Am J Transl Res 2022;14(9):6647-6658
www.ajtr.org /ISSN:1943-8141/AJTR0144799

Original Article

Prevalence and risk factors of *Helicobacter pylori* infection in Ningxia, China: comparison of two cross-sectional studies from 2017 and 2022

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Received June 16, 2022; Accepted July 30, 2022; Epub September 15, 2022; Published September 30, 2022

Abstract: Objectives: *Helicobacter pylori* (*H. pylori*) infection causes a variety of intragastric and extragastric diseases. Despite its decreasing global prevalence, it remains a major public health problem in many developing countries. This study aimed to understand the prevalence of *H. pylori* infection and its risk factors in five cities of the Ningxia Hui Autonomous Region, an area with high incidence of gastric cancer. Methods: Cross-sectional studies were conducted in Ningxia from 2017 and 2022, to detect the prevalence of *H. pylori* using the ^{14}C urea breath test. All participants completed a questionnaire that included demographics, personal habits, household economic characteristics, and previous health status. Multiple logistic regression analyses were used to identify independent factors for *H. pylori* infection. Results: Our findings demonstrated that the prevalence of *H. pylori* infection in Ningxia decreased significantly from 60.3% in 2017 to 43.6% in 2022, with an increase in public awareness rate from 35.9% in 2017 to 68.5% in 2022. The lowest infection rate was found in Zhongwei and highest in Guyuan. The prevalence of *H. pylori* infection was higher among Hui ethnicity, farmers, individuals living in rural areas, individuals with lower income, low education, and those who consumed less fruit. Gallbladder, respiratory, cardiovascular and autoimmune diseases were not associated with *H. pylori* infection. Conclusions: The prevalence of *H. pylori* in Ningxia decreased in the past five years. Ethnicity, location, occupation, income, education, and consumption of fruits were independent risk factors for *H. pylori* infection in Ningxia. It was not associated with extra-gastric disease.

Keywords: *Helicobacter pylori*, prevalence, risk factors, Ningxia

Introduction

Helicobacter pylori (H. pylori) is a gram-negative microaerobic bacillus that is found primarily in the gastrointestinal tract. It is widely recognized as an important causative agent of various gastric diseases [1, 2]. *H. pylori* has been estimated to coexist with humans since 100,000 years ago [3]. A recent meta-analysis showed an estimated overall global *H. pylori* infection rate of 44.3% and in developing countries, the rate is 50.8% [4]. The prevalence of *H. pylori* infection in the Chinese population is higher than the rest of the world, with an average of approximately 55-56% [5, 6]. Many studies have shown that various factors [7-10], including geographical location, living environment, socioeconomic status, personal habits, and socio-demographic characteristics, may be responsible for the wide variation in *H. pylori* infection rates among regions. In addition, *H. pylori* infection is an infectious disease and

humans are the main source of *H. pylori* transmission [11]. It is currently thought to be transmitted mainly through fecal-oral and oral-oral routes, but its exact transmission mechanism remains unclear.

Gastric cancer is the 5th leading cancer in incidence and the 4th in causes of death globally [12]. Chronic *H. pylori* infection is the most important risk factor for gastric cancer, and it is defined as a group I carcinogen [13]. China is a country with a large incidence of gastric cancer, and nearly half (43.9%) of new gastric cancer cases in the world occur in China [12]. The Ningxia region in northwest China ranks among the top three in the country for the incidence of gastric cancer. In 2017, a tumor survey in Ningxia showed that the incidence and mortality of gastric cancer were as high as 31.57/100,000 and 19.18/100,000, respectively [14], which were 2.8 and 2.5 times the global average, respectively [12]. *H. pylori* infection is a clear and treatable risk factor for the occurrence and development of gastric diseases including gastric cancer. Therefore, it is of great significance to clarify the current prevalence of *H. pylori* infection and risk factors in the Ningxia population.

Eradication of *H. pylori* is one of the most effective ways to prevent gastric cancer, and can significantly reduce the incidence and mortality, especially intestinal type gastric cancer or non-cardiac gastric adenocarcinoma [15, 16]. *H. pylori* eradication also has the potential to block and reverse gastric mucosal intestinal metaplasia, atrophy, and other gastric precancerous lesions [17, 18]. In 2017, the Ningxia government proposed the "Healthy Ningxia Action" and organized a region-wide standardized *H. pylori* eradication treatment program. We conducted a region-wide *H. pylori* epidemiological survey study twice, in January 2017 before the project started and in January 2022, 5 years after the project was carried out. We investigated the changes in *H. Pylori* infection rate and its influencing factors as a latest reference for appropriate prevention and treatment in Ningxia region.

H. pylori infection may also be associated with extra-gastric diseases including respiratory, cardiovascular, rheumatic immune, hepatobiliary and metabolic diseases [19]. Therefore, we added extra-gastric diseases to the questionnaire to understand the correlation between *H. pylori* infection and extra-gastric diseases.

Materials and methods

Study subjects

We conducted two cross-sectional studies in five cities in Ningxia (Yinchuan, Wuzhong, Guyuan, Zhongwei, and Shizuishan) incorporating 21 communities from January-May 2017 and from January-May 2022 (**Figure 1**). Specific institutions include the following: Yinchuan (Fengdeng Town Community Health Center, Xixia District Hospital 217, Yongning County Hospital, Bishui Blue Community Health Center, Sun Garden Community Health Center); Wuzhong (Wuzhong City People's Hospital, Yuxi Community Health Center, Jinhuayuan Community Health Center, New Jaguar Community Health Center); Guyuan (Baiyang Town Health Center, Jinyuan County People's Hospital, Perfume Town Health Center, Guyuan City People's Hospital, Yuanzhou District People's Hospital); Zhongwei (Yingshuiqiao Community Health Center, Rouyuan Community Health Center, Zhenluo Community Health Center, Xuanhe Town Community Health Center); and Shizuishan (Shizuishan Second People's Hospital, Pingluo County Hospital, Huinong Hospital). A random sample of residents who came to the hospital for inspection was surveyed. Inclusion criteria included those who voluntarily underwent the ^{14}C urea breath test (UBT) and awareness of the study. Exclusion criteria were as follows: (1) those who had taken proton pump inhibitors, gastric mucosal protective agents and antibiotics such as amoxicillin, clarithromycin, metronidazole, and sulfonamides within the last 1 month; (2) those who suffered from severe mental illnesses such as anxiety, depression, cognitive dysfunction and other diseases that might affect cooperation with the test; (3) pregnant, lactating and pregnant women; and (4) those aged < 18 years. All enrolled participants answered a structured questionnaire and underwent a ^{14}C-UBT.

The study was approved by the Ethics Committee of People's Hospital of Ningxia Hui Autonomous Region (approval number: 2017-0906, 2021-LL-017).

Questionnaire

All participants completed the *H. pylori* questionnaire (Table S1). It consisted of three main modules: (1) general personal information (sex, age, ethnicity, education, occupation, living area, permanent household size, etc.); (2) per-

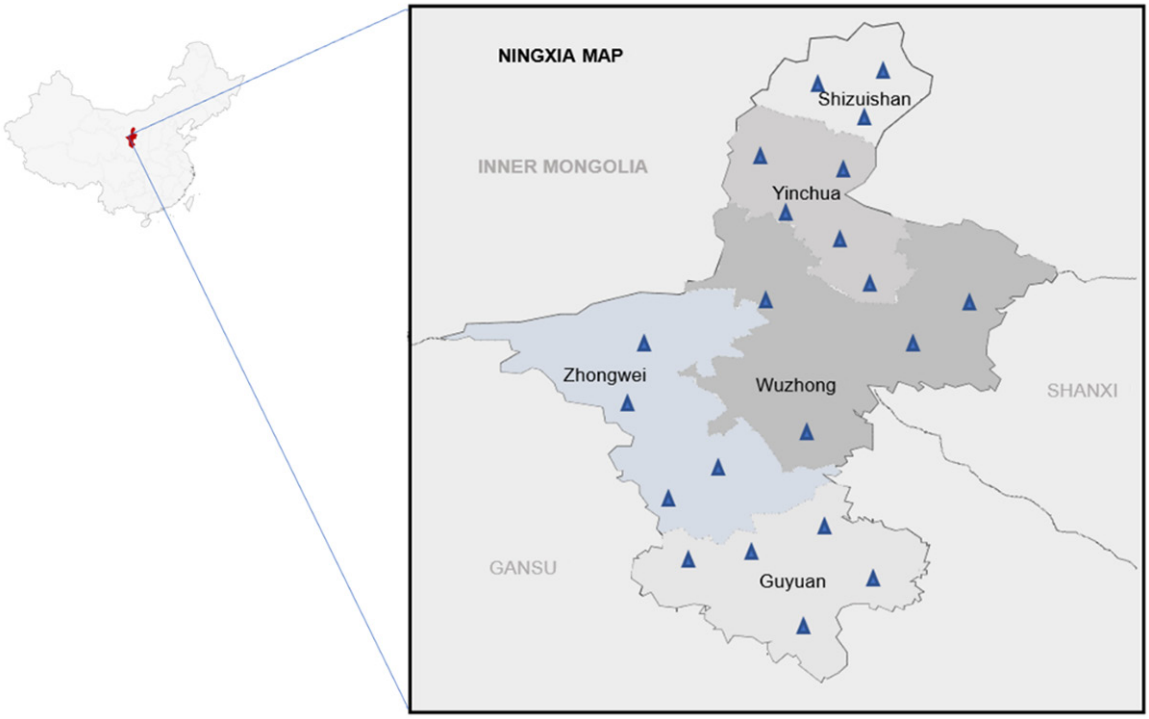

Figure 1. Geographic location of Ningxia and 21 community health care centers that participated in this study (triangle symbols).

sonal habits (smoking history, drinking history, usual living habits, dietary habits); and (3) personal health status (presence of digestive symptoms, chronic gastritis, peptic ulcer, cardiovascular disease, respiratory disease, autoimmune disease, etc.). Smoking was defined as smoking more than one cigarette per day, continuously or cumulatively for 6 months. Alcohol consumption was defined as drinking more than 25 g per day for men and 15 g for women in the past year. The frequency of consumption of fruits, vegetables, pickled foods, spicy and stimulating foods, and tea was defined and valued as follows: frequent consumption was defined as participants having eaten food more than three times in 1 week in the past 6 months. Other consumption was considered occasional. All questionnaires were filled in by specialized medical personnel to ensure their reliability, authenticity, and completeness.

Detection of H. pylori infection

H. pylori infection was detected by ^{14}C-UBT, which was administered by trained investigators following the instructions. Briefly, participants took one capsule of urea ^{14}C capsule (Shanghai Xinko Pharmaceutical Co., Ltd., State Drug Administration H20000228) with about 20 ml of drinking water on an empty stomach, sat for 15 min, and then blew into the breath card (Anhui Yanghe Medical Equipment Co., Ltd., Anhui Arm Note 20152400145) and stopped when the indicator in the indicator window of the breath card changed from blue to white. After this, the participant's name, sex, and test time were filled on the breath card label, which was inserted into the sample inlet of the *H. pylori* detector (Anhui Yanghe Medical Equipment Co., Ltd., YH04E). This instrument automatically detected and recorded the results obtained about 4 min after the measurement was taken. The sample was considered positive when the value was greater than or equal to 100 DPM/mmol CO_2.

Statistical analysis

Epidate (v3.1) was used to create a database from the participants' date. Statistical analyses were performed using SPSS 25.0, with continuous variables expressed as means, and categorical variables expressed as % and compared using chi-square test. A logistic regression model was used to conduct a multi-factor analysis of the influencing factors. $P < 0.05$ was

Table 1. Baseline characteristics of the participants in 2017 and 2022

Variable	N (%) [2017]	N (%) [2022]	P
Total	4780 (100.0)	3734 (100.0)	
Sex, male	2178 (45.6)	1340 (35.9)	< 0.001
Age, mean ± SD	50.8 ± 12.2	55.2 ± 13.4	< 0.001
< 44	2008 (42.0)	1166 (31.3)	
44~59	2169 (45.4)	1577 (42.2)	
> 60	603 (12.6)	991 (26.5)	
Ethnicity			
Hui	1334 (27.9)	1127 (30.2)	
Han	3321 (69.5)	2510 (67.2)	
Others	125 (2.6)	97 (2.6)	
Living area			
Rural	2358 (49.3)	1835 (49.1)	
Town	2422 (50.7)	1899 (50.9)	
Jobs			
Farmer or worker	2716 (56.8)	2200 (58.9)	
Civil servant or Other	2064 (43.2)	1534 (41.1)	
Province			< 0.001
Yinchuan	800 (16.7)	1150 (30.8)	
Wuzhong	841 (17.6)	426 (11.4)	
Shizuishan	710 (14.9)	590 (15.8)	
Zhongwei	730 (15.3)	826 (22.1)	
Guyuan	1699 (35.5)	742 (19.9)	

considered significant. The figures were presented using the software Origin®2019 (OriginLab Corp., USA, Washington).

Results

Baseline characteristics

In 2017, there were a total of 4780 participatants, including 2178 men (45.6%). The mean age was 50.8 ± 12.2 years, with the highest number aged 44-59 years (45.4%). Participants from the Hui ethnic group accounted for 27.9%. The proportions of urban and rural participants were comparable. Occupation as a farmer or worker accounted for 56.8%. The most common place of residence of participants was from Guyuan. In 2022, a total of 3734 participants participated in the study, including 1340 men (35.9%). The mean age was 55.2 ± 13.4 years. Participants from the Hui ethnic group accounted for 30.2%. Urban and rural participants were equally represented. Occupation as a farmer or worker accounted for 8.9%. Participants from Yinchuan made up the largest proportion. The distribution of sex, age, and place of residence was significantly different in 2022 compared to 2017 participants' data ($P < 0.001$) (**Table 1**).

Prevalence and awareness of H. pylori infection

We added questions about *H. pylori* awareness to the questionnaire. The 2022 survey showed that 68.5% of participants were aware of *H. pylori*, which is significantly higher than that in 2017 (35.9%, $P < 0.0001$) (**Figure 2A**). The *H. pylori* infection rate in 2022 was 43.6% in Ningxia, significantly lower than that in 2017 (60.3%, $P < 0.001$) (**Figure 2B**). In addition, we compared the *H. pylori* infection rate for different age groups and regions. Overall trends for both 2017 and 2022 showed an increasing trend of *H. pylori* infection with increasing age. However, the results in 2017 showed the highest prevalence of infection at the age of 51-60 years, and in 2022 at age ≥ 71 years. For different age groups and regions, the prevalence of *H. pylori* infection in 2022 was significantly lower than that in 2017 ($P < 0.001$) (**Figure 2C**, **2D**). Futhermore, we found that among the five cities in Ningxia, the infection rate in Guyuan was highest in both 2017 and 2022.

Factors associated with H. pylori infection in 2017 and 2022

The factors associated with the *H. pylori* infection are described in **Table 2**. The survey data in 2017 showed that the prevalence gradually increased with increasing age, and was significantly higher ($P < 0.05$) in men than in women, but this result was not reflected in the 2022 data. In addition, both the 2017 and 2022 data showed that the prevalence of *H. pylori* infection was associated with ethnicity, living area, education level, occupation, and household income ($P < 0.05$). Specifically, the prevalence of *H. pylori* infection was higher in Hui ethnicity than in Han ethnicity; higher in those living in rural areas than in urban areas; higher in those with occupations such as farmers or workers than in civil servants and other groups; higher in those with monthly household income <

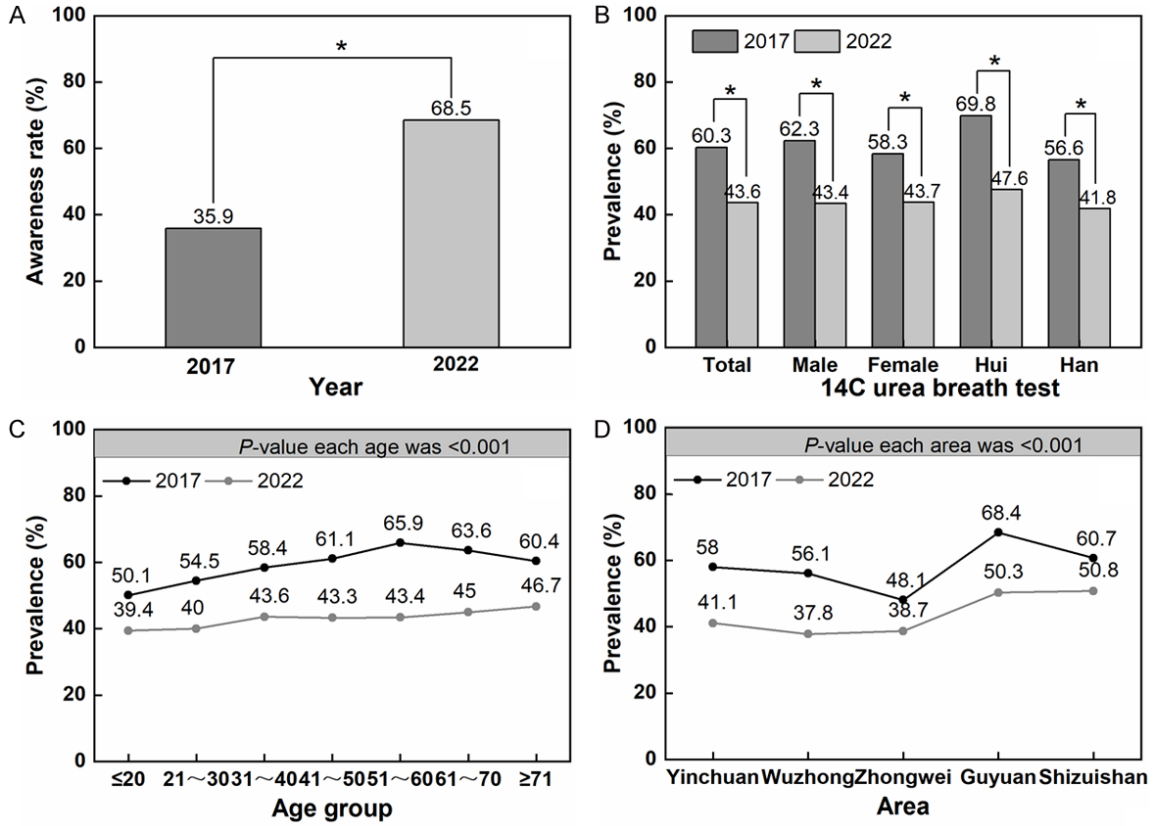

Figure 2. Awareness of *Helicobacter pylori* (A), and prevalence of *Helicobacter pylori* stratified by sex, ethnicity (B), age (C), and geographic region (D) in 2017 and 2022. * represent $P < 0.001$. (A) Awareness rate of *Helicobacter pylori* in the participating population in 2017 and 2022 by questionnaire. The prevalence of *Helicobacter pylori* infection in the participating population was detected by ^{14}C urea breath test in 2017 and 2022, respectively. (B) The prevalence of *Helicobacter pylori* and the comparison of prevalence by gender and ethnicity in 2017 and 2022. (C) Trends in prevalence of *Helicobacter pylori* by age in 2017 and 2022. (D) Prevalence of *Helicobacter pylori* in five regions of Ningxia in 2017 and 2022.

3,000 CNY and between 3,000-5,000 CNY than in those with income > 5,000 CNY; and lower in those with college or a tertiary education level.

In terms of lifestyle, the survey data in 2017 showed that the prevalence of *H. pylori* infection was significantly associated with smoking, alcohol consumption, eating fried foods, drinking tea, washing hands before and after meals, sharing utensils at home, and keeping pets indoors ($P < 0.05$), which was not reflected in the 2022 survey results. However, the results of the 2022 survey showed that the prevalence gradually increased with an increase in household members ($P < 0.05$). Moreover, both the 2017 and 2022 data showed that the prevalence of *H. pylori* infection was significantly associated with the consumption of fruits and pickled foods ($P < 0.05$). Specifically, the prevalence of *H. pylori* infection was lower in participants who ate fruit regularly than in those who ate fruit occasionally. In addition, participants who ate pickled foods frequently had higher prevalence rates than those who ate these food occasionally.

Logistic regression model analysis

The odds ratio (OR) for the the indicators with significant differences ($P < 0.05$) after screening were included in the logistic regression model (**Table 3**). The results showed that independent risk factors affecting *H. pylori* infection were Hui ethnicity (OR=1.919, 95% CI: 1.253~2.954), living in a rural area (OR=1.557, 95% CI: 1.029~2.321), occupation as farmer or worker (OR=2.329, 95% CI: 1.144~4.742), lower education level (OR=1.920, 95% CI:

Table 2. Correlation between the prevalence of *Helicobacter pylori* infection and demographic-economic, and lifestyle risk factors in 2017 and 2022

Variable category	2017 (n=4780)			2022 (n=3734)		
	No.	No. (%) positive	*P*	No.	No. (%) positive	*P*
Gender			0.003			0.918
Male	2178	1363 (62.6%)		1340	582 (43.4%)	
Female	2602	1517 (58.3%)		2394	1045 (43.7%)	
Ethnicity			< 0.001			0.001
Hui	1334	931 (69.8%)		1127	536 (47.8%)	
Han	3321	1878 (56.5%)		2510	1050 (41.8%)	
Age (years)			< 0.001			0.236
< 44	2008	1070 (53.3%)		1166	491 (42.1%)	
44~59	2169	1315 (60.6%)		1577	683 (43.3%)	
> 59	603	495 (82.1%)		991	453 (45.7%)	
Geographical location			< 0.001			0.013
Rural	2358	1587 (67.3%)		1835	762 (41.5%)	
Town	2422	1420 (58.6%)		1899	865 (45.6%)	
Jobs			< 0.001			0.019
Farmer or worker	2716	1743 (64.2%)		2200	994 (45.2%)	
Civil servant or other	2064	1137 (55.1%)		1534	633 (41.3%)	
Education level			< 0.001			< 0.001
Elementary	2907	1978 (68.0%)		1925	911 (47.3%)	
Junior/High School	992	567 (57.2%)		691	276 (39.9%)	
College and above	881	335 (38.0%)		1118	440 (39.4%)	
Household members			0.445			0.012
1	376	226 (60.1%)		125	50 (40.0%)	
2-4	3890	2331 (59.9%)		3096	1323 (42.7%)	
> 5	514	323 (62.8%)		513	254 (49.5%)	
Monthly household income			< 0.001			0.002
≤ 3000	1124	817 (72.9%)		1388	657 (47.3%)	
3000~5000	1942	1110 (57.2%)		1723	717 (41.6%)	
≥ 5000	1714	935 (54.6%)		623	253 (40.6%)	
Smoking			< 0.001			0.958
Yes	747	561 (75.1%)		413	179 (43.3%)	
No	4033	2319 (57.5%)		3321	1448 (43.6%)	
Drinking			< 0.001			0.550
Yes	574	406 (70.7%)		192	88 (45.8%)	
No	4206	2474 (58.8%)		3542	1539 (43.5%)	
Eating raw vegetables			0.090			0.460
Yes	1452	849 (58.5%)		1026	437 (42.6%)	
No	3328	2031 (61.0%)		2708	1190 (43.9%)	
Eating fruits			< 0.001			0.001
Occasionally	1314	962 (73.2%)		993	479 (48.25)	
Frequently	3466	1918 (55.3%)		2741	1148 (41.9%)	
Eating fried foods			< 0.001			0.814
Occasionally	3471	2074 (59.8%)		2881	1252 (43.5%)	
Frequently	1039	806 (77.6%)		853	375 (44.0%)	
Eating spicy foods			0.180			0.647
Occasionally	2826	1725 (61.0%)		2516	1103 (43.8%)	
Frequently	1954	1155 (59.1%)		1218	524 (43.0%)	

Eating pickled foods			0.029			< 0.001
Occasionally	3859	2296 (59.5%)		3208	1322 (41.2%)	
Frequently	921	584 (63.4%)		526	305 (58%)	
Drinking tea			0.021			0.146
Occasionally	3136	1852 (59.1%)		2647	1133 (42.8%)	
Frequently	1644	1028 (62.5%)		1087	494 (45.4%)	
Wash hands before eating and after using the toilet			< 0.001			0.607
Occasionally	872	603 (69.2%)		342	154 (45.0%)	
Frequently	3908	2277 (58.3%)		3392	1473 (43.4%)	
Families sharing tableware			< 0.001			0.974
Yes	2928	2036 (69.5%)		2043	891 (43.6%)	
No	1852	844 (45.6%)		1691	736 (43.5%)	
Indoor pets			< 0.001			0.170
Yes	927	660 (71.2%)		375	176 (46.9%)	
No	3853	2220 (57.6%)		3359	1451 (43.2%)	

Table 3. Multifactorial logistic regression analysis for *Helicobacter pylori* infection

Variable category	β	*SE*	Wald χ^2	*P*	*OR*	95% CI
Ethnicity	0.644	0.220	9.012	0.003	1.919	1.253~2.954
Geographic Location	0.429	0.211	4.429	0.038	1.557	1.029~2.321
Job	0.844	0.362	5.429	0.020	2.329	1.144~4.742
Education Level	0.652	0.236	7.630	0.006	1.920	1.209~3.049
Income	0.481	0.156	9.480	0.002	1.617	1.191~2.196
Eating fruits	0.388	0.160	5.867	0.015	1.474	1.077~2.018

1.209~3.049), lower income (OR=1.617, 95% CI: 1.191~2.196), and infrequent fruit consumption (OR=1.474, 95% CI: 1.077~2.018).

Relationship between H. pylori infection and personal health status

The questionnaire for this study also included questions related to the personal health status of the participants, and its relationship with *H. pylori* infection (**Table 4**). The results of both 2017 and 2022 surveys showed a higher prevalence of *H. pylori* infection in participants with chronic gastritis and peptic ulcer ($P < 0.05$); whereas the presence of gallbladder, respiratory, cardiovascular, or autoimmune diseases did not correlat with the infection ($P > 0.05$).

Discussion

H. pylori infection is still an issue of public concern worldwide. The current infection status in Ningxia, a region with a high incidence of gastric cancer, remains unclear. Using ^{14}C-UBT to determine *H. pylori* infection, we found that the prevalence in Ningxia was as high as 60.3% in 2017, but had decreased to 43.6% by 2022. The observed decline over time was consistent with a recent report on the decline in the seropositivity of *H. pylori* infection in Korea [20]. The prevalence of *H. pylori* infection has been reported to have been declining in highly industrialized countries in the western world, while in developing and newly industrialized countries, has remained high at the turn of the 21st century [5]. Furthermore, this decline may be associated with higher socioeconomic status, better sanitation, and greater changes in nuclear family distribution [21, 22]. However, in the current study, the decline in *H. pylori* infection may be associated with the implementation of a region-wide standardized *H. pylori* diagnosis and treatment initiative, i.e., spontaneous *H. pylori* eradication, during this period. Moreover, the survey results showed a significant increase in the participants' knowledge of *H. pylori*, which, in addition to the increasing standard of living and greater concern for their health, could not be separated from the efforts made by the government during these 5 years.

Table 4. Correlation between the prevalence of *Helicobacter pylori* infection and medical history in 2017 and 2022

Variable category	2017 (n=4780)			2022 (n=3734)		
	No.	No. (%) positive	*P*	No.	No. (%) positive	*P*
Chronic gastritis			0.006			0.001
Yes	1465	922 (62.9%)		1269	504 (39.7%)	
No	3315	1958 (59.1%)		2465	1123 (45.6%)	
Peptic ulcer			< 0.001			0.009
Yes	1213	795 (65.5%)		555	270 (48.6%)	
No	3567	2085 (58.5%)		3179	1357 (42.7%)	
Spouse's gastric disease			0.015			0.490
Yes	1279	807 (63.1%)		663	297 (44.8%)	
No	3501	2073 (59.2%)		3071	1330 (43.3%)	
Gallbladder disease			0.751			0.382
Yes	1058	633 (59.8%)		567	257 (45.3%)	
No	3722	2247 (60.4%)		3167	1370 (43.3%)	
Respiratory disease			0.559			0.770
Yes	436	257 (58.9%)		109	49 (45.0%)	
No	4344	2623 (60.4%)		3625	1578 (43.5%)	
Cardiovascular disease			0.255			0.612
Yes	484	280 (57.9%)		271	114 (42.1%)	
No	4296	2600 (60.5%)		3463	1513 (43.7%)	
Autoimmune disease			0.47			0.677
Yes	543	335 (61.7%)		224	101 (45.1%)	
No	4237	2545 (60.1%)		3510	1526 (43.5%)	

Consistent with previous studies, both findings in the present study showed a gradual increase in *H. pylori* infection with age [20, 23, 24]. However, the decrease in infection rate observed in participants over 70 years of age may be due to the lower *H. pylori* load after the development of atrophic gastritis, which limits UBT detection; and secondly to the somewhat higher odds of oral antibiotics in the elderly, which suppresses *H. pylori* after coincidental treatment with antibiotics [25, 26]. In terms of the geographical area, an overall declining trend in infection rate was observed in all areas. However, we found that *H. pylori* infection rates were consistently lowest in Zhongwei and highest in Guyuan. This is closely related to the fact that Ningxia is an ethnic minority (Hui) concentrated area. Coincidentally, multivariate analysis found that Hui ethnicity was an independent risk factor for *H. pylori* infection. The proportion of individuals of Hui ethnicity in Zhongwei (35.31%) was significantly lower than that in Guyuan (47.5%). Guyuan has the highest proportion of Hui ethnicity in Ningxia, so its highest infection rate may be related to ethnicity. The difference in *H. pylori* infection rate between Hui ethnicity and Han ethnicity may be due to their different dietary structure; while the Hui population prefers beef and mutton. Some literature reported that *H. pylori* was detected in both beef and mutton by bacterial culture and PCR analysis [27-29].

In addition, we analyzed the participants' general personal information and lifestyle habits, and found both different and consistent factors. Data from 2017 alone using univariate analysis showed a higher prevalence of *H. pylori* infection in men, but after adjusting for OR, multifactorial results showed no correlation between sex and infection, which was consistent with the findings of Wang et al. [30] and Van et al. [31]. However, a meta-analysis pooling 244 studies showed that *H. pylori* infection was predominant in men [32]. Multifactorial logistic analysis showed that residence area, occupation, educational level, and monthly income were correlated with *H. pylori* infection, which was consistent with the findings of other studies [26, 33]. The risk of *H. pylori* infection

was higher in participants living in rural areas, working in agriculture, with less education, and lower household income than in those living in towns, working in non-agricultural occupations, with higher education, and higher household income. This may be attributed to poor health habits, lifestyles, relative lack of medical facilities, family size clustering among farmers, less education in people, and low-income families [34].

H. pylori is usually transmitted by both direct and indirect means. Direct transmission usually refers to intimate interactions between people, while indirect transmission requires a medium such as water, food or other animals [35, 36]. The present study showed a higher prevalence of infection in participants with a larger household size and shared utensils, which is also consistent with the oral-oral transmission route of *H. pylori*. In addition, the prevalence was higher in households with pets than in households without pets. Many studies have found a high prevalence of *H. pylori* infection in butchers and meat processors, and *H. pylori* has been isolated from animals such as cattle, sheep, camels, and dogs [28, 29]. These animals may be reservoirs of *H. pylori*, but whether *H. pylori* infection is zoonotic has not yet been confirmed, and it has only been speculated that *H. pylori* may be transmitted from animals to humans. Hence, more studies are required to determine whether pet ownership leads to increased *H. pylori* infection in humans.

The relationship between smoking, drinking, and *H. pylori* infection is highly controversial. A study from asymptomatic individuals showed that smoking and drinking were risk factors for males but protective factors for women after adjusting for age [37]. However, there are also studies showing that smoking was inversely associated with *H. pylori* infection [38]. Our fingdings showed no significant correlation between smoking and *H. pylori* infection, which is consistent with the results of two studies from China [30, 39]. This result may be related to detailed data on the frequency and amount of drinking and smoking. Adjusting for relevant factors together may lead to consistent conclusions.

H. pylori infection was also associated with eating habits. Through analyzing dietary habits, we found that eating fruits may be a protective factor, and that regular consumption of fruits is associated with a lower risk of *H. pylori* infection, as supported by other studies [26, 30]. It has been reported that *H. pylori* infection is related to lipid metabolism [40, 41], and that good dietary habits can help prevent *H. pylori* infection. Individuals who consume fruits and vegetables regularly are better able to eliminate excess accumulated cholesterol in their bodies, which has the effect of lowering blood pressure and blood lipids. In addition, the high content of vitamin C in fresh vegetables and fruits can protect the gastric mucosa from *H. pylori* infection [42], but the specific mechanism at work needs further investigation. Some studies have shown a positive association between the consumption of pickled and fried foods and *H. pylori* infection [39]. However, the results of this study do not support this conclusion. Moreover, previous studies have reported that drinking tea is a protective factor against *H. pylori* infection, and it is believed that tea polyphenols have bactericidal effects reducing infection rate, but this study does not support these results [43]. The differences in these findings may be related to varying data such as the type and amount of tea consumed. Therefore, the correlation between tea drinking and *H. pylori* infection still needs to be confirmed by further studies.

Participants with a history of peptic ulcer and chronic gastritis had a higher rate of *H. pylori* infection ($P < 0.05$). This is consistent with the fact that *H. pylori* is the causative agent of various chronic gastric diseases; hence it is important to actively eradicate *H. pylori* to prevent peptic ulcer and gastric cancer. In addition, it has been reported that *H. pylori* is also the cause of some extra-gastric diseases including blood, cardiovascular, metabolic, immune and other diseases [19]. However, by analyzing the contents of the questionnaire, this study did not find *H. pylori* to be associated with extragastric disease.

Our research has the following advantages. First of all, we explored various regions of Ningxia and completed a population-based sampling design covering all areas of the population. Almost all participants provided complete data based on the questionnaires. Secondly, the centralized ^{14}C-UBT and strict exclusion criteria ensured the reliability of the test results. Third, Ningxia is an area inhabited by ethnic

minorities, and there were few studies on *H. pylori* infection based on Hui and Han populations. This study makes a significant contribution to the literature as the findings provide new insights into the relationship between *H. pylori* infection and high prevalence of gastric cancer in thses populations. In terms of limitations, this study did not involve all age groups, that is, people under the age of 18 years were not included in the study, which may lead to an overestimation of the infection rate in this region. Second, although we informed all participants of their *H. pylori* infection status, there was no follow-up or treatment, and future studies may require us to assist them for monitoring throughout their treatment.

In summary, this is the first study to investigate the prevalence of *H. pylori* infection and its associated risk factors on a large scale in the general population of Ningxia Hui Autonomous Region, a region with a high prevalence of gastric cancer. In 2017, the infection rate of *H. pylori* in Ningxia was 60.3%, which exceeded the national average. After 5 years of standardized diagnosis, treatment, and education, the prevalence of *H. pylori* infection decreased to 43.6% in 2022, and the public had a broader awareness of *H. pylori*. This showed that the "Healthy Ningxia Action" advocated by the Ningxia Hui Autonomous Region government had played a criticalrole. Moreover, binary multifactorial logistic regression analysis found that ethnicity, living area, occupation, income, level of education, and consumption of fruits were independent risk factors for *H. pylori* infection. The results of this study provide a new perspective on the reasons for the high incidence of gastric cancer in Ningxia, and could help reduce and control the incidence of gastric cancer in this region. In the future, we should follow up with established cohorts to study the changes in *H. pylori* infection and disease spectrum in the local population.

Acknowledgements

We thank the government departments county hospitals and community health centers of Ningxia Hui Autonomous Region for facilitating the study for the people of Ningxia region. This study is supported by the Central Guide Local Science and Technology Development Special Project fund (No. YDZX20176400004650), Ningxia Hui Autonomous Region Key Research and Development Program (No. 2019BFG-02003), Ningxia Hui Autonomous Region Key Research and Development Program (No. 2021BEG02025), Ningxia Hui Autonomous Region Science and Technology Special Project to Benefit the People (No. 2022CMG03039), and Hainan Province Clinical Medical Center (No. 2021818).

Disclosure of conflict of interest

None.

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Table S1. Questionnaire for *H. pylori* infection

General personal information	Name:	Years:		Telephone:	
Social and economic status	Sex	Male	Female		
	Ethnicity	Han	Hui	Other____	
	Occupation	Farmer	Worker	Civil servant or other	Other___
	marriage or not	Married	Divorced	Widowed	Unmarried
	Education level	Elementary	Junior/High	College or above	
	Monthly household income (CNY)	<3000	3000-5000	>5000	
	Household members	1	2-4	>5	
	Geographical location	Rural	Town		
Personal habits	Smoking	Yes	No		
	Dringking	Yes	No		
	Eating raw vegetables	Yes	No		
	Eating fruits	Occasionally	Frequently		
	Eating fried foods	Occasionally	Frequently		
	Eating spicy foods	Occasionally	Frequently		
	Eating pickled foods	Occasionally	Frequently		
	Drinking tea	Occasionally	Frequently		
	Wash hands before eating and after using the toilet	Occasionally	Frequently		
	Family shared tableware	Yes	No		
	Indoor pets	Yes	No		
Personal health status	Symptoms	Bad breath	Bitter mouth	Acid reflux	Heartburn
		Abdominal pain	Bloating	Diarrhea	Poor appetite
		Hiccups	Early satiety	Other____	
	Chronic gastritis	Yes	No		
	Peptic ulcer	Yes	No		
	Spouse's gastric disease	Yes	No		
	Gallbladder disease	Yes	No		
	Respiratory disease	Yes	No		
	Cardiovascular disease	Yes	No		
	Autoimmune disease	Yes	No		
Other	H. pylori awareness	Yes	No		
	History of gastric cancer in a relative	Yes	No		

Dear Patient: Thank you for your support and cooperation. I hope you will read the entries carefully and put a "tick" after the entry you choose, and do not miss to fill in. If you have any questions during the filling process, please contact the staff for consultation. Thank you again for your cooperation and wish you good health and complete success.