BMC Infectious Diseases

RESEARCH

Open Access

Epidemiology of *Helicobacter pylori*, gastric precancerous lesions and gastric cancer: a multicenter, population-based cross-sectional study in Nanjing

Chunyan Niu[1*†], Yongqiang Song[1†], Yue Chen[1], Yongqiang Shi[1], Hui Wang[1], Xinguo Wu[1], Xiaoping Wang[1], Xiangyang Zhao[1], Yongdan Bu[3], Jijin Li[4], Tao Tao[5], Jinhua Wu[6], Changlin Xue[7], Fuyu Zhang[8], Chunrong Han[9], Juan Yuan[9] and Qiang Zhang[2*]

Abstract

Background Nanjing City has a high-incidence gastric cancer (GC), but the epidemiology of gastric precancerous lesions (GPLs) remains poorly understood. This study aimed to investigate the epidemiological characteristics of *Helicobacter pylori* (*H. pylori*) infection, GPLs, and GCs in patients undergoing endoscopic examination in Lishui District, Nanjing.

Methods This retrospective, population-based, cross-sectional study was conducted collaboratively by the Nanjing Lishui People's Hospital and six medical community units within the county between July 2022 and June 2023. Data on biopsies and ^{13}C urea breath tests (^{13}C-UBT) were collected.

Results A total of 15,668 individuals were included, among whom 259 had GPL (1.65%) and 218 had GC (1.39%). The *H. pylori* infection rate in total patients was 5014 (32.00%) (males: 2684 (34.06%); females: 2335 (29.92%)). The *H. pylori* infection rate is 31.45% in benign gastric lesions, 44.40% in GPLs, and 55.50% in GC, respectively. The multivariable logistic regression analysis showed that male (OR = 3.156, 95% CI: 2.865–3.376, $P < 0.001$), age (OR = 1.785, 95% CI: 1.703–1.876, $P < 0.001$), fresh vegetable, fruit, and white meat intake frequently (OR = 0.865, 95% CI: 0.506–2.061, $P = 0.029$), high-salt diet and high-fat diet intake frequently (OR = 1.906, 95% CI: 1.101–2.932, $P = 0.014$), rural residence (OR = 2.682, 95% CI: 1.010–4.754, $P = 0.040$), *H. pylori* infection (OR = 2.022, 95% CI: 1.155–2.865, $P < 0.001$) and atrophic gastritis and/or intestinal metaplasia (OR = 4.875, 95% CI: 2.229–10.663, $P < 0.001$) were associated with GPLs. Male (OR = 2.021, 95% CI: 1.080–3.780, $P = 2.028$), age (OR = 1.201, 95% CI: 1.174–1.238, $P < 0.001$), digestive symptoms (OR = 2.256, 95% CI: 1.548–3.289, $P < 0.001$), bachelor degree below (OR = 4.792, 95% CI: 3.439–6.837, $P < 0.001$), farmer (OR = 1.039, 95% CI: 1.026–1.159, $P < 0.001$), fresh vegetable, fruit, and white meat intake (OR = 0.231, 95% CI: 0.141–0.379, $P < 0.001$), fried/barbecue/pickled food intake (OR = 6.781, 95% CI: 3.783–12.153, $P < 0.001$), high-salt diet and high-fat diet intake (OR = 4.374, 95% CI: 2.363–8.097, $P < 0.001$), rural residence (OR = 1.230, 95% CI: 1.121–1.437,

†Chunyan Niu and Yongqiang Song contributed equally to this work.

*Correspondence:
Chunyan Niu
nchy69@163.com
Qiang Zhang
zhangqiang2295@163.com
Full list of author information is available at the end of the article

P < 0.001), *H. pylori* infection (OR = 3.248, 95% CI: 2.357–4.477, *P* < 0.001) and atrophic gastritis and/or intestinal metaplasia (OR = 4.875, 95% CI: 2.636–9.016, *P* < 0.001) were associated with GCs.

Conclusions These findings underscore the importance of implementing targeted prevention strategies and early detection programs in high-risk populations to mitigate the burden of GPLs and GCs in Nanjing.

Keywords Gastroscopy examination, Gastric precancerous lesions, Gastric cancer, *Helicobacter pylori* infection, Screening, Retrospective cross-sectional study

Background

Gastric cancer (GC) poses a significant global health challenge, ranking as the fifth most frequently diagnosed malignant neoplasm, with 968,350 new cases in 2022, comprising 4.9% of all cancers. It is also the fifth leading cause of mortality (with 659,853 deaths in 2022 [1]. Males exhibit a twofold higher incidence rate of GC compared to females, with the highest rates observed in Asia, particularly in East Asian countries like China, Japan, and South Korea [1]. Incidence and mortality of GC increase with age [2], contributing to a growing social burden, particularly given the global aging population and the rise of high-risk groups. Recent reports indicated an increase in early-onset GC (EOGC) occurring in patients < 50 years old [3]. Most GC patients in China are diagnosed in the intermediate or advanced stage, resulting in a low overall 5-year survival rate of ≤ 50% [4].

The most important gastric precancerous lesions (GPLs) include chronic atrophic gastritis (CAG) and intestinal metaplasia (IM), primarily caused by *Helicobacter pylori* (*H. pylori*) infection, leading to intraepithelial neoplasia (IN) [5]. IN is considered the most direct oncogenic GPL preceding the occurrence of GC [6]. The risk of developing GC in confirmed IN ranges from 2.8% to 11.5% for low-grade IN (LGIN) and 10% to 68.8% for high-grade IN (HGIN). Guidelines recommend endoscopic resection for any confirmed IN [7]. Early GC (EGC) screening, primarily through endoscopic examination, has proven to be a cost-effective measure for secondary prevention, improving long-term survival rates and alleviating the social burden associated with early detection and treatment [8]. Screening has been associated with an increase in EGC cases [9]. Therefore, screening for *H. pylori* infection and GPLs holds public health significance in GC management.

Jiangsu Province and Nanjing City are recognized as high-incidence areas for GC [10]. While numerous epidemiological studies on GC in China exist [2, 10, 11], few have examined the epidemiology of GPLs. In addition, most previous studies focus on large cities, with limited research on the prevalence of GPLs and EGC in Jiangsu Province and Nanjing City. Investigating the epidemiology and characteristics of GPLs in Jiangsu Province and Nanjing City could enhance understanding of the high GC incidence observed in those areas.

Therefore, this study aimed to investigate the epidemiological characteristics of *H. pylori*, GPLs, and GC in patients undergoing endoscopic examination in Lishui District, Nanjing.

Methods

Study design and patients

This retrospective, population-based, cross-sectional study was conducted collaboratively by the Nanjing Lishui People's Hospital and six medical community units within the county between July 2022 and June 2023. The inclusion criteria were: 1) local residents or individuals residing in the local area for more than 10 years, 2) underwent endoscopic examination and histopathological diagnosis, 3) absence of a history of serious or special illnesses and digestive system surgery, and 4) ability to read, comprehend, and sign informed consent forms. The exclusion criteria were: 1) received proton pump inhibitors and antibiotic treatment within the past six months, 2) contraindications for gastroscopy or biopsy, 3) active upper gastrointestinal bleeding or emergency esophagogastroduodenoscopy, 4) diagnosis of malignant tumors of the digestive or other systems, 5) severe heart, liver, kidney, or lung diseases, 6) history of upper gastrointestinal surgery or residual stomach, 7) pregnancy or lactation, and 8) inability to cooperate with gastroscopy or other high-risk situations (Table 1). The study was approved by the Medical Ethics Committee of Nanjing Lishui People's Hospital (as the lead center) (approval #2023 KY0727-02) and by the Ethics Committee at each participating center. The requirement for individual informed consent was waived by the committees because of the retrospective nature of the study. This study was conducted in accordance with the Declaration of Helsinki.

All data were de-identified once extracted from the patient charts. Only the principal investigator at each hospital had access to the identity correspondence tables for the patients at the investigator's hospital. The study database is kept on the secure servers at the lead center and is protected by a password. Only the study personnel have access to the de-identified database.

Table 1 Inclusion and exclusion criteria

Inclusion criteria	1) Local residents or individuals residing in the local area for more than 10 years 2) Underwent endoscopic examination and histopathological diagnosis 3) Absence of a history of serious or special illnesses and digestive system surgery 4) Ability to read, comprehend, and sign informed consent forms
Exclusion criteria	1) Received proton pump inhibitors and antibiotic treatment within the past six months 2) Contraindications for gastroscopy or biopsy 3) Active upper gastrointestinal bleeding or emergency esophagogastroduodenoscopy 4) Diagnosis of malignant tumors of the digestive or other systems 5) Severe heart, liver, kidney, or lung diseases 6) History of upper gastrointestinal surgery or residual stomach 7) Pregnancy or lactation 8) Inability to cooperate with gastroscopy or other high-risk situations

Data collection and definition

Clinical and personal data were collected using a pre-examination survey questionnaire, including sex, age, occupation, education, family history of GC, living location, gastrointestinal symptoms, *H. pylori* infection status, dietary habits, smoking, and alcohol consumption. For the proportion of fresh vegetables, fruits, dairy products, eggs, and white meat intake per week, $<60\%$ was defined as rarely, and $\geq 60\%$ was defined as frequently. For the proportion of weekly intake of fried/grilled/pickled foods, $<60\%$ was defined as rarely, and $\geq 60\%$ was defined as frequently. For the frequency of how often the patient consumed high-salt and high-fat diets for three meals a day, <5 g/day was defined as rarely, and ≥ 5 g was defined as frequently. Smoking >10 cigarettes per week in the past 6 months or quitting smoking for <1 year was defined as smoking, and never or quitting smoking for more than 1 year was defined as non-smoking. Drinking 1000 mL of beer or 150 g of ethanol at least once a week in the past year was defined as drinking, and never or occasionally drinking in small amounts was defined as non-drinking. As per routine procedures, patients underwent electrocardiogram and infectious disease marker examinations, abstained from eating and drinking 6 h before gastroscopy, and underwent gastroscopy on an empty stomach. Experienced doctors conducted gastroscopy using standard procedures, primarily ordinary white light gastroscopy, and narrowband imaging magnifying endoscopy. Biopsy samples were immediately fixed in 10% formalin and sent to the pathology department for examination. During the study period, uniform examination and diagnostic standards were implemented based on relevant Chinese guidelines for EGC diagnosis and treatment. Endoscopic findings were categorized as flat, depressed, or elevated (polypoid) lesions accompanied by erosion/ulceration and changes in color [10, 12]. The gastric mucosal biopsy requirements for suspected early neoplastic lesions were to take one or two specimens within 2 cm in diameter and add one specimen for every 1 cm increase in diameter. It is recommended that the mucosa be taken at the junction of normal and lesions. If the boundary is not well determined, the biopsy can be taken in the center of the lesion. The number of biopsies can be increased if necessary [13].

Biopsy specimens were processed according to WHO guidelines. Diagnostic criteria included IN (LGIN and HGIN) for GPL and EGC and AGC for GC. Diagnosis was completed by three senior pathologists, with immunohistochemistry conducted if necessary. EGC refers to cancer tissue confined to the mucosal and submucosal layers, irrespective of regional lymph node metastasis. GPL denoted pathological changes closely related to GC, namely, IN of the gastric mucosa, categorized into LGIN (mild to moderate cellular atypia, deep nuclear staining, and relatively preserved glandular architecture) and HGIN (cuboidal or tall columnar cells with pronounced atypia frequently exhibiting pathological nuclear division). AGC indicated infiltrating cancer tissue into the submucosal layer, muscular layer, or beyond, with or without peripheral invasion and distant metastasis [10, 12]. *H. pylori* detection utilized an endoscopic rapid urease test (RUT) or ^{13}C urea breath test (^{13}C-UBT). To ensure the accuracy of tests and avoid false-negative results, participants who had any history of antibiotics use within the past month, proton pump inhibitor medication within the past 2 weeks, or *H. pylori* treatment within the past 3 months prior to the study were excluded.

Statistical analysis

The statistical analysis was performed using SPSS Statistics version 27.0 (IBM, Armonk, NY, USA) and GraphPad Prism (9.5.1). Continuous data with a normal distribution (according to the Kolmogorov–Smirnov test) were described as mean $\pm$ standard deviations (SD) and analyzed using Student's t-test. Otherwise, they were presented as median (interquartile range (IQR)) and analyzed using the Wilcoxon rank-sum test. The categorical

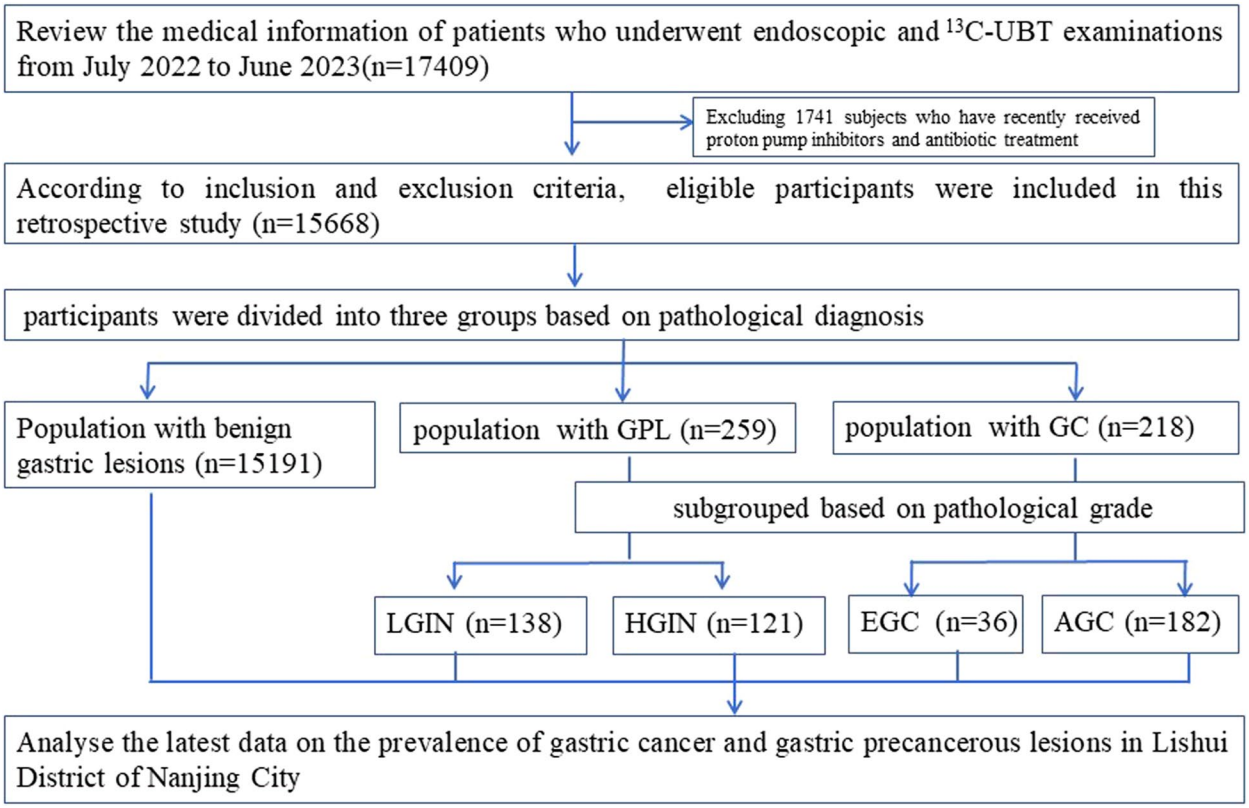

Fig. 1 Study flowchart

data were described as n (%) and analyzed using the chi-squared test or Fisher's exact test. Univariable and multivariable logistic regression analyses were used to examine factors independently associated with GPL or GC. Propensity score matching (PSM) was performed using the"psmatch2"package in R with nearest-neighbor matching, a caliper width of 0.5. Collinearity was tested using the variance inflation factor (VIF), with a VIF > 10 indicating significant collinearity. In the multivariable analyses, variables with collinearity were progressively excluded until no collinearity was observed. Before multivariate, all variables with univariate regression $P < 0.05$ were diagnosed collinearity, and the variables with collinearity were gradually eliminated. Two-sided *P*-values < 0.05 were considered statistically significant.

Results

Demographic characteristics

There were initially 17,409 patients who underwent endoscopic and 13 C-UBT examinations enrolled, and after excluding 1,741 subjects who had recently received proton pump inhibitors or antibiotic treatment, a total of 15,668 eligible participants were included in the study (Fig. 1). Among them, before PSM, 15,191 (96.95%) were diagnosed with benign gastric lesions (mean age: 54.05 ± 13.44 years, 7880 (50.29%) males), 259 (1.65%) were diagnosed with GPLs (mean age: 67.22 ± 9.26 years, 201 (77.61%) males), and 218 (1.39%) were diagnosed with GC (mean age: 68.76 ± 10.82 years, 162 (74.31%) males) (Table 2). The *H. pylori* infection rate in total patients was 5014 (32.00%) (males: 2684 (34.06%); females: 2335 (29.92%)). The *H. pylori* infection rate in participants with benign gastric lesions was 4778 (31.45) (males: 2558 (33.79%); females: 2220 (29.13%)). The *H. pylori* infection rate in the patients with GPL was 115 (44.40%) (males: 94 (46.77%); females: 21 (36.21%)). The *H. pylori* infection rate in patients with GC was 121 (55.50%) (males: 97 (59.88%); females: 23 (41.07%)) (Table 2 and Supplementary Table 1). After PSM, 171 patients were included in each group. The *H. pylori* infection rates were 32.16%, 49.12%, and 57.31% in patients with benign lesions, GPL, and GC, respectively ($P < 0.001$) (Table 3).

Among GPLs, 138 were LGIN (mean age: 66.91 ± 9.60), and 121 were HGIN (mean age: 67.65 ± 8.79). Among GCs, 36 were EGC (mean age: 68.86 ± 11.63), and 182 were AGC (mean age: 68.74 ± 10.69), without significant differences among groups Fig. 1andTable 4).

Table 2 Demographic pathological characteristics before PSM

Variables	Benign gastric lesion *n* = 15,191	GPL *n* = 259	GC *n* = 218	P
Age (years)				
Mean ± SD	54.02 ± 13.63	67.22 ± 9.26	68.76 ± 10.82	
> 45	9426 (62.05%)	254 (98.07%)	210 (96.33%)	
≤ 45	5765 (37.95%)	5 (1.93%)	8 (3.67%)	
Sex				
Male, %	7570 (49.83%)	201 (77.61%)	162 (74.31%)	
Digestive symptoms				0.004
With	3321 (21.86%)	76 (29.34%)	76 (34.86%)	
Without	11,870 (78.14%)	183 (70.66%)	142 (65.14%)	
Education level				0.002
Bachelor's degree below	4557 (30%)	101 (39%)	98 (44.95%)	
Bachelor's degree or above	10,634 (70%)	158 (61%)	120 (55.05%)	
Occupation				< 0.001
Technical personnel, staff, or faculty	6076 (40%)	48 (18.53%)	36 (16.51%)	
Worker	3038 (20%)	77 (29.73%)	71 (32.57%)	
Farmer	4558 (30%)	109 (42.08%)	93 (42.66%)	
Others	1519 (10%)	25 (9.65%)	18 (8.26%)	
Fresh vegetable, fruit, and white meat intake				0.002
Frequently	14,128 (93%)	228 (88.03%)	191 (87.61%)	
Rarely	1063 (7%)	31 (11.97%)	27 (12.39%)	
Fried/barbecue/pickled food intake				< 0.001
Frequently	1367 (9%)	78 (30.12%)	72 (33.03%)	
Rarely	13,824 (91%)	181 (69.88%)	146 (66.97%)	
High-salt diet and high fat diet intake				< 0.001
Frequently	2734 (18%)	72 (27.80%)	69 (31.65%)	
Rarely	12,457 (82%)	187 (72.20%)	149 (68.35%)	
Smoking				< 0.001
Current	2278 (15.00%)	65 (25.10%)	59 (27.06%)	
Never or former	12,913 (85.00%)	194 (74.90%)	159 (72.94%)	
Drinking				< 0.001
Current	2301 (15.15%)	59 (27.78%)	54 (24.77%)	
Never or former	12,890 (84.85%)	200 (77.22%)	164 (75.23%)	
Family history of GC				< 0.001
With	304 (2.00%)	17 (6.56%)	16 (7.345)	
Without	14,887 (98.00%)	242 (93.43%)	202 (92.66%)	
Residence				< 0.001
Rural	3797 (25.00%)	145 (55.98%)	129 (59.17%)	
Urban	11,394 (75.00%)	114 (44.02%)	89 (40.83%)	
Atrophic gastritis and/or intestinal metaplasia				< 0.001
with	5602 (36.88%)	174 (67.18%)	177 (81.19%)	
without	9419 (63.12%)	85 (32.82%)	41 (18.81%)	
Location				< 0.001
Cardia	/	42 (16.22%)	60 (27.52%)	
Non-cardia	/	217 (83.78%)	158 (72.48%)	
***H. pylori* infection**				< 0.001
Positive	4778 (31.45%)	115 (44.40%)	121 (55.50%)	
Negative	10,413 (68.55%)	144 (55.60%)	97 (44.50%)	

GPL gastric precancerous lesions, *GC* gastric cancer

Table 3 Demographic pathological characteristics after PSM

Variables	Benign gastric lesion (*n* = 171)	GPL (*n* = 171)	GC (*n* = 171)	P
Age (years) Mean ± SD	70.78 ± 12.66	67.71 ± 9.19	65.20 ± 9.71	
> 45	167 (97.66)	168 (98.25)	162 (94.74)	0.135
≤ 45	4 (2.34)	3 (1.75)	9 (5.26)	
Sex				0.221
Male	137 (80.12)	147 (85.96)	128 (74.85)	
Female	34 (19.88)	24 (14.04)	43 (25.15)	
Digestive symptoms				< 0.001
With	121 (70.76)	163 (95.32)	60 (35.09)	
Without	50 (29.24)	8 (4.68)	111 (64.91)	
Education level				< 0.001
Bachelor's degree below	80 (46.78)	26 (15.20)	73 (42.69)	
Bachelor's degree or above	91 (53.22)	145 (84.80)	98 (57.31)	
Occupation				
Technical personnel, staff, or faculty	90 (52.63)	48 (28.07)	30 (17.54)	< 0.001
Worker	1 (0.58)	75 (43.86)	53 (30.99)	
Farmer	75 (43.86)	44 (25.73)	74 (43.27)	
Others	5 (2.92)	4 (2.34)	14 (8.19)	
Fresh vegetable, fruit, and white meat intake				< 0.001
Frequently	105 (61.40)	165 (96.49)	152 (88.89))	
Rarely	66 (38.60)	6 (3.51)	19 (11.11)	
Fried/barbecue/pickled food intake				< 0.001
Frequently	100 (58.48)	9 (5.26)	113 (66.08)	
Rarely	71 (41.52)	162 (94.74)	58 (33.92)	
High-salt diet and high-fat diet intake				< 0.001
Frequently	92 (53.80)	11 (6.43)	56 (32.75)	
Rarely	79 (46.20)	160 (93.57)	115 (67.25)	
Smoking				< 0.001
Current	87 (50.88)	16 (9.36)	50 (29.24)	
Never or former	84 (49.12)	155 (90.64)	121 (70.76)	
Drinking				< 0.001
Current	87 (50.88)	11 (6.43)	44 (25.73)	
Never or former	84 (49.12)	160 (93.57)	127 (74.27)	
Family history of GC				< 0.001
With	53 (30.99)	6 (3.51)	8 (4.68)	
Without	118 (69.01)	165 (96.49)	163 (95.32)	
Residence				0.674
Rural	103 (60.23)	96 (56.14)	103 (60.23)	
Urban	68 (39.77)	75 (43.86)	68 (39.77)	
Atrophic gastritis and/or intestinal metaplasia				< 0.001
with	17 (9.94)	122 (71.35)	137 (80.12)	
without	154 (90.06)	49 (28.65)	34 (19.88)	
***H. pylori* infection**				< 0.001
Positive	55 (32.16)	84 (49.12)	98 (57.31)	
Negative	116 (67.84)	87 (50.88)	73 (42.69)	

GPL gastric precancerous lesions, *GC* gastric cancer

Table 4 Stratification detection results of gastric precancerous lesions and gastric cancer

Variables	LGIN	HGIN	EGC	AGC	P
N (detection rate %)	138 (0.88)	121 (0.77)	36 (0.23)	182 (1.16)	< 0.001
Males (detection rate, %)	102 (1.29)*	99 (1.26)*	25 (0.32)#	137 (1.74)*	< 0.001
Females (detection rate, %)	36 (0.46)	22 (0.28)	11 (0.14)	45 (0.58)	< 0.001
Mean age (years)	66.91 ± 9.6	67.65 ± 8.79	68.86 ± 11.63	68.74 ± 10.69	< 0.001
Mean age of males (years)	67.38 ± 9.13	67.98 ± 8.66	70.8 ± 11.05	69.29 ± 9.67	< 0.001
Mean age of females (years)	66.35 ± 9.52	66.25 ± 9.43	64 ± 12.19	66.26 ± 13.83	< 0.001
H. pylori-positive (n, %)	55 (39.86)	60 (49.59)	17 (47.22)	105 (57.69)	0.018
H. pylori positive in males (n, %)	41 (39.81)	54 (53.46)	14 (56)	83 (60.58)	< 0.001
H. pylori positive in females (n, %)	14 (38.89)	7 (31.82)	3 (30)	22 (48.89)	< 0.001
Atrophic gastritis and/or intestinal metaplasia (n, %)	89 (63.77)	85 (70.25)	29 (80.56)	148 (81.32)	< 0.001
Non-cardia lesions (n, %)	111 (80.43)	106 (87.60)	28 (77.78)	131 (71.98)	< 0.001
Low differentiation (n, %)	-	-	2 (5.56)	72 (39.56)	< 0.001

* $P < 0.001$ vs. females. # $P < 0.05$ vs. females. $P < 0.001$ vs. the LGIN group. $P < 0.05$ vs. the LGIN group of the same sex $P < 0.05$

GPL gastric precancerous lesions, *GC* gastric cancer

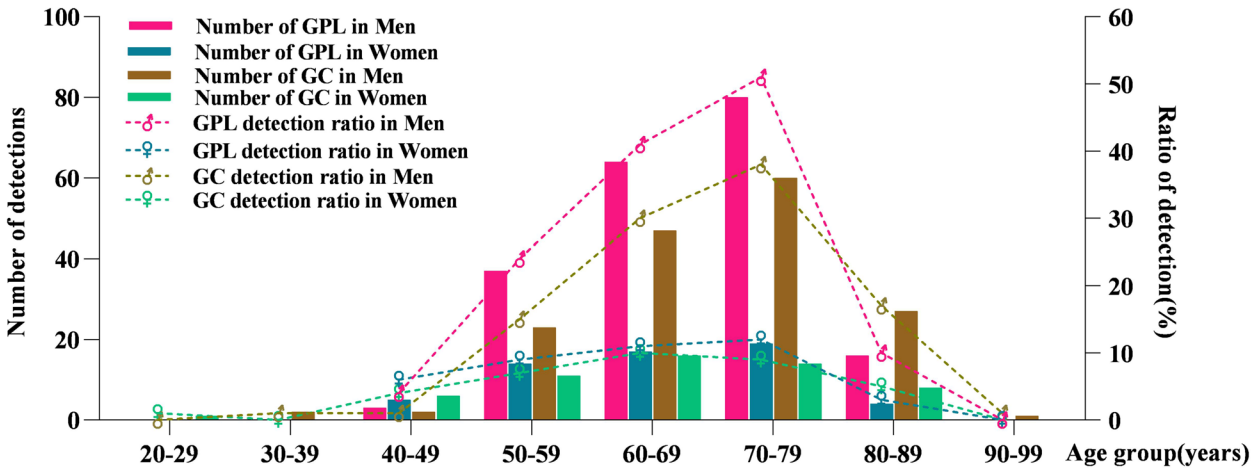

Fig. 2 Detection rate and age trends of gastric precancerous lesions (GPLs) and gastric cancer (GC) in different sexes. The red and brown columns represent the number of cases of GPLs and GC in males, while the blue and green columns represent the number of cases of GPL and GC in females, respectively. Dashed lines of the same color as the columns represent the detection rates of GPL and GC for males and females, respectively. The X-axis represents the age ranges, while the left Y-axis represents the specific number of detected cases. The right Y-axis represents the specific detection rate

Grouping by age range and detection rate of different pathological types

In patients with GPL, the detection rate peaked at 70–79 years old (99, 0.63%) in all patients and males (80, 0.51%) and females (19, 0.12%); the rates were higher in males than in females (all $P < 0.05$). In patients with GC, the detection rate peaked at 70–79 years (0.51%) in all patients and males (60, 0.38%) and females (14, 0.09%); the rates were higher in males than in females (all $P < 0.05$) (Fig. 2 and Supplementary Table 2).

The detection rates of LGIN and HGIN peaked at 70–79 years (55 cases, 0.35%, and 44 cases, 0.28%). The detection rates of EGC and AGC peaked at 70–79 years (13 cases, 0.08%, and 61 cases, 0.39%), with higher rates for AGC (0.39%) (all $P < 0.05$) (Fig. 3 and Supplementary Table 3).

Correlation between H. pylori infection rates and age in relation to GPL and GC

Figure 4 illustrates *H. pylori* infection rate by age group for benign lesions, GPLs, and GC. The infection rate of

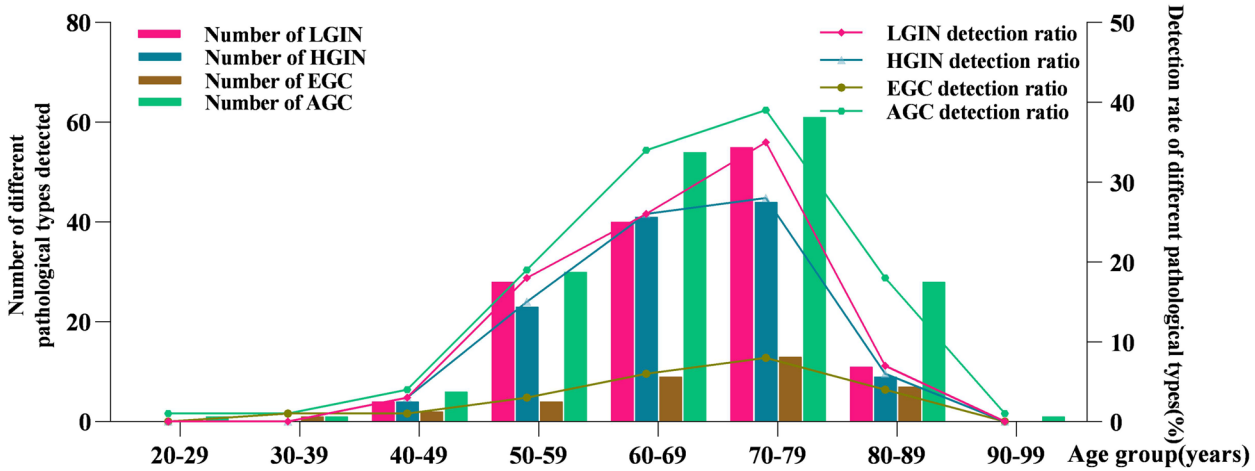

Fig. 3 Detection rate and age trend of different pathological types. The red, blue, brown, and green columns represent the number of detected cases of low-grade intraepithelial neoplasia (LGIN), high-grade intraepithelial neoplasia (HGIN), early gastric cancer (EGC), and advanced gastric cancer (AGC), respectively. The line with the same color as the column represents the detection rate of the corresponding pathological type. The X-axis represents the age ranges, while the left Y-axis represents the specific number of detected cases. The right Y-axis represents the specific detection rate

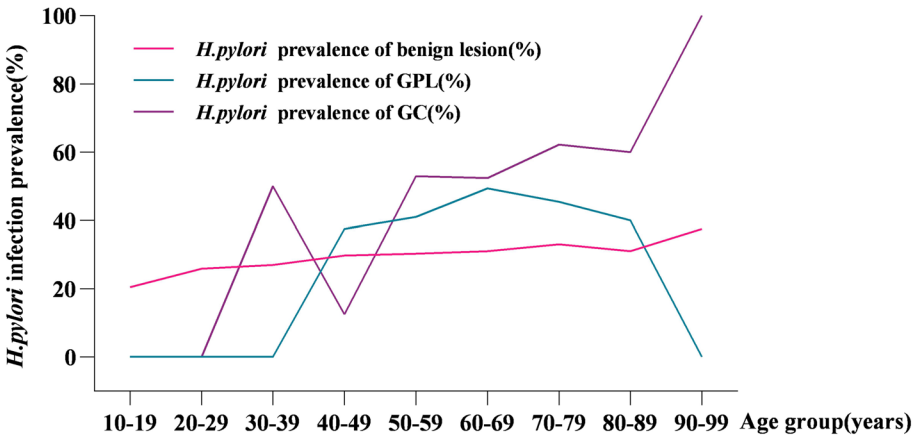

Fig. 4 Age trend of *Helicobacter pylori* infection rate. The red, blue, and purple lines represent the *H. pylori* infection rate in benign lesions, gastric precancerous lesions (GPLs), and gastric cancer (GC), respectively. The X-axis represents the age groups, while the Y-axis represents the specific values of *H. pylori* infection rate

H. pylori in benign lesions shows a gradual rise from 20% in younger individuals to around 30% by age 50–59, followed by a plateau. In contrast, the *H. pylori* infection rate in GPL remains low in younger ages but increases sharply after age 40, peaking at 40–50% by age 60–69. *H. pylori* infection rate in GC starts rising after age 30, peaking at 60% around age 50–59, with a second peak of nearly 80% in the 90–99 age group.

Factors associated with GPLs

Before PSM, the multivariable logistic regression analysis showed that male (OR = 3.156, 95% CI: 2.865–3.376, $P<$ 0.001), age (OR = 1.785, 95% CI: 1.703–1.876, $P<$ 0.001), fresh vegetable, fruit, and white meat intake (OR = 0.865, 95% CI: 0.506–2.061, $P=$ 0.029), high-salt diet and high-fat diet intake (OR = 1.906, 95% CI: 1.101–2.932, $P=$ 0.014), rural residence (OR = 2.682, 95% CI: 1.010–4.754, P = 0.040), *H. pylori* infection (OR = 2.022, 95% CI: 1.155–2.865, $P<$ 0.001) and atrophic gastritis and/or IM (OR = 4.875, 95% CI: 2.229–10.663, $P<$ 0.001) were independently associated with GPLs (Table 5).

After PSM, age (OR = 1.055, 95% CI: 1.016–1.095, $P=$ 0.005), digestive symptoms (OR = 4.346, 95% CI: 1.574–11.997, $P=$ 0.005), education below bachelor's

Table 5 Multivariable logistic regression analysis of GPLs before PSM

Variables	Univariable			Multivariable		
	OR	95% CI	P	OR	95% CI	P
Sex						
Female	Ref			Ref		
Male	3.489	2.601–4.681	< 0.001	3.156	2.865–3.376	< 0.001
Age	31.070	12.814–75.335	< 0.001	1.785	1.703–1.876	< 0.001
Digestive symptoms						
No	Ref			Ref		
Yes	1.007	1.002–1.013	0.004	0.724	7.503E + 80–0.000	0.876
Education level						
Bachelor's degree or above	Ref			Ref		
Below bachelor's degree	1.007	1.002–1.012	0.002	0.000	0.000–3.145E + 148	0.930
Occupation						
Technical personnel/staff/faculty/worker	Ref			Ref		
Farmer	1.816	1.416–2.330	< 0.001	0.000	0.000–4.457e + 286	0.769
Fresh vegetable, fruit, and white meat intake						
Rarely	Ref			Ref		
Frequently	0.553	0.378–0.809	0.002	0.865	0.506–2.061	0.029
Fried/barbecue/pickled food intake						
Rarely	Ref			Ref		
Frequently	4.358	3.323–5.716	< 0.001	3.979E + 23	0.000–1.555E + 288	0.861
High-salt diet and high-fat diet intake						
Rarely	Ref			Ref		
Frequently	1.754	1.333–2.310	< 0.001	1.906	1.101–2.932	0.014
Smoking						
Never or former	Ref			Ref		
Current	1.899	1.429–2.524	< 0.001	0.834	0.440–1.618	0.054
Drinking						
Never or former	Ref			Ref		
Current	1.653	1.232–2.217	< 0.001	0.851	0.379–1.702	0.057
Family history of GC						
No	Ref			Ref		
Yes	3.440	2.077–5.699	< 0.001	0.000	0.000–1.151E + 221	0.912
Residence						
Urban	Ref			Ref		
Rural	3.817	2.978–4.891	< 0.001	2.682	1.010–4.754	0.040
H. pylori infection						
No	Ref			Ref		
Yes	1.742	1.359–2.232	< 0.001	2.022	1.155–2.865	< 0.001
Atrophic gastritis and/or intestinal metaplasia						
No	Ref			Ref		
Yes	3.442	2.650–4.470	< 0.001	4.875	2.229–10.663	< 0.001

OR odds ratio, *CI* confidence interval, *GC* gastric cancer

degree (OR = 4.258, 95% CI: 1.322–13.713, $P = 0.015$), and atrophic gastritis and/or IM (OR = 21.425, 95% CI: 10.619–43.227, $P < 0.001$) were independently associated with GPLs (Table 6).

Factors associated with GC

Before PSM, male (OR = 2.021, 95% CI: 1.080–3.780, $P = 2.028$), age (OR = 1.201, 95% CI: 1.174–1.238, $P < 0.001$), digestive symptoms (OR = 2.256, 95% CI:

Table 6 Multivariable logistic regression analysis of GPLs after PSM

Variables	Univariable			Multivariable		
	OR	95% CI	P	OR	95% CI	P
Sex						
Female	Ref					
Male	1.520	0.858–2.693	0.151			
Age	0.975	0.956–0.994	0.011	1.055	1.016–1.095	0.005
Digestive symptoms						
No	Ref			Ref		
Yes	8.419	3.850–18.413	< 0.001	4.346	1.574–11.997	0.005
Education level						
Bachelor's degree or above	Ref			Ref		
Below Bachelor's degree	4.903	2.932–8.200	< 0.001	4.258	1.322–13.713	0.015
Occupation						
Technical personnel/staff/faculty/worker/others	Ref			Ref		
Farmer	0.443	0.281–0.700	< 0.001	0.380	0.131–1.098	0.074
Fresh vegetable, fruit, and white meat intake						
Rarely	Ref					
Frequently	0.058	0.024–0.138	< 0.001			
Fried/barbecue/pickled food intake						
Rarely	Ref					
Frequently	25.352	12.133–52.973	< 0.001			
High-salt diet and high-fat diet intake						
Rarely	Ref					
Frequently	16.939	8.574–33.465	< 0.001			
Smoking						
Never or former	Ref					
Current	10.033	5.531–18.202	< 0.001			
Drinking						
Never or former	Ref					
Current	15.065	7.628–29.752	< 0.001			
Family history of GC						
No	Ref					
Yes	12.352	5.140–29.680	< 0.001			
Residence						
Urban	Ref					
Rural	1.183	0.770–1.819	0.443			
H. pylori infection						
No	Ref			Ref		
Yes	2.036	1.313–3.159	0.002	1.444	0.783–2.662	0.239
Atrophic gastritis and/or intestinal metaplasia						
No	Ref			Ref		
Yes	22.555	12.370–41.124	< 0.001	21.425	10.619–43.227	< 0.001

OR odds ratio, *CI* confidence interval, *GC* gastric cancer

1.548–3.289, $P < 0.001$), bachelor degree below (OR = 4.792, 95% CI: 3.439–6.837, $P < 0.001$), farmer (OR = 1.039, 95% CI: 1.026–1.159, $P < 0.001$), fresh vegetable, fruit, and white meat intake (OR = 0.231, 95% CI: 0.141–0.379, $P < 0.001$), fried/barbecue/pickled food intake (OR = 6.781, 95% CI: 3.783–12.153, $P < 0.001$), high-salt diet and high-fat diet intake (OR = 6.781, 95% CI: 3.783–12.153, $P < 0.001$), rural residence (OR = 1.230, 95% CI: 1.121–1.437, $P < 0.001$), *H. pylori* infection (OR = 3.248, 95% CI: 2.357–4.477, $P < 0.001$)

Table 7 Multivariable logistic regression analysis of GC before PSM

Variables	Univariable			Multivariable		
	OR	95% CI	P	OR	95% CI	P
Sex						
Female	Ref			Ref		
Male	2.912	2.146–3.953	< 0.001	2.021	1.080–3.780	0.028
Age	16.005	7.919–32.550	< 0.001	1.201	1.174–1.238	< 0.001
Digestive symptoms						
No	Ref			Ref		
Yes	1.913	1.444–2.534	< 0.001	2.256	1.548–3.289	< 0.001
Education level						
Bachelor's degree or above	Ref			Ref		
Below bachelor's degree	1.614	1.250–2.153	< 0.001	4.792	3.439–6.837	< 0.001
Occupation						
Technical personnel/staff/faculty/worker	Ref			Ref		
Farmer	1.736	1.324–2.275	< 0.001	1.039	1.026–1.159	< 0.001
Fresh vegetable, fruit, and white meat intake						
Rarely	Ref			Ref		
Frequently	0.532	0.354–0.800	0.005	0.231	0.141–0.3793	< 0.001
Fried/barbecue/pickled food intake						
Rarely	Ref			Ref		
Frequently	4.987	3.740–6.649	< 0.001	6.781	3.783–12.153	< 0.001
High-salt diet and high-fat diet intake						
Rarely	Ref			Ref		
Frequently	2.110	1.581–2.815	< 0.001	4.374	2.363–8.097	< 0.001
Smoking						
Never or former	Ref			Ref		
Current smoker	2.103	1.555–2.845	< 0.001	0.000	2.829E + 12–0.000	0.995
Drinking						
Never or former	Ref			Ref		
Current	1.845	1.352–2.517	< 0.001	0.000	0.000–0.000	0.995
Family history of GC						
No	Ref			Ref		
Yes	3.879	2.303–6.534	< 0.001	0.404	0.233–0.774	0.520
Residence						
Urban	Ref			Ref		
Rural	4.349	3.312–5.712	< 0.001	1.230	1.121–1.437	< 0.001
H. pylori infection						
No	Ref			Ref		
Yes	2.719	2.077–3.559	< 0.001	3.248	2.357–4.477	< 0.001
Atrophic gastritis and/or intestinal metaplasia (with)						
No	Ref			Ref		
Yes	7.259	5.160–10.211	< 0.001	4.875	2.636–9.016	< 0.001

OR odds ratio, *CI* confidence interval, *GC* gastric cancer

and atrophic gastritis and/or IM (OR = 4.875, 95% CI: 2.636–9.016, $P < 0.001$) were independently associated with GCs (Table 7).

After PSM, the presence of digestive symptoms (OR = 11.894, 95% CI: 5.192–27.249, $P < 0.001$), frequently consuming high-salt diet and high-fat diet (OR = 6.658, 95% CI: 2.451–18.080, $P < 0.001$), a family history of GC (OR = 6.283, 95% CI: 1.476–26.914, $P = 0.013$), *H. pylori* infection (OR = 3..768, 95% CI: 1.814–7.825, $P < 0.001$), and atrophic gastritis and/or IM (OR = 34.286,

Table 8 Multivariable logistic regression analysis of GC after PSM

Variables	Univariable			Multivariable		
	OR	95% CI	P	OR	95% CI	P
Sex						
Female	Ref					
Male	1.354	0.813–2.255	0.245			
Age	0.957	0.938–0.976	< 0.001	0.970	0.934–1.007	0.108
Digestive symptoms						
No	Ref			Ref		
Yes	4.477	2.840–7.058	< 0.001	11.894	5.192–27.249	< 0.001
Education level						
Bachelor's degree or above	Ref					
Below Bachelor's degree	1.180	0.770–1.808	0.447			
Occupation						
Technical personnel/staff/faculty/ Worker/Others	Ref					
Farmer	0.976	0.637–1.497	0.913			
Fresh vegetable, fruit, and white meat intake						
Rarely	Ref			Ref		
Frequently	0.199	0.113–0.351	< 0.001	0.378	0.107–1.340	0.132
Fried/barbecue/pickled food intake						
Rarely	Ref					
Frequently	0.723	0.466–1.121	0.147			
High-salt diet and high-fat diet intake						
Rarely	Ref			Ref		
Frequently	2.392	1.542–3.708	< 0.001	6.658	2.451–18.080	< 0.001
Smoking						
Never or former	Ref					
Current	2.506	1.605–3.913	< 0.001			
Drinking						
Never or former	Ref					
Current	2.989	1.896–4.714	< 0.001			
Family history of GC						
No	Ref			Ref		
Yes	9.151	4.194–19.969	< 0.001	6.283	1.476–26.914	0.013
H. pylori infection						
No	Ref			Ref		
Yes	2.831	1.821–4.402	< 0.001	3.768	1.814–7.825	< 0.001
Atrophic gastritis and/or intestinal metaplasia						
No	Ref			Ref		
Yes	36.502	19.517–68.266	< 0.001	34.286	15.732–74.721	< 0.001

OR odds ratio, *CI* confidence interval, *GC* gastric cancer

95% CI: 15.732–74.721, $P < 0.001$) were independently associated with GC (Table 8).

Discussion

The findings of this study revealed high detection rates of GPLs and GCs in Nanjing City, with higher rates observed in males compared to females, which increased with age. The rates of *H. pylori* infection increased from patients with benign lesions to those with GPLs and GC.

Many GPLs serve as direct precursors of GC [6]. The detection rates of GPLs in China between 2011 and 2019 ranged from 0.04% to 4.06%, showing significant sex, age, and regional differences [10, 14]. Generally, areas with a high incidence of GC tend to exhibit higher GPL

detection rates, with rates of 1.65% and 1.39% recorded in high and low-incidence areas, respectively. In the present study, the detection rates for LGIN, HGIN, EGC, and AGC were 0.88%, 0.77%, 0.23%, and 1.16%, respectively, falling within the reported range for China and categorized at a moderate level [10]. Notably, the detection rates for GPL, LGIN, and HGIN were consistently higher in males than females, reflecting the sex-specific incidence pattern observed in GC [10, 15] and aligning with the sex distribution characteristics of GC incidence in China.

Upon grouping by sex, age, and pathological grade, a positive correlation between detection rates and age emerged for both GPL and GC, as well as LGIN, HGIN, EGC, and AGC. This age-related increase indicates that environmental exposures accumulate with age, contributing to the multifactorial and multi-stage mechanisms that drive the occurrence and progression of GC. Notably, a study suggested increased tumor markers during GC tumorigenesis from LGIN to HGIN, sharing expression profiles with EGC [16], providing a potential explanation for the results observed here. The lack of a recognized standard for the starting and ending age of GC screening prompts careful consideration of international and Chinese guidelines, combined with the local age distribution of GPL and GC. While most Asian countries set the starting age at 40–45 years [10, 17], the Japanese GC screening guidelines (2018) recommend starting at 50 years [18]. The detection rates of 447 cases of GPL and GC were low before the age of 40, rapidly increasing from the age of 40, reaching a peak between 70 and 79. The upper age limit for cancer screening remains a topic of debate, and this study indicates a certain detection rate even in the age group of 80–89 years, differing slightly from the recommended "75 years old or life expectancy < 5 years" in the Chinese guidelines [10, 14]. Despite the global decline in the incidence and mortality of GC, the increase in life expectancy and the continuous aging of the population may lead to a rise in the absolute number of GC patients and deaths [1].

The overall *H. pylori* infection rate among the 15,668 patients was 32%, indicating a notable regional disparity compared to the national average (40.66%) and the specific rate reported in Jiangsu Province (50.0%) [19]. The lower infection rate in the region may be attributed to improved economic conditions, increased income levels, and enhanced health service accessibility. Notably, the infection rate of *H. pylori* exhibited an upward trend with age. Moreover, the *H. pylori* infection rate in populations with GPLs and GC exceeded that of individuals with benign lesions. These results also highlight the need to improve *H. pylori* control.

Over the past 50 years, the global incidence and mortality of GC have steadily declined [1], accompanied by a continuous decrease in *H. pylori* infection rate from 60.5% before 2000 to the current 40.66% in China [20]. The attributable risk of *H. pylori* infection for GC ranges from 75 to 88% [21], and compelling evidence supports the significant reduction in GC incidence through *H. pylori* eradication in healthy individuals, those with atrophic gastritis, and those with a family history of GC [22]. *H. pylori* screening can potentially prevent one case of GC out of every 4–6 screened cases [23], establishing *H. pylori* detection and eradication as the most effective primary prevention strategy for GC. Furthermore, considering the increasing *H. pylori* infection with age, early eradication (for example, before atrophy and IM occur) becomes increasingly beneficial [24].

EOGC is defined as GC occurring under the age of 50 (although definitions vary, with some definitions setting it at 45 years) [9, 25], with estimates predicting a significant rise globally from 2020 to 2035, particularly in China and South Korea [26]. Still, it was suggested that EOGC has a different pathogenesis compared with GC in older populations [11]. The etiology of EOGC among young people may be influenced by factors beyond *H. pylori*, such as a sedentary lifestyle, dietary patterns, obesity, gastroesophageal reflux, race [27], smoking, alcohol consumption, and changes in the gastric microbiota [28, 29].

In this study, before PSM, sex, age, digestive symptoms, lower education, farmer occupation, rural residence, unhealthy eating habits, *H. pylori* infection, cardia lesions, atrophic gastritis and/or IM were risk factors of GCs, while fresh vegetable, fruit, and white meat intake was a protective factor against GCs. After PSM, digestive symptoms, frequently consuming a high-salt diet and high-fat diet, a family history of GC, *H. pylori* infection, and atrophic gastritis and/or IM were risk factors for GC. Those factors are known to participate in the pathogenesis of GC. Indeed, in addition to age, sex, and *H. pylori* infection discussed above, a family history of GC significantly increases the risk of GC in Asian populations [30]. Although the infection rate of *H. pylori* in GC patients was lower (55.5%) than in the literature (the most recent study on the Chinese population reported an *H. pylori* infection rate of 93.33% in patients with GC [31], the rate of infection in patients with AGC was still higher than in the general population, as well as in patients with LGIN, HGIN, and EGC. This lower infection rate may be related to 1) prior eradication treatment for *H. pylori*, 2) the overall lower *H. pylori* infection rate in the population of this region (23.1%), 3) severe gastric mucosal atrophy or IM can cause false-negative RUT and UBT, and 4) the presence of risk factors other than GC. In addition, it

is consistent with the finding that global *H. pylori* infection rates and GC incidence are significantly decreasing [32]. In this local area, individuals with a family history of GC had a significantly higher risk than those with benign lesions, consistent with the literature [33, 34]. Xu et al. identified that a high genetic risk for GC may be mitigated through the treatment of *H. pylori*, indicating that primary prevention strategies could be customized according to genetic risk factors for enhanced efficacy in prevention efforts [34]. Several studies have shown the impact of diet on GC pathogenesis [35–37]. Unhealthy diets or "Western diets" are associated with the development of GC, including red and processed meats, trans fatty acids, and high sodium or salt intake, and increase the risk of CAG and IM. On the other hand, a healthy diet such as fresh vegetables, fruits, and whole grains may have a preventive effect on GPLs and GC. Smoking and alcohol consumption are recognized as risk factors for GC, with mechanisms including activation of nicotinic acetylcholine receptors and ethanol-induced mucosal inflammation [38, 39]. In the present study, however, smoking and alcohol consumption were not independently associated with GC in the multivariable analysis, although they showed significant associations in the univariable analyses. Several factors may explain this discrepancy. First, the relatively low rate of smoking in the study population (15%) could have reduced the statistical power to detect an independent association. Second, the definition of smoking (i.e., more than 10 cigarettes per week and quitting for less than one year) may have categorized light smokers alongside more heavy smokers, possibly weakening the observed relationship. The presence of digestive symptoms should prompt patients to consider the possibility of gastric disease and should prompt consultation [40, 41]. Socioeconomic status (including education, income, and occupation) is a major determinant of health literacy [41]. Large disparities in healthcare are observed between rural and urban China, possibly contributing to GC occurrence [42]. With the progression of the disease, the proportion of lesions in the cardia area gradually increases. Such results could be attributed to age. When a certain age is reached, the rate of *H. pylori* infection tends to decrease, so the proportion of GC in the uncolonized area of *H. pylori* (cardia) increases. With the continuous expansion of eradication indications, the rate of *H. pylori* infection is rapidly decreasing worldwide, so the GC of non-*H. pylori* infection (such as the cardia area) is increasing, as observed elsewhere [43, 44].

Recent studies have shown that the risk of GC increases with the severity of the histopathological aspects of the gastric mucosa (e.g., CAG and/or IM) and with age [45]. The present study is consistent with the literature, before and after PSM. In recent years, the role of gastric microbiota in the development of GC has attracted attention, and recent studies suggest that *H. pylori* infection can induce significant dysbiosis in the stomach and play a key role in promoting the development of GC by interacting or synergizing with other microorganisms and the host cells [29]. Nevertheless, at present, a significant proportion of individuals in China still have an insufficient understanding of the risk factors for GC, and they do not pay enough attention and are less willing to participate in screening [46]. In China, most GCs are diagnosed by endoscopy, and due to the large population, the shortage of endoscopists, the experience of endoscopists, and the lack of public attention to screening, endoscopy-based EGC screening is not yet popular, which may lead to a low diagnostic rate of EGC. In the future, it will be necessary to improve the identification of CAG and IM to increase the diagnostic rate of EGC. In addition, more than 70% of the risk factors of GC can be modified [47]. Therefore, targeted education, questionnaire screening, controllable risk factor intervention, individualized management strategies, and awareness and participation of high-risk groups for GC will be of great significance for the primary prevention of GC and the reduction of GC incidence. There are promising prospects for regulating microbial imbalances, including *H. pylori*, and developing intragastric microbial markers for the prevention, diagnosis, management, and prognosis prediction of GC.

This study has acknowledged limitations. Its retrospective design limited data to chart records, potentially leading to incomplete data and limiting comprehensive risk factor analysis for GC and GPLs, including past infection or more detailed information about occupation and serodiagnosis results. Future research should prioritize prospective studies with larger datasets. It was performed in a single geographical area in China. The single geographical area of patient recruitment limits generalizability, although the study focused specifically on GPLs and GC in Nanjing. In addition, biases due to local practices and policies are possible. The relatively small number of cases within the age ranges of 20–49 and 90–99 may introduce bias into the analysis results for these groups, highlighting a need for larger sample sizes in future studies. Nevertheless, a PSM was performed to balance the groups, and similar risk factors were observed before and after PSM. The low detection rate of EGC highlights the need for improvement in research and screening efforts, limiting the generalizability of that patient population. Further investigation into factors influencing EGC detection rates and strategies for enhancing early diagnosis is essential.

Conclusions

The present multicenter population-based study in Nanjing City provides valuable insights into the epidemiological characteristics of GPLs, GC, and *H. pylori* infection. These findings will serve as a solid scientific foundation for public health policies in Nanjing and other high-incidence GC areas.

Abbreviations

GC	Gastric cancer
GPLs	Gastric precancerous lesions
LGIN	Low-grade IN
HGIN	High-grade IN
RUT	Rapid urease test
IQR	Interquartile range

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12879-025-11147-3.

Supplementary Material 1.

Supplementary Material 2.

Acknowledgements

None.

Authors' contributions

Integrity and accuracy: Niu Chunyan ensured the overall content's integrity and accuracy, coordinated the research implementation, and revised the paper. Conception and design: Niu Chunyan conceived and designed the study. Drafting of the manuscript: Niu Chunyan and Yongqiang Song were responsible for drafting the manuscript. Data analysis, chart-making, and creation: Zhang Qiang. Research performance and data collection: Chen Yue, Shi Yongqiang, Song Yongqiang, Wang Hui, Wu Xinguo, Wang Xiaoping, Zhao Xiangyang, Bu Yongdan, Li Jijin, Tao Tao, Wu Jinhua Wu, Xue Changlin Xue, and Fuyu Zhang conducted the research and collected data. Pathological diagnosis and quality control of pathology: Han Chunrong and Yuan Juan were responsible for pathological diagnosis and quality control of pathology. All authors had full access to the data used to generate the results, and they critically reviewed and approved the manuscript for publication. All authors had full access to the data used to generate the results, and they critically reviewed and approved the manuscript for publication.

Funding

This work was supported by the 2022 Nanjing Health Science and Technology Development Special Fund Project (YKK22240) and the Project of Modern Hospital Management and Development Institute, Nanjing University, and the Aid project of Nanjing Drum Tower Hospital Health, Education & Research Foundation (No. NDYG2023037).

Data availability

All data generated or analysed during this study are included in this published article and its supplementary information files.

Declarations

Ethics approval and consent to participate

The study was approved by the Medical Ethics Committee of Nanjing Lishui People's Hospital (as the lead center) (approval #2023 KY0727-02) and by the Ethics Committee at each participating center. The requirement for individual informed consent was waived by the committees because of the retrospective nature of the study. This study was conducted in accordance with the Declaration of Helsinki.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Author details

[1]Department of Gastroenterology, Nanjing Lishui People's Hospital (Zhongda Hospital Lishui Branch, Southeast University), Nanjing 211200, China. [2]Department of Gastroenterology, Yancheng Third People's Hospital (The Yancheng School of Clinical Medicine of Nanjing Medical University), Yancheng 224000, China. [3]Dongping Street Health Center in Nanjing Lishui District, Nanjing 211212, China. [4]Jingqiao Central Health Center in Nanjing Lishui District, Nanjing 211224, China. [5]Honglan Street Health Center in Nanjing Lishui District, Nanjing 211219, China. [6]Shiqiu Central Health Center in Nanjing Lishui District, Nanjing 211222, China. [7]Baima Central Health Center in Nanjing Lishui District, Nanjing 211225, China. [8]Yongyang Street Community Health Service Center in Nanjing Lishui District, Nanjing 211299, China. [9]Department of Pathology, Nanjing Lishui People's Hospital (Zhongda Hospital Lishui Branch, Southeast University), Nanjing 211200, China.

Received: 5 September 2024 Accepted: 20 May 2025
Published online: 27 May 2025

References

1. Bray F, Laversanne M, Sung H, et al. Global cancer statistics 2022: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA Cancer J Clin. 2024;74:229–63.
2. Wang J, Yang Y, Geng Y. Trend analysis of incidence, morbidity and mortality of gastric cancer in China 1990–2017. Chron Dis Prev Control Chin. 2020;28:321–32.
3. Triantafillidis JK, Georgiou K, Konstadoulakis MM, Papalois AE. Early-onset gastrointestinal cancer: an epidemiological reality with great significance and implications. World J Gastrointest Oncol. 2024;16:583–97.
4. Ji YT, Liu SW, Zhang YM, et al. Comparison of the latest cancer statistics, cancer epidemic trends and determinants between China and the United States. Zhonghua Zhong Liu Za Zhi. 2024;46:646–56.
5. Gullo I, Grillo F, Mastracci L, et al. Precancerous lesions of the stomach, gastric cancer and hereditary gastric cancer syndromes. Pathologica. 2020;112:166–85.
6. Conti CB, Agnesi S, Scaravaglio M, et al. Early gastric cancer: update on prevention, diagnosis and treatment. Int J Environ Res Public Health. 2023;20:2149.
7. de Vries AC, van Grieken NC, Looman CW, et al. Gastric cancer risk in patients with premalignant gastric lesions: a nationwide cohort study in the Netherlands. Gastroenterology. 2008;134:945–52.
8. Luu XQ, Lee K, Jun JK, et al. Effect of gastric cancer screening on long-term survival of gastric cancer patients: results of Korean national cancer screening program. J Gastroenterol. 2022;57:464–75.
9. Ben-Aharon I, van Laarhoven HWM, Fontana E, et al. Early-onset cancer in the gastrointestinal tract is on the rise-evidence and implications. Cancer Discov. 2023;13:538–51.
10. He J, Chen W, Li Z. Expert Group of China Guideline for the Screening, Early Detection and Early Treatment of Gastric Cancer; Working Group of China Guideline for the Screening, Early Detection and Early Treatment of Gastric Cancer. China Guideline for the Screening, Early Detection and Early Treatment of Gastric Cancer (2022, Beijing). China Cancer. 2022;31:488-527.
11. Ning FL, Zhang NN, Zhao ZM, et al. Global, regional, and national burdens with temporal trends of early-, intermediate-, and later-onset gastric cancer from 1990 to 2019 and predictions up to 2035. Cancers (Basel). 2022;14:5417.
12. Nagtegaal ID, Odze RD, Klimstra D, et al. The 2019 WHO classification of tumours of the digestive system. Histopathology. 2020;76:182–8.
13. Group of Digestive Diseases of Chinese Society of Pathology. Consensus for diagnostic pathology in biopsies of chronic gastritis and epithelial neoplasms. Chin J Pathol. 2017;46:289–93.

14. Wang FH, Shen L, Li J, et al. The Chinese Society of Clinical Oncology (CSCO): clinical guidelines for the diagnosis and treatment of gastric cancer. Cancer Commun (Lond). 2019;39:10.
15. Luan X, Zhao L, Zhang F, et al. Sex disparity, prediagnosis lifestyle factors, and long-term survival of gastric cancer: a multicenter cohort study from China. BMC Cancer. 2024;24:1149.
16. Zhang Y, Wu X, Zhang C, et al. Dissecting expression profiles of gastric precancerous lesions and early gastric cancer to explore crucial molecules in intestinal-type gastric cancer tumorigenesis. J Pathol. 2020;251:135–46.
17. Xu J, Ma J, Chen J, et al. No genetic causal association between iron status and osteoporosis: a two-sample Mendelian randomization. Front Endocrinol (Lausanne). 2022;13: 996244.
18. Hamashima C. Update version of the Japanese Guidelines for Gastric Cancer Screening. Jpn J Clin Oncol. 2018;48:673–83.
19. Zhou XZ, Lyu NH, Zhu HY, et al. Large-scale, national, family-based epidemiological study on Helicobacter pylori infection in China: the time to change practice for related disease prevention. Gut. 2023;72:855–69.
20. Ren S, Cai P, Liu Y, et al. Prevalence of Helicobacter pylori infection in China: a systematic review and meta-analysis. J Gastroenterol Hepatol. 2022;37:464–70.
21. Correa P, Piazuelo MB. The gastric precancerous cascade. J Dig Dis. 2012;13:2–9.
22. Choi IJ, Kim CG, Lee JY, et al. Family history of gastric cancer and helicobacter pylori treatment. N Engl J Med. 2020;382:427–36.
23. Yang K, Lu L, Liu H, et al. A comprehensive update on early gastric cancer: defining terms, etiology, and alarming risk factors. Expert Rev Gastroenterol Hepatol. 2021;15:255–73.
24. Thrift AP, Wenker TN, El-Serag HB. Global burden of gastric cancer: epidemiological trends, risk factors, screening and prevention. Nat Rev Clin Oncol. 2023;20:338–49.
25. Mazurek M, Szewc M, Sitarz MZ, Dudzinska E, Sitarz R. Gastric cancer: an up-to-date review with new insights into early-onset gastric cancer. Cancers (Basel). 2024;16:3163.
26. Kono Y, Kanzaki H, Iwamuro M, et al. Reality of gastric cancer in young patients: the importance and difficulty of the early diagnosis. Prevention and Treatment Acta Med Okayama. 2020;74:461–6.
27. Tavakkoli A, Pruitt SL, Hoang AQ, et al. Ethnic disparities in early-onset gastric cancer: a population-based study in Texas and California. Cancer Epidemiol Biomarkers Prev. 2022;31:1710–9.
28. Ugai T, Sasamoto N, Lee HY, et al. Is early-onset cancer an emerging global epidemic? Current evidence and future implications. Nat Rev Clin Oncol. 2022;19:656–73.
29. Zeng R, Gou H, Lau HCH, Yu J. Stomach microbiota in gastric cancer development and clinical implications. Gut. 2024;73:2062–73.
30. Huang D, Song M, Abe SK, et al. Family history and gastric cancer incidence and mortality in Asia: a pooled analysis of more than half a million participants. Gastric Cancer. 2024;27:701–13.
31. Zhao W, Han Y, Xiao Y, et al. Relationship between Helicobacter pylori infection and digestive tract diseases and analysis of risk factors: a cross-sectional study based on 3867 Chinese patients. Aging (Albany NY). 2024;16:11917–25.
32. Chen YC, Malfertheiner P, Yu HT, et al. Global prevalence of helicobacter pylori infection and incidence of gastric cancer between 1980 and 2022. Gastroenterology. 2024;166:605–19.
33. Lim SH, Kwon JW, Kim N, et al. Prevalence and risk factors of Helicobacter pylori infection in Korea: nationwide multicenter study over 13 years. BMC Gastroenterol. 2013;13:104.
34. Xu HM, Han Y, Liu ZC, et al. Helicobacter pylori treatment and gastric cancer risk among individuals with high genetic risk for gastric cancer. JAMA Netw Open. 2024;7: e2413708.
35. Pu K, Feng Y, Tang Q, Yang G, Xu C. Review of dietary patterns and gastric cancer risk: epidemiology and biological evidence. Front Oncol. 2024;14: 1333623.
36. Takasu A, Gotoda T, Suzuki S, et al. Daily diet and nutrition risk factors for gastric cancer incidence in a Japanese population. Gut Liver. 2024;18:602–10.
37. Cheng W, Lin X, Wang T, et al. Healthy plant-based diet might be inversely associated with gastric precancerous lesions: new evidence from a case-control study based on dietary pattern and fecal metabolic profiling. Int J Food Sci Nutr. 2024;75:102–18.
38. Hatta W, Koike T, Asano N, et al. The impact of tobacco smoking and alcohol consumption on the development of gastric cancers. Int J Mol Sci. 2024;25:7854.
39. Kang SJ, Shin CM, Han K, et al. Impact of smoking and alcohol consumption on early-onset gastric cancer development in young Koreans: a population-based study. J Gastric Cancer. 2024;24:145–58.
40. Black CJ, Paine PA, Agrawal A, et al. British Society of Gastroenterology guidelines on the management of functional dyspepsia. Gut. 2022;71:1697–723.
41. Li Y, Jiang F, Wu CY, Leung WK. Prevalence and temporal trend of gastric preneoplastic lesions in Asia: a systematic review with meta-analysis. United European Gastroenterol J. 2024;12:139–51.
42. Guo B, Xie X, Wu Q, et al. Inequality in the health services utilization in rural and urban china: a horizontal inequality analysis. Medicine (Baltimore). 2020;99:e18625.
43. He F, Wang S, Zheng R, et al. Trends of gastric cancer burdens attributable to risk factors in China from 2000 to 2050. Lancet Reg Health West Pac. 2024;44:101003.
44. Iwu CD, Iwu-Jaja CJ. Gastric cancer epidemiology: current trend and future direction. Hygiene. 2023;3:256–68.
45. Liu H, Song S, Geng X, et al. Gastric mucosal status and risk of gastric cancer in high-risk individuals: a population-based, multicenter prospective study in China. Cancer Med. 2024;13:e70331.
46. Wang Q, He XC, Geng LX, et al. Public awareness of gastric cancer risk factors and screening behaviours in Shijiazhuang, China: a community-based survey. PLoS ONE. 2024;19:e0311491.
47. Ilic M, Ilic I. Epidemiology of stomach cancer. World J Gastroenterol. 2022;28:1187–203.

Publisher's Note