RESEARCH ARTICLE

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Refrigerator Ownership and the Decline of Gastric Cancer: A Global Overview

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Abstract

Objective: Refrigeration of food has been shown to mitigate environmental and dietary risk factors important in the pathogenesis of gastric cancer. Globally, the incidence of gastric cancer has decreased. This study aims to determine the relationship between refrigerator ownership and gastric cancer. **Methods:** Gastric cancer data were obtained from the Global Burden of Disease study, and refrigerator ownership data were sourced from GlobalDataLab. Countries were excluded from the analysis if they lacked refrigerator ownership data for more than 10 years or had over 80% ownership at the start of data collection. The relationship between the two variables was assessed using Spearman's rank correlation coefficient. **Result:** Countries were screened using the inclusion criteria, and 85 countries from five continents were included in the study. Seventy-three countries demonstrated a negative correlation between refrigerator ownership and gastric cancer among their male populations, and 55 countries showed comparable results among their female populations. Thirteen countries exhibited a positive correlation between the two variables. **Conclusion:** Increasing refrigerator ownership appears to be associated with decreasing gastric cancer rates. Further research is needed to identify the specific risk factors involved in gastric cancer pathogenesis in the 13 countries where this association was not observed.

Keywords: Gastric Cancer- Refrigeration- Global Health

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Introduction

Gastric cancer has been referred to as an "unplanned triumph" from an epidemiological perspective given an observed global decline in incidence over the 21st century [1]. This decline has been attributed to the addressing of the numerous risk factors associated with gastric cancer including H. Pylori eradication [2]. Modernization and globalization have allowed for advancements in food transport, storage and preservation allowing for increased access to fresh foods high in antioxidants and vitamins while simultaneously allowing for a reduction in the usage of carcinogenic processes such as salt-preservation and the adding of nitrates [3]. Howson et al put forward the hypothesis that the accessibility of refrigeration has played a key role in the reduction in gastric cancer since its widespread integration in the 1920s [1].

Researchers have further attempted to classify the impact of refrigeration on preventing the progression of the 'precancerous cascade' which has been estimated to take years to decades to take effect [4, 5]. Initial studies in the United Kingdom noted that refrigerators only provided a protective benefit against the development of the precancerous cascade when utilized in a country for greater than 30 years [6]. Similarly, researchers in Sweden noted that the length of refrigerator ownership had an inverse relationship with gastric cancer prevalence [7]. It is possible that certain populations may see protective benefits of refrigeration in as little as 5 years [8]. This trend, however, was not statistically significant when generalized for all westernized countries as evident in a 2018 systematic review and meta-analysis whereas Asian countries did demonstrate an overarching protective influence of refrigeration on the development of gastric cancer [9]. A major gap in the literature is none of the studies included were from low-income countries.

With gastric cancer remaining the 4th most prevalent cancer worldwide and its known ties to an individual's environment it is important to understand how each country's population responds to refrigerator ownership as a method of better understanding how to address modifiable risk factors for gastric cancer [10]. Through

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a global analysis of refrigerator ownership and gastric cancer rates, this study aims to identify countries that either conform or reject to the hypothesis that refrigerator ownership correlates with decreased gastric cancer rates.

Materials and Methods

Data Collection

Gastric cancer prevalence rates for individual countries were obtained utilizing the Global Burden of Disease study conducted by the Institute for Health Metrics and Evaluation which has been cited in over 11,000 publications [11]. Data regarding refrigerator ownership rates based on country were accessed via GlobalDataLab Database (v4.2.1) by Radboud University (Netherlands) which collates data from over 600 household surveys conducted by Demographic and Health Surveys, World Bank Living Standard Measurement Surveys, UNICEF Multiple Indicator Cluster Surveys and census data and has been previously utilised in peer-review literature to look at how socioeconomic factors correlate with outcomes [12]. Refrigerator data was available in 1024 subnational regions [12].

Inclusion Criteria

Countries were included for analysis if data were present for greater than 10 years within the datasets and had less than 80% refrigerator ownership prior to 1990 to evaluate for a trend.

Statistical Analysis

Statistical analysis was conducted using IBM SPSS Statistics version 28 with Spearman's rank correlation coefficient (ρ) being utilized to determine the strength and direction of the relationship between gastric cancer incidence and refrigerator ownership with 95% Confidence Interval (CI). Statistical significance was assessed using a two-tailed asymptotic test All the analyses were evaluated at the level of statistical significance of p-value < 0.05.

Results

Refrigerator ownership data for 122 countries were examined using the GlobalDataLab database. Nineteen countries were excluded due to having refrigerator ownership data of less than 10 years and another 18 countries were excluded due to having refrigerator ownership over 80% leaving 85 countries in the analysis (Supplementary Data). The number of countries per continent included in analysis are: Africa: 44, Americas: 17, Asia: 21, Europe: 3. Distribution by income level is as follows: low-income countries: 24 (28%), lower-middle income countries: 38 (45%), and upper-middle income countries: 23 (27%). All countries had estimates on gastric cancer incidence beginning from 1990.

Africa

Data from 44 African countries were included for analysis after exclusion of 4 countries. Twenty-one countries are low-income countries, 20 of the countries are lower-middle income countries and 3 of the countries are upper-middle income countries. Twenty-seven (62.8%) countries had a statistically significant negative correlation for refrigerator ownership and male age-standardized rate (ASR) of gastric cancer with similar findings present among the female population in 24 (55.8%) countries (Table 1). Nine of the 44 countries experienced an initial rise in gastric cancer rates and subsequent decline with a statistically significant correlation to the rise in refrigerator ownership for 7 of those countries (Cote d'Ivoire, Eritrea, Ghana, Rwanda, South Africa, Uganda, and Zambia). Chad, Egypt, Ghana, Kenya, Mozambique, Niger, Togo, and Zimbabwe all demonstrated a significant relationship with an increase in gastric cancer corresponding to an increase in refrigerator ownership.

Refrigerator ownership had not risen above 10% in 16 countries

Benin, Burundi, Burkina Faso, Central African Republic, Chad, Democratic Republic of Congo, Eritrea, Ethiopia, Liberia, Madagascar, Malawi, Mali, Niger, Rwanda, Togo and Uganda.

Americas

For the Americas, 17 countries were included for analysis following the exclusion of 9 countries. One country (Haiti) is a low-income country, 4 countries are lower-middle income countries and 12 countries are upper-middle income countries. Among males and females, 12 (70.6%) countries had a statistically significant negative correlation of ASR and refrigerator ownership (Table 2).

The 5 countries that did not show a negative Spearman correlation were Bolivia, Dominican Republic (male ASR), Guatemala, Honduras (female ASR) and Panama. Bolivia, Guatemala and Panama did not have a statistically significant positive or negative correlation for their rates of gastric cancer and refrigerator ownership. The Dominican Republic experienced a positive correlation among their female population while Honduras experienced a similar positive correlation within their male population. Of note – Honduras is the only country with a rising age-standardized rate of gastric cancer.

Asia

For Asia, 21 countries were analysed after excluding 15 using the inclusion criteria. All countries had refrigerator ownership greater than 20% with over a quarter of countries achieving refrigerator ownership above 90% by 2021. Two countries are low-income countries, 14 countries are lower-middle income countries and five are upper-middle income countries. Eighteen (85.7%) countries had a statistically negative correlation for male ASR for gastric cancer and refrigerator ownership and 17 (81.0%) countries had a statistically negative correlation for the female population (Table 3).

For the countries with a positive correlation between gastric cancer and refrigerator ownership –the rates of gastric cancer in Nepal and Timor Leste have plateaued over last decade despite having an overall statistically significant positive correlation with refrigerator ownership over the duration of the data collection period (Appendix A). Timor Leste has the lowest refrigerator ownership

Table 1. Correlation between Refrigerator Ownership and Gastric Cancer in Africa Using Spearman's Rank Correlation Coefficient (ρ) for Men and Women with 95% Confidence Interval (CI).

	Country	Male ρ (p-value)	95% CI	Female ρ (p-value)	95% CI
1	Angola	-0.999***	-1.000, -0.998	-0.973***	-0.989, -0.935
2	Benin	0.009 (0.962)	-0.368, 0.384	-0.088 (0.649)	-0.450, 0.298
3	Burkina Faso	0.127 (0.528)	-0.277, 0.493	-0.254 (0.201)	-0.586, 0.151
4	Burundi	-0.323 (0.178)	-0.685, 0.168	-0.323 (0.178)	-0.685, 0.168
5	Cameroon	-0.620***	-0.814, -0.304	-0.621***	-0.814, -0.305
6	Central African Republic	-0.647***	-0.820, -0.364	-0.608***	-0.798, -0.307
7	Chad	0.783***	0.571, 0.897	0.870***	0.730, 0.940
8	Comoros	-0.975***	-0.990, -0.940	-0.970***	-0.988, -0.928
9	Congo	-1.000***	. , .	-1.000***	. , .
10	Cote d'Ivoire	-0.999***	-1.000, -0.998	-0.143 (0.487)	-0.511, .0270
11	Democratic Republic of Congo	-0.816***	-0.931, -0.554	-0.816***	-0.931, -0.554
12	Egypt	0.882***	0.747, 0.948	0.936***	0.857, 0.972
13	Eritrea	-0.846***	-0.952, -0.561	-0.938***	-0.981, -0.806
14	Eswatini	-0.227 (0.322)	-0.609, 0.240	-0.266 (0.243)	-0.634, 0.200
15	Ethiopia	-0.998***	-0.999, -0.994	-1.000***	. , .
16	Gabon	-1.000***	. , .	-0.984***	-0.993, -0.962
17	Gambia	-0.230 (0.269)	-0.581, 0.194	-0.040 (0.848)	-0.439, 0.371
18	Ghana	-0.928***	-0.968, -0.840	0.753***	0.508, 0.886
19	Guinea	-0.689***	-0.870, -0.342	-0.995***	-0.998, -0.988
20	Guinea-Bissau	-0.686***	-0.873, -0.324	0.391 (0.098)	-0.091, 0.725
21	Kenya	0.341 (0.066)	-0.034, 0.631	0.653***	0.373, 0.824
22	Lesotho	-0.374 (0.095)	-0.701, 0.082	-0.129 (0.579)	-0.541, 0.333
23	Liberia	0.164 (0.515)	-0.341, 0.596	0.319 (0.197)	-0.188, 0.692
24	Madagascar	-0.961***	-0.982, -0.917	-0.964***	-0.983, -0.923
25	Malawi	-0.955***	-0.982, -0.886	-0.953***	-0.982, -0.883
26	Mali	-0.466*	-0.713, -0.116	-0.939***	-0.972, -0.873
27	Mauritania	-0.284 (0.178)	-0.625, 0.147	-0.368 (0.077)	-0.678, 0.054
28	Morocco	-0.929***	-0.977, -0.788	-0.775***	-0.924, -0.422
29	Mozambique	0.982***	0.954, 0.993	0.279 (0.220)	-0.187, 0.643
30	Namibia	-0.341 (0.096)	-0.656, 0.075	-0.687***	-0.854, -0.390
31	Niger	0.714***	0.397, 0.879	0.216 (0.348)	-0.251, 0.601
32	Nigeria	-0.888***	-0.950, -0.758	-0.832***	-0.924, -0.649
33	Rwanda	-0.801***	-0.903, -0.612	-0.811***	-0.908, -0.630
34	Sao Tome and Principe	-0.818***	-0.919, -0.618	-0.967***	-0.986, -0.924
35	Senegal	-0.051 (0.791)	-0.413, 0.326	0.328 (0.077)	-0.048, 0.622
36	Sierra Leone	-0.990***	-0.997, -0.971	-0.446 (0.073)	-0.770, 0.059
37	Somalia	-1.000***	. , .	-1.000***	. , .
38	South Africa	-0.915***	-0.963, -0.809	-0.701***	-0.861, -0.412
39	Sudan	-0.997***	-0.999, -0.992	-0.999***	-1.000, -0.997
40	Tanzania	-0.993***	-0.997, -0.984	-0.998***	-0.999, -0.997
41	Togo	0.575*	0.231, 0.792	0.685***	0.395, 0.851
42	Uganda	-0.938***	-0.972, -0.865	-0.830***	-0.920, -0.655
43	Zambia	-0.876***	-0.942, -0.745	-0.988***	-0.995, -0.974
44	Zimbabwe	0.080 (0.676)	-0.299, 0.437	0.461*	0.109, 0.710

*, p-value < 0.05, ***, p-value < 0.001.

at 24.2% for Asian countries. Uzbekistan had a positive correlation between gastric cancer and refrigerator ownership with both the rates of refrigerator ownership and gastric cancer declining.

Table 2. Correlation between Refrigerator Ownership and Gastric Cancer in the Americas Using Spearman's Rank Correlation Coefficient (ρ) for Men and Women with 95% Confidence Intervals (CI).

	Country	Male ρ (p-value)	95% CI	Female ρ (p-value)	95% CI
1	Belize	-0.972***	-0.993, -0.897	-0.853***	-0.960, -0.533
2	Bolivia	0.074 (0.779)	-0.435, 0.546	0.083 (0.751)	-0.427, 0.553
3	Brazil	-1.000***		-1.000***	
4	Chile	-0.944***	-0.985, -0.801	-0.972***	-0.993, -0.897
5	Colombia	-0.998***	-0.999, -0.996	-0.999***	-1.000, -0.999
6	Dominican Republic	0.195 (0.312)	-0.196, 0.532	-0.668***	-0.835, -0.390
7	El Savador	-0.616*	-0.869, -0.110	-0.233 (0.422)	-0.689, 0.355
8	Guatemala	0.114 (0.573)	-0.289, 0.482	-0.132 (0.512)	-0.496, 0.272
9	Guyana	-0.981***	-0.993, -0.948	-0.916***	-0.968, -0.785
10	Haiti	-1.000***	-1.000, -0.999	-0.992***	-0.996, -0.983
11	Honduras	0.659*	0.292, 0.856	-0.149 (0.531)	-0.564, 0.327
12	Mexico	-0.974***	-0.989, -0.938	-0.995***	-0.998, -0.988
13	Nicaragua	-0.516*	-0.780, -0.094	-0.721***	-0.882, -.0408
14	Panama	0.291 (0.334)	-0.326, 0.734	0.060 (0.845)	-0.521, - 0.603
15	Paraguay	-0.975***	-992, -0.930	-0.993***	-0.997, -0.979
16	Peru	-0.857***	-0.939, -0.680	-0.836***	-0.930, -0.639
17	Suriname	-0.779***	-0.913, -0.492	-0.809***	-0.926, -0.095

*, p-value < 0.05; ***, p-value < 0.001.

Europe

There were limited countries with data [12]. Six countries were excluded from analysis. The three included countries were all upper-middle income countries. Only Armenia and the female population in Moldova showed a statistically significant negative correlation for gastric cancer (Table 4). There was no statistical significance for the male population of Moldova or the female population of Georgia. There was a statistically positive correlation between gastric cancer and refrigerator ownership in the

Table 3. Correlation between Refrigerator Ownership and Gastric Cancer in Asia Using Spearman's Rank Correlation Coefficient (ρ) for Men and Women with 95% Confidence Interval (CI).

	Country	Male ρ (p-value)	95% Confidence Interval	Female ρ (p-value)	95% Confidence interval
1	Afghanistan	-0.985***	-0.996,-0.944	-0.969***	-0.991, -0.890
2	Bangladesh	-0.952***	-0.985, -0.846	-0.982***	-0.995, -0.942
3	Cambodia	-1.000***		-1.000***	
4	China	-0.918***	-0.969, -0.797	-0.990***	-0.996, -0.973
5	Fiji	-0.509*	-0.794, -0.040	0.430 (0.075)	-0.061, 0.754
6	India	-0.897***	-0.951, -0.789	-0.629***	-0.811, -0.338
7	Indonesia	-0.514*	-0.753, -0.155	-1.000***	
8	Kazakhstan	-0.837***	-0.925, -0.664	-0.838***	-0.926, -0.665
9	Kyrgyzstan	-0.837***	-0.925, -0.663	-0.837***	-0.925, -0.664
10	Laos	-1.000***		-1.000***	
11	Malaysia	-0.923***	-0.978, -.794	-0.912***	-0.975, -0.717
12	Mongolia	-0.958***	-0.984, -.892	-0.997***	-0.999, -0.992
13	Nepal	0.826***	0.586, .933	0.868***	0.676, 0.950
14	Pakistan	-0.756***	-0.880, -.536	-0.768***	-0.886, -0.556
15	Philippines	-0.926***	-0.967, -.838	-0.810***	-0.912, -0.613
16	Tajikistan	-0.763***	-0.894, -510	-0.797***	-0.910, -0.571
17	Timor Leste	0.864***	0.604, .958	0.495 (0.072)	-0.066, 0.818
18	Thailand	-0.665*	-0.863, -.286	-0.839***	-0.938, -0.612
19	Uzbekistan	0.993***	0.979, .997	0.892***	0.713, 0.962
20	Vietnam	-0.997***	-0.999, -.994	-1.000***	
21	Yemen	-0.996***	-0.998, -.991	-0.992***	-0.997, -0.982

*, p-value < 0.05; ***, p-value < 0.001.

Table 4. Correlation between Refrigerator Ownership and Gastric Cancer in Europe Using Spearman's Rank Correlation Coefficient for Men and Women with 95% Confidence Intervals (CI).

	Country	Male ρ (p-value)	95% CI	Female ρ (p-value)	95% CI
1	Armenia	-0.910 ***	-0.963,-0.792	-0.941 ***	-0.976,-0.860
2	Georgia	0.487 *	0.043, 0.771	0.026 (0.915)	-0.433, 0.474
3	Moldova	0.165 (0.573)	-0.415, 0.650	-0.754 *	-0.920, -0.357

*, p-value < 0.05; ***, p-value < 0.001

male population of Georgia.

Discussion

These data represent the first global overview on refrigerator ownership and its relationship to gastric cancer incidence. The results of this study have demonstrated that countries with increasing refrigerator ownership had decreasing rates of gastric cancer across 49 of the studied 85 low-, middle- and high-income countries. This suggests an association between refrigerator ownership and a decrease in gastric cancer.

The identification of countries that experienced a negative correlation between gastric cancer and refrigerator ownership is in congruence with much of the available literature from middle- and high-income countries [6-9,13,14,15]. Further, these data included low-income countries which have not been previously studied in this capacity. Some countries demonstrated a positive or null correlation which has been previously observed for select countries within South and Central America as well as Asia [16,17]. Countries with a positive correlation between gastric cancer and refrigerator ownership were spread across all 5 continents.

With varied demographics and exposures among those countries, research is needed to identify significant modifiable risk factors. This research focus has already proven to be effective for one of the countries included in these data. Within Honduras, researchers were able to identify that the population specific genetics made individuals more susceptible to the carcinogenic fumes from woodstove despite an increase in refrigerator usage, thus allowing for more directed efforts against gastric cancer pathogenesis [18]. Additionally, countries with negligible refrigerator ownership rates and a decreasing cancer rate offer further avenues for research. Burundi, one of the poorest countries in the world, has a refrigerator ownership rate of 1.2% and yet experienced a significant reduction in the ASR for gastric cancer by 43.7% and 34.7% in the male and female population respectively. Further insight into specific health demographics within this population may then be able to be applied to countries experiencing poverty with the inability to use refrigeration to address gastric cancer.

There are limitations within this study as the data presented here are reliant on publicly available databases (Global Burden of Disease study and GlobalDataLab) and therefore the accuracy of our results depends on the accuracy of the sources. GlobalDataLab relies on household surveys for their data collection which could provide a limited insight into a subset of an entire population and certain isolated communities may not be represented. Further, the available refrigerator ownership data has never been utilised to compare it against disease incidence. The Global Burden of Disease study only includes gastric cancer rates over the last 30 years and with many countries experiencing a decline in gastric cancer rates prior to the 1990s, the data presented here may not demonstrate the protective benefit that refrigerators have already conveyed. Cancer aetiology is multifactorial and includes other factors such as H, pylori, smoking, low socioeconomic status and male sex which are confounders we have not factored in this analysis.

In conclusion, this study has shown an association between refrigerator ownership and a decrease in incidence of gastric cancer globally. The burden of disease, however, cannot be entirely mitigated through refrigerator ownership and this study does not consider additional risk factors known to contribute to gastric cancer nor how an individual's lifestyle was changed with refrigerator ownership. The identification of several countries where a negative correlation was not demonstrated allows for a more focused direction for future research efforts in discerning other modifiable risk factors that may contribute to reducing gastric cancer development.

Author Contribution Statement

Conceptualization (KL), Data Curation (YL, EH, TC, YT, KL), Formal Analysis (YL, EH, TC, YT, AH, MF, KL), Methodology, (YL, EH, TC, YT, KL), writing (AH, YL, EH, TC, YT, KL) writing – review and editing (MF, AH, KL)

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Approval

This study did not require any institutional ethics approval as all of the information were freely available in the public domain.

Disclosure

This research was presented at International Surgery Week 2024 by YL.

Data Availability

All data generated and analysed during this study are available on publicly available platforms.

Ethical Declaration

This study did not require any ethical approval as all of the information were freely available in the public domain.

Conflict of Interest

The authors declare that they have no conflicts of interest.

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