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Research article

Colorectal and gastric cancer and its association with dietary patterns in Colombia

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ABSTRACT

Introduction: Cancer is a leading cause of death in the Americas. Colorectal cancer is the third most common cancer, while stomach cancer is the sixth most common cancer worldwide. Tobacco and alcohol consumption, unhealthy diet, physical inactivity and air pollution are risk factors for these cancers. This study aimed to identify the association between dietary patterns and gastric and colorectal cancer.

Methodology: A multi-cluster ecological study, using as secondary sources two national databases, the HIGIA (High-Cost Account) and the ENSIN 2015 (National Survey of Nutritional Status of Colombia 2015), was carried out. The population consisted of 2585 people over 50 years of age, distributed in six regions of Colombia: *Atlántica, Central, Oriental, Pacífica, Amazonía-Orinoquía,* and *Bogotá*. Multiple linear regression was performed using R2 to measure goodness of fit to estimate the effect between colorectal cancer incidence rate/gastric cancer incidence rate and exposure factors.

Results: A positive association was observed between colorectal cancer and non-compliance with the recommendation of vigorous physical activity ($p = 0.00$) and consumption of beverages/grilled food pattern ($p = 0.001$). Conversely, it decreased incidence by enjoying some specific health insurance and following a conservative dietary pattern ($p = 0.05$). Gastric cancer incidence was found to increase with age ($p = 0.000$), sex ($p = 0.001$), and consumption of the beverages/grilled food pattern ($p = 0.006$). However, being in the first wealth quartile decreased the incidence ($p = 0.002$).

Conclusion: There is evidence of an association between diet, physical activity and wealth quartile with colorectal and gastric cancer. This information should be considered for preventive interventions in the population.

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1. Introduction

Cancer is one of the leading causes of death worldwide. In 2022, nearly 9.7 million deaths will be attributed to cancer [1]. The most common cancers in 2022, in terms of new cases, were colorectal and gastric cancer [2].

Colorectal cancer (CRC) is the fourth most common cancer worldwide, with an incidence of 24.4 per 100,000 population in 2022. It accounts for 9.4 % of all cancers in Latin America and the Caribbean [3]. It is estimated that the number of CRC cases worldwide will reach 3.2 million by 2040, especially in countries with a high and very high Human Development Index (HDI), according to the projected population ageing and growth. The increased incidence of CRC is due to increased exposure to environmental risk factors, lifestyle changes, westernisation of diet (consumption of red and processed meats, low fibre intake), alcohol and tobacco use, obesity, sedentary lifestyles [4,5], and genetic susceptibility [6].

Gastric cancer ranked sixth in the world in 2022, with an incidence of 10.8 per 100,000 population, and accounted for 4.8 % of all cancers in Latin America and the Caribbean [3]. According to GLOBOCAN 2022, in Colombia, gastric cancer was fourth in incidence (8938 cases) and first in mortality (5640 deaths) [7].

Regarding the aetiopathogenesis of gastric cancer, the interaction of environmental, genetic and epigenetic factors is highlighted, although less than 3 % of cases are truly hereditary or familial [8]. This pathology is associated with infectious agents, environmental factors and a lifestyle characterised by alcohol consumption, salty foods and sedentary lifestyles [9]. Some studies suggest that high fruit and vegetable consumption may be inversely associated with gastric cancer risk, especially in locations other than the cardia. However, other studies have not found conclusive evidence for this association [10,11]. The World Cancer Research Fund reports that being overweight, obese, eating alcohol consumption and eating salty foods increase the risk of stomach (cardia) cancer. At the same time, there is limited evidence of an association with the consumption of processed meat, grilled meat and fruit [12].

Eating, as a daily activity essential for life, is influenced by social, cultural, and economic factors, which are reflected in region-specific dietary patterns. These patterns can significantly impact human health and act as risk factors for the development of cancer. In particular, frequent consumption of preserved foods, red meat, and processed meats is associated with gastric and colorectal cancer [13].

Meneses et al. conducted a comprehensive analysis of dietary patterns in Colombia using data from the 2015 National Survey of the Nutritional Situation of Colombia (ENSIN), focusing on the population aged 15–64 years. They identified four distinct dietary patterns. The first, known as the 'traditional' pattern, includes dairy, potato/legumes, cereals, fried foods, coffee, panela/sugar/honey and meat/fish/eggs/meat products. The second, the 'industrial' pattern, is characterised by sweets/packaged foods, fast food and soft drinks. The third, the 'conservative' pattern, is marked by whole grains, light/supplementary foods, fruits and vegetables. The fourth, the 'beverages/grilled foods' pattern, includes alcoholic beverages, grilled foods and energy drinks. These patterns serve as the foundation for our research, allowing us to delve deeper into their association with gastric and colorectal cancer. To date, no national population-based studies have been conducted in Colombia to examine the relationship between dietary patterns and the incidence of stomach and colorectal cancer. While numerous international studies have explored these associations, there remains a significant gap in localised research that considers the unique dietary habits, genetic factors, and environmental influences present in the Colombian population.

This study aims to identify the association between dietary patterns and gastric and colorectal cancer to consolidate the basis for designing and implementing effective interventions to reduce the risk or impact of these diseases in the general population.

2. Methodology

2.1. Study design

We employed a multi-cluster ecological study was conducted using two national databases as secondary sources, the HIGIA (High-Cost Account) and the ENSIN 2015 (National Survey of Nutritional Status of Colombia 2015).

2.2. Participants

The population of this study comprised the participants of the National Health Survey (ENSIN 2015), which included a sample of 151343 people in 295 municipalities in the 32 departments of the country. The table summarises coverage by region (Atlantic, Eastern, Central, Amazon-Orinoquia, Bogotá, Pacific) and more detailed information on participants and sampling techniques can be found in Annex 11 - ENSIN sample, available in the National Nutrition Situation Survey document [15].

Inclusion criteria were the population residing in the household and signing informed consent. Exclusion criteria included people with differential cognitive or physical abilities. The study's population consisted of people over 50 years of age, comprising 2768 women and men distributed in the six regions of Colombia.

2.3. Data source

A multi-cluster ecological study was conducted using two national databases as secondary sources, the HIGIA (High-Cost Account) and the ENSIN 2015 (National Survey of Nutritional Status of Colombia 2015).

2.4. Variables

The categories of variables were defined based on the methodology of previous studies [16], and included area of residence (Municipality seat, Dispersed rural centre), affiliation regime (contributory, subsidised, unaffiliated), wealth quartile (first quartile, second or higher), level of education (Primary Education Incomplete, Between Primary Education Complete and Secondary Education Complete, University Degree) age in ranges (50–54 years, 55–59 years, 60–64 years), adherence to physical activity recommendations, adherence to 30 min of physical activity per day (at least five days), adherence to vigorous physical activity recommendations, overweight or obesity, hypertension, diabetes mellitus, adherence to a special diet, adherence to a vegetarian diet, and consumption of dietary patterns. The area of residence was subdivided into a variable with two categories: the municipality seat, defined as the urban perimeter where the administrative headquarters of the municipality is located, and the populated or dispersed rural centre, defined as the concentration of at least twenty contiguous or dispersed dwellings located in the rural area of a municipality or a departmental district [17].

The affiliation regime was characterised by two categories: (i) the subsidised regime, which is understood as the mechanism by which the population without the capacity to pay has access to health services through a subsidy offered by the State, and (ii) the contributory regime, which refers to the set of rules governing the affiliation of individuals and families to the social security health system, through the payment of a contribution financed directly by the affiliate or by agreement between the affiliate and its employer [18].

For the independent variable "dietary patterns", reference was made to those defined in the study by Meneses et al., where four patterns were identified: the traditional, industrialised, conservative, and beverages/grilled foods patterns [14]. These variables ranged on a continuous scale from 0 to 100 %, with 100 % representing the highest dietary pattern consumption percentage. For the present study, these variables were transformed into dichotomous variables using the binomial distribution. A cut-off point for consumption was established, with one [1] representing some consumption and zero (0) representing no consumption.

Considering this was an ecological design, a summary measure of the incidence rate was generated by grouping three variables: age group, region, and sex. The incidence rate of colorectal and gastric cancer was defined as the dependent variable, using the figures reported in 2020 by the High-Cost Account in the HIGIA platform. The exposure factors (independent variables) used were those collected by the National Survey of Nutritional Status of Colombia (ENSIN) 2015.

2.5. Statical analysis

Exploratory data analysis was performed as follows: first, variables were described according to their measurement scale. For quantitative variables, central tendency and dispersion measures were calculated, and their normality was assessed using the Kolmogorov-Smirnov test. For qualitative variables, absolute and relative frequency tables were prepared, obtaining proportions according to region, age, sex and age group as a summary measure. A bivariate analysis was performed by region (Atlantic, Eastern, Amazon-Orinoquia, Bogotá, Central and Pacific) considering sociodemographic, clinical and lifestyle variables. The Chi-square test was used to establish statistically significant differences between regions.

Considering this was an ecological design, a summary measure of the incidence rate was generated by grouping three variables: age group, region, and sex. The incidence rate of colorectal and gastric cancer was defined as the dependent variable, using the figures reported in 2020 by the High-Cost Account in the HIGIA platform. The exposure factors (independent variables) used were those collected by the National Survey of Nutritional Status of Colombia (ENSIN) 2015. For the multivariate analysis, a multiple linear regression analysis was performed for each dependent variable (colorectal and gastric cancer incidence rates), considering the goodness-of-fit measure R2 and the principle of statistical parsimony [19]. The independent variables were retained in the final models using the backward method, with a p-value <0.10 in the coefficients obtained for each factor. Data processing was carried out using the statistical software SPSS version 26.

2.6. Ethical considerations

This study was approved by the Institutional Ethics Committee of the University of Santiago de Cali by Act No. 11 of May 29, 2020. The databases used are licensed by the Family Welfare Institute of Colombia (ICBF). Following the protocol described by the ENSIN, all participants signed prior informed consent (verbal or signed). The data used were anonymised.

3. Results

3.1. Univariate results

Regarding the age ranges, it was found that 1122 individuals (40.5 %) were between 50 and 54 years old, 893 individuals (32.3 %) were between 55 and 59 years old, and 753 individuals (27.2 %) were between 60 and 64 years old. A total of 1621 women participated (58.6 %). Regarding the educational level, there were 1015 individuals in primary education (36.7 %). The most common area of residence was the municipal seat with 2005 individuals (72.4 %). In the health affiliation regime, the subsidised regime was the most prevalent with 1569 individuals (56.7 %). For the wealth quartile, which was dichotomized, the majority were in the second quartile or higher, accounting for 55.9 % (Table 1)

Hypertension was identified in 1337 individuals (51.7 %), and diabetes in 73 individuals (2.6 %). Overweight was present in 40 %,

and obesity in 23.8 %. A total of 85.1 % did not meet the physical activity recommendations. Only 22 participants engaged in vigorous physical activity (Table 2).

Regarding the consumption of Pattern 1, it was identified that 2603 individuals (94.03 %) followed this pattern. For Pattern 2, 1884 individuals (68.06 %) followed it. Pattern 3 was followed by 2534 individuals (91.55 %), and finally, Pattern 4 was followed by 1332 individuals (48.12 %) (Table 3).

3.2. Bivariate results

It was observed that 40.5 % of them were aged between 50 and 54 years old, with the majority (43.1 %) originating from the country's eastern region. 58.6 % were female, with the *Pacífica* region having the highest concentration of female population (71 %). In terms of schooling, 62.9 % had completed primary or lower secondary education, with a higher percentage (82.4 %) in the *Bogotá* region. On the other hand, 72.4 % lived in the capital city, 57 % had subsidised health insurance, and 47.1 % belonged to the first wealth quartile. The region with the highest proportion of this type of health affiliation and wealth quartile was *Amazonía-Orinoquía*, with 68.3 % and 62.1 %, respectively. Significant differences were found between the regions and the variables of age, sex, level of education, wealth quartile and health system affiliation (Table 4).

About the lifestyle and health status variables, 14.9 % of the population met the physical activity recommendations, with the *Bogotá* region standing out with 22.4 %. At the national level, only 2 % of the population adhered to the recommendations of engaging in at least 30 min of physical activity at least five times a week, and 0.8 % complied with vigorous activity.

Regarding health status, it was found that 40 % were overweight and 23.8 % were obese, with the Amazonía-Orinoquia region exhibiting the highest obesity rate at 27.8 %. In addition, 48.3 % reported high blood pressure, with 63.9 % in the Bogotá region and 2.6 % reported diabetes. The *Amazonía-Orinoquía* region had the highest prevalence, with 5.2 %. There were also regional differences in the prevalence of chronic diseases (hypertension, diabetes), obesity, physical activity for at least 30 min 5 days a week and vigorous physical activity (Table 5).

When the percentage of consumption of each dietary pattern in Colombia and by region was examined, it was found that 94 % of Colombians frequently consumed the foods included in the traditional dietary pattern. The second most consumed dietary pattern was the conservative one (pattern 3), with 91.4 %. The industrialised and beverages/grilled foods patterns accounted for 67.9 % of food consumption. Table 6 and Fig. 2 show the distribution of dietary patterns by region.

The incidence of colorectal cancer in people over 50 years of age at the national level in 2020 was 23/100,000 inhabitants. The Bogotá region had the highest incidence in men, with 28.2/100,000 inhabitants, while the *Amazonía-Orinoquía* region had the lowest rate in this group, with 8.8/100,000 inhabitants. The highest incidence in women was in *Bogotá* (24.2/100,000 inhabitants) and the lowest in the *Pacífica* (11.1/100,000 inhabitants) (Fig. 1).

On the other hand, the incidence of gastric cancer at the national level and in people over 50 years of age was 16/100,000 inhabitants in the same year. *Bogotá* had the highest rate for men (21.4/100,000 inhabitants) and women (10.3/100,000 inhabitants). In contrast, the lowest rate for men was found in the *Atlántica* region (4.6/100,000) and for women in the *Amazonía-Orinoquía* region (2.6/100,000) (Fig. 1).

3.3. Multivariate results

A multivariate analysis was performed to evidence those factors associated with colorectal and stomach cancer incidence.

This multivariable model shows that the incidence of colorectal cancer increases with non-compliance with the recommendation

Table 1
Description of sociodemographic characteristics.

Variable	Category	N = 2.768	%
Age Range	50–54	1122	40.5
	55–59	893	32.3
	60–64	753	27.2
Sex	Woman	1621	58.6
	Man	1147	41.4
[a]Educational level	PE	1015	36.7
	PE-SE	1562	56.4
	UE	159	5.7
	NA	32	1.2
Area	Municipality seat	2005	72.4
	Dispersed rural centre	763	27.6
Health affiliation regime	Contributory	1093	39.5
	Subsidised	1569	56.7
	Unaffiliated	97	3.5
	NA	9	0.3
Wealth quartile (Dichotomous)	First quartile	1222	44.1
	Second or higher	1546	55.9

[a] PE: Primary Education Incomplete; PE-SE: Between Primary Education Complete and Secondary Education Complete; UE: University Degree; NA: Not Available.

Table 2
Description of Lifestyle and health status.

Variable	Category	N = 2.768	%
Hypertension	Yes	1337	51.7
	No	1431	48.3
Diabetes	Yes	73	2.6
	No	2695	97.4
Overweight*	Yes	1104	40
	No	1664	60
Obesity*	Yes	655	23.8
	No	2113	76.2
Physical activity	Compliant	425	14.9
	Non-compliant	2343	85.1
30 min per day (at least 5 days)	Compliant	55	2
	Non-compliant	2713	98
Vigorous physical activity	Compliant	22	0.8
	Non-compliant	2746	99.2

Table 3
Description of Dietary patterns.

Variable	Category of consume	N = 2.768	%
Pattern 1	Yes	2603	94.03
	No	165	5.96
Pattern 2	Yes	1884	68.06
	No	884	31.94
Pattern 3	Yes	2534	91.55
	No	234	8.45
Pattern 4	Yes	1332	48.12
	No	1436	51.88

for vigorous physical activity ($p = 0.00$) and consumption of the beverages/grilled foods pattern ($p = 0.01$). On the other hand, consumption of the conservative dietary pattern ($p = 0.046$), belonging to the contributory ($p = 0.01$) and subsidised ($p = 0.02$) insurance regime, as opposed to having no insurance, reduced the incidence (Table 7).

For stomach cancer, belonging to the *Pacífica* region ($p = 0.001$), older age ($p = 0.00$) and consumption of beverages/grilled foods (0.006) increase the incidence. On the contrary, belonging to the first wealth quartile ($p = 0.002$) and being overweight ($p = 0.01$) or obese (0.01) were protective factors (Table 8).

4. Discussion

A clear association was found between the incidence of colorectal and gastric cancer and dietary habits, socio-demographic characteristics and lifestyle.

Colorectal cancer can be considered a marker of socioeconomic development in countries undergoing significant transformations. The incidence rate rises as the HDI (Human Development Index) increases [20]. In countries previously considered low-risk and that have experienced economic growth, this pathology has been observed due to changes in lifestyle, diet and socio-demographic factors [21,22].

According to the World Cancer Research Fund/American Cancer Institute (WCRF/AICR) and the American Cancer Society, physical activity is essential to cancer prevention. At least 150 min of moderate-intensity physical activity, 75 min of vigorous-intensity physical activity, or an equivalent combination of the two is recommended each week [23,24]. Globally, 28 % of adults aged 18 were insufficiently active in 2016 [25]. In this context, our research shows that a lack of vigorous physical activity increases the incidence of colorectal cancer. According to Matthew et al., in a study of a U.S. and European population aged over 57 years, high levels of physical activity were associated with a reduced risk of cancer, including colorectal cancer (HR, 0.84; 95 % CI, 0.77–0.91), with no differences in BMI associated with vigorous physical activity ($P = 0.10$), which the authors interpreted as non-linear associations [26]. Some authors have hypothesised that physical activity's protective factor is due to the increased vagal tone, decreased intestinal transit time, and reduced contact time of potential carcinogens such as food residues and bile acids with the colonic mucosa [27]. It also improves insulin sensitivity and glucose metabolism [28] and reduces levels of systemic inflammation by altering inflammatory cytokines or adipokines [29,30].

On the other hand, diet is considered an important environmental factor in cancer development. The research found that the dietary pattern of beverages/grilled foods, consisting of alcoholic beverages, energy drinks and grilled foods, was associated with an increased incidence of colorectal cancer. These findings are consistent with those of Cheng et al. and Li et al., who found an increased risk of colorectal cancer in those with high alcohol consumption [31,32]. On the other hand, several studies have reported the presence of polycyclic aromatic hydrocarbons (PAHs) and heteroaromatic amines (HAA) in meat exposed to high temperatures during grilling

Table 4
Socio-demographic characteristics.

Variable	Category	Region														p value
		Atlántica		*Oriental*		*Amazonía-Orinoquia*		*Bogotá*		*Central*		*Pacífica*		Total		
		n = 494	%	n = 568	%	n = 385	%	n = 183	%	n = 728	%	n = 410	%		%	
Age Range	50–54	192	38.9	245	43.1	146	37.9	76	41.5	299	41.1	164	40	1122	40.5	0.43
	55–59	167	33.8	175	30.8	144	37.4	60	32.8	225	30.9	122	29.8	893	32.3	
	60–64	135	27.3	148	26.1	95	24.7	47	25.7	204	28	124	30.2	753	27.2	
Sex	Woman	269	54.5	307	54.0	225	58.4	114	62.3	415	57	291	71	1621	58.6	0.00
	Man	225	45.5	261	46.0	160	41.6	69	37.7	313	43	119	29	1147	41.4	
Educational level	PE	189	38.3	194	34.2	157	40.8	32	17.5	270	37.1	173	42.2	1015	36.7	0.00
	PE-SE	266	53.8	334	58.8	196	50.9	144	78.7	412	56.6	210	51.2	1562	56.4	
	UE	33	6.7	35	6.2	25	6.5	6	3.3	38	5.2	22	5.4	159	5.7	
	NA	6	1.2	5	0.9	7	1.8	1	0.5	8	1.1	5	1.2	32	1.2	
Area	Municipality seat	351	71.1	367	64.6	363	94.3	183	100	503	69.1	238	58	2005	72.4	0.596
	Dispersed rural centre	143	28,9	201	35.4	22	5.7	0	0	225	30.9	172	42	763	27.6	
Health affiliation regime	Contributory	148	30	252	44.4	110	28.6	127	69.4	324	44.5	132	32.2	1093	39.5	0.00
	Subsidised	328	66.4	292	51.4	263	68.3	49	26.8	367	50.4	270	65.9	1569	56.7	
	Unaffiliated	17	3.4	23	4.0	11	2.9	7	3.8	32	4.4	7	1.7	97	3.5	
	NA	1	0.2	1	0.2	1	0.3	0	0	5	0.7	1	0.2	9	0.3	
Wealth quartile (*Dichotomous*)	First quartile	264	53.4	215	37.9	239	62.1	5	2.7	281	38.6	218	53.2	1222	44.1	0.00
	Second or higher	230	46.6	353	62.1	146	37.9	178	97.3	447	61.4	192	46.8	1546	55.9	

PE: Primary Education Incomplete; PE-SE: Between Primary Education Complete and Secondary Education Complete; UE: University Degree; NA: Not Available.

Table 5
Lifestyle and health status.

Variable	Category	Region														p-value
		Atlántica		*Oriental*		*Amazonía-Orinoquia*		*Bogotá*		*Central*		*Pacífica*		Total		
		n	%	n	%	n	%	n	%	n	%	n	%	n	%	
Hypertension	Yes	199	40.3	322	56.7	150	39	117	63.9	353	48.5	196	47.8	1337	51.7	0.001
	No	295	59.7	246	43.3	235	61	66	36.1	375	51.5	214	52.2	1431	48.3	
Diabetes	Yes	7	1.4	21	3.7	20	5.2	5	2.7	9	1.2	11	2.7	73	2.6	0.001
	No	487	98.6	547	96.3	365	94.8	178	97.3	719	98.8	399	97.3	2695	97.4	
Overweight[a]	Yes	187	37.9	245	43.1	153	39.7	78	42.6	285	39.1	156	38.0	1104	40	0.014
	No	307	62.1	323	56.9	232	60.3	105	57.4	443	60.9	254	62	1664	60	
Obesity[a]	Yes	131	26.5	97	16.1	107	22.9	39	21.3	169	23.2	112	15.4	655	23.8	0.000
	No	363	73.5	507	83.9	360	77.1	144	78.7	559	76.8	298	40.9	2113	76.2	
Physical activity	Compliant	75	15.2	95	16.7	60	15.6	41	22.4	111	15.2	43	10.5	425	14.9	0.131
	Non-compliant	419	84.8	473	83.3	325	84.4	142	77.6	617	84.8	367	89.5	2343	85.1	
30 min per day (at least 5 days)	Compliant	12	2.4	18	3.2	3	0.8	4	2.2	11	1.5	7	1.7	55	2	0.045
	Non-compliant	482	97.6	550	96.8	382	99.2	179	97.8	717	98.5	403	98.3	2713	98	
Vigorous physical activity	Compliant	4	0.8	2	0.4	8	2.1	2	1.1	5	0.7	1	0.2	22	0.8	0,000
	Non-compliant	490	99.2	566	99.6	377	97.9	181	98.9	723	99.3	409	99.8	2746	99.2	

[a] Classification according to BMI [Kg/height (in meters)^2]: Overweight (25.0–29.9 kg/m^2); Obesity ($\geq$30 kg/m^2).

Table 6
Dietary patterns.

Variable	Category of consume	Region												p value
		Atlántica		Oriental		Amazonía-Orinoquia		Bogotá		Central		Pacífica		
		n	%	n	%	n	%	n	%	n	%	n	%	
Pattern 1	Yes	462	93.5 %	535	94.2 %	358	93 %	172	94.%	681	93.5 %	395	96.3 %	0.390
	No	32	6.5 %	33	5.8 %	27	7 %	11	6 %	47	6.5 %	15	3.7 %	
Pattern 2	Yes	359	72.7 %	405	71.3 %	242	62.9 %	129	70.5 %	488	67 %	261	63.7 %	0.005
	No	135	27.3 %	163	28.7 %	143	37.1 %	54	29.5 %	240	33 %	149	36.3 %	
Pattern 3	Yes	449	90.9 %	521	91.7 %	341	88.6 %	172	94.%	663	91.1 %	388	94.6 %	0.044
	No	45	9.1 %	47	8.3 %	44	11.4 %	11	6.%	65	8.9 %	22	5.4 %	
Pattern 4	Yes	225	45.5 %	308	54.2 %	205	53.2 %	73	39.9 %	328	45.1 %	193	47.1 %	0.001
	No	269	54.5 %	260	45.8 %	180	46.8 %	110	60.1 %	400	54.9 %	217	52.9 %	

Pattern 1: Traditional; Pattern 2: Industrialised; Pattern 3: Conservative; Pattern 4: Beverages/grilled foods.

[33–35]. One of the PAHs is benzo(*a*)pyrene (BaP), which is known to be a class a and b carcinogen, capable of modulating cellular processes in differentiation, proliferation, immune response, cancer promotion and apoptosis [36,37].

A conservative dietary pattern (whole grains, fruits and vegetables) was associated with a lower incidence of colorectal cancer. Fang et al. and Rehm et al. report that inadequate consumption of whole grains is one of the major dietary factors associated with the burden of preventable cancer in the USA [38,39]. In the same vein, Alegría et al. found that whole grain consumption reduced the risk of colorectal cancer [40]. In Latin American countries, fibre consumption was 16 g/day in 2015 and 17.31 g/day in Colombia [41]. This number is below the recommended intake of 38 g/day for men and 25 g/day for women [42]. Lack of public awareness of the health benefits of whole grains and poor knowledge of identifying products containing whole grains may contribute to their low consumption [43]. Fibre produces short-chain fatty acids (SCFAs) during the fermentation process, which stimulate the growth of micro-organisms in the colon and increase stool weight, causing bulk and anticarcinogenic effects [44]. Fruits and vegetables, which contain antioxidants such as flavan-3-ols, flavanones and flavanols in addition to fibre, have been associated with a reduced risk of CRC, mainly due to their anti-allergic effects [31,45].

Concerning socio-demographic characteristics, research has shown that having some form of health system affiliation reduces the incidence of colorectal cancer. According to the report "*Situación del cáncer en Colombia en 2021*", the incidence of colorectal cancer was higher in the contributory system than in the subsidised system [46]. This fact suggests that there are barriers to early diagnosis in the subsidised system, so it is crucial to strengthen screening strategies in this population to control the burden of this disease. Navarro et al. reported that among the most accessible, cost-effective and least invasive methods are guaiac tests and faecal immunochemical tests [47].

On the other hand, the results of the research showed that the incidence of gastric cancer increases according to the consumption of beverages/grilled foods pattern, region of the country, age, and belonging to the first quartile of wealth, while being overweight or obese decreases it.

According to the World Cancer Research Fund International, alcohol consumption of 45 g or more per day is significantly associated with gastric cancer [48,49]. However, Bouras et al. found an increased risk of cancer at 42 g/day [9]. Alcohol acts as a solvent in the stomach, allowing substances with carcinogenic properties to enter gastric cells, and interferes with prostaglandin production and retinoid metabolism, both of which promote the maintenance and integrity of the mucosa [50]. Energy drinks contain caffeine, carbonated water, glucose, sucrose, dextrose, citric acid, sodium citrate, taurine, natural and artificial flavours and plant extracts (guarana seed, panax ginseng root extract and sucralose). The effects described with caffeine include increased gastric acid production, gastro-oesophageal reflux, decreased absorption, and altered motility and have been linked to gastric metaplasia [51]. In relation to barbecued foods, they have been shown to significantly increase the risk of gastrointestinal cancer, which may be due to benzo[α] pyrene from the smoke generated by the cooking process. In addition, N-nitroso compounds, including nitrosamines, formed in the stomach by the interaction of ingested nitrites or nitrate derivatives with secondary and tertiary amines have also been identified as risk factors for cancer [52].

The results of our research concerning the wealth quartile differ from those of Guimaraes et al., who found that belonging to the low and middle socioeconomic levels increased the incidence of gastric cancer [53]. Similarly, Otero et al. found more cases of low socioeconomic status than those with high socioeconomic status [54]. This evidence is consistent with the study by Etemadi et al., where increasing wealth score and education were associated with a reduced risk of incidence and mortality from gastric and oesophageal cancer [55]. These differences may be because, in Colombia, 99.6 % of the population is covered by health insurance [56], and it has been shown that low-income people are less likely to be screened and therefore underdiagnosed, resulting in a lower incidence of stomach and oesophageal cancer [57].

In addition, a significant association was found between older age and gastric cancer incidence, similar to that found by Gonzalez et al., who reported that the incidence of gastric cancer increased with age, particularly between 70 and 79 years of age [58].

Regarding weight, a negative association with gastric cancer has been found. Several studies showed a positive association between a high BMI and an increased risk of gastric cancer [59,60], while others found no statistically significant association [61,62]. The differences may be because this study was an ecological design using pooled and cross-sectional data, which may have reduced the

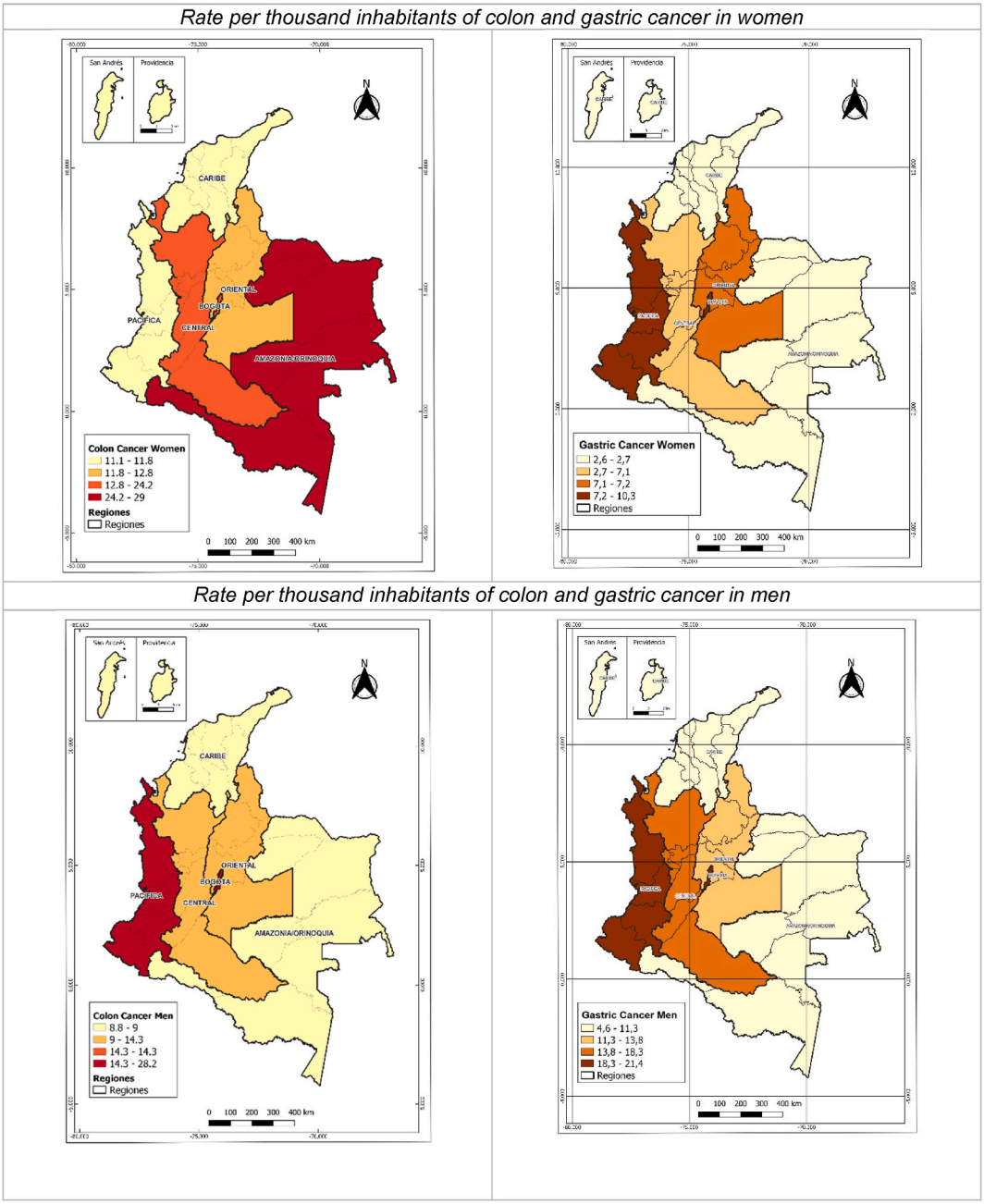

Fig. 1. Incidence map of colorectal and gastric cancer by sex.

measurement of the effect of overweight or obesity on the incidence of gastric cancer. This study is consistent with longitudinal and individual studies that control for this type of bias.

Finally, a higher incidence of stomach cancer was associated with the Pacific region. According to Torres et al., about the geographical distribution in western Latin American countries along the Pacific coast, an association between altitude and gastric cancer incidence has been observed, with higher rates in mountainous areas than along the banks of large rivers; so this may be because altitude is a surrogate for genetic, bacterial, dietary and environmental host factors [63].

The data found add valuable evidence for a positive association between dietary patterns, including beverages and grilled foods, and stomach and colorectal cancer. For these reasons, national education programs should be designed and developed to reduce the intake of these foods. However, further studies are needed to identify other associations and strengthen these findings.

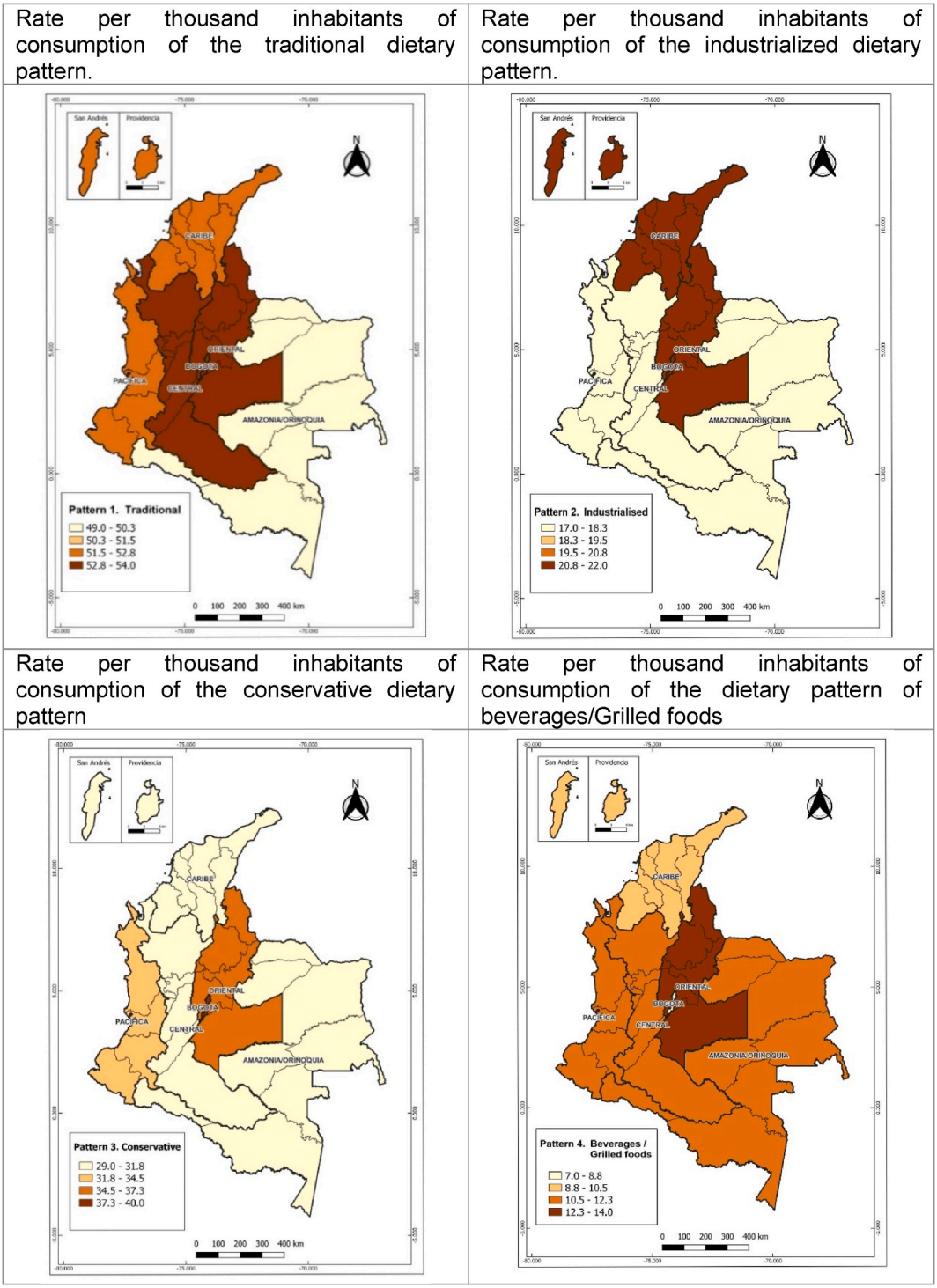

Fig. 2. Dietary patterns by region.

4.1. Limitations

Ecological studies, while valuable for examining broad patterns and trends within populations, have inherent limitations primarily due to their reliance on aggregated data rather than individual-level data. This aggregation can mask variations and obscure the underlying causal relationships that might exist at the individual level. As a result, ecological studies are susceptible to the ecological

Table 7
Model Factors of major influence on the incidence of colorectal cancer.

Variable	Raw						Adjusted				
	B	Standard Error	Lower limit	Upper limit	R2	p-value	B	Standard Error	Lower limit	Upper limit	p-value
Does not meet recommendations for vigorous physical activity	3.38	1.22	0.89	5.87	0,18	0.01	3.59	0.85	1.85	5.33	0.00
Pattern 3	0.23	0.45	−0.68	1.13	0.01	0.61	−0.63	0.30	−1.25	−0.01	0.05
Pattern 4	−0.08	0.09	−0.26	0.10	0.02	0.39	0.21	0.08	0.05	0.37	0.01
Contributory Regime	−0.35	0.08	−0.51	−0.19	0.36	0.00	−4.41	1.66	−7.80	−1.01	0.01
Subsidised Regime	0.30	0.08	0.14	0.47	0.29	0.00	−4.19	1.64	−7.55	−0.83	0.02

Pattern 3: Conservative; Pattern 4: Beverages/grilled foods.

Table 8
Model Factors with the greatest influence on the incidence of gastric cancer.

Variable	Raw						Adjusted				
	B	Standard Error	Lower limit	Upper limit	R2	p-value	B	Standard Error	Lower limit	Upper limit	p-value
Region	1.75	0.68	0.37	3.13	0.16	0.01	1.513	0.421	0.652	2.375	0.001
Age	3.30	1.44	0.37	6.23	0.13	0.03	4.186	0.956	2.230	6.142	0.000
First quartile of wealth	−0.07	0.06	−0.19	0.05	0.04	0.24	−0.133	0.039	−0.213	−0.052	0.002
Pattern 4	0.15	0.07	0.01	0.30	0.12	0.04	0.183	0.061	0.058	0.308	0.006
Overweight	−0.15	0.20	−0.55	0.26	0.02	0.47	−0.300	0.119	−0.544	−0.056	0.018
Obesity	−0.46	0.12	−0.72	−0.21	0.29	0.00	−0.277	0.110	−0.501	−0.053	0.017

Region: 1: Atlántica; 2: Oriental; 3: Amazonía-Orinoquía; 4: Bogotá; 5: Central; 6: Pacífica.
Age (ranges): 1:50–54 years, 2: 55–59 years old, 3: 60–64 years' old.
Pattern 4: Beverages/grilled foods.
Classification according to BMI [Kg/height (in meters)^2]: Overweight (25.0–29.9 kg/m^2); Obesity ($\geq$30 kg/m^2).

fallacy, where inferences about individual behaviour are incorrectly drawn from group-level data. Additionally, it's important to note that confounding variables that differ across populations can lead to biased results, making it challenging to establish direct cause-and-effect relationships. These limitations underscore the need for careful interpretation of findings and, where possible, complementary analyses with individual-level data to validate ecological inferences. Finally, it should be noted that the annual ENSIN is not conducted in Colombia, which could influence the representativeness of the results for the current population (the last was carried out in 2015).

5. Conclusion

In conclusion, this study identified a positive association between colorectal cancer, the beverage/grilled food dietary pattern and the lack of vigorous physical activity. In contrast, adherence to a conservative dietary pattern and healthcare affiliation decreased this risk. On the other hand, for stomach cancer incidence, consumption of the beverage/grilled food pattern was found to increase it, along with older age and being from regions other than the Pacific and Caribbean. On the contrary, the first quartile wealth and weight-related conditions (overweight/obesity) appeared to decrease the risk.

Understanding the relationship between dietary patterns and gastrointestinal neoplastic processes provides elements to formulate health policies and interventions that guide the population towards modifying their eating habits, decreasing the consumption of dietary patterns based on beverages and grilled foods, and promoting the increase of healthier patterns characterised by the consumption of fruits, vegetables, and whole foods.

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Data availability statement

Availability of data and materials Data associated with the study has not been deposited into a publicly available repository. Data are available from the corresponding author on reasonable request.

CRediT authorship contribution statement

Luz Adriana Meneses-Urrea: Writing – review & editing, Writing – original draft, Formal analysis, Data curation, Conceptualization. **Manuel Vaquero-Abellán:** Methodology, Formal analysis, Conceptualization. **Dolly Villegas Arenas:** Writing – original draft, Formal analysis. **Narly Benachi Sandoval:** Writing – original draft, Formal analysis. **Mauricio Hernández-Carrillo:** Methodology, Formal analysis, Data curation. **Guillermo Molina-Recio:** Writing – review & editing, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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