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Original article

Factors affecting treatment adherence among patients with hypertension based on the PRECEDE model: A cross-sectional study from a delay discounting perspective

Zhiqing Hu [a,b], Huiying Zhang [a,b], Yanjun Sun [a,b], Yiping Wang [c], Rui Meng [c], Ke Shen [d], Jiali Chen [d], Yuan He [a,b,e,*]

[a] Institute of Medical Humanities, Nanjing Medical University, Nanjing 211166, China
[b] School of Marxism, Nanjing Medical University, Nanjing 211166, China
[c] School of Nursing, Nanjing Medical University, Nanjing 211166, China
[d] School of Health Policy & Management, Nanjing Medical University, Nanjing 211166, China
[e] Laboratory for Digital Intelligence & Health Governance, Nanjing Medical University, Nanjing 211166, China

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ABSTRACT

Background: Hypertension is a significant global public health concern, and research shows that treatment adherence plays an important role in hypertension control. This study incorporated a novel factor in behavioral economics, delay discounting, into the predisposing factors within the PRECEDE model to explore the factors influencing adherence to treatment of patients with hypertension.

Design: This cross-sectional study was conducted in Jiangsu Province, China, in 2023 and included 1,123 patients with hypertension.

Methods: Data collection tools included demographic variables and predisposing, reinforcing, and enabling factors. Delay discounting was assessed using a self-designed computer program. The collected data were analyzed using descriptive statistics and hierarchical regression. This study used the STROBE Reporting Checklist.

Results: The variables accounted for 30.4% of the total variance in adherence to treatment of patients with hypertension. Hierarchical regression analyses revealed that the predisposing (knowledge, delay discounting, and self-efficacy), reinforcing, and enabling factors were significantly associated with treatment adherence.

Conclusions: Delay discounting was associated with hypertension treatment adherence. Enhancing the predisposing, enabling, and reinforcing factors may lead to increased adherence among patients with hypertension. It is recommended that hospitals and healthcare providers offer educational lectures and training sessions, and that some simple delayed discount interventions be added to supplement this. Additionally, government and institutional efforts should be made to increase the availability of community-level resources for patients with hypertension.

Introduction

Hypertension is widely acknowledged as the foremost risk factor of cardiovascular, cerebrovascular, and kidney diseases (Yano et al., 2022). Hypertension has become a significant global public health issue, with an estimated 1.28 billion adults already having hypertension and 1.56 billion adults predicted to have hypertension by 2025 (Khan et al., 2021; WHO, 2023). The prevalence of hypertension in China has increased in recent decades; according to a report on the cardiovascular health and disease burden in China in 2022 (Wang et al., 2023), 245 million people have hypertension in China, which places a considerable burden on government medical expenditure. In the urban and rural areas of China, the direct medical costs associated with diagnosis, examination, medication, and outpatient and inpatient treatment for hypertension are $115.7 and $109.0 per patient per year, respectively (Zhang et al., 2021). Therefore, hypertension has become a major public health problem that must be urgently addressed in China.

Poor treatment adherence is the primary factor affecting the

* Corresponding author at: Institute of Medical Humanities, Nanjing Medical University, 101 Longmian Road, Nanjing, China.
E-mail address: heyuan@njmu.edu.cn (Y. He).

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management of hypertension. Adherence to treatment is defined as the extent to which a person's medication-taking behavior, following a diet, and/or executing lifestyle changes corresponds with the prescribed recommendations of a health care professional" (Burkhart & Sabaté, 2003). Several studies (Georges et al., 2022; Menditto et al., 2020; Yap et al., 2016) have shown that effective treatment programs are applicable only to patients who are willing to actively cooperate with treatment plans. These findings suggest that long-term adherence to treatment is an important factor in the success of antihypertensive therapy and blood pressure control (Abegaz et al., 2017). However, because hypertension is chronic and asymptomatic, more than half of patients receiving antihypertensive medication have low adherence (Morrissey et al., 2017). Several studies conducted in China reported that 60.9–72.5% of participants with hypertension had low adherence to medications (Pan et al., 2019; Shen et al., 2020). Another study revealed that the overall hypertension control rate among Chinese community residents was relatively low, with only 31.4% of patients receiving antihypertensive treatment having their condition under control (Xing et al., 2023). Hence, improving treatment adherence in Chinese patients with hypertension is crucial for preventing and controlling hypertension in Chinese communities.

Although many studies have explored the psychosocial factors related to managing hypertension (Magrin et al., 2015; Saarti et al., 2016; Suárez-Argüello et al., 2022), few have focused on the health behaviors of patients with hypertension from a behavioral economics perspective. Delay discounting, a focus of behavioral economics, may be an important factor associated with the adherence to treatment of patients with hypertension. Delay discounting refers to the trade-offs individuals make between time and profit/loss (Furrebøe, 2022), such as choosing between current gratification and future satisfaction (e.g., immediate pleasure of smoking and long-term health consequences).

Since hypertension is commonly asymptomatic, the benefits of treatment adherence may take more time to manifest. Patients with hypertension who are more "present-oriented" may perceive themselves to be less vulnerable to the consequences of high blood pressure than those who are more "future-oriented." Recently, researchers have begun to focus on the relationship between health behaviors and delay discounting. Several studies have revealed that delay discounting is associated with different health behaviors (e.g., exercise, a healthy diet, sun protection, and adherence to medical advice (Adams, 2009; Axon et al., 2009; Gellert et al., 2012)). However, the degree to which patients with hypertension value future benefits has not received much attention. Previous studies have reported that delay discounting of patients with hypertension is associated with routine medical examinations (Kim & Radoias, 2016) and preventive health behaviors (Axon et al., 2009). However, the relationship between treatment adherence and delay discounting in patients with hypertension has not yet been examined. Therefore, exploring the delay discounting behavior of Chinese patients with hypertension and its correlation with health behavior is crucial.

In this study, a conceptual framework was constructed to examine the adherence of patients with hypertension to treatment. The PRECEDE model, a health framework introduced by Green and Kreuter (Ghaffari et al., 2021), was employed as the theoretical foundation. The PRECEDE model comprises five phases: social, epidemiological, behavioral and environmental, educational and ecological, and administrative and policy assessments. This model has been validated in the realm of health behavior by various populations in cross-cultural contexts, including breast self-examination (Cereda et al., 2020), hypertension self-care (Axon et al., 2009), and physical activity (Kim & Choo, 2023). Moreover, this model provides a comprehensive and consistent structure for the design, implementation, and evaluation of health behaviors. It not only focuses on an individual's behavior but also considers the socio-ecological environmental factors influencing the individual. Considering the complexity of factors affecting the health behaviors of patients with hypertension, it was helpful for our study to employ the PRECEDE model as a participatory and planning framework.

Fig. 1 illustrates our research model. The educational and ecological assessment of the PRECEDE model is critical for identifying the factors of health behaviors related to a health problem, which comprise predisposing, enabling, and reinforcing factors.

The predisposing factors in the PRECEDE model typically refer to an individual's motivation or inclination to engage in a specific behavior and the factors that induce a certain behavior prior to its occurrence (i.e., knowledge, beliefs, attitudes, values, and individual preference). The predisposing factors included in this study were knowledge of hypertension (Ghembaza et al., 2014) and self-efficacy (Li et al., 2019; Maheri et al., 2020). Predisposing variables are elements that influence the incentives to modify one's behavior. Predisposing factors provide the underlying motivation or reason for behavior; they precede behavioral change and effectively induce positive or eliminate negative attitudes. A previous study (Axon et al., 2009) suggested that individual delay discounting could be incorporated into the framework as a predisposing factor in the PRECEDE model. Delay discounting is a stable trait-level characteristic (Horan et al., 2017; MacKillop et al., 2016) and is considered a dimension of impulsivity that is closely related to other dimensions such as self-reported impulsivity (MacKillop et al., 2016). Studies have shown that delay discounting may be associated with adherence to treatment among patients with hypertension (Barlow et al., 2016; Hayden, 2016). Delay discounting is similar to but different from attitudes and values. It meets the definition of predisposing factors and represents a relatively stable individual characteristic that can precede behavioral change and influence the motivation of patients with hypertension to change their behavior. In this study, we incorporated delay discounting as a predisposing factor.

Enabling factors are various elements that facilitate accomplishing a behavior or motivation, such as the skills and resources required to enhance treatment adherence among patients with hypertension. In this study, enabling factors included the convenience of resource acquisition and relevant community and medical resources (Calano et al., 2019; Han et al., 2020; Tan et al., 2019).

Reinforcing factors contain elements that follow a behavior and provide rewards or incentives for continuing and reinforcing a behavior, which primarily stems from societal norms, significant others, and vicarious reinforcement. In this study, reinforcing factors included encouragement and support provided by the family, friends, and physicians of patients with hypertension (Magrin et al., 2015; Pan et al., 2021; Zhang et al., 2021).

The dependent variable in this study was the adherence of patients with hypertension to treatment. This study aimed to assess the efficacy of our research model, which contains predisposing, enabling, and reinforcing factors. The study results are expected to offer a new perspective for policymakers and healthcare providers to enhance the comprehensiveness of current health promotion planning and policies.

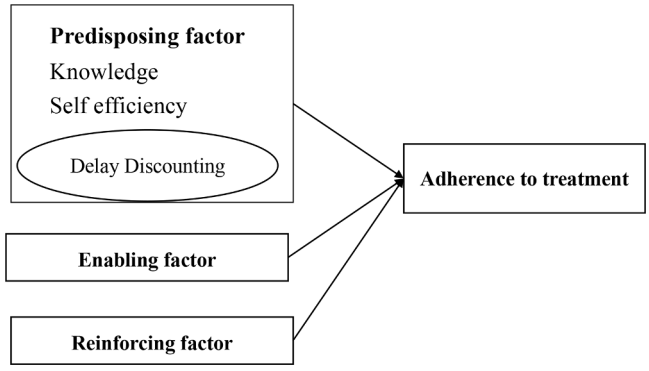

Fig. 1. Research model of adherence to treatment among patients with hypertension.

Methods and materials

Instrument with validity and reliability

A questionnaire was developed based on predisposing, reinforcing, and enabling factors and was subsequently validated and revised through feedback from the pilot study to produce the final version. The structured questionnaire comprised three sections. The first section addressed the sociodemographic characteristics of patients with hypertension (e.g., income, sex, and age). The second section included predisposing, enabling, and reinforcing factors. The items in the validated scales of previous studies did not focus on the health behaviors of patients with hypertension (Ong et al., 2018; Shen et al., 2022). Moreover, considering the cognitive levels of our participants, comprehensive questionnaires closely related to our research topic were required. Most studies (Alizadeh-Siuki et al., 2020; Saulle et al., 2020) that used the PRECEDE model as a theoretical guide chose to develop their own questionnaires. Therefore, we decided to employ several self-designed questionnaires in the second section of the questionnaire. All items of the self-designed questions used in our study are reported in Supplementary File 1.

The predisposing factors included three dimensions (knowledge of hypertension, delay discounting, and self-efficacy), and knowledge of hypertension was measured via a self-designed questionnaire. It comprised 16 binary items aimed at assessing patients' knowledge of hypertension, covering topics such as the definition of hypertension, lifestyle, diet, and medical treatment (e.g., Do you believe that patients should only take medication when they feel uncomfortable?). Self-efficacy was measured using the Perceived Health Competence Scale (Smith et al., 1995), which includes eight items, such as "I handle myself well with respect to my health, no matter how hard I try, my health just does not turn out the way I would like." Respondents rated their self-efficacy in controlling and managing their health outcomes on a five-point Likert scale, ranging from 1 (strongly agree) to 5 (strongly disagree). Higher scores indicate that respondents are more capable of effectively managing their health outcomes.

Enabling factors

The self-constructed questionnaire on enabling factors comprised nine items rated on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The results are summed to produce a total scale score ranging from 9 to 45. Enabling factors included access to relevant knowledge, health education provided by social or official sources, time, availability of relevant medicines and equipment, and distance to healthcare facilities. Higher scores indicate that individuals have more relevant community and medical resources that are beneficial to treatment adherence. An example item from the scale is, "In my opinion, the community's health education for hypertension patients is adequate."

Reinforcing factors

The self-administered questionnaire on reinforcing factors comprised nine items, including peer, healthcare, and familial support, rated on a five-point scale from 1 (strongly disagree) to 5 (strongly agree). Higher scores on the scale indicate more encouragement and support provided to patients with hypertension by their family members, friends, and primary care physicians. An example from the scale is, "Family members/physicians/friends were very concerned about your diet, medication adherence, and appointment adherence'.

The third section of the questionnaire served as the dependent variable, measuring adherence to treatment via the Chinese version of the Hill-Bone High Blood Pressure Compliance Scale (HBCS) developed by Kim, Hill, Bone, and Levine and translated to the Chinese version (Kim et al., 2000; Saleem et al., 2015). The questionnaire comprised 14 items across three domains: diet (salt intake; two items), apparent adherence (three items), and medication adherence (nine items). Medication adherence had the greatest contribution to the total adherence score. Each item received four possible responses (4 = none of the time, 1 = all the time). Higher scores indicate higher compliance. Kim et al. (2000) reported good reliability coefficients, with Cronbach's alpha values of 0.74 and 0.84, on the basis of two different samples of patients with hypertension. The Chinese version of the HBCS has shown good validity and reliability in Chinese patients with hypertension (Saleem et al., 2015).

Delay discounting

A titration program written in E-Prime 2.0 was used to assess delay discounting. The participants engaged in a computer-based delay-discounting task lasting 10–15 min, which comprised 54 decision-making choices. During each trial, the participants were required to decide whether to receive a larger reward following a specified delay or a smaller but immediate reward. Monetary rewards are a common scientific method of assessing delay discounting across diverse populations (Johnson & Bickel, 2002). The settings for the monetary reward and delay periods in this study were based on prior research. A larger reward always started at 1000 RMB (Mellis et al., 2017) and the delay periods were 1, 7, 30, 90, 180, 365, and 730 days (Garza et al., 2019; Rung et al., 2019). Delays are presented in increasing order. Six trials were conducted for each delay with a smaller reward amount varying according to the participants choice in each trial. The starting value reward for the immediate amount of each delay was always 50% of the larger delay reward, with the example provided being 500 RMB, which is half of the 1000 RMB larger reward mentioned previously. As shown in Fig. 2, both a smaller immediate reward and larger delayed reward were displayed on the computer. Participants were directed to carefully evaluate both options before selecting either the left key (for a smaller immediate reward) or the right key (for a larger delayed reward). If the participants selected a larger reward (1000 RMB), a red triangle located beneath the chosen option was displayed on the screen for 500 ms as feedback. The immediate reward in subsequent trials increased by 50% (750 RMB). By contrast, if participants selected a immediate reward, the immediate reward in subsequent trials decreased by 50% (RMB).

MATLAB R2018a was used to perform nonlinear regression based on the subjective value of each participant. Logistic functions were first used to fit the participants' choices and an indifference point (a point of subjective equality for immediate and delayed rewards, $p = 0.5$) was quantified at each delay (Guo, Chen, & Feng, 2017). The subjective values of delayed gains V (V is equal to the value of the outcome at the indifference point or the value at which the immediate and delayed options are of equal value), delayed time D, and delayed reward A are subsequently substituted into the hyperbolic Equation $V = A/(1 + k \times$

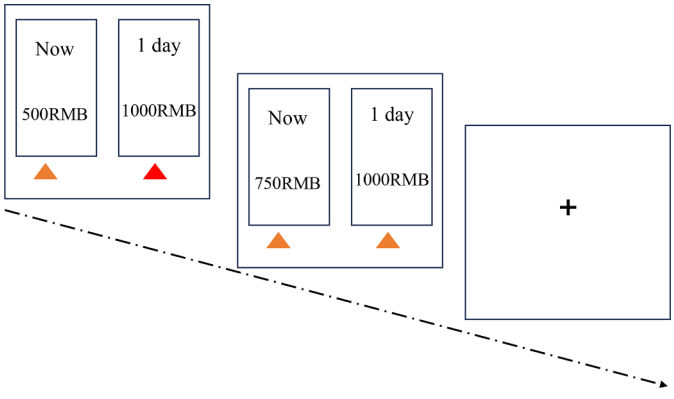

Fig. 2. Sample trial from the delay discounting task.

D) to fit k, which represents the estimated rate at which delayed rewards are discounted (k) (Mazur, 1986). The distribution of k tends to be highly positively skewed. Therefore, a logarithmic transformation was performed using the natural logarithm of k (lnk) to create a model that resembles a normal distribution. All analyses incorporated these transformed values, with larger negative values indicating less discounting of delayed rewards and smaller negative values indicating more discounting, favoring immediate rewards, and greater impulsivity.

Pilot survey

A pilot survey was conducted at two community health service centers in Nanjing from April to May 2023, and 247 completed questionnaires from patients with hypertension were collected. First, we measured the reliability of each questionnaire. The Cronbach's alpha coefficients for perceived health competence, knowledge, enabling factors, and reinforcing factors were 0.730, 0.673, 0.736, and 0.807, respectively. Exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) were performed to test the validity of the two self-developed questionnaires (enabling and reinforcing factors). We randomly divided the sample into two groups, and half ($N = 123$) of the original data were used for the EFA. The results showed that the KMO values for the questionnaires on the reinforcing and enabling factors were 0.716 and 0.741, respectively, with significance levels of <0.001, indicating that the data were suitable for factor analysis. The maximum variance method was used to rotate the factors of the two questionnaires separately. The results revealed that both self-developed questionnaires had three factors with eigenvalues greater than one, and the cumulative variance contribution rates of these three factors were 81.189% and 74.411%.

CFA was used to test the factor structures of the two self-developed questionnaires based on the other half ($N = 124$) of the original data. The fit indices of the reinforcing factors were as follows: χ^2/df=1.193, RMSEA=0.040, CFI=0.995, NFI=0.972, TLI=0.993, and SRMR=0.047. The fit indices of the enabling factors were as follows: χ^2/df=1.289, RMSEA=0.049, CFI=0.983, NFI=0.930, TLI=0.975, and SRMR=0.048. Additionally, the CR and AVE of each construct in both questionnaires exceeded the recommended thresholds of 0.7 and 0.5 (Black & Babin, 2019), and the correlation coefficients between the dimensions were less than the square root of the AVE of the dimension itself. Overall, predisposing, enabling, and reinforcing factors exhibited high levels of reliability and validity. Owing to word count limitations in the main text, the detailed processes of the EFA and CFA are provided in Supplementary File 2. Based on the feedback from the pilot survey, adjustments were made to the content, layout, font size, and language of the questionnaire. The data from this study have not been previously published.

Study setting and sampling

A formal study utilizing the revised questionnaire was conducted between May and August 2023. The participants of this cross-sectional study were selected using a multi-stage stratified sampling method. Two cities, Yangzhou (North Jiangsu) and Nanjing (South Jiangsu), were chosen based on their economic development levels and geographic locations. In the second stage, two community health service centers were selected in Yangzhou, and five were randomly chosen in Nanjing with expert guidance. In the final stage, patients with hypertension were randomly selected from these community health service centers. The minimum sample size was computed using Raosoft (www.raosoft.cpm/samplesize.html), with a confidence level of 95%, a margin of error of 5%, and a response distribution of 50%; the recommended sample size was 377. All the selected hospitals had separate outpatient departments for the treatment and follow-up of chronic diseases, and all the selected patients with hypertension had medical records at the health center. We used the list of all patients as the sample frame and then used a simple random sampling method to select participants through a computer-generated number. We contacted all selected participants to invite them to participate in the study. This study followed the EQUATOR's checklist for cross-sectional studies (von Elm et al., 2007).

Inclusion and exclusion criteria

The inclusion criteria for this study were patients who were diagnosed with mild or moderate essential hypertension according to the diagnostic criteria outlined in the Chinese Guidelines for the Prevention and Control of Hypertension 2018 Revision and who had been consistently taking at least one antihypertensive medication for at least six months. The exclusion criterion included individuals over 80 years of age or those lacking fundamental behavioral capabilities. Participants who could not understand the computer procedures were excluded.

Ethical consideration and data collection

This study was approved by the Ethics Committee of the Nanjing Medical University (No.2021378; approval date: March 03, 2021). To ensure the validity of the results, all researchers underwent training to communicate effectively with elderly individuals. Primary care physicians assisted in recruiting patients with hypertension by informing them of the study's objectives and procedures. The recruited patients visited the community health service centers, where they completed the computer-based delay-discounting task. Before the formal experiment, trained researchers explained the computer tasks to the participants in detail and demonstrated how to perform them. After ensuring that they understood the experiment, each participant was required to complete a pre-test to familiarize themselves with the experiment. For a few participants who were not proficient in using computers, the researchers showed them the computer screen, asked them their choices, and assisted them in completing the tasks. The participants subsequently completed the questionnaire with the assistance of the researchers, who reviewed the completed questionnaires to verify the completion of all items. Participants who completed the questionnaire received a gift worth 30 yuan. All participants had the right to withdraw from the study at any point, and patients who withdrew were also provided a gift worth 10 yuan.

Statistical methods

First, the statistical software SPSS 22.0 was used to conduct descriptive analyses, such as the mean, standard deviation (SD), frequency, and EFA, on the database. The researchers checked each retrieved questionnaire, resulting in minimal missing data in our study (<1%), including household monthly income and education level, which did not influence the results. Therefore, missing data were excluded from our study. The model was initially constructed through EFA, with reliability assessed via Cronbach's α coefficient. Subsequently, a CFA was performed using Amos 22.0 to further evaluate the reliability and stability of the model. Demographic variables were expressed as frequencies (n) and proportions (%) and analyzed using univariate analysis. Finally, Pearson's correlation coefficient and hierarchical regression analyses were performed using SPSS 22.0 to examine the impact of individual factors on the adherence behaviors of patients with hypertension. Multicollinearity was excluded, and differences were considered statistically significant at $p < 0.05$.

Results

In the formal study, 1435 questionnaires were distributed and 1123 eligible questionnaires were collected, resulting in a valid response rate of 78.26%. Questionnaires with extreme data were excluded. Table 1 presents the sociological and demographic characteristics of the

Table 1
Participant background information and univariate analysis of adherence to treatment ($N = 1123$).

Demographic variables	Groups	Frequency/Mean	Percentage/SD	t/F	p
Age	≤66	65.53	7.69	−3.57	<0.001
	>67				
Duration	≤10	12.75	10.01	−4.21	<0.001
	>10				
Sex	Male	500	44.52	0.362	0.718
	Female	623	55.48		
Household monthly income	≤1000	74	6.59	1.170	0.322
	1000–2999	245	21.82		
	3000–4999	524	46.61		
	5000–9999	204	18.17		
	≥10,000	71	6.32		
Education level	Illiteracy and Semiliterate	58	5.16	1.160	0.327
	Elementary school	189	16.83		
	Middle school	403	35.89		
	High school/ Technical school/ Secondary school	358	31.88		
	College, university and above	108	9.62		
	Not clear	2	0.18		
Marriage status	Unmarried	10	0.89	1.95	0.101
	Married	1010	89.94		
	Widowed	81	7.21		
	Divorced	16	1.42		
	Not clear	6	0.53		
Follow-up experience	Yes	897	79.88	2.83	0.09
	No	226	20.12		

participants. The age of participants ranged from 32 to 80 years, with a mean age of 65.53±7.69. Among the participants, 55.48% were female and 44.42% were male. Furthermore, most of the participants reported a monthly household income ranging from 3000 to 4999 RMB per capita (46.61%). Moreover, participants had a history of diagnosed hypertension for an extended period (12.75±10.01 years). Most patients had only completed junior high school, potentially indicating a correlation with the age of the participants. Additionally, a significant proportion of patients with hypertension were married (89.94%), and 79.88% had received follow-up management in the last three months. Chi-square tests or independent *t*-tests were subsequently used to compare differences in treatment adherence among participants with different demographic information (e.g., sex, age, and duration of hypertension). The results revealed significant differences in the degree of adherence to treatment among different age and disease duration groups.

This study demonstrated that participants exhibited a high level of adherence to treatment, as indicated by a mean score of 52.51 and a standard deviation of 3.28 (range: 14–56). However, the participants reported low levels of self-efficacy, with a mean score of 29.32± 4.34 (range: 8–40). Additionally, participants demonstrated a good level of knowledge regarding hypertension, with a mean score of 12.35±2.23 (range: 0–16). Furthermore, our participants reported receiving high levels of support from their family, friends, and physicians, as indicated by an average score of 36.06 (SD=5.28) on the reinforcing factors scale, ranging from 9 to 45. For the enabling factors, the mean score was 31.87 (SD=6.24) on a similar scale, ranging from 9 to 45. Additionally, the delay discounting variable yielded a mean score of −6.21 (SD=1.84).

Pearson's correlation analyses were conducted to investigate the association between adherence to treatment and various factors, including knowledge, delay discounting, self-efficacy, reinforcing factors, and enabling factors. The results in Table 2 indicate significant positive correlations between treatment adherence and knowledge ($r = 0.379, p < 0.01$), self-efficacy ($r = 0.410, p < 0.01$), reinforcing factors ($r = 0.295, p < 0.001$), and enabling factors ($r = 0.316, p < 0.01$). Additionally, a negative correlation was observed between delay discounting and adherence to treatment ($r=-0.165$; $p < 0.01$) among patients with hypertension.

This study further explored the effects of the independent variables on the dependent variable, adherence to treatment, through hierarchical regression analysis, with the findings shown in Table 3. Based on the independent *t*-test and one-way ANOVA results, age and duration were included in Model 1 as control variables. In Models 2, 3, and 4, we add three predisposing factors (delay discounting, self-efficacy, and knowledge). The results revealed that self-efficacy explained most of the variance in adherence to treatment ($\Delta R^2=0.149$, $p = 0.000$). In Model 4, there were significant correlations among delayed discounting, knowledge, self-efficacy, and adherence to treatment ($R^2=0.276$, $F = 89.935$, $p < 0.001$). Model 5 incorporated the enabling factors, which increased the ability to explain the dependent variable to 30.1% ($\Delta R^2=0.026$, $F = 80.013$; $p < 0.001$). Model 6 added reinforcing factors to the hierarchical regression model, and the final hierarchical regression model explained 30.4% of the variability in adherence to treatment ($R^2=0.304$, $\Delta R^2=0.04$, $F = 69.696$, $p < 0.001$). The results revealed that delay discounting ($\beta=-0.088$, $p = 0.000$), self-efficacy ($\beta=0.275$, $p = 0.000$), knowledge ($\beta=0.266$, $p = 0.000$), enabling factors ($\beta=0.138$, $p = 0.011$), and reinforcing factors ($\beta=0.071$, $p = 0.000$) were significantly associated with adherence to treatment. We then conducted collinearity diagnostics and revealed that all variance inflation factors (VIFs) were less than two and that the tolerance values ranged from 0.719 to 0.998 > 0.6, indicating that the regression equation was not collinear.

Table 2
Correlation matrix of predisposing, enabling, and reinforcing factors and adherence to treatment.

	1	2	3	4	5	6
1. Adherence to treatment						
2. Knowledge	0.379**					
3. Delay discounting	−0.165**	−0.104**				
4. Self-efficacy	0.410**	0.213**	0.279**			
5. Reinforcing factors	0.295**	0.202**	−0.055	0.304**		
6. Enabling factors	0.316**	0.190**	−0.078**	0.279**	0.494**	

Note: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Table 3
Hierarchical regression analysis of predisposing, enabling, and reinforcing factors and adherence to treatment ($N = 1123$).

Variables	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	Control variables		Predisposing factors		Predisposing factors		Predisposing factors		Predisposing		Predisposing, Enabling	
			Delay discounting		(Delay discounting and self-efficacy)		(Delay discounting, self-efficacy and knowledge)		and enabling factors		and Reinforcing factors	
	β	t	β	T	β	t	β	t	β	t	β	t
Duration	0.111	3.01**	0.109	3.648***	0.072	3.46***	0.078	3.289***	0.073	3.176***	0.072	3.128***
Age	0.091	3.68**	0.083	2.79***	0.095	2.627***	0.085	3.018***	0.081	2.843***	0.080	2.833***
Delay discounting			−0.156	−5.278***	−0.119	−4.392***	−0.095	−3.688***	−0.089	−3.503***	−0.088	−3.48***
Self-efficacy					0.389	14.298***	0.329	12.5***	0.287	10.747***	0.275	10.16***
Knowledge							0.294	11.168***	0.272	10.404***	0.266	10.164***
Enabling factor									0.169	6.343***	0.138	4.692***
Reinforcing factor											0.071	2.393***
Adj R2	0.022		0.045		0.194		0.276		0.301		0.304	
ΔR2	0.023		0.024		0.149		0.082		0.026		0.004	
F	13.245***		89.935***		67.401***		84.935***		80.013***		69.696***	

Note: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Discussion

To the best of our knowledge, this is the first study to introduce the critical behavioral economics concept of delay discounting into research on individual treatment adherence in the Chinese context, expanding the understanding of predisposing factors. Overall, the study participants demonstrated a high level of treatment adherence, including sodium intake, appointment keeping, and medication use. The participants' level of adherence to treatment had a mean score of 52.51 ±3.28 (14–56), which surpassed that reported in a previous study conducted in Xi'an (Pan et al., 2020). This discrepancy may be attributed to the greater availability of medical resources and educational opportunities among patients with hypertension in Jiangsu Province.

We analyzed the complicated predictors of adherence to treatment among patients with hypertension using predisposing, reinforcing, and enabling constructs based on the PRECEDE model. The results showed that the hierarchical regression analysis explained 30.4% of the variance in adherence to treatment among patients with hypertension. Discounting, self-efficacy, knowledge, enabling factors, and reinforcing factors were significantly associated with the adherence scores. In the multivariate model, predisposing factors accounted for 27.6% of the variance in adherence to treatment, followed by the enabling factor, whereas the reinforcing factor accounted for the minimum (0.4%) variance. Our results indicate that behavioral changes in patients with hypertension may be related to more intrapersonal (cognitive and psychological) factors. In contrast, external support and resources may be distal factors that have a steady but relatively minor effect on adherence to treatment in patients with hypertension. Although this study is exploratory in nature and the results need to be replicated before definitive conclusions can be drawn, these findings still provide a preliminary framework for understanding the health behaviors among patients with hypertension and offer new directions for future clinical research.

Among the predisposing factors, knowledge and self-efficacy accounted for most of the variance. Self-efficacy was defined as confidence in the effective management of health outcomes. Our results showed that self-efficacy was the most important predisposing factor for predicting treatment adherence, indicating that a high level of self-efficacy is an important prerequisite for patients with hypertension to achieve their self-management goals. Similar findings have been revealed in previous research, including that of Shen et al. (2020), who revealed that self-efficacy partially mediated the relationship between medication literacy and adherence. Moreover, Kara (2022) demonstrated that treatment adherence is positively correlated with an individual's self-efficacy in medication management. These findings will be useful for the secondary prevention of hypertension. From a life-course perspective, most patients with hypertension are elderly (Adisa et al., 2017) and may experience more death anxiety while feeling less control over their health (Chalabaev et al., 2023). Healthcare physicians should prioritize screening patients with hypertension with low self-efficacy and implement interventions to improve their confidence in their treatment plans and health outcomes. During the treatment process, doctors should focus on patients with hypertension who are worried about their treatment plan and health outcomes, as these individuals may have lower self-efficacy. Appropriate encouragement and reminders, such as "Stay positive; you are not too old to manage your health," can help them improve their confidence. Simultaneously, providing positive feedback and enhanced empowerment during treatment, facilitated by shared decision-making and effective communication, can augment self-efficacy in patients with hypertension, consequently improving their adherence to treatment regimens. In addition, for patients with lower levels of education, tailored educational interventions that include additional content explanations may be necessary to increase their self-efficacy (Foroumandi et al., 2020).

Knowledge is an important factor in determining an individual's health behavior. Our study demonstrates that patients with a more comprehensive understanding of hypertension are more likely to adhere to their prescribed treatment regimen. This conclusion aligns with those of previous studies by Machaalani et al. (2022) and Kebede et al. (2022). Knowledge of the side effects of hypertension may help patients understand why it is important to adhere to healthy behaviors. In a study (Abdalla, 2021) on the knowledge level of patients with hypertension, the most common reason why participants reported not implementing lifestyle changes was that they did not think it was important. This can be explained by a lack of knowledge regarding the importance of adherence to treatment. Health education during the early stages of disease may improve patients' quality of life (Wang et al., 2017). Therefore, primary hospitals should prioritize implementing training sessions, competitions, lectures, and other educational activities aimed at informing patients with hypertension about the significance of lifestyle modifications to prevent, manage, and control hypertension. Additionally, these institutions should offer comprehensive guidance on lifestyle practices, including strategies for salt reduction, blood pressure monitoring, and appropriate exercise regimens. Moreover, the frequency and methodology of knowledge interventions warrants careful consideration. A study by Van 't Riet et al. (2014) indicated that repeated exposure to health-promoting messages could result in their neglect or disregard. However, integrating knowledge-based

interventions with additional intervention strategies may mitigate the risk of message fatigue.

This study reveals a relatively weak but stable association between delay discounting and treatment adherence among patients with hypertension. Delay discounting is an emerging area in hypertension management research, and this is one of the first studies to examine the relationship between delay discounting and adherence to treatment among patients with hypertension. Our results suggest that heterogeneity in treatment adherence among patients with hypertension is partially attributable to their tendency to discount the future. From a time window perspective (Snider et al., 2019), some shortsighted patients with hypertension value immediate rewards, such as consuming salt and delaying medication, over delayed health benefits. Although the findings presented here suggest a modest relationship between delay discounting and treatment adherence among patients with hypertension, this relationship holds some clinical value. Considering the increasing prevalence of hypertension (Andrew et al., 2022), even small improvements in health-related behaviors can have a cumulative effect on the entire population, thereby significantly impacting public health. Research indicates that brief and simple interventions targeting delay discounting can effectively improve individuals' health behaviors (Hollis-Hansen et al., 2019; Sofis et al., 2017). These cost-efficient methods could serve as valuable supplements to traditional interventions (e.g., lectures for health education), particularly when applied before or after traditional interventions. Integrating these strategies may not only enhance behavioral outcomes but also foster greater engagement and participation among older adults. Episodic future thinking, an intervention method that reduces delay discounting by allowing people to vividly imagine positive future events, is relatively simple to perform and can be used in the daily management of patients with hypertension. For example, primary care physicians can train patients with hypertension to visualize a healthy future in which they become physically comfortable or have a better quality of life through adherence to treatment (Epstein et al., 2022). Exposing patients with hypertension to natural scenes can be another intervention to reduce delay discounting, as viewing natural scenes may increase the baseline level of attention in patients with high blood pressure, thereby allowing them to allocate more attentional resources to the consequences of health-related decisions (Berry et al., 2014). Finally, at the macro level, primary hospitals should consider offering immediate incentives to patients diagnosed with hypertension who have impatience tendencies as part of their lifestyle intervention strategies. By providing small immediate rewards or positive feedback for achieving incremental goals or effective management of hypertension, this strategy may be effective in sustaining the health behaviors of patients with hypertension.

In this study, enabling factors emerged as a secondary predictor of treatment adherence among patients with hypertension in the PRECEDE model. A previous study (Chalabaev et al., 2023) indicated that interventions requiring participants to utilize their personal resources (e.g., motivation to engage in the intervention) may exclude some disadvantaged groups. Encouragingly, certain interventions do not require personal resources, such as "nudging" measures targeting the microenvironment; these approaches are more likely to ensure equity. Moreover, systemic interventions, including legislative measures (e.g., restrictions and regulations) and financial initiatives (such as the allocation of medical resources and fiscal subsidies), can complement individual-level interventions (Chater & Loewenstein, 2023). Therefore, in addition to conventional hypertension intervention measures, primary hospitals and government organizations should focus on improving the availability of medications for patients with hypertension, as well as the accessibility of health services and community resources. For example, increasing the availability of healthier food options in community stores, rather than junk food such as instant noodles, canned goods, and sweets, may be a useful way to improve salt reduction intake in patients with hypertension. Moreover, improving the accessibility and distribution of medications within the community may help patients adhere to prescribed medication regimens. Establishing family physician offices and pharmacies within the community is also a recommended strategy for assisting patients with hypertension in obtaining the necessary medications and receiving appropriate medical guidance, ultimately enhancing their treatment adherence.

The reinforcing factor was the least significant predictor of treatment adherence, with a lower proportion of variance (an additional 0.4%). A previous study (Darvishpour et al., 2022) reported that the role of family support in improving compliance among patients with chronic diseases was moderated by subjective interpretations of the motivation of supporters by patients. Xiong et al. (2023) revealed no significant association between family support and medication adherence. A previous study revealed that family and friends can offer reminders, assistance, and emotional support to patients to facilitate self-management behaviors (Tang et al., 2008). Owing to the contradiction of extant findings, future research needs to determine the relationship between these two factors. The reason for the low association in this study may be that health behavior change is a long-term process in which an individual's cognitive and psychological factors play a more significant role. Increased encouragement and support for people with hypertension may be necessary, but may not be sufficient to change their health behaviors in the long term. Furthermore, recommendations and motivation from physicians, family, and friends could inadvertently reduce the sense of responsibility that patients feel about managing their health.

Limitations and strengths

Our study has several limitations. First, the association between delay discounting and treatment adherence is relatively weak. This result may be attributed to the measurement instruments used to assess delay discounting. Similarly, relatively weak associations between delay discounting and health behaviors have been reported in other studies (DeFulio & Rzeszutek, 2022; Lee & Liao, 2022). Given that the dependent variable encompasses various treatment-adherent behaviors, we opted to use a monetary reward in the delay-discounting task (Odum et al., 2020) rather than specific health behaviors or health outcomes. Future investigations employing health-related delay discounting tasks may enhance our understanding of these relationships. Second, in our study, the dependent variable, treatment adherence, comprised three distinct behaviors: dietary, appointment, and medication. While the benefits associated with these behaviors accrue over an extended period when viewed through the lens of delay discounting, the specific actions required for each behavior are distinct. Future research should investigate the relationship between delay discounting and each of these treatment-adherence dimensions. Third, constraints related to labor, cost, time, and participant willingness restricted the geographical scope of this study to the Jiangsu Region, which may have limited the generalizability of our findings. This study offers a new perspective on the predisposing factors within the PRECEDE framework. However, variables such as self-efficacy, knowledge, and social support have been extensively studied, which may have reduced the originality of these findings. Furthermore, the small effects observed for most variables, except self-efficacy, limit the study's theoretical and practical impact.

This study has several strengths. First, delay discounting is an emerging area in hypertension management research, and we applied behavioral economic factors to analyze the health behaviors of patients with hypertension in an innovative manner. Previous research on the PRECEDE model has rarely included delay discounting as a component of predisposing factors. By incorporating this behavioral economics construct into predisposing factors, our study provides a novel perspective and exploratory attempt to enhance our understanding of the PRECEDE framework. The findings based on the extended model provide a more comprehensive understanding the behavior of patients with hypertension in terms of adherence to treatment. Second, we employed a relatively large sample ($N = 1123$) and conducted a preliminary survey to increase the robustness, validity, and reliability of the

findings. Third, most health behavior research has focused on high-income populations, with limited attention paid to low-income groups (Chalabaev et al., 2023). This study expands the scope of existing research by examining treatment adherence among elderly patients with hypertension in a developing country and provides actionable insights for interventions targeting vulnerable populations in resource-constrained environments.

Conclusions

This study explored the complicated predictors of treatment adherence in patients with hypertension via predisposing, reinforcing, and enabling constructs. Our results indicate that delay discounting, knowledge, self-efficacy, enabling factors, and reinforcing factors play significant roles in influencing treatment adherence among patients with hypertension. Our findings offer new perspectives for future studies in this field. Interventions targeting knowledge, self-efficacy enhancement, and resource improvement strategies can be implemented to enhance the health behaviors of patients with hypertension. In addition, governments and healthcare institutions should implement simple delayed discount interventions and encourage adopting a future-oriented mindset.

CRediT authorship contribution statement

Yuan He: Methodology, Supervision, Funding acquisition, Project administration, Resources, Writing- review and editing. **Zhiqing Hu:** Methodology, Software, Formal analysis, Writing-original draft preparation. **Huiying Zhang:** Methodology, Software, Writing–original draft preparation. **Yiping Wang:** Validation, Data curation. **Yanjun Sun:** Data curation, Investigation. **Rui Meng:** Validation, Data curation. **Ke Shen:** Visualization, Investigation. **Jiali Chen:** Resources.

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Data availability statement

Data supporting the findings of this study are available upon reasonable request from the corresponding author. The data are not publicly available because of privacy and ethical restrictions.

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.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ijchp.2025.100553.

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