can be linked to ten modifiable risk factors [4,5]. Despite this knowledge, the control rate of these risk factors for stroke remains unsatisfactory [6,7]. Particularly concerning is the low control and awareness rate of hypertension and diabetes, with only 47.7 % and 28.4 % control rates for blood glucose, blood pressure, and serum lipid at 36.1 % [8]. Research has revealed that health management plays a crucial and indispensable role in reducing the risk factors associated with stroke [9]. Remarkably, as much as 80% of strokes can be prevented by effectively modifying stroke risk factors through health management strategies, which may include interventions such as lipid-lowering medications, anti-hypertensive treatments, smoking cessation, alcohol consumption reduction, and efforts to improve health knowledge, health beliefs, and health behaviors [10,11].

The high-risk group for stroke is closely associated with stroke risk factors [12–15]. Generally, individuals aged ≥40 years who meet any of the following criteria are considered to be at high risk for stroke [13]: (a) having hypertension, dyslipidemia, diabetes, atrial fibrillation or valvular heart disease, a smoking history, obvious overweight or obesity, lack of exercise or engaging in light physical activity, and a family history of stroke with three or more of the eight factors; (b) having a history of stroke; or (c) having a history of transient ischemic attack (TIA).

Implementing early health management practices among high-risk groups for stroke can significantly reduce the burden on individuals, families, and society, ultimately leading to a decrease in stroke incidence [16–18]. Health management originated in the United States [19] and has since evolved, guided by new health concepts and incorporating modern medical and management theories, technologies, and monitoring methods. It involves analyzing and evaluating the health of individuals or groups and providing a continuous service process of health consultation, guidance, and intervention [20].

However, the current state of health management for individuals at high risk of stroke is far from optimistic. There are limitations in health management knowledge, lack of confidence in the effectiveness of health management, and poor compliance with the prescribed interventions [21]. Furthermore, the existing health management model lacks the necessary integration of interactions between individuals, their environment, and their behaviors, making it fall short as a comprehensive, multi-level management model. It also fails to incorporate various stakeholders from hospitals, communities, families, and individuals into a coordinated and cohesive approach.

In this regard, a health management model is constructed based on the Health Ecology Model (HEM) and Self-Determination Theory (SDT). HEM takes into account the dynamic interaction of humans, their environment, behavior, and health. Moreover, it aims to enhance individuals' enthusiasm for participating in health management through a multi-level approach involving hospitals, communities, and families [22,23]. On the other hand, SDT emphasizes that stimulating intrinsic potential is crucial for individuals to independently adopt healthy behaviors [24–26]. By maximizing autonomy, competence, and a sense of belonging, individuals are more likely to sustain healthy behaviors over the long term. Thus, the HEM-SDT health management model addresses the shortcomings of previous models. The study aims to introduce this innovative health management model and evaluate its effectiveness and applicability.

2. Methods

2.1. Study design

A randomized controlled trial was conducted in Zhengzhou, located in central China, from May 1st, 2020, to December 31st, 2020. The pre-test phase took place during the first two months of the study. Ethical approval for the study was obtained from the Ethics Committee of the First Affiliated Hospital of Zhengzhou University (Approval No. 2020-KY-459), and the trial was registered with the China Clinical Trial Registry under the registration number ChiCTR2000032817 (https://www.chictr.org.cn/searchproj.html).

To ensure the quality of the study, the researchers used the CONSORT 2010 checklist. The study employed a multi-stage stratified random cluster sampling method, and informed consent was obtained from all participating individuals.

2.2. Participants

Inclusion criteria for the study were as follows: (1) individuals meeting the criteria for high risk of stroke as mentioned previously; (2) aged 40 years or older; (3) possessing effective communication skills.

Exclusion criteria were as follows: (1) individuals who were dependent on others for activities of daily living, with a Barthel Index (BI) Chinese version score of less than 60; (2) those with cognitive impairment, scoring less than 20 on the Mini-Mental State Examination (MMSE) Chinese version; (3) individuals who had already participated in other similar studies.

The sample size was calculated by the formula, $n_1 = n_2 = 2[(t_{\alpha/2}+t_{\beta})\sigma/\delta]^2$. According to the pre-test results ($\alpha = 0.05$, $t_{0.05/2} =$

1.96 , $\beta = 0.1$, $t_{\beta} = 1.282$, $\sigma = 11.49$, and $\delta = 4.96$). The same size was maintained in each group, $n1 = n2 = 112.67$. With considering the 10 % non-respondent rate, the total estimated sample size reached 248.

2.3. Randomization, allocation concealment and blinding

Zhengzhou is the capital city of Henan Province, and having 6 municipal districts. In the first stage, the three districts, Jinshui District (high level), Erqi District (medium level) and Huiji District (low level) were randomly selected based on the comprehensive strength of economy, health and education. In the second stage, the communities in each of the three selected districts were numbered, and two of those communities were randomly selected from each district. Finally, all the people at high risk of stroke from the selected community were recruited to the study. Study sites were set up in all six community Health Service Centers. The staff of Community Health Service Centers assisted in screening eligible subjects based on the community health records and physical examination findings.

Ultimately, 260 subjects were included, and numbered from 1 to 260. Based on an online random number generator (https://www.random-online.com/), 130 random numbers were automatically generated. One principal researcher randomly assigned them in two groups with 1:1 ratio. Therefore, 130 cases were assigned to the intervention group and control group. Fig. 1 (CONSORT 2010 flow diagram) shows the details of participation.

All researchers were professionally trained before the commencement of the study. Only the principal members were aware of the order of random assignment, and the interveners, examiners and participants were blinded.

2.4. Research team

The research group encompasses 9 members, including a professor with more than 30-years of experience in clinical nursing research in stroke, a chief nurse from stroke center (national stroke health manager), a nurse with more than 10 years of experience in clinical nursing related to stroke (national stroke health manager), a doctor with 5-years of experience in clinical neurology, a PhD candidate in nursing, two postgraduate candidates in nursing, and two medical staff of Community Health Service Centers. The main tasks were to formulate the intervention plan, implement the intervention, and evaluate and analyze the results.

2.5. Intervention group

2.5.1. Theoretical framework of intervention program

The HEM-SDT model serves as a comprehensive theoretical framework for multi-level and multi-stage health management,

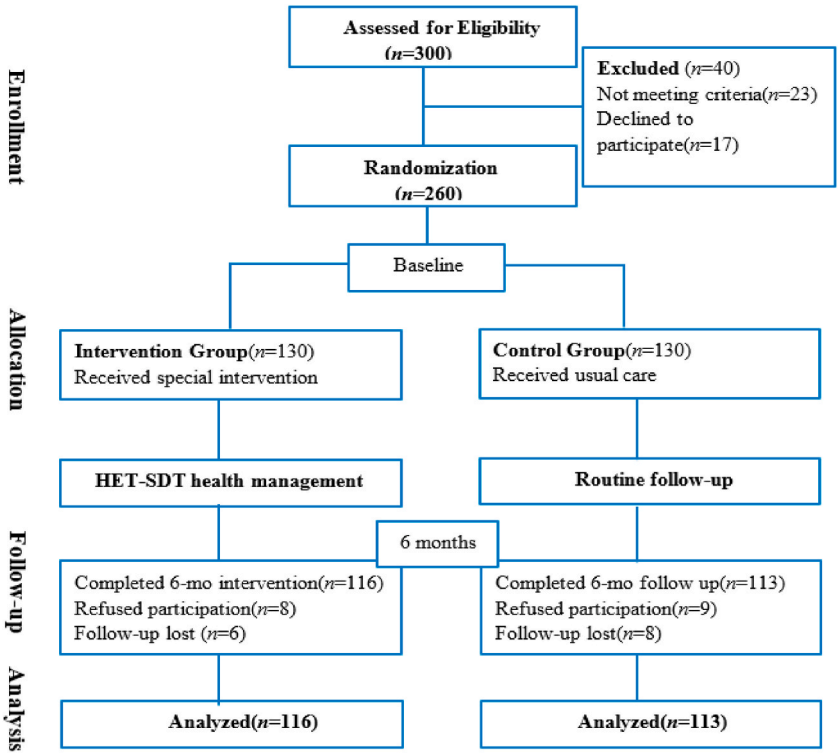

Fig. 1. Flow diagram of participants.

incorporating elements from the Health Ecology Model (HEM) and Self-determination Theory (SDT). This model is visually depicted in Fig. 2, which illustrates the theoretical framework of the HEM-SDT program. At all four levels of management (hospital, community, family, and individual), the national stroke health manager (nurse) acts as the link between the hospital and the community, while the medical staff from the community health service center serves as the link between the community and the family. The multi-level health management approach of the HEM-SDT model fosters the continuous transformation of individuals through multiple stages of motivation, including no motivation, external motivation, and internal motivation. Ultimately, this process leads to the enhancement and maintenance of individuals' self-health management ability.

2.5.2. Development of intervention program

The health management model was formulated based on the literature and theoretical framework considering the specific and advanced management of people at high risk of stroke. In the process of health management, the problems such as "who will manage", "what to manage" and "how to manage" were clarified at the beginning of the study. Delphi's expert consultation method was used to evaluate and revise the key points of health management. After two rounds of expert consultation, the three stages of intervention and 37 intervention elements were finalized. See ***Appendix 1***.

2.5.3. Implementation

The effectiveness of implementation of the HEM-SDT health management program requires the guidance and support in the hospitals and communities, and the active participation of families and individuals. The research team was exclusively responsible for the intervention and quality control of the whole program. The expert team included nurses, doctors, health managers, rehabilitation specialists, psychological consultants and nutritionists. offline intervention was taken place in community health service centers, and online intervention were conducted via social software "Tencent Conference" and "WeChat". In order to prevent the spread of COVID-19, participants were required to wear protective masks and keep at least 1 m distance with others during the offline activities. The problems encountered during the intervention process and its solutions are shown in ***Appendix 2***.

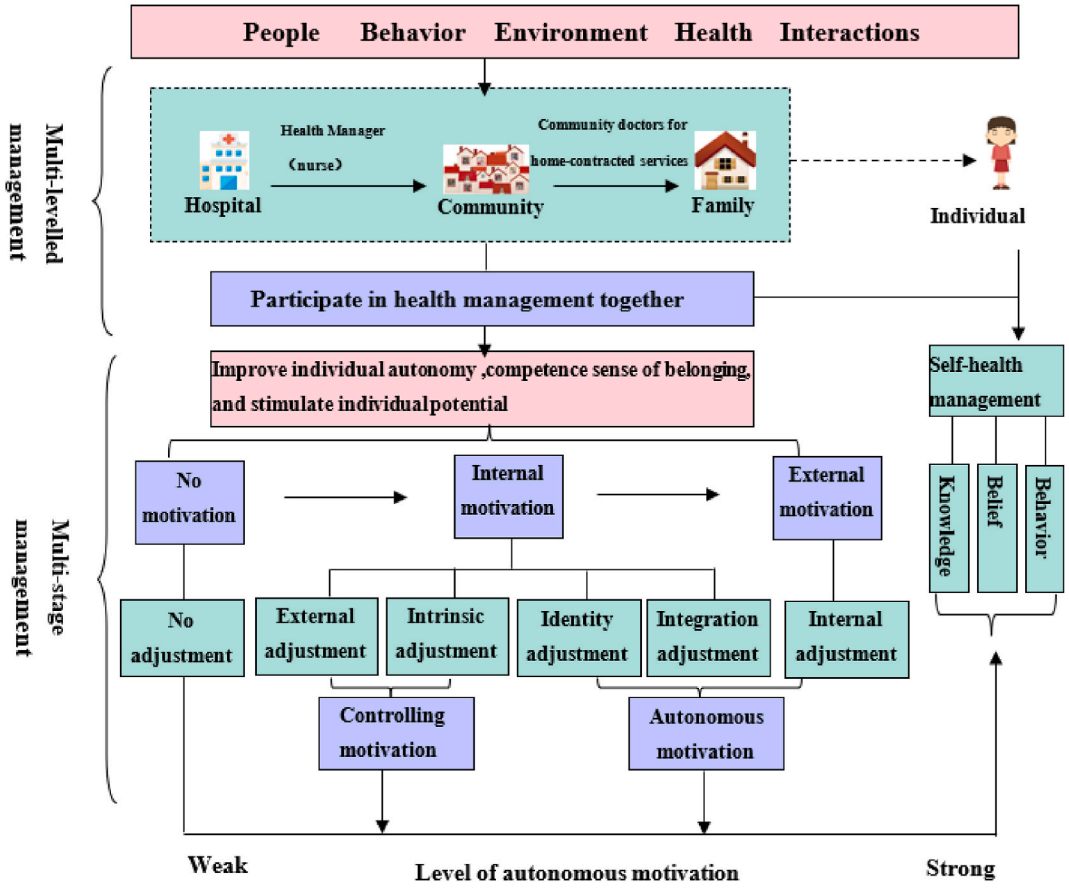

Fig. 2. Theoretical framework.

2.6. Control group

The intervention standards of the control group were formulated based on the current routine requirements of the National Stroke Prevention and Control Commission. It was established mainly through telephone follow-up and face-to-face interview. The contents included the status of disease, control of risk factor, drug administration, diet management, exercise guidance and stress relief practices. In addition, any other special interventions were not undertaken, and the normal living conditions of individuals in the community was maintained.

2.7. Outcome indicators and evaluation methods

2.7.1. Social-demographic information

The researcher designed a questionnaire to collect social-demographic information and verified it before the intervention. The content included name, age, sex, permanent address, height, weight, marital status, education, monthly income, sleeping time, family history of stroke, TIA history, contact information (phone number, WeChat). By collecting this information, the researcher aimed to understand the participants' background and characteristics, which could be relevant to the study and intervention.

2.7.2. Subjective indicators

The stroke-related health knowledge, belief, and behavior of the participants were assessed before the intervention and at three follow-up points: 1 month, 3 months, and 6 months after the intervention. This allowed the researchers to track changes in these variables over time and evaluate the impact of the intervention on the participants' health-related knowledge, beliefs, and behaviors.

The Stroke Prevention Knowledge Questionnaire (SPKQ) was employed to assess the stroke-related health knowledge of the participants. This questionnaire was developed by Chinese scholars Wan and her colleagues [27] and has demonstrated good reliability and validity through widespread usage. The SPKQ consists of 36 items, categorized into 8 dimensions: daily living, exercise, diet, risk factors of stroke, taking medicine, blood pressure monitoring, symptoms of stroke, and stroke management. Each item presents two choices: "know" for 1 point and "don't know" for 0 points. The total score ranges from 0 to 36 points, with a higher score indicating better knowledge regarding stroke prevention and management. The item-to-total correlations ranged from 0.296 to 0.638 and the Cronbach's α was 0.882 in this study.

The Champion Health Belief Model Scale (CHBMS) was used to assess the level of health belief related to stroke. The scale was first developed by Champion [28]. Then, it was translated and revised and has been used in China with a good reliability and validity. It composed of 35 items under 6 dimensions, including susceptibility, severity, benefits, obstacles, health motivation and self-efficacy. A 5-grade Likert scoring method was used varying from "completely disagreed - 1″ to "completely agreed - 5". Total score ranges from 35 to 175, higher score indicates a higher level of belief. The Cronbach's α was 0.881 in this study.

The Health Promoting Lifestyle Profile II (HPLP-II) was used to evaluate the status of health promotion behaviors. It was revised on the basis of HPLP by an American scholar. It consists of 52 items under 6 dimensions, including health responsibility, exercise, nutrition, self-realization, interpersonal relationship and stress response. Each item of the scale adopts 4-point Likert scoring method. The responses "never" to "always" carry 1 to 4 points for each of the item and total score varies from 52 to 208. A higher score indicates a better status of health promotion behaviors. HPLP II has been translated and improved for assessing people's pre-stroke health behavior in China. The Cronbach's α was 0.913 in this study.

2.7.3. Objective indicators

It includes blood pressure (systolic pressure, SBP; diastolic pressure, DBP), blood glucose (fasting plasma glucose, FPG; glycosylated hemoglobin, HbA1c-NGSP), blood lipids (total cholesterol, TC; triglycerides, TG; low-density lipoprotein, LDL; high-density lipoprotein, HDL), homocysteine (Hcy), body mass index (BMI), physical exercise, smoking and alcohol usage status [29]. The evaluation of these indicators was carried out before the intervention to establish baseline values and then repeated six months after the intervention to observe any changes or improvements resulting from the health management program.

Blood pressure, blood glucose, blood lipid and homocysteine were tested with the "Follow up kit for screening and intervention of people at high risk of stroke" provided by Shanghai Vebery Biotechnology Co., Ltd. The instruments included Chaosi blood pressure monitor (to assess SBP and DBP), Sannuo Stable + Air blood glucose meter (to assess FPG), Cardiac blood lipid meter (to assess TG, TC, LDL and HDL) and Hipro-AFS/1pro specific protein analyzer (to assess HbA1c-NGSP and Hcy).

BMI was calculated based on the height and weight.

Physical exercise, smoking and alcohol use status were recorded according to the results of particular investigations.

2.7.4. Other related indicators

Control rate: the risk factors control is expressed by the control rate.

Control rate= (number of patients before the intervention-number of patients after the intervention)/number of patients participated in the intervention × 100 %

Example: Hypertension control rate=(number of people whose blood pressure was high before the intervention - number of people whose blood pressure is high after the intervention)/number of patients participated in the intervention × 100 %

Risk condition of stroke: The Essen Stroke Risk Assessment Scale (ESRS) was used to assess the risk condition. ESRS is a widely used tool to assess the control of stroke risk factors and the risk of stroke occurrence. According to the total score, it can be divided into three groups: low risk group (0–2 points), medium risk group (3–6 points) and high risk group (7–9 points).

This study included control rates of Obesity, smoking, drinking alcohol, physical inactivity, hypertension, hyperglycemia, hyperlipidemia, hyperhomocysteinemia, high or medium risk in ESRS, which were measured before and after 6 months of intervention.

2.7.5. Definition of the outcome indicators

Hypertension: SBP≥140 mmHg and/or DBP≥90 mmHg.
Dyslipidemia: TG ≥ 2.26 mmol/L and/or TC ≥ 6.22 mmol/L and/or LDL≥4.14 mmol/L and/or HDL<1.04 mmol/L.
Hyperglycemia: FPG≥7.0 mmol/L and/or HbA1c NGSP > 6.5.
Obesity: BMI > 26 kg/m^2.
Lack of exercise: Did not reach the standard of "exercise≥3 times a week, and exercise of moderate intensity≥30 min each time".
Smoking history: ≥1 cigarette per day, duration≥6 months; This includes people who were smokers.
Family history of stroke: refers to the occurrence of stroke among immediate family members, including parents and siblings.
Alcohol consumption: the daily intake of alcohol for adult males is ≥ 25g, and for adult females is ≥ 15g.
High homocysteine: Hcy≥15 μmol/L.

2.8. Statistical analysis

The statistical analysis was performed by SPSS, version21.0. The measurement data conforming the normal distribution were expressed as mean and standard deviation. Count data were expressed as frequency and percentage (*n*, %). A *t*-test and chi-square test were conducted to examine the differences in age, gender, spouse, education, monthly income, sleeping hours, family history of stroke and TIA history before the intervention. A chi-square test was used to compare the difference in risk factor control rate after the intervention. The Generalized Estimating Equation model (GEE) was used to evaluate the effect of health management on health behavior, belief and knowledge of high-risk stroke population. Since health behavior, belief and knowledge scores are continuous variables, the connection function adopted linear function, and the working correlation matrix adopted independent structure. All *P*-values were from a bilateral test, and $P < 0$ 0.05 was considered as statistically significant.

3. Results

3.1. Description of the study sample

The mean age of all participants was 63.99 years (SD = 11.31) of which 57.6 % were male. More than half of them had low educational level. At the time of admission, 18.3 % had a family history of stroke. There were no significant differences observed in age, gender, spouse, education, monthly income, sleeping hours, family history of stroke, and history of TIA between the two groups ($P > 0.05$). The details are compared in the table (See Table 1).

Table 1
Comparison of the characteristics of the participants.

Characteristics	Control group ($n = 113$)	Intervention group ($n = 116$)	$t/\chi 2$	P
	n (%)/(Mean ± SD)	n (%)/(Mean ± SD)		
Age	62.94 ± 11.71	65.03 ± 10.91	−1.402	0.162
Gender				
Male	65(57.5)	67(57.8)	0.001	0.971
Female	48(42.5)	49(42.2)		
Spouse				
Have	91(80.5)	90(77.6)	0.300	0.584
No	22(19.5)	26(22.4)		
Education (in years)				
≤9	56(49.6)	56(48.3)	0.038	0.846
> 9	57(50.4)	60(51.7)		
Monthly income				
≤5000 RMB	78(69.0)	78(67.2)	0.084	0.772
> 5000RMB	35(31.0)	38(32.8)		
Sleeping hours	6.24 ± 1.24	6.23 ± 1.63	0.032	0.974
Family history of stroke				
Have	22(19.5)	19(16.4)	0.372	0.542
No	91(80.5)	97(83.6)		
TIA				
Have	18(15.9)	19(16.4)	0.009	0.926
No	95(84.1)	97(83.6)		

Abbreviation: TIA, history of Transient Ischemic Attack.

3.2. Effectiveness of HEM-SDT in health knowledge, belief, and behavior

3.2.1. Fixed and interaction effects

The analysis of GEE was conducted to examine changes across group and time between two groups on scores of health konwledge, health belief and health behavior. Table 2 showed significance of group and time interaction ($P < 0.001$).

3.2.2. A GEE model for intervention outcomes

The benefits of the intervention were observed through health knowledge, beliefs, and behavior (shown inTable 3). The health behavior score of the intervention group increased from 136.82 to 173.28 over the time. Health knowledge and belief scores also improved significantly. In addition, the interaction effect demonstrated that the health management had a positive interaction effect on the health knowledge, belief and behaviors of high-risk groups for stroke [$\beta = 8.774$, 95 % *CI* (7.944,9.604)], [$\beta = 26.943$, 95 % *CI* (23.999,29.887)] and [$\beta = 29.618$, 95 % *CI* (22.332, 36.904)] after the intervention.

3.3. Rate of risk factors of pre-intervention and post-intervention

Before the intervention, there was no significant differences in stroke risk factors between the two groups ($P > 0.05$). However, the control rates of hypertension, hyperlipidemia, BMI, homocysteine, and ESRS were higher than those in the control group after 6 months of intervention. The difference was statistically significant ($P < 0.05$), the hypertension control rate reached 75.3 % and more than half of the patients with high-risk stroke turned to low risk. Details are given in Table 4.

4. Discussion

The HEM-SDT health management model is scientific and seems feasible. While stroke prevention and treatment continues as a tremendous challenge for global public health, the health management of high-risk population shows a positive trend in improving the situation [30]. The HEM-SDT health management model connects the hospitals, communities and families through multidisciplinary collaboration and health management team. The HEM-SDT health management model mobilizes the enthusiasm of family members and the high risk groups of stroke, stimulates the autonomy motivation of high-risk groups, and drives the high-risk groups more willingly to change their behavior, which is conducive to effective health management. Through a three-stage health management system, the people at high risk of stroke gradually deepen their understanding of themselves and their diseases, and participate more actively in their own health management under the continuous guidance of the health management team. At the end, the patient's knowledge, beliefs, and behavior levels were highly improved, and risk factors were optimally controlled. It shows that the model significantly impacts the health management of the high risk groups of stroke.

The HEM-SDT health management model improves the health knowledge, belief, and behavior of high-risk stroke group. The improvement of health knowledge, beliefs and behaviors is the basic requirement for the health management of high-risk groups for stroke [31]. As the onset and recurrence of stroke are closely related to unhealthy behaviors, promoting the healthy behaviors is the key function of the health management of this group of people. Health knowledge is the foundation for behavior change [32]. Hospitals and community personnel regularly conducted lectures and skills training in accordance with the three-stage management of hospitals, communities, and work groups. Besides, the health manager who served as a link conducted regular follow-up appointments and clarified the questions of the participants. Gradually, the intervention group gained a better understanding of how stroke occurs and develops. Following that, the stroke-related knowledge in the intervention group was continuously strengthened and consolidated over time. Therefore, the health knowledge of the people in the intervention group was better improved compared to the control group. Which is similar to the results of Yi-No Kang [33]. Health belief is the driving force for healthy behavior change and the most direct influencing factor for health behavior improvement [34]. The intervention group's health management motivation was continuously generated and strengthened, and their health beliefs were greatly improved, which was consistent with the result of other researchers [35,36]. Compared to the results of the Meng Yao Wang's study [37], health behaviors of high-risk for stroke groups have been greatly improved after the intervention in this study. The HEM-SDT health management model fully addressed both the internal and external factors affecting health behavior, and managed health behavior through the multi-level link of hospital-community-family. On the other hand, health management team also involved in providing professional guidance and support to the intervention groups. Ultimately, health behaviors are sustainable and health management is remarkable.

The HEM-SDT health management model has effectively controlled the modifiable risk factors of stroke. The most effective strategy for preventing stroke is the management of modifiable risk factors. And the most important modifiable risk factors for stroke is

Table 2
Fixed and interaction effects test of GEE model.

Variable	Health knowledge			Health belief			Health behavior		
	Wald	df	P	Wald	df	P	Wald	df	P
Intercept	13252.444	1	$P < 0.001$	18325.953	1	$P < 0.001$	21835.763	1	$P < 0.001$
Group	206.952	1	$P < 0.001$	214.648	1	$P < 0.001$	94.991	1	$P < 0.001$
Time	1746.796	3	$P < 0.001$	727.847	3	$P < 0.001$	152.027	3	$P < 0.001$
Group*Time	518.055	3	$P < 0.001$	419.273	3	$P < 0.001$	75.766	3	$P < 0.001$

Table 3
Contrast of health behavior, belief, knowledge based on GEE.

	Baseline		Follow-up		Follow-up	
	Control (Mean, SD)	Intervention (Mean, SD)	Control (Mean, SD)	Intervention (Mean, SD)	*B* (95%CI)	*P*
Health knowledge	13.29 ± 4.06	13.64 ± 3.86	16.50 ± 3.89	25.62 ± 3.88	8.774(7.944, 9.604)	0.001
Health belief	54.80 ± 12.07	55.48 ± 12.37	59.56 ± 12.66	87.18 ± 14.21	26.943(23.999, 29.887)	0.001
Health behavior	133.42 ± 29.22	136.82 ± 32.76	140.27 ± 37.45	173.28 ± 24.22	29.618(22.332, 36.904)	0.001

The coefficient of the interaction term Time*Group confirms the mean difference in terms of intervention outcomes over time between the two groups.

Table 4
The control of risk factors in pre-intervention and post-intervention.

Risk factors		Control group [$n = 113$, n (%)]	Intervention group [$n = 116$, n (%)]	χ^2	*P*
Hypertension	Pre-intervention	76(57.6)	77(66.4)	2.025	0.155
	Post-intervention	51(38.3)	19(16.4)	14.794	0.000
	Control rate (%)	32.9	75.3		
Hyperglycemia	Pre-intervention	58(54.5)	62(53.4)	0.103	0.748
	Post-intervention	41(36.3)	21(18.1)	21.233	0.000
	Control rate (%)	29.3	66.1		
Dyslipidemia	Pre-intervention	57(50.4)	59(50.9)	0.004	0.949
	Post-intervention	38(33.6)	22(19.0)	6.365	0.012
	Control rate (%)	33.3	62.7		
Obesity	Pre-intervention	36(31.9)	38(32.8)	0.021	0.884
	Post-intervention	27(23.9)	14(15.7)	5.445	0.020
	Control rate (%)	25.0	63.2		
hyperhomocysteinemia	Pre-intervention	46(40.7)	51(44.0)	0.249	0.618
	Post-intervention	43(38.1)	30(25.9)	3.917	0.048
	Control rate (%)	6.5	41.2		
Smoking	Pre-intervention	41(36.3)	41(35.3)	0.022	0.882
	Post-intervention	34(30.1)	21(18.1)	4.505	0.034
	Control rate (%)	17.1	48.8		
Alcohol consumption	Pre-intervention	44(38.9)	47(40.5)	0.060	0.807
	Post-intervention	41(36.3)	28(24.1)	4.011	0.045
	Control rate (%)	6.8	40.4		
Lack of exercise	Pre-intervention	54(47.8)	56(48.3)	0.005	0.941
	Post-intervention	47(41.6)	33(28.4)	4.351	0.037
	Control rate (%)	13.0	41.1		
ESRS > 2	Pre-intervention	46(40.7)	47(40.5)	0.001	0.977
	Post-intervention	34(30.1)	13(12.2)	12.511	0.000
	Control rate (%)	26.1	72.3		

Abbreviation: ESRS, Essen Stroke Risk Assessment Scale.

hypertension, which is responsible for more than half of all strokes [38]. Further, strokes are more likely to occur in diabetic patients than in the general population by a factor of 2–5 [34]. In this study, the control rate of hypertension (75.2 %), hyperglycemia (66.1 %) and hyperlipidemia (62.7 %) were improved through the HEM-SDT health management model, which is higher than Amytis Towfighi's results [39]. In addition, BMI, smoking, drinking, etc. had also been controlled to a certain extent. The reason for the success of the model highlights the usage of multi-level management system in the hospital, community, and family to identify the individual stroke risk factors, and stimulate the individual's autonomous motivation to control the risk factors for stroke.

4.1. Limitation

The majority participants of the intervention group were the middle-aged and elderly with limited education level, that resulted in difficulties in understanding the intervention content and utilizing smart phones. As the indicators selected in this study can measure the effect of health management well, a complete evaluation system has not been established. Therefore, future research should pay attention to the development of an evaluation system for health management effects. The intervention time of this study is 6 months. The Transtheoretical Model of Change (TTM) believes that it takes at least 6 months for individuals to change a negative health behavior or obtain and maintain a positive health behavior. Health management is mainly achieved through the management of health behavior, and health management of stroke high-risk groups should be a long-term and uninterrupted process. Future studies should focus on multi-center based long term studies with large-sample to verify the effect of health management.

5. Conclusion

The HEM-SDT health management model is a multi-level and phased comprehensive management model. It has proven to be

effective in improving the health behavior, knowledge and belief of the individuals at high risk for stroke. Interventional risk factors such as hypertension, hyperlipidemia, smoking, and alcohol consumption have also been successfully managed. Which can serve as a theoretical and practical reference for systematic health management for people at high risk of stroke in the future.

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Data availability statement

Data will be made available on request.

Availability of data and materials

All data used during the study are available at the first author(guolina09@126.com).

Ethics approval and consent to participate

The study design and consent form were approved by the Ethics Committee of the First Affiliated Hospital of Zhengzhou University (Approval No. 2020-KY-459).

Patient consent for publication

Written informed consent was obtained from each participant for publication of their data.

CRediT authorship contribution statement

Lina Guo: Conceptualization, Funding acquisition, Investigation, Resources, Supervision, Writing – original draft. **Mengyv Zhang:** Data curation, Methodology, Writing – original draft. **Genoosha Namassevayam:** Writing – review & editing. **Miao Wei:** Data curation, Formal analysis, Writing – original draft. **Gege Zhang:** Data curation, Investigation. **Yv He:** Data curation, Investigation. **Yuanli Guo:** Funding acquisition, Project administration. **Yanjin Liu:** Conceptualization, Funding acquisition, Project administration.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e21301.

References

[1] V. Saini, L. Guada, D.R. Yavagal, Global epidemiology of stroke and access to acute ischemic stroke interventions, Neurology 97 (20 Suppl 2) (2021) S6–s16, https://doi.org/10.1212/wnl.0000000000012781.

[2] C.W. Tsao, A.W. Aday, Z.I. Almarzooq, A. Alonso, A.Z. Beaton, M.S. Bittencourt, A.K. Boehme, A.E. Buxton, A.P. Carson, Y. Commodore-Mensah, et al., Heart disease and stroke statistics-2022 update: a report from the American heart association, Circulation 145 (8) (2022) e153–e639, https://doi.org/10.1161/cir.0000000000001052.

[3] B. Lin, Z. Zhang, Y. Mei, C. Wang, H. Xu, L. Liu, W. Wang, Cumulative risk of stroke recurrence over the last 10 years: a systematic review and meta-analysis, Neurol. Sci. 42 (1) (2021) 61–71, https://doi.org/10.1007/s10072-020-04797-5.

[4] C.S. Anderson, Progress-defining risk factors for stroke prevention, Cerebrovasc. Dis. 50 (6) (2021) 615–616, https://doi.org/10.1159/000516996, 10.1159/000516996.

[5] W. Qi, J. Ma, T. Guan, D. Zhao, A. Abu-Hanna, M. Schut, B. Chao, L. Wang, Y. Liu, Risk factors for incident stroke and its subtypes in China: a prospective study, J. Am. Heart Assoc. 9 (21) (2020), e016352, https://doi.org/10.1161/jaha.120.016352.

[6] A. Nutakki, M. Chomba, L. Chishimba, S. Zimba, R.F. Gottesman, M.N. Bahouth, D. Saylor, Risk factors and outcomes of hospitalized stroke patients in Lusaka, Zambia, J. Neurol. Sci. 424 (2021), 117404, https://doi.org/10.1016/j.jns.2021.117404.

[7] C.V.S. Ram, S. Kumar, P.N. Renjen, G.P. Kumar, J. Swaminathan, C.R. Reddy, S. Kondati, M. Sharma, V.L.A. Selvan, M. Sundaram, et al., Risk factors predisposing to acute stroke in India: a prospective study, J. Hypertens. 39 (11) (2021) 2183–2189, https://doi.org/10.1097/hjh.0000000000002915.

[8] S. Zhang, W. Zhang, G. Zhou, Extended risk factors for stroke prevention, J. Natl. Med. Assoc. 111 (4) (2019) 447–456, https://doi.org/10.1016/j.jnma.2019.02.004.

[9] A. Budreviciute, S. Damiati, D.K. Sabir, K. Onder, P. Schuller-Goetzburg, G. Plakys, A. Katileviciute, S. Khoja, R. Kodzius, Management and prevention strategies for non-communicable diseases (NCDs) and their risk factors, Front. Public Health 8 (2020), 574111, https://doi.org/10.3389/fpubh.2020.574111.

[10] L. Liu, W. Chen, H. Zhou, W. Duan, S. Li, X. Huo, W. Xu, L. Huang, H. Zheng, J. Liu, et al., Chinese Stroke Association guidelines for clinical management of cerebrovascular disorders: executive summary and 2019 update of clinical management of ischaemic cerebrovascular diseases, Stroke Vasc Neurol 5 (2) (2020) 159–176, https://doi.org/10.1136/svn-2020-000378.

[11] J. Joubert, S.M. Davis, G.A. Donnan, C. Levi, G. Gonzales, L. Joubert, G.J. Hankey, ICARUSS: an effective model for risk factor management in stroke survivors, Int. J. Stroke 15 (4) (2020) 438–453, https://doi.org/10.1177/1747493019830582.

[12] B. Bridgwood, K.E. Lager, A.K. Mistri, K. Khunti, A.D. Wilson, P. Modi, Interventions for improving modifiable risk factor control in the secondary prevention of stroke, Cochrane Database Syst. Rev. 5 (5) (2018), Cd009103, https://doi.org/10.1002/14651858.CD009103.pub3.

[13] X. Wang, W. Li, F. Song, L. Wang, Q. Fu, S. Cao, Y. Gan, W. Zhang, W. Yue, F. Yan, et al., Carotid atherosclerosis detected by ultrasonography: a national cross-sectional study, J. Am. Heart Assoc. 7 (8) (2018), https://doi.org/10.1161/jaha.118.008701.

[14] X. Zhang, J. Dai, W. Li, Y. Yang, High-risk population and factors of stroke has changed among middle-aged and elderly Chinese-Evidence from 1989 to 2015, Front. Public Health 11 (2023), 1090298, https://doi.org/10.3389/fpubh.2023.1090298.

[15] H. Wang, M. Wu, Q. Tu, M. Li, Risk factors for stroke in a population of central China: a cross-sectional study, Medicine (Baltim.) 101 (46) (2022), e31946, https://doi.org/10.1097/md.0000000000031946.

[16] B.C.V. Campbell, D.A. De Silva, M.R. Macleod, S.B. Coutts, L.H. Schwamm, S.M. Davis, G.A. Donnan, Ischaemic stroke, Nat. Rev. Dis. Prim. 5 (1) (2019) 70, https://doi.org/10.1038/s41572-019-0118-8.

[17] Y. Han, Y. Hu, C. Yu, Y. Guo, P. Pei, L. Yang, Y. Chen, H. Du, D. Sun, Y. Pang, et al., Lifestyle, cardiometabolic disease, and multimorbidity in a prospective Chinese study, Eur. Heart J. 42 (34) (2021) 3374–3384, https://doi.org/10.1093/eurheartj/ehab413.

[18] S. Wu, B. Wu, M. Liu, Z. Chen, W. Wang, C.S. Anderson, P. Sandercock, Y. Wang, Y. Huang, L. Cui, et al., Stroke in China: advances and challenges in epidemiology, prevention, and management, Lancet Neurol. 18 (4) (2019) 394–405, https://doi.org/10.1093/ageing/afaa127.

[19] D.E. Craig, L. Hartka, W.H. Likosky, W.M. Caplan, P. Litsky, J. Smithey, Implementation of a hospitalist system in a large health maintenance organization: the Kaiser Permanente experience, Ann. Intern. Med. 130 (4 Pt 2) (1999) 355–359, https://doi.org/10.7326/0003-4819-130-4-199902161-00005.

[20] A.K.C. Wong, F.K.Y. Wong, C. So, Cost-effectiveness of a preventive self-care health management program for community-dwelling older adults: a randomised controlled trial, Age Ageing 50 (2) (2021) 440–446, https://doi.org/10.1093/ageing/afaa127.

[21] L. Guo, Y. Guo, J. Booth, M. Wei, L. Wang, Y. Zhu, Y. He, Y. Liu, Experiences of health management among people at high risk of stroke in China: a qualitative study, Nurs Open 10 (2) (2023) 613–622, https://doi.org/10.1002/nop2.1327.

[22] D.J. Rapport, J. Howard, R. Lannigan, W. McCauley, Linking health and ecology in the medical curriculum, Environ. Int. 29 (2–3) (2003) 353–358, https://doi.org/10.1016/s0160-4120(02)00169-1.

[23] M.E. Riner, S. Ofner, Global nurse/midwife workforce and reproductive health through social ecology lens, Publ. Health Nurs. 36 (5) (2019) 683–693, https://doi.org/10.1111/phn.12648.

[24] C.C. Lee, C.J. Enzler, B.H. Garland, C.J. Zimmerman, J.L. Raphael, A.C. Hergenroeder, C.M. Wiemann, The development of health self-management among adolescents with chronic conditions: an application of self-determination theory, J. Adolesc. Health 68 (2) (2021) 394–402, https://doi.org/10.1016/j.jadohealth.2020.05.053.

[25] S.J. Sebire, Z. Toumpakari, K.M. Turner, A.R. Cooper, A.S. Page, A. Malpass, R.C. Andrews, I've made this my lifestyle now": a prospective qualitative study of motivation for lifestyle change among people with newly diagnosed type two diabetes mellitus, BMC Publ. Health 18 (1) (2018) 204, https://doi.org/10.1186/s12889-018-5114-5.

[26] R.M. Ryan, E.L. Deci, Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being, Am. Psychol. 55 (1) (2000) 68–78, https://doi.org/10.1037//0003-066x.55.1.68.

[27] M. Shen, X. Wang, J. Tan, S. Wang, Y. Zhang, L. Wan, Effect of comprehensive reminder system on health knowledge, belief and behaviors, and clinical outcomes for stroke patients six months after discharge, Chin. J. Rehabil. Theory Pract. 26 (7) (2020) 856–862, https://doi.org/10.1097/JCN.0000000000000631.

[28] V.L. Champion, Instrument development for health belief model constructs, ANS Adv Nurs Sci 6 (3) (1984) 73–85, https://doi.org/10.1097/00012272-198404000-00011.

[29] S. Opoku, Y. Gan, W. Fu, D. Chen, E. Addo-Yobo, D. Trofimovitch, W. Yue, F. Yan, Z. Wang, Z. Lu, Prevalence and risk factors for dyslipidemia among adults in rural and urban China: findings from the China National Stroke Screening and prevention project (CNSSPP), BMC Publ. Health 19 (1) (2019) 1500, https://doi.org/10.1186/s12889-019-7827-5.

[30] G. Meredith, A. Rudd, Reducing the severity of stroke, Postgrad Med J 95 (1123) (2019) 271–278, https://doi.org/10.1136/postgradmedj-2018-136157.

[31] J.J. Li, J.X. Tan, F.Y. Zhu, Z. Wu, H.F. Ruan, Z.R. Li, L.H. Wan, Comparisons of stroke knowledge and health behaviors in patients with hypertensive stroke at different recurrence risk strata: the comprehensive reminder system based on the health belief model study, J. Cardiovasc. Nurs. 37 (2) (2022) 184–191, https://doi.org/10.1097/jcn.0000000000000765.

[32] Q.H. Liu, J.X. Tan, C.X. Hu, D.L. Hu, L.H. Wan, A decade-long Comparison of prestroke health behaviors among hypertensive stroke patients in mainland China, J. Neurosci. Nurs. 54 (1) (2022) 42–47, https://doi.org/10.1097/jnn.0000000000000628.

[33] Y.N. Kang, H.N. Shen, C.Y. Lin, G. Elwyn, S.C. Huang, T.F. Wu, W.H. Hou, Does a Mobile app improve patients' knowledge of stroke risk factors and health-related quality of life in patients with stroke? A randomized controlled trial, BMC Med. Inf. Decis. Making 19 (1) (2019) 282, https://doi.org/10.1186/s12911-019-1000-z.

[34] L. Zhang, X. Li, C.D.A. Wolfe, M.D.L. O'Connell, Y. Wang, Diabetes as an independent risk factor for stroke recurrence in ischemic stroke patients: an updated meta-analysis, Neuroepidemiology 55 (6) (2021) 427–435, https://doi.org/10.1159/000519327.

[35] X.P. Zhang, J.H. Pan, L.H. Wan, Z.Y. Liu, M.M. Mo, M.Y. Wang, L.L. Li, Factors influencing health behaviour, blood pressure control, and disability in hypertensive ischaemic stroke patients after a comprehensive reminder intervention, J. Adv. Nurs. 76 (6) (2020) 1384–1393, https://doi.org/10.1111/jan.14340.

[36] Y. He, L. Guo, Y. Liu, M. Wei, Y. Guo, X. Dong, C. Yang, Q. Zhou, X. Lei, G. Zhang, et al., Can goal-based health management improve the health knowledge, health belief and health behavior in people at high risk of stroke? A non-randomized controlled trial, Neuropsychiatric Dis. Treat. 17 (2021) 3085–3095, https://doi.org/10.2147/ndt.S334229.

[37] M.Y. Wang, M.J. Shen, L.H. Wan, M.M. Mo, Z. Wu, L.L. Li, S.H. Neidlinger, Effects of a comprehensive reminder system based on the health belief model for patients who have had a stroke on health behaviors, blood pressure, disability, and recurrence from baseline to 6 Months: a randomized controlled trial, J. Cardiovasc. Nurs. 35 (2) (2020) 156–164, https://doi.org/10.1097/jcn.0000000000000631.

[38] L.H. Wan, X.P. Zhang, L.M. You, H.F. Ruan, S.X. Chen, The efficacy of a comprehensive reminder system to improve health behaviors and blood pressure control in hypertensive ischemic stroke patients: a randomized controlled trial, J. Cardiovasc. Nurs. 33 (6) (2018) 509–517, https://doi.org/10.1097/jcn.0000000000000496.

[39] A. Towfighi, E.M. Cheng, V.A. Hill, F. Barry, M. Lee, N.P. Valle, B. Mittman, M. Ayala-Rivera, L. Moreno, A. Espinosa, et al., Results of a pilot trial of a lifestyle intervention for stroke survivors: healthy eating and lifestyle after stroke, J. Stroke Cerebrovasc. Dis. 29 (12) (2020), 105323, https://doi.org/10.1016/j.jstrokecerebrovasdis.2020.105323.