

Epidemiology Note

Estimation of lifetime cumulative incidence and mortality risk of gastric cancer

Yukari Taniyama¹, Kota Katanoda^{2,*}, Hadrien Charvat³, Megumi Hori², Yuko Ohno¹, Shizuka Sasazuki³, and Shoichiro Tsugane⁴

¹Department of Mathematical Health Science, Graduate School of Medicine, Osaka University, Osaka, ²Division of Cancer Statistics Integration, Center for Cancer Control and Information Services, National Cancer Center, ³Division of Prevention, and ⁴Center for Public Health Sciences, National Cancer, Tokyo, Japan

*For reprints and all correspondence: Kota Katanoda, Center for Cancer Control and Information Services, National Cancer Center, 5-1-1 Tsukiji Chuo-ku Tokyo 104-0045 Japan. E-mail: kkatanod@ncc.go.jp

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Abstract

Objective: To estimate cumulative incidence and mortality risk for gastric cancer by risk category.

Methods: Risk was classified into four types according to the presence/absence of *Helicobacter pylori* infection and chronic atrophic gastritis: in order of lowest to highest risk, Group A: *H. pylori* (–) and atrophic gastritis(–); Group B: *H. pylori*(+) and atrophic gastritis(–); Group C: *H. pylori*(+) and atrophic gastritis(+); and, Group D: *H. pylori*(–) and atrophic gastritis(+). We used vital statistics for the crude all-cause and crude gastric cancer mortality rates in 2011 and data from population-based cancer registries (the Monitoring of Cancer Incidence in Japan) for gastric cancer incidence in 2011. For relative risk and prevalence, we used the results of a meta-analysis integrating previous studies and data from the Japan Public Health Center-based Prospective Study for the Next Generation, respectively (baseline survey 2011–16). We calculated the crude incidence and mortality rates and estimated the cumulative risk using a life-table method.

Results: The estimated lifetime cumulative incidence risk was 11.4% for men and 5.7% for women. The estimated risk for Groups A, B, C and D was 2.4%, 10.8%, 26.7% and 35.5% for men, and 1.2%, 5.5%, 13.5% and 18.0% for women, respectively. Similarly, the estimated lifetime cumulative mortality risk was 3.9% for men and 1.8% for women. The estimated risk of mortality for Groups A, B, C and D was 0.8%, 3.6%, 9.0% and 12.0% for men, and 0.4%, 1.7%, 4.2% and 5.7% for women, respectively.

Conclusions: Our results may be useful for designing individually tailored prevention programs.

Key words: *Helicobacter pylori*, incidence, mortality, risk, stomach neoplasms

Introduction

Cancer is the top cause of death among Japanese people. Half of Japanese people will develop cancer over their lifetime, and one in four men and one in six women will die from cancer (1,2). While the age-standardized incidence and mortality rates of gastric cancer are decreasing for both men and women, gastric cancer has the highest incidence for men and the third-highest incidence for women of any cancer. Furthermore, the gastric cancer mortality is second-highest for men and third-highest for women of any cancer (1).

Infection with *Helicobacter pylori* (*H. pylori*), excessive sodium intake, and smoking are established risk factors for gastric cancer (3–5).

The presence or absence of risk factors that are strongly associated with gastric cancer, such as *H. pylori* infection, greatly affects individual disease risk, and such information is necessary for tailored disease prevention. Individually tailored disease prevention refers to an individual engaging in health and medical behavior that is dependent on their own disease risk, or being provided with health and medical services in accordance with their individual

disease risk. When devising individual preventive measures, it is vital to quantify disease risk in accordance with the risk factors that apply to the individual. While there have been attempts to calculate cumulative disease risk by risk factors for gastric, colorectal and liver cancer, these methods used data from a single cohort study (6–8). As results are dependent on the cohort population that was used, bias may have arisen from the entire population. An alternative way is to combine data from descriptive epidemiology, which involved constantly monitoring disease incidence risk in the entire population, with data from analytical epidemiology, which involved quantifying disease incidence risk ratios by individual risk factors. This allows us to calculate disease risk depending on the presence of risk factors in a population for which more applicable extrapolation would be possible than those of previous studies.

The aim of this study was to calculate the cumulative incidence and mortality risk for gastric cancer by four risk classification types based on the presence/absence of *H. pylori* infection and chronic atrophic gastritis, by combining data from population-based surveillance and cohort studies.

Methods

Risk category

Risk category was classified into four groups (A, B, C and D) according to the presence/absence of *H. pylori* infection and chronic atrophic gastritis (9). *H. pylori* infection was determined by serum levels of IgG antibodies to *H. pylori*, and atrophic gastritis was diagnosed by serum levels of pepsinogen I and pepsinogen II (6,10–12).

The risk was lowest for Group A (*H. pylori* infection: negative, atrophic gastritis: negative), followed by Group B (*H. pylori* infection: positive, atrophic gastritis: negative) and Group C (*H. pylori* infection: positive, atrophic gastritis: positive), with the highest risk associated with Group D (*H. pylori* infection: negative, atrophic gastritis: positive). As *H. pylori* infection is known to disappear with the progression of atrophic gastritis, the highest risk is associated with individuals with atrophic gastritis but not *H. pylori* infection.

Data source

Vital statistics were used to calculate the crude all-cause and crude gastric cancer mortality rates (13). For the gastric cancer crude incidence rate, we used the national estimates of the Monitoring of Cancer Incidence in Japan data (14). All data were from 2011 (13,14). Group-specific relative risk estimates were obtained by meta-analysis of four previously published studies conducted in the Japanese population (6,10–12). Details of four previous studies are shown in Table 1. Meta-analysis of risk measures pertaining to multiple risk groups should take into account the fact that group-specific relative risk estimated in each study are correlated. Consequently, we performed a multivariate meta-analysis using the methodology described in Woods et al. (15). Heterogeneity between studies was accounted for by the inclusion of a random effect. Prevalence for each risk group was determined based on the Japan Public Health Center-based Prospective Study for the Next Generation data, as shown in Table 2 (baseline survey 2011–16) (16). Life-table method is the way to accumulate age-specific crude incidence and mortality rates at particular time. Considering the consistency with the property of the life-

Table 1. Summary of characteristics for four previous studies

Reference		Study period	Study subjects					No. of subjects by risk category ^a				No. of incidence cases by risk category ^a			
Author	Ref. (Year)		Sex	Ranged age	Event	A	B	C	D	A	B	C	D		
Watabe	10 (2005)	1995–97 ^b	Men and women	≥39	Incidence	3324	2134	1082	443	7	6	18	12		
Mizuno	11 (2010)	1987–96	Men and women	≥35	Incidence	642	1094	1054	69	2	15	41	3		
Yoshida	12 (2013)	1994–2011	Men	40–59	Incidence	965	2328	1329	33	2	37	44	4		
Charvat	6 (2016)	1993–2009	Men and women	40–69	Incidence	5408	5.608	7417	595	12	104	272	24		

^aGroup A: *H. pylori* (HP) negative [–]/atrophic gastritis (AG) negative [–], Group B: HP positive [+/AG [–], Group C: HP [+/AG [+], Group D: HP [–]/AG [+].

^bThe period was for registration of the study subjects. The mean of duration of follow up was reported 4.7 years in Watabe et al. (10).

Table 2. Distribution by age for each risk group (Unit %)

Risk category ^a	Distribution by age ^b									
	0–9	10–19	20–29	30–39	40–49	50–59	60–69	70–74	75+	
A	99	95	89.5	85.5	80	65	55	50	50	
B	1	4	8	11	15	20	20	15	15	
C	0	1	2	3	4	13	20	25	25	
D	0	0	0.5	0.5	1	2	5	10	10	

^aGroup A: *H. pylori* (HP) negative [–]/atrophic gastritis (AG) negative [–], Group B: HP positive [+/AG [–], Group C: HP [+/AG [+], Group D: HP [–]/AG [+].

^bThe prevalence of individuals aged 0–9 years was defined as 99% for Group A, and the prevalence of age groups from 10 to 39 years old was interpolated by applying a linear regression model to the prevalence of age groups of 0–9 and 40–49 years old.

The prevalence of individuals aged 40–74 years was obtained from the Japan Public Health Center-based Prospective Study for the Next Generation data.

The prevalence of individuals aged 75 years or older was assumed to be the same as that of individuals aged 70–74 years.

table method, we used age-specific prevalence of *H. pylori* infection during the period including the calendar year 2011. Prevalence was investigated in individuals aged 40–74 years old, as cancer tends to develop later in life. Age was stratified into 10-year periods for analysis. There was no actual or extrapolate data for the prevalence of *H. pylori* infection to individuals aged 0–39 years and 75 years or older, so we assumed as follows. In this study, the prevalence of individuals aged 0–9 years was defined as 99% for Group A, and the prevalence of age groups from 10 to 39 years old was interpolated by applying a linear regression model to the prevalence of age groups of 0–9 and 40–49 years old. We hypothesized that the prevalence of individuals aged 75 years or older was the same as that of individuals aged in their 70–74 years old.

Statistical analysis

To calculate the crude gastric cancer incidence and mortality rates for each risk group, crude gastric cancer incidence and mortality rates in Japanese people overall were apportioned using relative risk and prevalence for each risk group (17). Using the following formula, in which Absolute Rate Reference is crude incidence and mortality rates for Group A, and Absolute Rate All is crude incidence and mortality rates for all groups. In addition, RR_i is relative risk in the risk group ($i = a,b,c,d$) and $Prev_i$ is prevalence in the risk group ($i = a,b,c,d$), we calculated the crude incidence and mortality rates for Group A, which was used as the reference group. We calculated crude incidence and mortality rates for Groups B, C, and D using the crude incidence and mortality rates for Group A and relative risk for each group.

$$\text{Absolute Rate Reference} = \text{Absolute Rate All} / (1 + \sum_i ((RR_i - 1) \times Prev_i))$$

To estimate cumulative incidence and mortality risk for gastric cancer by risk category, we created a life chart for a population in which cancer did not develop, estimated figures for incidence and deaths by age range in this life table, and accumulated these for all age ranges (18).

Results

The results of relative risk by meta-analysis are shown in Table 3. Similar to the result of previous studies, relative risk increased in the high-risk groups.

Lifetime cumulative incidence risk for gastric cancer was estimated to be 11.4% (1-in-9 people) for men and 5.7% (1-in-18 people) for women. The lifetime cumulative incidence risk increased

markedly from the lowest-risk to the highest-risk group. As shown in Table 4, the estimated risk for men was 2.4% (1-in-42 people) for Group A, 10.8% (1-in-9 people) for Group B, 26.7% (1-in-4 people) for Group C, and 35.5% (1-in-3 people) for Group D. As shown in Table 5, the estimated risk for women was 1.2% (1-in-83 people) for Group A, 5.5% (1-in-18 people) for Group B, 13.5% (1-in-7 people) for Group C, and 18.0% (1-in-6 people) for Group D. Although the cumulative incidence risk in Group D was markedly higher than in other groups, the cumulative incidence risk in 10-year-olds by the time they reached 40 years of age was less than 1% for both men and women in all groups.

Similarly, the lifetime cumulative mortality risk for gastric cancer was estimated to be 3.9% (1-in-26 people) for men and 1.8% (1-in-56 people) for women. As shown in Table 6, the estimated risk for men was 0.8% (1-in-125 people) for Group A, 3.6% (1-in-28 people) for Group B, 9.0% (1-in-11 people) for Group C, and 12.0% (1-in-8 people) for Group D. As shown in Table 7, the estimated risk for women was 0.4% (1-in-250 people) for Group A, 1.7% (1-in-59 people) for Group B, 4.2% (1-in-24 people) for Group C, and 5.7% (1-in-18 people) for Group D. As for lifetime cumulative incidence risk, lifetime cumulative mortality risk increased markedly in both men and women in higher risk groups.

Discussion

In this study, we calculated the cumulative incidence and mortality risk for gastric cancer by risk classifications and sex.

Our results confirmed that there was a large difference in lifetime cumulative risk between Group A (lowest risk) and Group D (highest risk). In Group D, lifetime cumulative incidence risk of gastric cancer was 35.5% (1-in-3 people) for men, which was three-times higher than the lifetime risk of developing site-specific cancers among the entire population (11%, 10% and 10% for gastric, colorectal and lung cancer, respectively) (1). For women in Group D, the estimated lifetime cumulative incidence of gastric cancer was 18.0% (1-in-6 people), which equated to almost double the lifetime cumulative risk of developing breast and colorectal cancers among the entire population (9% and 8%, respectively) (1). Since there is a large difference in lifetime cumulative incidence risk according to risk category, risk estimation needs to be done for each risk group separately.

According to the latest guideline published by the National Cancer Center (20), citizens aged 50 years or older are encouraged to undergo organized gastric cancer screening using endoscopy or X-ray examination conducted at municipalities or workplaces; from

Table 3. Summary estimates of relative risk for each risk group

Study	Risk category ^a									
	Author	Ref.	(Year)	A		B		C		D
RR ^b				(95% CI)	RR ^b	(95% CI)	RR ^b	(95% CI)	RR ^b	(95% CI)
Watabe	10	(2005)	1.00	Reference	1.10	(0.40–3.40)	6.00	(2.40–14.50)	8.20	(3.20–21.50)
Mizuno	11	(2010)	1.00	Reference	4.20	(0.96–18.40)	11.23	(2.71–46.51)	14.81	(2.47–88.80)
Yoshida	12	(2013)	1.00	Reference	8.90	(2.70–54.70)	17.70	(5.40–108.60)	69.70	(13.60–502.90)
Charvat	6	(2016)	1.00	Reference	7.58	(4.16–13.79)	13.86	(7.76–24.75)	14.09	(7.03–28.26)
Results of meta-analysis			1.00	Reference	4.47	(1.83–10.03)	11.06	(4.86–25.58)	14.78	(6.46–38.21)

^aGroup A: *H. pylori* (HP) negative [–]/atrophic gastritis (AG) negative [–], Group B: HP positive [+/AG [–], Group C: HP [+/AG [+], Group D: HP [–/AG [+].

^bRR, relative risk.

Table 4. Cumulative incidence risk for gastric cancer in each risk group (men) (Unit %)

Risk category ^a	Current age (years)	Attained age (years)									
		9	19	29	39	49	59	69	79	Lifetime	
Overall	0	0.0	0.0	0.0	0.1	0.3	1.3	3.8	7.7	11.4	
	10		0.0	0.0	0.1	0.3	1.3	3.8	7.7	11.4	
	20			0.0	0.1	0.3	1.3	3.8	7.7	11.5	
	30				0.0	0.3	1.3	3.8	7.8	11.5	
	40					0.2	1.3	3.8	7.8	11.6	
	50						1.1	3.7	7.7	11.6	
	60							2.8	7.0	11.2	
	70								5.0	9.7	
	80									6.7	
A	0	0.0	0.0	0.0	0.0	0.1	0.5	1.0	1.7	2.4	
	10		0.0	0.0	0.0	0.1	0.5	1.0	1.8	2.4	
	20			0.0	0.0	0.1	0.5	1.0	1.8	2.5	
	30				0.0	0.1	0.5	1.0	1.8	2.5	
	40					0.1	0.4	1.0	1.8	2.5	
	50						0.3	0.9	1.7	2.4	
	60							0.6	1.4	2.2	
	70								0.9	1.8	
	80									1.2	
B	0	0.0	0.0	0.0	0.1	0.6	2.1	4.6	7.8	10.8	
	10		0.0	0.0	0.1	0.6	2.1	4.6	7.8	10.9	
	20			0.0	0.1	0.6	2.1	4.6	7.8	10.9	
	30				0.1	0.6	2.1	4.6	7.9	11.0	
	40					0.5	2.0	4.5	7.8	11.0	
	50						1.5	4.1	7.5	10.7	
	60							2.8	6.4	9.8	
	70								4.1	8.1	
	80									5.6	
C	0	0.0	0.0	0.1	0.3	1.6	5.1	11.3	19.1	26.7	
	10		0.0	0.1	0.3	1.6	5.1	11.3	19.2	26.8	
	20			0.1	0.3	1.6	5.1	11.3	19.2	26.8	
	30				0.3	1.5	5.1	11.4	19.3	27.0	
	40					1.3	4.8	11.2	19.2	27.0	
	50						3.7	10.2	18.5	26.5	
	60							7.1	16.0	24.7	
	70								10.7	21.1	
	80									15.4	
D	0	0.0	0.0	0.1	0.4	2.1	6.8	15.0	25.4	35.5	
	10		0.0	0.1	0.5	2.1	6.8	15.1	25.5	35.6	
	20			0.1	0.5	2.1	6.8	15.1	25.6	35.7	
	30				0.4	2.1	6.8	15.1	25.7	35.9	
	40					1.7	6.5	14.9	25.6	35.9	
	50						4.9	13.7	24.7	35.4	
	60							9.6	21.6	33.3	
	70								14.7	29.0	
	80									22.1	

^aOverall: We do not stratify risk. Group A: *H. pylori* (HP) negative [-]/atrophic gastritis (AG) negative [-], Group B: HP positive [+]/AG [-], Group C: HP [+]/AG [+], Group D: HP [-]/AG [+].

that perspective, public policies are only taking age-related risk into consideration. In addition to aging, we showed that gastric cancer risk differs greatly depending on the presence of risk factors, such as *H. pylori* infection and chronic atrophic gastritis. Although the presence of *H. pylori* increases risk, it has been suggested that eradication of *H. pylori* lowers the risk of gastric cancer (19). The results of this study are useful for setting intervention targets for primary and secondary prevention of gastric cancer. Further, although we only

Table 5. Cumulative incidence risk for gastric cancer in each risk group (women) (Unit %)

Risk category ^a	Current age (years)	Attained age (years)									
		9	19	29	39	49	59	69	79	Lifetime	
Overall	0	0.0	0.0	0.0	0.1	0.3	0.7	1.5	3.0	5.7	
	10		0.0	0.0	0.1	0.3	0.7	1.6	3.0	5.7	
	20			0.0	0.1	0.3	0.7	1.6	3.0	5.7	
	30				0.1	0.2	0.7	1.5	3.0	5.7	
	40					0.2	0.6	1.5	3.0	5.7	
	50						0.4	1.3	2.8	5.6	
	60							0.9	2.5	5.3	
	70								1.7	4.6	
	80									3.5	
A	0	0.0	0.0	0.0	0.0	0.1	0.3	0.5	0.7	1.2	
	10		0.0	0.0	0.0	0.1	0.3	0.5	0.7	1.2	
	20			0.0	0.0	0.1	0.3	0.5	0.7	1.2	
	30				0.0	0.1	0.3	0.5	0.7	1.2	
	40					0.1	0.2	0.4	0.7	1.2	
	50						0.1	0.3	0.6	1.1	
	60							0.2	0.5	1.0	
	70								0.3	0.8	
	80									0.6	
B	0	0.0	0.0	0.0	0.2	0.6	1.2	2.1	3.3	5.5	
	10		0.0	0.0	0.2	0.6	1.2	2.1	3.3	5.5	
	20			0.0	0.2	0.6	1.2	2.1	3.3	5.5	
	30				0.2	0.6	1.1	2.0	3.3	5.5	
	40					0.4	1.0	1.9	3.1	5.3	
	50						0.6	1.5	2.8	5.0	
	60							0.9	2.2	4.5	
	70								1.4	3.8	
	80									2.9	
C	0	0.0	0.0	0.1	0.5	1.5	2.9	5.1	8.1	13.5	
	10		0.0	0.1	0.5	1.5	2.9	5.1	8.1	13.5	
	20			0.1	0.6	1.5	2.9	5.1	8.1	13.6	
	30				0.4	1.4	2.8	5.0	8.0	13.5	
	40					1.0	2.4	4.6	7.7	13.2	
	50						1.5	3.7	6.8	12.5	
	60							2.3	5.6	11.4	
	70								3.5	9.7	
	80									7.4	
D	0	0.0	0.0	0.2	0.7	2.0	3.9	6.8	10.8	18.0	
	10		0.0	0.2	0.7	2.0	3.9	6.8	10.8	18.1	
	20			0.2	0.7	2.0	3.9	6.8	10.9	18.1	
	30				0.6	1.9	3.8	6.7	10.7	18.0	
	40					1.3	3.2	6.2	10.3	17.6	
	50						2.0	5.0	9.2	16.7	
	60							3.1	7.5	15.3	
	70								4.7	13.1	
	80									10.1	

^aOverall: We do not stratify risk. Group A: *H. pylori* (HP) negative [-]/atrophic gastritis (AG) negative [-], Group B: HP positive [+]/AG [-], Group C: HP [+]/AG [+], Group D: HP [-]/AG [+].

examined gastric cancer, this method can be applied to other cancers for which strong risk factors are established.

Our results of cumulative incidence risk of gastric cancer were generally higher than the results of a previous study (6). A possible reason is the difference of crude incidence rates between two studies; we used the national estimates of age-specific crude incidence rates in 2011; while the previous study used the Japan Public Health Center (JPHC) cohort II data followed-up between 1993 and 1994 and 2009. Crude gastric incidence rates in 2011 were known to be

Table 6. Cumulative mortality risk for gastric cancer in each risk group (men) (Unit %)

Risk category ^a	Current age (years)	Attained age (years)								
		9	19	29	39	49	59	69	79	Lifetime
Overall	0	0.0	0.0	0.0	0.0	0.1	0.3	1.1	2.4	3.9
	10		0.0	0.0	0.0	0.1	0.3	1.1	2.4	3.9
	20			0.0	0.0	0.1	0.3	1.1	2.4	4.0
	30				0.0	0.1	0.3	1.1	2.4	4.0
	40					0.1	0.3	1.1	2.4	4.0
	50						0.3	1.0	2.4	4.0
	60							0.8	2.3	4.0
	70								1.7	3.6
	80									2.6
A	0	0.0	0.0	0.0	0.0	0.1	0.3	0.5	0.8	0.8
	10		0.0	0.0	0.0	0.0	0.1	0.3	0.5	0.8
	20			0.0	0.0	0.0	0.1	0.3	0.5	0.8
	30				0.0	0.0	0.1	0.3	0.5	0.8
	40					0.0	0.1	0.3	0.5	0.8
	50						0.1	0.3	0.5	0.8
	60							0.2	0.5	0.8
	70								0.3	0.7
	80									0.5
B	0	0.0	0.0	0.0	0.1	0.2	0.5	1.3	2.4	3.6
	10		0.0	0.0	0.1	0.2	0.5	1.3	2.4	3.6
	20			0.0	0.1	0.2	0.5	1.3	2.4	3.7
	30				0.0	0.2	0.5	1.3	2.4	3.7
	40					0.1	0.5	1.2	2.4	3.7
	50						0.4	1.1	2.3	3.6
	60							0.8	2.0	3.4
	70								1.4	2.9
	80									2.1
C	0	0.0	0.0	0.0	0.1	0.4	1.3	3.1	5.9	9.0
	10		0.0	0.0	0.1	0.4	1.3	3.1	5.9	9.0
	20			0.0	0.1	0.4	1.3	3.1	5.9	9.0
	30				0.1	0.4	1.3	3.1	5.9	9.1
	40					0.3	1.2	3.0	5.9	9.0
	50						0.9	2.8	5.7	8.9
	60							2.0	5.1	8.5
	70								3.4	7.3
	80									5.3
D	0	0.0	0.0	0.0	0.2	0.6	1.7	4.2	7.9	12.0
	10		0.0	0.0	0.2	0.6	1.7	4.2	7.9	12.1
	20			0.0	0.2	0.6	1.7	4.2	7.9	12.1
	30				0.1	0.5	1.7	4.2	7.9	12.1
	40					0.4	1.5	4.1	7.8	12.1
	50						1.2	3.7	7.6	11.9
	60							2.7	6.8	11.3
	70								4.6	9.7
	80									7.0

^aOverall: We do not stratify risk. Group A: *H. pylori* (HP) negative [-]/atrophic gastritis (AG) negative [-], Group B: HP positive [+]/AG [-], Group C: HP [+]/AG [+], Group D: HP [-]/AG [+].

higher than those in the years around 2000, especially among old age groups. The geographical difference may have also affected the difference in crude incidence rates. Another possibility is the difference in *H. pylori* prevalence. While we used the prevalence data from the JPHC-NEXT study (baseline survey 2011–16), the previous study used the prevalence data at the baseline survey of JPHC cohort II (1993,1994). Lower prevalence of high-risk groups in our data may have resulted in higher risk of estimates, as described below.

Table 7. Cumulative mortality risk for gastric cancer in each risk group (women) (Unit %)

Risk category ^a	Current age (years)	Attained age (years)								
		9	19	29	39	49	59	69	79	Lifetime
Overall	0	0.0	0.0	0.0	0.0	0.1	0.2	0.4	0.9	1.8
	10		0.0	0.0	0.0	0.1	0.2	0.4	0.9	1.8
	20			0.0	0.0	0.1	0.2	0.4	0.9	1.8
	30				0.0	0.1	0.2	0.4	0.9	1.8
	40					0.0	0.2	0.4	0.9	1.8
	50						0.1	0.4	0.9	1.8
	60							0.3	0.7	1.7
	70								0.5	1.5
	80									1.2
A	0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.4
	10		0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.4
	20			0.0	0.0	0.0	0.1	0.1	0.2	0.4
	30				0.0	0.0	0.1	0.1	0.2	0.4
	40					0.0	0.1	0.1	0.2	0.4
	50						0.0	0.1	0.2	0.4
	60							0.1	0.1	0.3
	70								0.1	0.3
	80									0.2
B	0	0.0	0.0	0.0	0.1	0.2	0.3	0.6	1.0	1.7
	10		0.0	0.0	0.1	0.2	0.3	0.6	1.0	1.7
	20			0.0	0.1	0.2	0.3	0.6	1.0	1.7
	30				0.1	0.1	0.3	0.6	1.0	1.7
	40					0.1	0.3	0.5	0.9	1.7
	50						0.2	0.4	0.8	1.6
	60							0.3	0.7	1.5
	70								0.4	1.3
	80									1.0
C	0	0.0	0.0	0.0	0.2	0.4	0.8	1.4	2.4	4.2
	10		0.0	0.0	0.2	0.4	0.8	1.4	2.4	4.3
	20			0.0	0.2	0.4	0.8	1.4	2.4	4.3
	30				0.1	0.4	0.8	1.4	2.4	4.3
	40					0.2	0.7	1.3	2.2	4.2
	50						0.4	1.1	2.0	4.0
	60							0.7	1.7	3.6
	70								1.0	3.1
	80									2.4
D	0	0.0	0.0	0.0	0.2	0.5	1.1	1.9	3.2	5.7
	10		0.0	0.0	0.2	0.5	1.1	1.9	3.2	5.7
	20			0.0	0.2	0.5	1.1	1.9	3.2	5.7
	30				0.2	0.5	1.0	1.9	3.2	5.7
	40					0.3	0.9	1.7	3.0	5.5
	50						0.6	1.4	2.7	5.3
	60							0.9	2.2	4.8
	70								1.4	4.2
	80									3.2

^aOverall: We do not stratify risk. Group A: *H. pylori* (HP) negative [-]/atrophic gastritis (AG) negative [-], Group B: HP positive [+]/AG [-], Group C: HP [+]/AG [+], Group D: HP [-]/AG [+].

The present study has several strengths over previous studies (6–8). First, we calculated lifetime cumulative risk, which provides useful information for determining the timing of the preventive intervention. Second, our study targeted the entire Japanese population, so the results can be generalized.

Our study has several limitations. First, we adopted an indirect method to estimate the crude incidence and mortality rates stratified by risk category. However, the data for overall crude incidence and mortality rates were obtained from population-based Japanese national data,

and the data for relative risks were derived from a meta-analysis of Japanese studies. Second, our prevalence data for each risk group had some uncertainty. The prevalence of each risk group within each age group changes according to birth year, and the results will depend on which calendar year is chosen for the prevalence data. When we adopted prevalence data from earlier calendar years, in which there was a higher prevalence of high-risk individuals, the cumulative risk was lower compared with our reported results. This is because fixed values were used for the crude incidence and mortality rates in the entire population and for the relative risk of each risk group. Also, we estimated prevalence of *H. pylori* infection to individuals aged 75 years or older in 2011 from the previous study (21). The results were between 30% and 50%, which showed no big difference compared with prevalence in our study. Furthermore, we performed sensitivity analysis to calculate lifetime cumulative incidence risk by altering prevalence of Group A for individuals aged 75 years or older from 30% to 50%. Results indicated that the absolute change of lifetime cumulative incidence risk for Group D was 6% at maximum. Thus it was reasonable to consider prevalence data used in our study was appropriate. Third, we only considered *H. pylori* infection and atrophic gastritis as risk factors for gastric cancer occurrence. This is because the relative risk of gastric cancer occurrence due to excessive sodium intake and smoking is much lower than that for *H. pylori* infection and atrophic gastritis (4,5). Therefore, we consider that the effect of excessive sodium intake and smoking was not so large. Finally, we estimated the risk without considering individuals who had accepted the eradication therapy against *H. pylori*. In 2011, application of *H. pylori* eradication was covered only for people who had gastric and duodenal ulcer (22). Therefore, we considered that the number of such people in the year was so small. Also, the purpose of this study was the estimation of the risk before the intervention, thus we did not estimate the risk after intervention of *H. pylori* eradication therapy. However, it is necessary to estimate the risk after *H. pylori* eradication therapy to assess the effect of the intervention for policy making.

In conclusion, we estimated lifetime cumulative incidence and mortality risk for gastric cancer by risk category. The results of this study may be useful for designing individually tailored prevention programs.

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Conflict of interest statement

None declared.

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