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Health education based on precede-proceed model in eradication evaluation of *Helicobacter pylori* infection: a retrospective cohort study

Huihui Shang¹, Xinya Zhang¹, Yan Li², Li Gui¹, Yu Wang^{3*}, Song Xu^{4*} and Kaifu Zheng^{5*}

Abstract

Background/Objectives To investigate the influence of health education based on the precede-proceed model (PPM) on the eradication rate and experience of *Helicobacter pylori* (*H. pylori*) infection.

Methods 200 patients with asymptomatic *H. pylori* infections were randomly assigned to a PPM group ($n = 100$) or a control group ($n = 100$) using the random number table method based on the time of their medical records. The control group received modified bismuth quadruple therapy (BQT), while the PPM group received modified BQT and health education based on the PPM. Completion rate, eradication rate, drug-related adverse events (AEs), discontinuation rate due to AEs, reexamination rate, recurrence rate, *H. pylori* knowledge scores, and satisfaction with medical experience were evaluated.

Results The treatment completion rate was 96% vs. 84% ($P < 0.05$), the reexamination rate was 93% vs. 79% ($P < 0.05$), the eradication rate according to intention-to-treat (ITT) was 83% vs. 69% ($P < 0.05$), according to per-protocol (PP) was 89.25% vs. 87.34% ($P > 0.05$) in the PPM and control groups, respectively. The recurrence rate was lower in the PPM group than in the control group (2.41% vs. 5.80%, $P > 0.05$); the drug-related AEs were 14% vs. 16% ($P > 0.05$), the discontinuation rate due to AEs was 14.3% vs. 37.5% ($P > 0.05$) in the PPM and control groups, respectively. After treatment, the mean *H. pylori* knowledge scores were significantly higher in the PPM than in the control groups; the mean knowledge scores of the recurrent patients were significantly lower than those of the non-recurrent patients ($P < 0.001$). Satisfaction with the medical experience was significantly higher in the PPM group than in the control group ($P < 0.001$).

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Conclusions Health education based on the PPM can effectively improve the completion rate of *H. pylori* eradication treatment, the eradication rate of the ITT analysis, the reexamination rate, and patient compliance, significantly improving patients' knowledge of *H. pylori* and their experience.

Keywords *Helicobacter pylori*, Precede-proceed model, Eradication, Health education

Introduction

Helicobacter pylori (*H. pylori*) is a gram-negative *Helicobacter* that selectively colonizes the stomach epithelium. It is closely associated with a variety of diseases, from chronic gastritis and peptic ulcer disease to gastric cancer (GC) and gastric mucosa-associated lymphoid tissue (MALT) lymphoma [1, 2]. *H. pylori* infects approximately half of the world's population, but prevalence varies widely between countries and regions [3]. Epidemiological studies have shown that the prevalence of *H. pylori* infection in China ranges from 28% – 82% [4], and the overall prevalence is approximately 44.2% [5]. *H. pylori* infection is typically asymptomatic initially but may manifest a range of associated symptoms as the duration of infection increases.

Early detection and eradication of *H. pylori* infection can effectively reduce the incidence and development of *H. pylori*-related disease [6, 7]. Many experts recommend a 14-day bismuth quadruple therapy (BQT) for the treatment of infection [1]. Recent literature has reported *H. pylori* BQT eradication rate of 93.74% [8]. With the emergence of BQT as first-line therapy for *H. pylori* eradication, the rate of *H. pylori* eradication has decreased, mainly due to incorrect or forgotten medication and discontinuation rate due to adverse events (AEs), which reduces patient compliance and leads to failure of *H. pylori* eradication [9]. The eradication of *H. pylori* depends on several factors, including the actions of both physicians and patients. A recent meta-analysis of 1433 patients in 7 trials found that providing the necessary counseling and health education along with routine *H. pylori* treatment had a positive effect on both *H. pylori* eradication and adherence in infected patients [10].

Education on *H. pylori*-related knowledge for individuals infected with the bacterium must be based on established principles and models that can achieve successful results. Green and Kreuter introduced the Precede-Proceed Model (PPM) in the 1970s as an evaluation tool for analyzing the determinants of behavior change relevant to improving health status over time. This model can be used to examine behavior change and the possible outcomes of educational programs. The elements of this model are predisposing factors, reinforcing factors, and enabling factors [11]. A considerable number of studies have used PPM, mainly in the planning, implementation, and evaluation phases of various health promotion programs in different populations and settings [12–14]. Health education based on PPM is a widely used

approach for inducing lifestyle changes in hypertensive patients [15], health education for parents of obese children [16], long-term management of diabetes mellitus (DM) [17], improving the knowledge and beliefs of liver cancer patients seeking oral health [18], and promoting vaccination and self-protection against infection [19]. The model's effectiveness stems from its comprehensive integration of individual and environmental factors, overcoming the limitations of conventional management methods [20, 21]. While PPM has been validated in chronic disease management, its application in infectious diseases like *H. pylori* infection remains unexplored. We hypothesized that PPM-based education would enhance treatment compliance and knowledge retention, thereby improving ITT eradication rates.

In this study, asymptomatic patients with *H. pylori* infection were given 14-day modified BQT, and supplemented with the health education based on PPM, compared to the normal education model. This study aimed to investigate the treatment of *H. pylori* asymptomatic infected individuals based on the PPM of health education in a population of 30–40 years old undergoing health checkups to find out whether it is possible to increase the eradication rate, the reexamination rate, to reduce the recurrence rate, and to improve the compliance and experience.

Materials and methods

Research object

In this retrospective cohort study, 200 asymptomatic *H. pylori* infection patients who completed *H. pylori* eradication treatment at the Department of Health Medicine, Joint Logistics Support Force 991 Hospital between March 2024 and March 2025 were included in this study. All employed the method of random number tables; 100 patients received structured PPM-based health education during treatment (PPM group); the other 100 patients received standard verbal/written instructions (Control group).

Inclusion criteria: ①Age 30–40 years, no gastrointestinal symptoms; ②No use of antibiotics, bismuth, gastric mucosal protectors and proton pump inhibitors (PPI) within 1 month before the physical examination; ③Positive 14 C-urea breath test, value > 75; ④No allergy to penicillin or clarithromycin; ⑤No history of *H. pylori* infection; ⑥Gastric ultrasound to rule out organic conditions such as gastric ulcers; ⑦No family history of GC in close relatives; ⑧No major diseases such as malignant

tumors, severe liver and kidney failure, etc.; ⑤With normal ability to communicate and read, to sign the informed consent form and to voluntarily participate in the study. The exclusion criteria: ①Allergic to any of the drugs in the eradication program; ②Suffering from underlying diseases such as abnormal liver and kidney function, hypertension, coronary heart disease, mental illness, and tumors, etc.; ③Unable to communicate effectively; ④Pregnant and lactating women.

Methods

¹⁴C-urea breath test

This test was performed in the morning on an empty stomach. The client was asked to swallow a 14 C-urea capsule with appropriate warm water, sit still for 15 min, remove the test breath card, and exhale into the card for 3–5 min until the indicator in the indicator window turned white and stopped collecting. During the test, a card was inserted into the detector inlet approximately five minutes after the test was completed and the results were displayed and printed. A 14 C-urea breath test value >75 dpm was considered *H. pylori* positive, and there was a possibility of false-positive results in the 50–75 dpm range [22].

Enrollment management

Individuals with asymptomatic infection were enrolled and underwent gastric ultrasound to exclude organic disease. A questionnaire was used to assess demographics, knowledge of *H. pylori*, and risk factors. Knowledge was re-assessed at the follow-up visit. The *H. pylori* knowledge questionnaire used in this study was developed by Malek et al. [23] and adapted for the general population in China. To ensure clarity and suitability for the general population, a pilot study was conducted with a convenience sample of 20 individuals. Following the pilot test, linguistic and grammatical modifications were made to improve the comprehensibility of the questions. The internal consistency of the survey was assessed and the Cronbach's alpha coefficient for knowledge was calculated to be 0.84.

Treatment regimen

All participants received a 14-day modified BQT comprising esomeprazole (AstraZeneca Pharmaceutical Co., LTD.), 20 mg twice daily, bismuth potassium citrate (Lizhu Group Pharmaceutical Co., LTD.), 220 mg twice daily, amoxicillin (North China Pharmaceutical Co., LTD.), 1 g, twice daily, clarithromycin (Shandong Xinhua), 0.5 mg, twice daily. Esomeprazole and bismuth potassium citrate were taken 30 min before meals. Amoxicillin and clarithromycin were taken 30 min after meals.

The PPM group implementation steps

Formation of the PPM health education team

Members of the health education team include the deputy chief physician, attending physician, health manager, clinical pharmacist, psychologist, and senior nurse. The health education team establishes a companionate partnership with patients and sets up a doctor-patient WeChat group and a punch card applet. Pre-intervention questionnaires and face-to-face interviews were used to assess lifestyle and dietary habits, history of chronic diseases, and history of previous gastroscopy. To focus the intervention on the three aspects of predisposing factors, contributing factors, and reinforcing factors, the following information was collected: history of smoking and drinking, consumption of spicy foods, frequency of eating out, presence of oral diseases, presence of other medications, history of *H. pylori* infection in family members, results of gastroscopy and history of antibiotic use.

The PPM Steps

(1) Predisposing factors: In this mode, we mainly focus on mastering patients' knowledge and changing attitudes through lectures, centralized training, WeChat, and one-on-one guidance. For example: ① Transmission routes for *H. pylori* include oral-oral and faecal-oral transmission. Contaminated water and shared utensils may also facilitate its spread. ② Risks of *H. pylori* infection: Infection is closely associated with gastritis, peptic ulcers, and GC. ③ Preventive measures: Using serving chopsticks and spoons, eating alone, and consuming healthy, safe food can reduce transmission. Maintaining good oral hygiene, avoiding smoking and excessive alcohol consumption, adopting a positive attitude, and getting enough sleep. The importance of co-treatment by family members and standardized treatment. ④ Benefits of standardized treatment: Irregular treatment may lead to bacterial resistance, which complicates subsequent eradication efforts. Through health education, we can achieve good cooperation with patients and enhance treatment compliance. (2) Reinforcing factors: In this mode, we mainly focus on patients who take oral medication regularly and avoid stopping the medication at will. We used medication boxes and WeChat to ensure that patients took their medication consistently and accurately. When AEs occur, patients can communicate with doctors and clinical pharmacists promptly and determine the need to discontinue drug treatment. WeChat was used to disseminate credible health information in real-time and to respond to queries. (3) Enabling factors: In this mode, the focus is on assessing whether the full course of treatment and reexamination can be effectively completed, and reminding them to promote long-term habits, in addition to completing the examination and treatment process within family members. Notify the patient of the end

of medication and advise them to calculate the amount of remaining medication. WeChat and phone calls were used to remind patients to reexamine the ^{14}C -urea breath test 4–8 weeks after the end of treatment.

Outcome assessment

Primary outcome: treatment completion rate, reexamination rate, eradication rate; secondary outcome: incidence of AEs rate, discontinuation rate due to AEs, recurrence rate (based on per-protocol (PP) analyses), *H. pylori* knowledge scores, and medical experience. Treatment completion rate was assessed by the medication possession ratio (MPR), which was calculated as the percentage of days that the patient took the medication (estimated by the number of pills left) to complete the treatment. If the MPR was $< 80\%$, treatment was considered to be uncompleted. Conversely, if the MPR was $\geq 80\%$, treatment was considered completed [24]. Patients who underwent a ^{14}C -urea breath test recheck between weeks 4 and 8 after completion of treatment were considered to have completed the reexamination. *H. pylori* recurrence: *H. pylori* recurrence referred to the situation of *H. pylori* status became positive again in a patient with previously confirmed successful eradication. Recurrence of *H. pylori* was defined as a recrudescence that occurred during the 6–12 months period immediately following successful eradication. A follow-up examination was performed at 6–12 months to assess the recurrence rate. The Malek et al. questionnaire was used to compare knowledge scores before and after treatment in both groups. A score of 5–6 is excellent, 2–4 is average, and ≤ 1 is poor. Satisfaction with the medical experience was measured by the Outpatient Visit Questionnaire [25], which included the inspection process, treatment process, staff attitude, reexamination process, and overall satisfaction. The Likert scale was used, with each question divided into five options: very dissatisfied, dissatisfied, average, relatively satisfied, and very satisfied. These options were then

given a score of 1–5 and the mean score was calculated as the satisfaction score. The satisfaction rate was the percentage of satisfied and very satisfied respondents. The Cronbach's alpha coefficient for knowledge was calculated to be 0.89.

Management of recurrence cases

Personal interviews were conducted with people who had recurred to identify the factors that led to the recurrence. The subsequent treatment phase was also formulated according to the patient's wishes.

Ethical considerations

This study design was approved by the ethical principles of the Medical Ethics Committee of the 991st Hospital of the Joint Logistics Support Force of People's Liberation Army (No. 991YJ-202315).

Statistical data analysis

SPSS 22 software was used for statistical analysis. Continuous and categorical variables were presented as mean $\pm$ standard deviation (SD) and counts or percentages, using Student's *t* test or one-way ANOVA and chi-square test for comparisons between the two groups, respectively. Both intention-to-treat (ITT) and per-protocol (PP) analyses were used to assess eradication rates. ITT analysis included all participants, while PP analysis excluded those with protocol violations. $P < 0.05$ was considered statistically significant.

Results

Baseline characteristics

There were no statistically significant differences in age, gender, smoking, alcohol history, or education, between the two groups ($P > 0.05$) (Table 1).

Table 1 Baseline characteristics of the two groups (using chi-square test or student's *t* test)

Variable	Control group <i>n</i> = 100(%)	PPM group <i>n</i> = 100(%)	χ^2	<i>p</i>
Gender			1.05	0.31
Male	97(97)	94(94)		
female	3(3)	6(6)		
Average age/year	33.99 $\pm$ 3.07	33.81 $\pm$ 2.87	0.43	0.67
Smoke			1.28	0.26
yes	52(52)	44(44)		
no	48(48)	56(56)		
Drink			0.02	0.89
yes	47(47)	46(46)		
no	53(53)	54(54)		
Grade of education			2.89	0.09
Junior/senior high school	47(47)	59(59)		
College or higher	53(53)	41(41)		

Table 2 Comparative the treatment conditions of the two groups (using chi-square test)

Variable	Control group n=100 (%)	PPM group n=100 (%)	X ²	p
Completion			8.00	0.01
Yes	84(84)	96(96)		
No	16(16)	4(4)		
Reexamination			8.14	0.01
Yes	79(79)	93(93)		
No	21(21)	7(7)		
ITT analysis	69(69)	83(83)	5.37	0.02
PP analysis	69(87.34)	83(89.25)	0.15	0.70
Recurrence	4(5.80)	2(2.41)	1.14	0.29

The treatment completion status, reexamination rate, eradication rate, and recurrence rate

In the control group, 84 patients completed treatment, with a completion rate of 84%. 16 patients did not complete treatment, 6 patients discontinuation due to AEs, and 10 patients had an MPR of <80%. In the PPM group, 96 patients completed the treatment. 4 patients did not complete treatment, 2 patients' MPR was <80%, and 2 patients discontinuation due to AEs. Compared with the control group, the PPM group had a better completion rate than the control group, and the difference was statistically significant ($P=0.01$).

The reexamination rate was significantly higher in the PPM group than in the control group (93% vs. 79%, $P=0.01$). In the ITT analysis, 83 out of 100 patients in the PPM group and 69 out of 100% patients in the control group were eradicated from *H. pylori* infection (83% vs. 69%, $P=0.02$). In the PP analysis, the eradication rates were 89.25% and 87.34%, respectively ($P=0.70$).

The recurrence rate was 2.44% (2/83) in the PPM group, and 5.80% (4/69) in the control group. The overall recurrence rate was 3.95% (6/152). The reasons for recurrence were understood through personal interviews, that all 6 patients were addicted to spicy and stimulating foods, did not smoke or drink alcohol, and did not use serving chopsticks and spoons during communal meals. Family members of 5 patients did not complete the evaluation and treatment, and 1 case was a community- living person who was unsure whether his peers had *H. pylori* infection (Table 2).

AEs

All AEs were mild to moderate, with no severe to intolerable AEs. There were 16 AEs in the control group and 14 AEs in the PPM group. 6 patients' discontinuation due to AEs in the control group (including 4 cases of taste disorder, 1 case of diarrhea, and 1 case of skin rash). 2 patients' discontinuation due to skin rash in the PPM group. The discontinuation rate due to AEs was 37.5% (6/16)

Table 3 Comparative AEs between the two groups (using chi-square test)

Variable	Control group n = 100(%)	PPM group n = 100(%)	X ²	p
taste disorder	8(8)	6(6)		
abdominal pain	4(4)	4(4)		
diarrhea	2(2)	0(0)		
constipation	0(0)	2(2)		
skin rash	2(2)	2(2)		
dizziness and headache	0(0)	0(0)		
total	16(16)	14(14)	0.16	0.69
discontinuation due to AEs	6(37.5)	2(14.3)	2.06	0.15

Table 4 Knowledge scores between the two groups before treatment

Variable	Control group n = 100(%)	PPM group n = 100(%)
Excellent		
5	17(17)	19(19)
6	1(1)	2(2)
Average		
2	11(11)	8(8)
3	21(21)	24(24)
4	48(48)	45(45)
Poor		
1	2(2)	2(2)

vs. 14.3% (2/14) in the control group and PPM group, ($P=0.15$) (Table 3).

H. pylori knowledge scores

There was no difference in the *H. pylori* knowledge scores between the PPM and control groups before treatment, as detailed in Table 4. Figure 1 illustrates the *H. pylori* knowledge scores mean $\pm$ SD of the two groups before treatment ($P=0.62$). The *H. pylori* knowledge scores of the PPM group were significantly higher than those of the control group after treatment (Table 5), and Fig. 2 illustrates the *H. pylori* knowledge scores mean $\pm$ SD of the two groups after treatment ($P<0.001$). Comparative the mean knowledge scores of the recurrent and non-recurrent patients, the results showed that the knowledge scores mean $\pm$ SD of the recurrence were significantly lower than those of the non-recurrent patients ($P<0.001$) (Fig. 3).

Patients' satisfaction with their medical experience

Through the questionnaire to understand the satisfaction of the medical expertise, the results indicate that the PPM group in the treatment process, staff attitude, reexamination process, and overall satisfaction were significantly higher than that of the control group, and the difference is statistically significant ($P<0.05$). (Table 6.). The mean $\pm$ SD inspection process satisfaction score (Fig. 4a), treatment process satisfaction score (Fig. 4b), staff attitude satisfaction score (Fig. 4c), reexamination

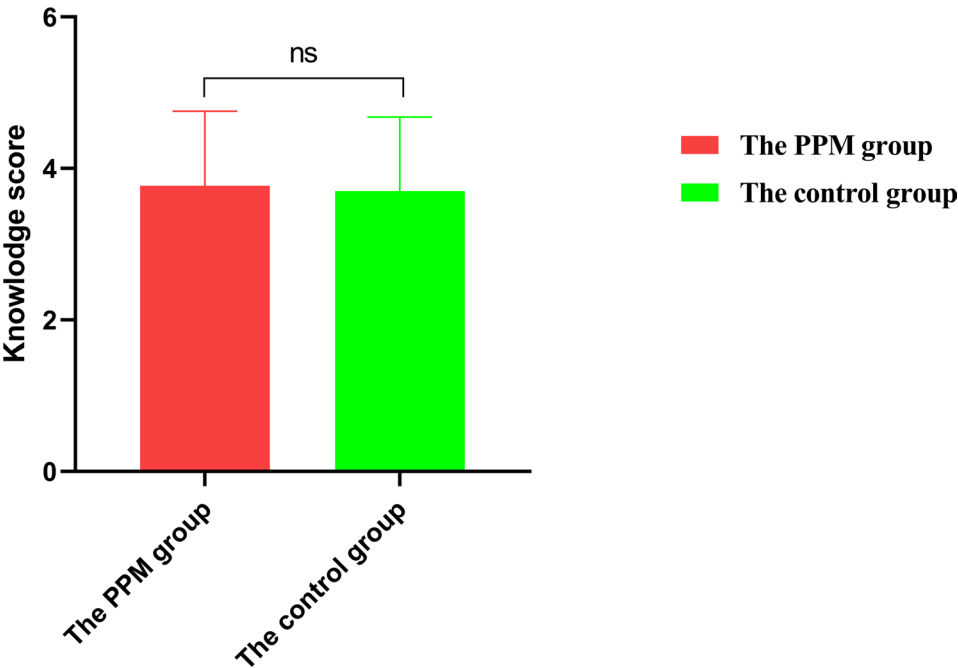


Fig. 1 Illustration of the mean $\pm$ SD of the knowledge score between two groups before treatment. *** indicates significance <0.01 , ns indicates significance >0.05

Table 5 Knowledge scores between the two groups after treatment

Variable		Control group n = 100(%)	PPM group n = 100(%)
Excellent	5	22(22)	65(65)
	6	1(1)	15(15)
	Average		
Average	2	12(12)	0(0)
	3	18(18)	4(4)
	4	47(47)	16(16)
Poor	0	0(0)	0(0)

process satisfaction score (Fig. 4d), and overall satisfaction score (Fig. 4e) are illustrated in Fig. 4.

Discussion

Since *H. pylori* was first isolated from the gastric mucosa in 1982, there has been concern about the problems associated with *H. pylori* infection. The International Agency for Research on Cancer (IARC), a subsidiary of the World Health Organization, classified *H. pylori* as a Group 1 carcinogen for GC in 1994 [26], the fifth most commonly diagnosed cancer and the third leading cause of cancer-related death worldwide [27]. The IARC reported that in 2018, 2.2 million new cancer cases were attributable to infections, and *H. pylori* was responsible for 810,000 of these cases [28]. Eradication of *H. pylori* has been shown to reduce the recurrence of GC, particularly in regions with high incidence rates [29]. Recent studies have

suggested that *H. pylori* eradication may also suppress the development of GC in asymptomatic adults [30, 31]. Screening for *H. pylori* is a cost-effective and effective way to prevent GC in China. To prevent more GC, the population should take an *H. pylori* test from the age of 20 with a frequency of every 5 years in low GC incidence areas or age, and every 2 years in high GC incidence areas or age [32]. Chronic *H. pylori* infection is considered the principal cause of non-cardia GC, with almost all cases attributed to *H. pylori* infection [33].

The current diagnostic and therapeutic status of *H. pylori* can be summarized as follows: high infection rate, high pathogenicity, high drug resistance rate, and low eradication rate [34]. The main reasons for eradication failure can be attributed to several factors, including drug resistance to selected antibiotics, non-standard treatment regimens, poor patient compliance, and numerous other considerations. In addition, there has been a gradual increase in the number of refractory *H. pylori* infections, defined as persistently positive non-serological *H. pylori* test results (i.e. urea breath test, stool or gastroscopy results) for at least four weeks after receiving one or more courses of first-line *H. pylori* eradication therapy recommended by current guidelines, without taking any medication (e.g. proton pump inhibitors) [35]. The main factors responsible for the observed decline in eradication rates include bacterial factors (spherical shape and drug resistance), host factors (influenced by gene polymorphisms), patient-related factors (irregular medication

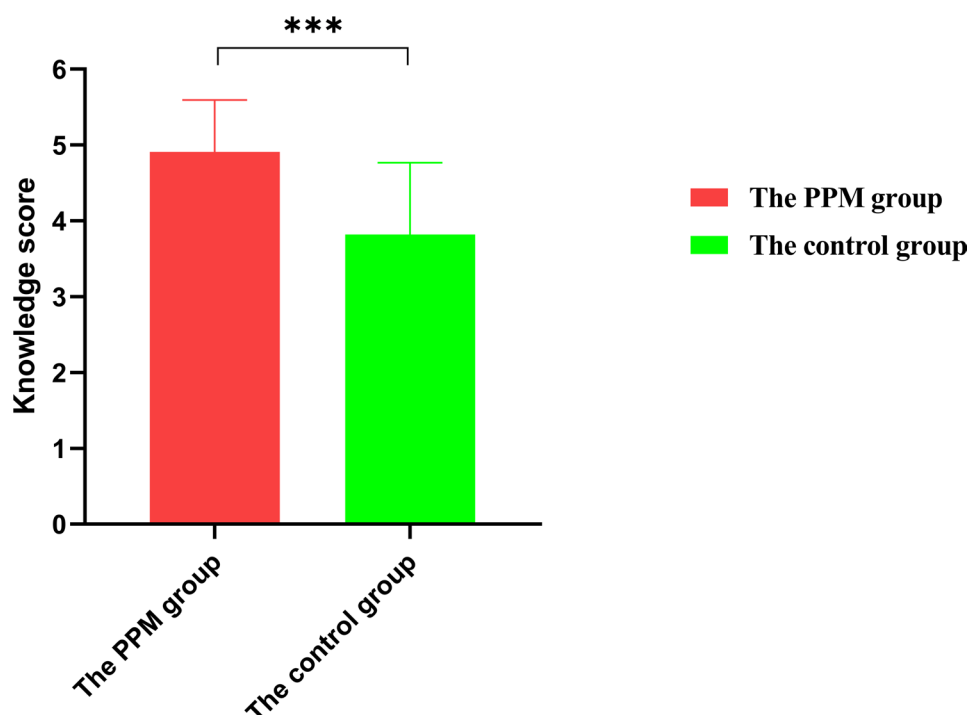


Fig. 2 Illustration of the mean $\pm$ SD of the knowledge score between two groups after treatment. *** indicates significance <0.01 , ns indicates significance >0.05

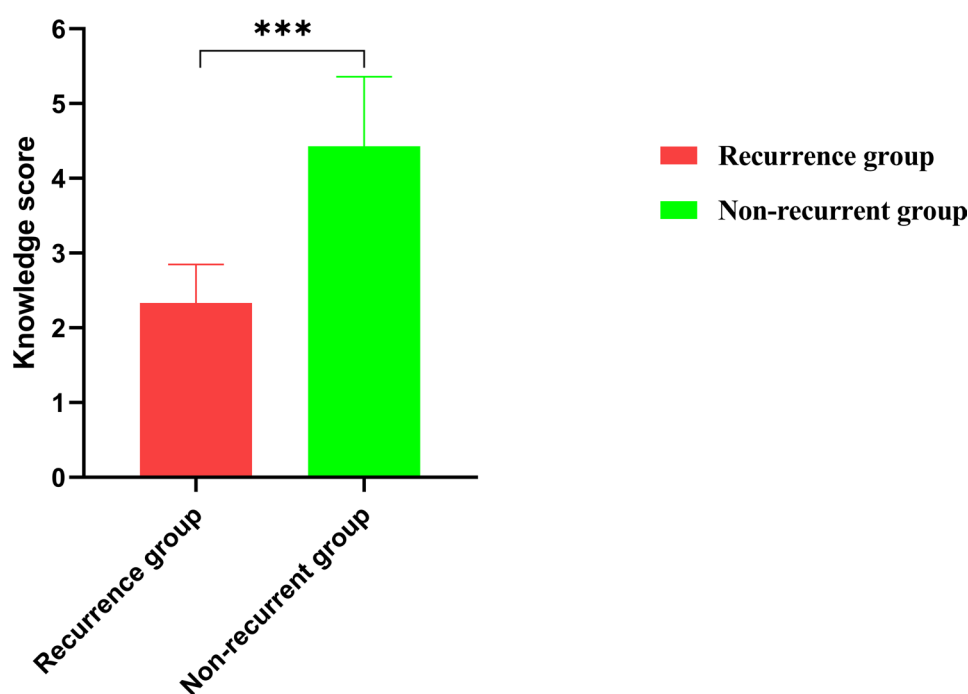


Fig. 3 Illustration of the mean $\pm$ SD of the knowledge score between the recurrence and non-recurrent patients. *** indicates significance <0.01 , ns indicates significance >0.05

and poor compliance), and physician-related factors (repeated, blind, and irregular treatment plans) [36].

Public awareness of *H. pylori* infection may influence diagnosis, treatment, and prognosis [37, 38]. Public

education can effectively raise awareness of the dangers of *H. pylori* and other risk factors for GC [39]. Increasing public awareness of *H. pylori* eradication as a preventive measure against GC is imperative [40]. Increasing

Table 6 Patients' medical experience in the two groups

Variable	Control groupn=100(%)	PPM groupn=100 (%)	χ^2	<i>p</i>
Inspection process				
very satisfactory	34(34)	38(38)		
relatively satisfactory	50(50)	54(54)		
average	14(14)	6(6)		
unsatisfactory	1(1)	1(1)		
very unsatisfactory	1(1)	1(1)		
satisfaction rate	84(84)	92(92)	3.58	0.47
Treatment process				
very satisfactory	2(2)	44(44)		
relatively satisfactory	70(70)	50(50)		
average	4(4)	4(4)		
unsatisfactory	20(20)	2(2)		
very unsatisfactory	4(4)	0(0)		
satisfaction rate	72(72)	94(94)	17.15	0.00
Staff attitude				
very satisfactory	2(2)	62(62)		
relatively satisfactory	78(78)	34(34)		
average	6(6)	2(2)		
unsatisfactory	12(12)	1(1)		
very unsatisfactory	2(2)	1(1)		
satisfaction rate	80(80)	96(96)	12.12	0.00
Reexamination process				
very satisfactory	6(6)	28(28)		
relatively satisfactory	70(70)	68(68)		
average	10(10)	2(2)		
unsatisfactory	12(12)	2(2)		
very unsatisfactory	2(2)	0(0)		
satisfaction rate	76(76)	96(96)	16.61	0.00
Overall satisfaction				
very satisfactory	8(8)	42(42)		
relatively satisfactory	70(70)	50(50)		
average	8(8)	4(4)		
unsatisfactory	7(7)	3(3)		
very unsatisfactory	7(7)	1(1)		
satisfaction rate	78(78)	92(92)	7.69	0.01

awareness of *H. pylori* infection and addressing the challenges of treatment compliance could potentially reduce rates of *H. pylori* antibiotic resistance and progression to GC or other complications of *H. pylori* infection [41]. A survey confirmed that different hospital levels have different perceptions of *H. pylori* infection, including inconsistent perceptions of time to review and time to re-eradication after failure. It also found that hospital physicians need to improve their understanding of and adherence to guidelines for the management of *H. pylori* infection [42]. A nationwide study found that 10% of physicians did not inform their patients of the need for reexamination 1–2 months after eradication therapy [43], making it impossible to determine whether *H. pylori* has been eradicated. If the result remains positive after a second test, the lesion will continue to progress, increasing the likelihood of infection in the surrounding areas. It

is therefore essential to take preventive measures and to continue treatment promptly.

In this study, we used modified BQT to eradicate *H. pylori*. The ACG clinical guideline recommends BQT as a first-line treatment option in treatment-naïve patients with *H. pylori* infection [44]. Before starting any *H. pylori* treatment, it is important to establish whether the patient has any underlying organic gastric disease. This information is necessary to determine the appropriate duration of PPI use. Therefore, organic disease was excluded from the enrolled participants. The PPM group received comprehensive PPM-based health education. All patients were advised to stop smoking and drinking alcohol during treatment, to have their teeth cleaned, and to change their toothbrushes before undergoing eradication treatment. A recent meta-analysis [45] showed that smoking was associated with an increased failure rate of *H. pylori*

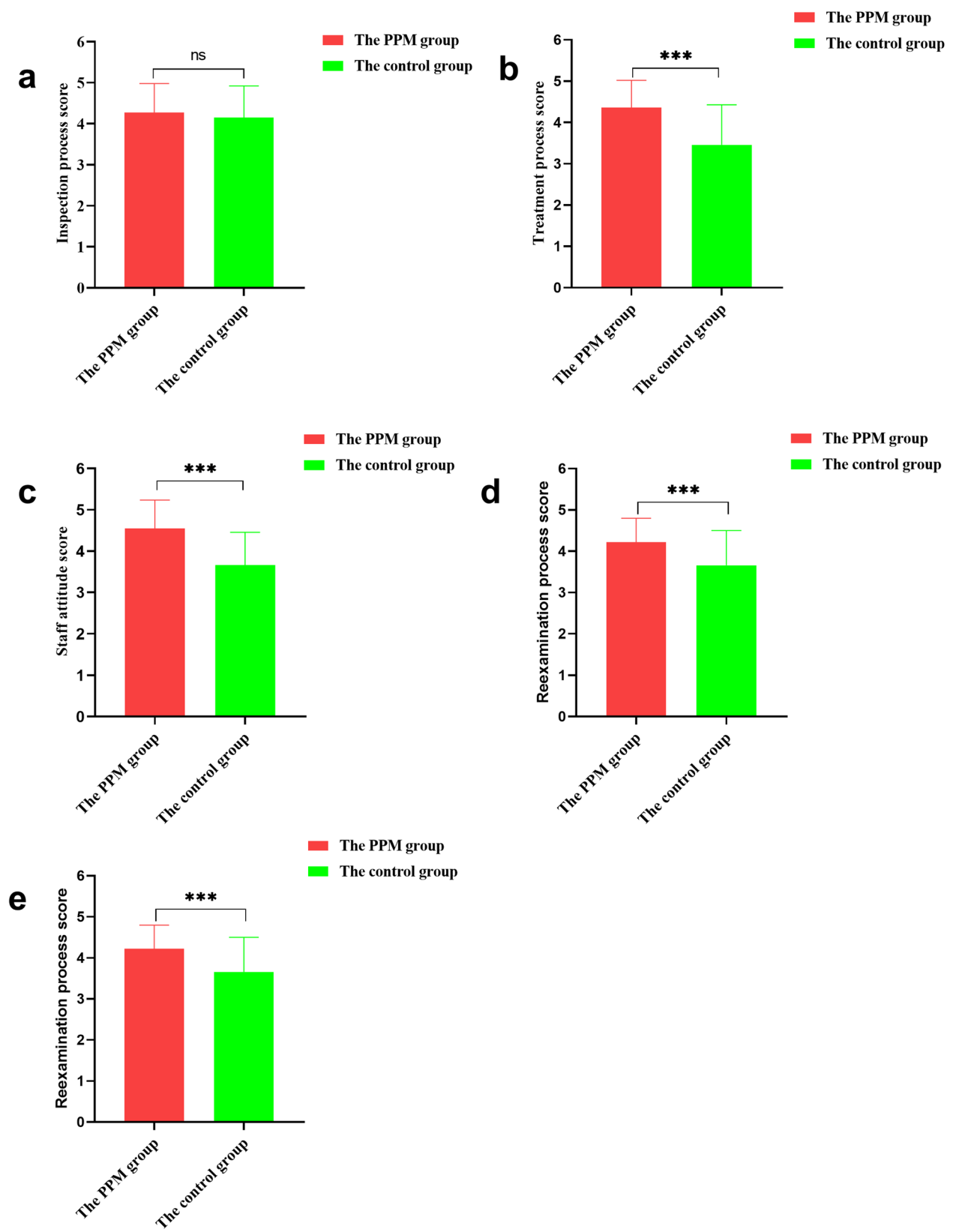


Fig. 4 Illustration of the mean $\pm$ SD of the satisfaction score between two groups: **a**, inspection process satisfaction score; **b**, treatment process satisfaction score; **c**, staff attitude satisfaction score; **d**, reexamination process satisfaction score; **e**, overall satisfaction score

eradication therapy. A review reported that the oral cavity may play a role as a reservoir in the transmission and colonization of *H. pylori* [46]. Based on the PPM health education, patients in the PPM group were provided with educational materials explaining the transmission dynamics of *H. pylori* and means of prevention. In addition, the potential benefits of treatment are standardized, and family members are encouraged to undergo testing and participate in a unified treatment plan. During treatment, WeChat was used to remind patients to take their medication regularly and to monitor for adverse events. In the case of bitter taste or mild nausea, these symptoms can be tolerated and the patient is advised to continue taking oral medication until the end of treatment. At the end of the medication, WeChat was used to inform the patient of this outcome and to initiate a follow-up process aimed at encouraging the formation of beneficial habits. In the fourth week, after completion of the medication regimen, the patient was contacted via WeChat and by phone to schedule a follow-up examination.

The treatment completion rate was significantly higher in the PPM group than in the control group (96% vs. 84%). The reexamination rate was considerably higher in the PPM group than in the control group (93% vs. 79%), and the differences were statistically significant. Consistent with the study by Sun et al. [47], patient compliance with *H. pylori* eradication was improved by daily mini-app-based reminders. The eradication of ITT analysis was 83% and 69% in the PPM and control groups, respectively, and the difference was statistically significant. The eradication of PP analysis was 89.25% and 87.34% in the PPM and control groups, respectively, with no statistical significance. Wang et al. [48] reported that twice-daily short message-based re-education (SMRE) improved the eradication rate and compliance in *H. pylori* eradication in a young population. As the ITT analysis encompasses all participants, the PPM approach increases the re-examination rates among the entire population, while reducing discontinuation rates due to AEs and improving the MPR rate. This significantly improves the ITT rate for the PPM group. Conversely, the PP analysis excludes participants who violated the study protocol. After excluding participants with poor compliance, incomplete treatment, and missed follow-up appointments, no significant difference in PP rates was observed between the two groups. Unlike previous studies focusing on medication reminders alone, our PPM-based health education integrated predisposing, reinforcing, and enabling factors, which may explain the higher ITT eradication rates despite comparable PP analysis. The main value of PPM-based health education lies in enhancing treatment completion and compliance, rather than directly increasing drug efficacy. We used a retrospective cohort design to confirm that PPM-based health education reduces the risk of eradication failure

and emphasized the importance of behavioral interventions for real-world ITT outcomes. The rate of AEs was 16% and 14% in the PPM and control groups, respectively; the discontinuation rate due to AEs was lower in the PPM group than in the control group (14.3% vs. 37.5%), without statistical significance; similar to a meta-analysis, the health education intervention did not affect the incidence of AEs or the discontinuation rate [10]. The recurrence rate was 2.41% (2/83) in the PPM group and 5.80% (4/69) in the control group, and the overall recurrence rate was 3.95% (6/152). One study reported that after the successful eradication of *H. pylori* in China, the annual recurrence rate was 3.1%, with a reinfection rate of 1.5% [49]. According to data from the *H. pylori* infection flow survey in China, the infection rate of *H. pylori* is 40.66%, while the family infection rate is as high as 71.21% [50]. Therefore, family-based *H. pylori* eradication treatment is particularly important. Notably, in this study, the family members of the recurrent patients had not completed screening and treatment. After treatment, the mean knowledge score of the PPM group was significantly higher than that of the control group ($P < 0.001$). The mean knowledge score of the recurrent group was significantly lower than that of the non-recurrent group ($P < 0.001$). One study assessed knowledge, attitudes, and practices (KAP) related to *H. pylori*-induced peptic ulcer and cancer. The study found that public health education targeting people with *H. pylori* infection could help reduce the incidence of *H. pylori*-related complications [51]. A review and meta-analysis showed that the PPM model can be used as a theoretical framework for health promotion interventions in different populations. These interventions are particularly effective in improving knowledge [52]. Considering that PPM indirectly improves *H. pylori* knowledge and compliance, thus improves eradication rates. Future studies could employ mediation models to quantify the contribution of knowledge improvement to adherence and eradication rates. Satisfaction with the medical experience was significantly higher in the PPM group than in the control group. In conclusion, health education based on PPM can improve *H. pylori* treatment completion rates, reexamination rates, and patient compliance, as well as patient knowledge scores and medical experience.

This study has several limitations. Firstly, it is a retrospective study and there is a selection bias. Secondly, it is a single-centre study and the results need to be validated more widely. Thirdly, studies have confirmed that strains possessing a functional *Cag* pathogenicity island (*Cag* PAI) and the *CagA* protein are associated with a higher risk of GC compared to *Cag*-negative strains, due to the oncogenic effects of *CagA* [53]. However, our study did not include different strains of *H. pylori* and did not evaluate the eradication effects of different strains in detail.

Fourth, the lack of data on the antibiotic resistance profile of *H. pylori* may limit the generalizability of eradication rates. Finally, the population in this study was asymptomatic and aged 30–40 years, and the results cannot be generalized to the whole population. Many gastric diseases (e.g., early-stage GC, atrophic gastritis, and occult lesions caused by *H. pylori* infection) may be completely asymptomatic or exhibit very mild symptoms in the early stages. By the time typical symptoms appear, the disease may have progressed to the middle or late stages, meaning the optimal time for treatment has been missed. Therefore, this study focuses on the asymptomatic group to explore a screening model that can identify and intervene in the “pre-symptomatic” or “early stage” of the disease. This is of great public health significance in reducing the morbidity and mortality of major gastric diseases. Selecting individuals who were free of specific symptoms and excluded from organic disorders by gastric ultrasound can maximize the homogeneity of the study population. This avoids confusion caused by mixed symptoms, such as some patients being symptomatic while others are asymptomatic, or some populations experiencing severe symptoms while others experience mild symptoms. This results in inconsistent levels of compliance, which could affect eradication results. Further studies should include randomized controlled trials and long-term follow-up to understand the long-term effects. The inclusion of *H. pylori* typing could be considered to understand the differences in eradication efficacy between different strains of *H. pylori*. The intervention was primarily targeted at individual patients, while family-based screening and treatment and a known predictor of recurrence were not systematically implemented, which may underestimate the impact of PPM. In addition, more evidence is needed on the effectiveness of PPM-based health education for *H. pylori* eradication in patients with recurrent or new peptic ulcer disease.

Conclusions

During *H. pylori* eradication treatment, there may be cases of medication forgetting, discontinuation due to medication AEs, incomplete adherence to the prescribed treatment course, and lack of reexamination, which may contribute to a decrease in the eradication rate. In conclusion, our study showed that health education based on PPM can effectively improve the completion rate of *H. pylori* eradication treatment, the reexamination rate, the eradication rate of the ITT analysis, and patient compliance, significantly improving patients' knowledge of *H. pylori* and their experience. However, there were no significant differences in the eradication rate of the PP analysis, the AE rate, or the discontinuation rate due to AEs.

Abbreviations

<i>H. pylori</i>	<i>Helicobacter pylori</i>
PPM	Precede-proceed model
ITT	Intention-to-treat
PP	Per-protocol
PPI	Proton pump inhibitor
AEs	Adverse events
GC	Gastric cancer
BQT	Bismuth quadruple therapy
MALT	Mucosa-associated lymphoid tissues
DM	Diabetes mellitus
MPR	Medication possession ratio
IARC	International Agency for Research on Cancer
SMRE	Short message-based re-education

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Authors' contributions

HHS played a pivotal role in shaping the conceptual framework, conceptualizing and designing this study, assisting in data collection, supervising data entry, carrying out the initial analyses, drafting the initial manuscript, and reviewing and revising the final manuscript. XYZ, GL and YL were responsible for collecting data and conducting data analysis, the creation of new software used in the work. XYZ, KFZ, YW and SX drafted the initial manuscript and reviewed and revised the final manuscript. Furthermore, all ICMJE requirements for authorship have been met, and this work is original and honest. All authors have read and agreed to the published version of the manuscript.

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Data availability

The dataset utilized in the present study can be obtained from the corresponding author upon a reasonable request.

Declarations

Ethics approval and consent to participate

The studies involving human participants underwent review and approval by the Ethics Committee of the 991st Hospital of the Joint Logistics Support Force of People's Liberation Army (No. 991YJ-202315), with written informed consent obtained from all patients prior to their inclusion in this study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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