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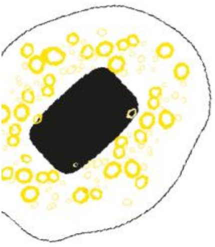

Exploring Gender Disparities in Global Cancer Trends:

The Role of Socioeconomic Status

by

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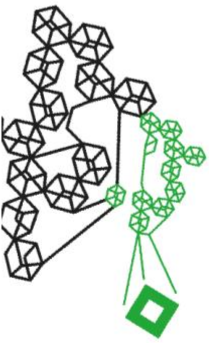

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Abstract

Introduction Past cancer research prioritizes the global health impact of the disease, yet often overlooks gender differences. Current trends focus on the etiology with gender treated as an associated variable, thereby missing critical insights into how cancer incidence and mortality differ by gender, particularly across varying socioeconomic status. Socioeconomic status (SES) influences cancer trends, but the interaction between SES and gender disparities in cancer remains underexplored. This study aims to address this knowledge gap, providing a global overview of gender-based differences in cancer incidence and mortality. **Method** data on cancer incidence from the CI5-XII database was obtained from the International Agency for Research on Cancer (IARC). 63 cancer types were grouped into 12 categories for further analysis, excluding sex-specific cancers. The Human Development Index (HDI) and Gender Inequality Index (GII) were used to assess a country's SES. Multivariable regression models explored the relation between SES and gender disparities worldwide with the male-to-female ratio (MFR) for incidence or mortality as the outcome variable. **Results** High gender disparities are found in European countries mostly, particularly in men, respectively followed by African and Asian countries. This disparity is reflected in mortality rates, where Europe consistently records higher rates of gender-specific cancers compared to Asian and African countries for men, and American and Australian countries for women. In most cancers higher HDI or GII means lower MFR. **Conclusion** This study highlights global gender disparities in cancer trends with variation across countries. More developed countries, with high HDI, show narrower gender gaps. On the other hand, less developed countries scoring higher on inequality leads to reduced disparity as well. Clinicians and policymakers should focus on targeted health-promoting behaviors among high SES men, raising awareness of cancer risks among less educated and prioritizing screening programs for low SES women.

Keywords: Cancer Incidence, Cancer Mortality, Gender Disparities, Socioeconomic, Human Development Index, Gender Inequality Index, CI5-XII Volume, Multivariable Regression Analysis.

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Introduction

Cancer research has become a high-priority area due to its significant global health impact. Despite this focus, gender differences in cancer have been consistently overlooked ((1–5). Current research trends prioritize understanding the disease's etiology, with gender primarily treated as an associated variable (6,7). Suggesting that researchers believe there is a significant difference (8–11). However, the actual differences in cancer between genders have rarely been the primary focus, leaving questions about what these differences are and how they vary across countries worldwide.

Previous studies have highlighted distinct gender disparities in cancer incidence and mortality. According to a 2024 OECD report, age-adjusted cancer incidence is 40% higher in men, with cancer mortality almost 70% higher compared to women, based on data from European countries (2). In the United States the gender gap in cancer incidence has narrowed but men still have 14% higher rates generally, except for breast and thyroid cancers (1). In Asian countries, there has been an increase in cancer incidence among women, along with a greater decrease in mortality trends among men compared to women (12). The varying disparity in cancer among these countries emphasizes the necessity for gender-focused research to understand the underlying reasons behind this imbalance.

The socioeconomic status (SES) emerges as a potential factor which may influence gender disparities in cancer trends. SES encompasses elements such as income, education, and life expectancy, which can affect the risk of cancer diagnosis or mortality differently for each gender. For instance, the 2024 OECD report highlights that high SES men often face risk factors like obesity, alcohol consumption, and physical inactivity. In European countries, men are 51% more likely to be daily smokers and over twice as likely to report heavy alcohol drinking compared to their female counterparts (2). Additionally, high SES women are more likely to engage in health-promoting behaviors due to their education attainment and health literacy, resulting in different cancer risks among more developed countries and potentially leading to gender-based differences in cancer (13). In lower developed countries, such as African or Asian nations, healthcare is not universally accessible, and screening and treatment programs are less advanced, leading to poorer health outcomes (14–16). Limited healthcare access, due to factors like inadequate public transport to hospitals in poor neighborhoods and unaffordable out-of-pocket costs for low SES individuals, contributes to relatively lower incidence rates for both genders(13,17). Generally, lower SES is linked to reduced participation in screening programs (2). However, low SES women often participate more frequently in cancer screening programs than their male counterparts, who typically seek medical attention only when symptoms become severe, affecting reported incidence rates (13). SES may differently affect health-seeking behavior, risk and symptom awareness, and ability to access healthcare by gender, raising questions about its role in global gender disparities.

Despite previous research, the relationship between SES and gender disparities in cancer remains largely unexplored. This study aims to fill this gap by providing a comprehensive global overview of gender-based differences in cancer trends. Insights from this research could assist healthcare policymakers anticipate and address disparities based on a country's socioeconomic development and corresponding cancer trends.

Method

Data Sources

To initiate this research, data on cancer incidence and mortality from the CI5-XII volume covering the period 2012 to 2017 was obtained from the International Agency for Research on Cancer (IARC). The datasets included case information for both genders from 65 and 39 countries, encompassing various cancer types, including head and neck, colorectal, and lung cancer, amounting to a total of 63 distinct types. For this research, cancer types were grouped into 12 categories (Appendix A), excluding sex-specific cancers (1,18–24).

SES measurements

To relate a country's SES to gender-based differences in cancer incidence and mortality, two measures were used: the Human Development Index (HDI) and the Gender Inequality Index (GII). The HDI measures achievements in key dimensions of human development: life expectancy, education level, and national income (GDP) (25). The GII reflects a country's status by delineating the disparities in opportunities presented to both men and women in three dimensions: reproductive health, empowerment, and labor market participation (25,26). Both HDI and GII range from 0 to 1 and are interpretably different. For HDI, a value closer to 1 indicates high human development, while a value closer to 0 indicates low development. Conversely, for GII, a value of 0 represents absolute gender equality, while a value of 1 denotes the highest level of gender inequality. Therefore, more developed countries typically have high HDI and low GII values, whereas less developed countries often have the opposite.

Data for both indices was obtained from the United Nations statistical reports covering the period from 1992 to 2012 (25,27–45).

Statistical Analysis

Cancer Incidence and Mortality

The incidence rate (IR) was calculated to determine the number of cases that got diagnosed with cancer in the period of 2012 to 2017 and is presented as an annual rate per 100,000 individuals (46). The mortality rate (MR) refers to a country's count of cancer-related deaths over the same period. Both IR and MR were age-standardized according to the population size of each gender for every country, to maintain the age distribution and life expectancy per country. The population data was provided by the IARC and World Health Organization (WHO) (47). The standardized IR and MR were visualized in a heatmap using a color spectrum to denote varying rates, with darker areas indicating higher rates.

Global Gender Disparity

The Male-to-female ratio (MFR) was calculated for both IRs and MRs to measure gender disparity (Appendix B). The ratio above 1 indicates higher incidence or mortality rates among men for a specific cancer category, while a ratio below 1 suggests higher rates among women.

SES and Cancer Trends

Initially, scatterplots were used to identify the relationships between HDI, GII, and MFR across all countries. Subsequently, the MFR was transformed using a logarithmic scale, denoted as log(MFR), to ensure a fitting distribution. To explore the impact of SES on gender-based differences in cancer, regression models were developed. These models incorporated HDI, GII, and age as variables, with MFR as the outcome variable. Separate models were constructed for each of the 12 cancer categories, analyzing both incidence and mortality datasets. Relationships between HDI, GII, or age were considered statistically significant if the p-values were less than 0.05.

Results

Cancer Incidence

Disparities in cancer IRs are observed among different countries worldwide, varying per cancer category (Figure 1). Colorectal, lung, urinary, and skin and bone cancers exhibit high rates among men. Women demonstrate elevated IRs as well for these categories, with higher rates additionally found for breast cancer.
The IRs vary between countries as well; for instance, skin and bone cancer shows higher rates in European nations like Denmark, United Kingdom, and Iceland. The IRs surpass 450 cases per 100,000 individuals for men and over 350 cases for women (Supplementary material). In contrast, less developed countries such as India, Benin, and Kenya report relatively lower rates, with 15 cases or less per 100,000 individuals for both genders (Supplementary material). For women, breast cancer shows high IRs across most countries ranging from 21 to 241 cases per 100,000 women, with European countries reporting the highest rates, while the lowest rates are predominantly found in African countries (Supplementary material).

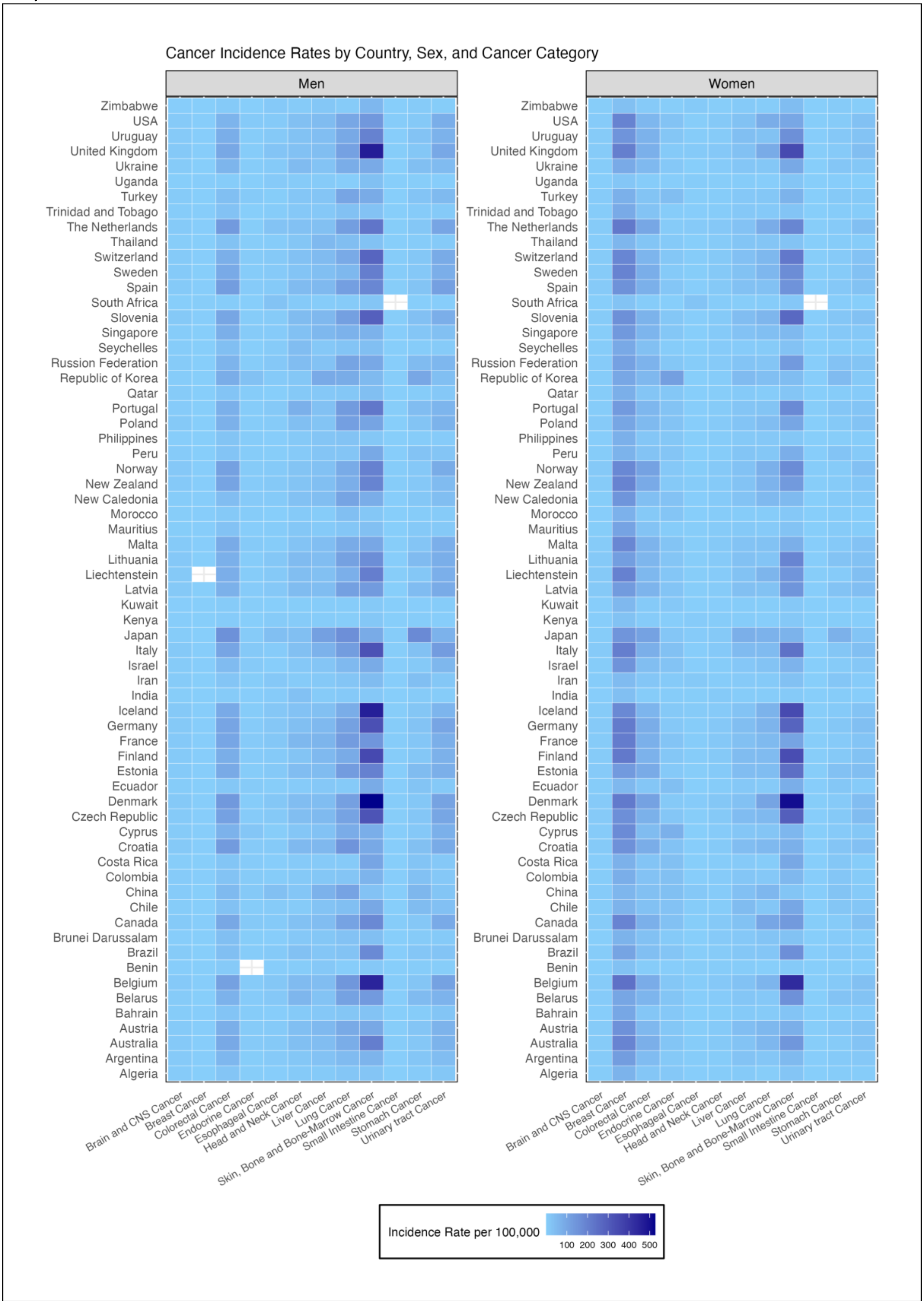
Brain and central nervous system (CNS), esophageal, and small intestinal cancers have relatively low IRs. For instance, esophageal cancer rates peak at 38 cases for men and 26 cases for women per 100,000 individuals, with even lower rates observed for the other two cancer types (Supplementary material).

Cancer Mortality

Relatively high MRs are found for colorectal, liver, and lung cancer across all countries, regardless of gender (Figure 2). Poland, South Africa, Chile, Argentina, and Brazil exhibit the highest rates. For instance, in Poland and South Africa, colorectal cancer mortality rates surpass 2700 and 1710 cases per 100,000 men and 1980 and 1040 cases per 100,000 women, respectively (Supplementary material). Countries such as the USA, Israel, and Iceland report lower rates ranging from 5 to 16 per 100,000 cases for men and 4 to 14 cases per 100,000 for women (Supplementary material).

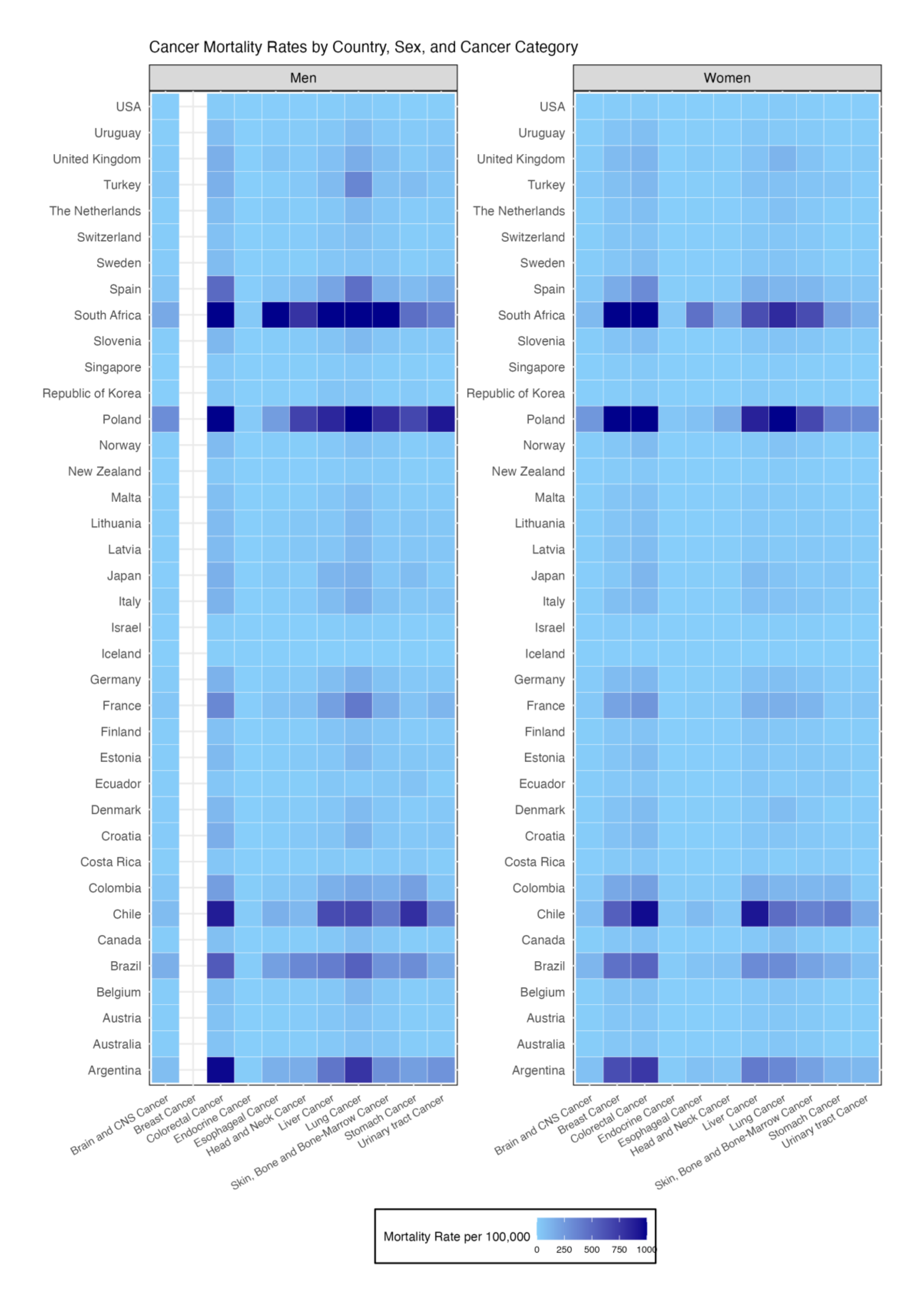
In women relatively high MRs are observed for breast cancer, with South Africa and Poland reporting over 1100 and 1500 deaths per 100,000 individuals (Supplementary material). Countries such as Singapore, USA, Israel, the Republic of Korea, and Iceland demonstrate rates below 15 deaths per 100,000 individuals (Supplementary material).

Figure 1: Heatmap of cancer incidence rates by country, sex, and cancer category with IR given per 100,000 individuals.



Ranges of legend are based on maximum and minimum IR in dataset. Blank spaces indicate missing case data.

Figure 2: Heatmap of cancer mortality rates by country, sex, and cancer category with MR given per 100,000 individuals.



The blue color gradient, ranging from light to dark blue, represents low to high incidence rates. The legend is scaled to correspond with the IR in Figure 1 to ensure consistent interpretation of both rates. Black spaces indicate missing case data.

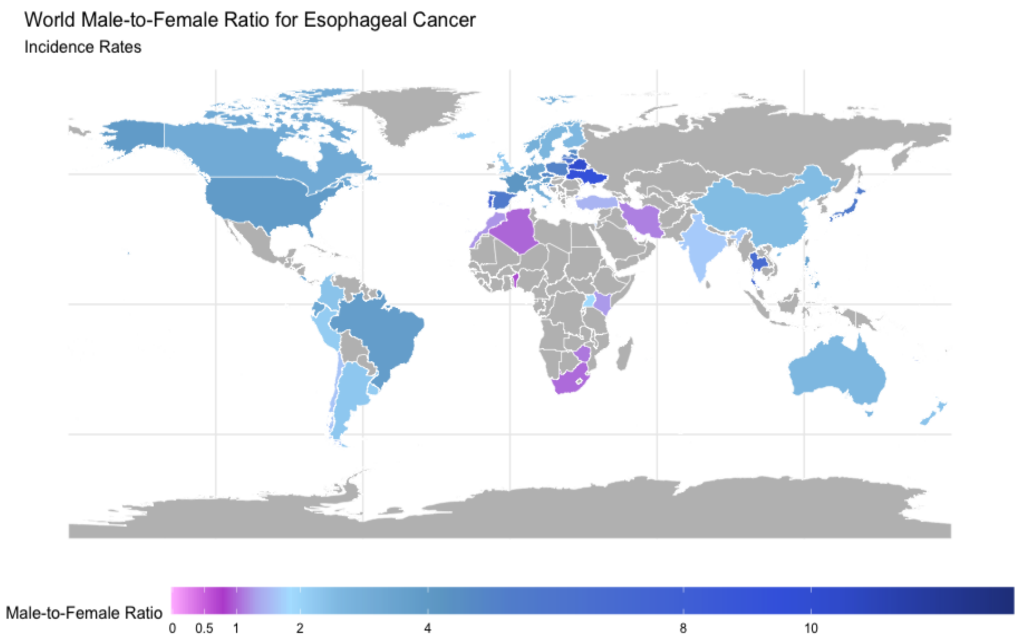
Global Gender Disparity

Incidence

The MFR shows varied distributions across cancer categories, indicating that some cancers are more prevalent in men and others more in women. For breast cancer the MFR is ranging between 0 and 0.04 with two African countries, Uganda and South Africa, with an outlying ratio of 0.10 (Figure 9, Appendix C). For endocrine cancers the MFR is between 0 and 0.5, where the top 5 lowest MFRs are less developed countries, and the top 5 highest ratios are all European with exception of New Zealand (Figure 11, Appendix C). Both cancer categories show by far higher incidence among women.

Higher IRs in men were evident across esophageal, head and neck, lung, and urinary cancers (Figures 12, 13, 15, 19 in Appendix C). The MFR consistently exceeded one, except for esophageal cancer. Qatar and Benin were the only two countries where more women were diagnosed with esophageal cancer than men (Figure 3). In most African and Asian countries MFR is ranging between 1 and 2 (11 out of 14). However, in Singapore, Japan, Thailand, and 14 European countries, men were over four times more frequently diagnosed with esophageal cancer than women. In Belarus and Seychelles, men were diagnosed ten times more often than women.

Figure 3: Global Gender Disparity for Esophageal Cancer Incidence

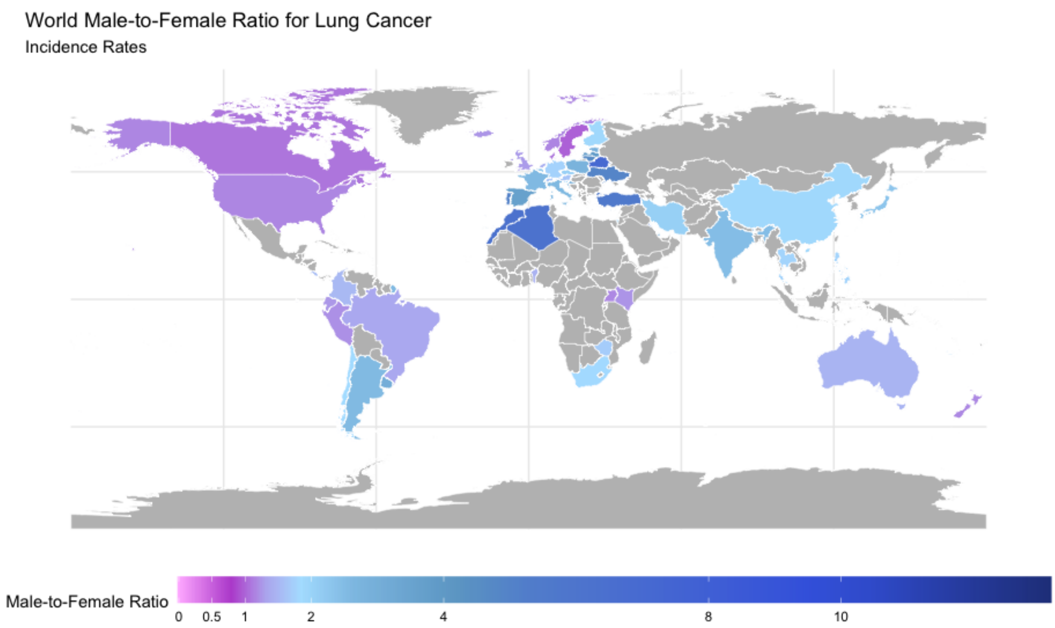


Male-to-female incidence ratio (MFR) less than 1 is represented by a pink-violet color spectrum indicating higher IRs for women, while a violet-blue color spectrum indicates an MFR greater than 1, indicating higher IRs for men.

For head and Neck cancer eight out of ten countries had a MFR exceeding 4, predominantly European countries, except for Qatar and Seychelles (Figure 13, Appendix C).

Regarding lung cancer, the highest IRs were observed in numerous European countries, the highest MFRs were found in Algeria, Morocco, and Belarus, where men were diagnosed over six times more frequently than women (Figure 4). Smaller gender disparities were found in America, Australia and Northern Europe.

Figure 4: Global Gender Disparity for Lung Cancer Incidence



Male-to-female incidence ratio (MFR) less than 1 is represented by a pink-violet color spectrum indicating higher IRs for women, while a violet-blue color spectrum indicates an MFR greater than 1, indicating higher IRs for men.

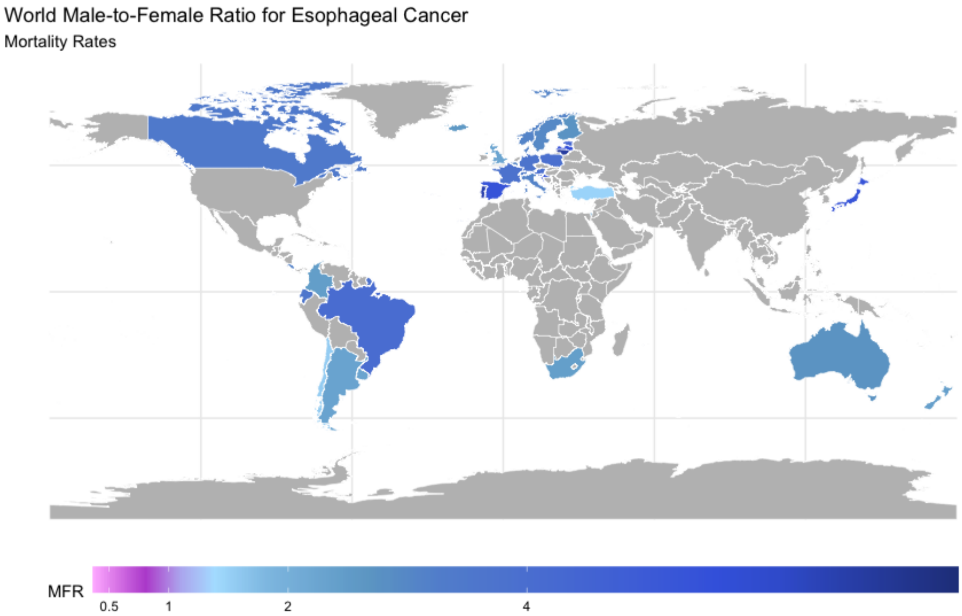
For urinary tract cancer, the lowest ratios slightly above 1 were found in African countries; Zimbabwe, Kenya, and Uganda, while most countries exhibited MFRs between 2 and 3 (Figure 19, Appendix C).

Mortality

Similar to the global MFR for incidence, the mortality data reveals gender-specific patterns as well. Higher mortality rates among women were found for endocrine cancer, with ratios ranging from 0.37 to 0.89, except for Iceland, which stands as an exception at 1.13 (Figure 22, Appendix D). New Zealand, Australia, and the United States exhibit the highest ratios, while ratios below 0.5 are predominantly found in European countries followed by south American countries.

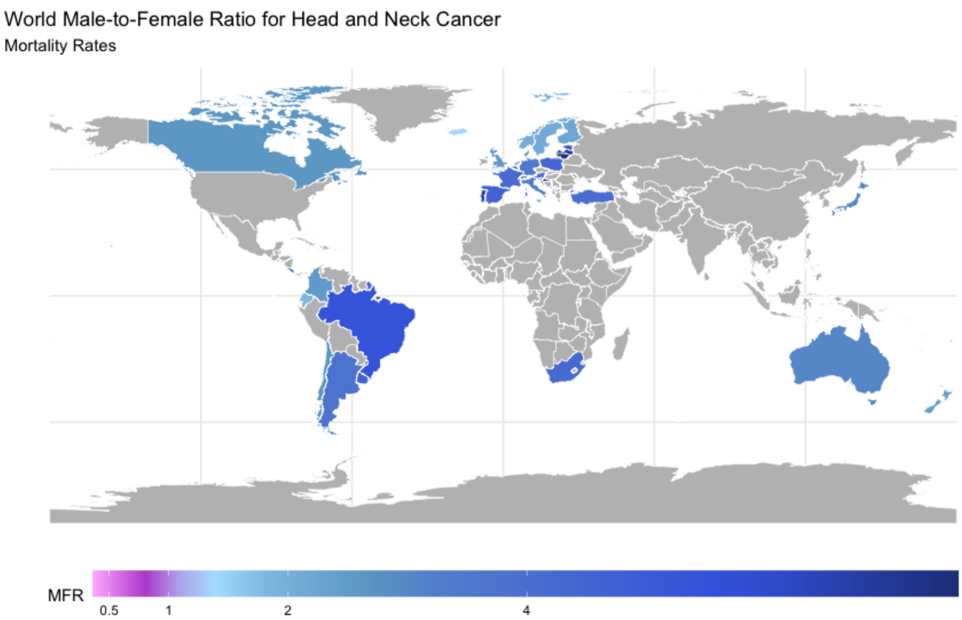
Esophageal cancer mortality rates vary widely, with MFR ranging from 1.5 to 6.9. Turkey and Chile are the exceptions, with ratios below 2, scaling up to 6 times more deaths among men in the other 37 countries (Figure 5). European countries and Brazil top the list with the highest gender disparities, with MFR exceeding 5.4. Similarly, head and neck cancer disparity ranges from 1.4 to 7.6, with only Iceland, Malta, and Ecuador having an MFR below 2 (Figure 6). Once again, European countries demonstrate high gender disparity, with over 6 times more deaths among men.

Figure 5: Global Gender Disparity for Esophageal Cancer Mortality



Male-to-female mortality ratio (MFR) less than 1 is represented by a pink-violet color spectrum indicating higher MRs for women, while a violet-blue color spectrum indicates an MFR greater than 1, indicating higher MRs for men.

Figure 6: Global Gender Disparity for Head and Neck Cancer Mortality

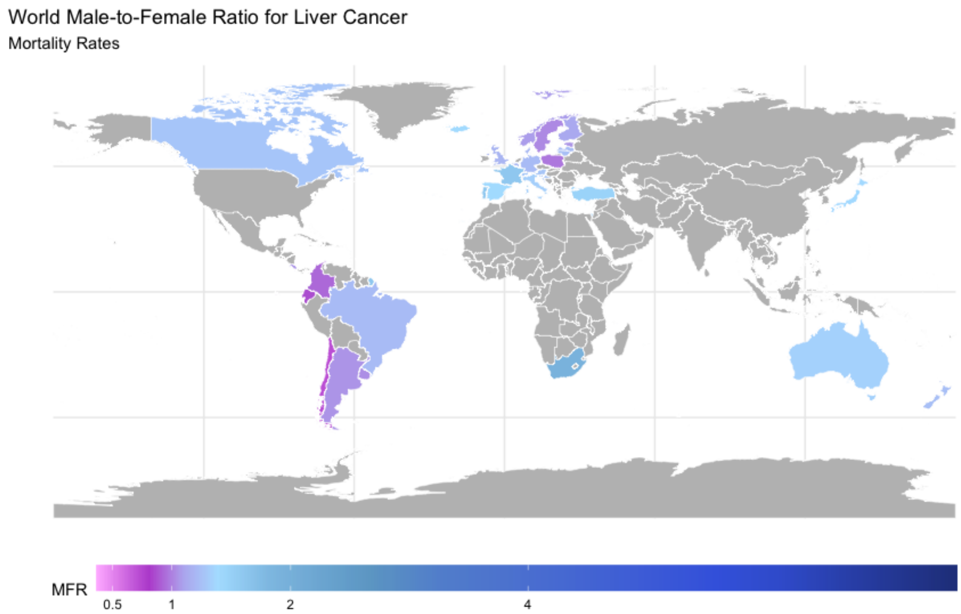


Male-to-female mortality ratio (MFR) less than 1 is represented by a pink-violet color spectrum indicating higher MRs for women, while a violet-blue color spectrum indicates an MFR greater than 1, indicating higher MRs for men.

Men face a greater risk of mortality from urinary cancer, with a risk that is 1.8 to 3.7 times higher than that of women (Figure 29, Appendix D). Turkey, Spain, and Israel exhibit the highest rates, while South American, Central and Northern European countries demonstrate comparatively lower rates.

Liver cancer mortality rates show diverse trends globally (Figure 7). In countries like Chile, Ecuador, Colombia, and Poland, women exhibit higher MRs, while in South Africa, Singapore, Portugal, and France, men are over 1.5 times more likely to die from liver cancer.

Figure 7: Global Gender Disparity for Liver Cancer Mortality



Male-to-female mortality ratio (MFR) less than 1 is represented by a pink-violet color spectrum indicating higher MRs for women, while a violet-blue color spectrum indicates an MFR greater than 1, indicating higher MRs for men.

Mortality gender gaps for brain and CNS, colorectal, skin, and stomach cancers are comparatively narrower, with MFR ranging between 1 and 2 (Figure 20, 21, 27, 28 in Appendix D).

SES and Cancer Trends

For breast, colorectal, and liver cancer, a higher HDI is significantly associated with a reduced MFR (Table 1). While this trend also applies to endocrine and small intestinal cancers, these relationships are not significant. In contrast, for brain and CNS cancer, a higher HDI corresponds to an increased MFR. This pattern is similarly observed in esophageal, stomach, and skin and bone cancers, though these associations are not significant.

Increasing GII, indicating greater inequality in a country, is linked to a reduced MFR for colorectal, endocrine, esophageal, and liver cancers (Table 1). This trend also appears in head and neck and urinary tract cancers, though the associations are not significant. Breast and skin and bone cancers show a positive relationship with GII; as gender inequality rises, so does the MFR, resulting in more pronounced gender-based differences in cancer incidence. This pattern is also recognized in brain and CNS and lung cancers.

Table 1: Relation between SES and gender disparity in cancer incidence

Cancer Category	HDI (95% CI)	p-value HDI	GII (95% CI)	p-value GII
Brain and CNS	**1.07 [1.02; 1.11]**	**0.001**	1.01 [0.98; 1.05]	0.525
Breast	**0.79[0.74; 0.85]**	**<0.001**	**1.08 [1.01; 1.15]**	**0.024**
Colorectal	**0.93 [0.90; 0.96]**	**<0.001**	**0.94 [0.91; 0.96]**	**<0,001**
Endocrine	0.96 [0.92; 1.01]	0.082	**0.92 [0.88; 0.95]**	**<0,001**
Esophageal	1.08 [1.00; 1.17]	0.060	**0.89 [0.83; 0.96]**	**0,002**
Head and Neck	1.00 [0.95; 1.05]	0.959	0.96 [0.92; 1.01]	0.126
Liver	**0.88 [0.84; 0.92]**	**<0.001**	**0.90 [0.86; 0.94]**	**<0,001**
Lung	1.00 [0.94; 1.06]	0.999	1.02 [0.97; 1.08]	0.401
Skin, Bone and Bone Marrow	1.01 [0.98; 1.03]	0.585	**1.04 [1.02; 1.06]**	**<0,001**
Small Intestine	0.97 [0.91; 1.04]	0.430	0.97 [0.92; 1.02]	0.255
Stomach	1.03 [0.99; 1.07]	0.125	0.98 [0.95; 1.02]	0.314
Urinary Tract	1.00 [0.99; 1.08]	0.128	0.98 [0.94; 1.03]	0.380

Regression analysis of the Male-to-female ratio (MFR) for incidence rates across 12 distinct cancer types, using HDI and GII as predictor variables with age as an interacting variable. The coefficients must be interpreted relatively by 0.1 increase in SES. **Note**: Bold indicates significant values. HDI: Human Development Index, GII: Gender Inequality Index, CI: Confidence Interval. * See Appendix E for regression results concerning the age groups.

In general, higher human development, indicated by higher HDI, corresponds to a decreased MFR (Table 2). This trend does not apply to brain and CNS cancer and Liver cancer where no significant relationship between HDI and MFR is observed.
Increasing gender inequality, reflected by high GII, is linked to a decrease in MFR, except for brain and CNS cancer. The strength of the associations between SES and MFR varies across cancer categories; the impact of increasing HDI and GII is most pronounced on the MFR of esophageal, head and neck, and lung cancer.

Table 2: Relation between SES and Gender Disparity in Cancer Mortality

Cancer Categories	HDI (95% CI)	p-value HDI	GII (95% CI)	p-value GII
Brain and CNS	1.01 [0.99; 1.04]	0.289	1.00 [0.99; 1.01]	0.927
Colorectal	**0.92 [0.90; 0.94]**	**<0.001**	**0.94 [0.93; 0.95]**	**<0.001**
Endocrine	**1.13 [1.08; 1.17]**	**<0.001**	**0.93 [0.91; 0.96]**	**<0.001**
Esophageal	**0.81 [0.77; 0.84]**	**<0.001**	**0.81 [0.79; 0.84]**	**<0.001**
Head and Neck	**0.64 [0.61; 0.67]**	**<0.001**	**0.80 [0.78; 0.82]**	**<0.001**
Liver	0.88 [0.86; 1.22]	0.082	**0.90 [0.89; 0.92]**	**<0.001**
Lung	**0.62 [0.60; 0.65]**	**<0.001**	**0.83 [0.81; 0.85]**	**<0.001**
Skin, Bone and Bone Marrow	0.99 [0.97; 1.00]	0.155	0.99 [0.98; 1.00]	0.036
Stomach	**0.88 [0.85; 0.90]**	**<0.001**	**0.96 [0.94; 0.98]**	**<0.001**
Urinary Tract	**0.88 [0.85; 0.92]**	**<0.001**	**0.92 [0.91; 0.94]**	**<0.001**

Regression analysis of the Male-to-female ratio (MFR) for mortality rates across 10 distinct cancer types, using HDI and GII as predictor variables with age as an interacting variable. The coefficients must be interpreted relatively by 0.1 unit increase in SES. **Note**: Bold indicates significant values, CI: Confidence Interval. * See Appendix E for regression results concerning the age groups.

Discussion

Incidence

This study highlights higher IRs in European countries compared to less developed regions such as Africa and Asia. According to Pramesh et al. (2022), cancer research is predominantly focused on more developed countries (48). Effective cancer control measures, such as screening programs, are prevalent in developed countries but are less applicable in less developed countries due to differing healthcare contexts, sociocultural factors, resource availability, and implement ability of intervention costs. Consequently, less developed countries cannot adopt the same strategies for diagnosing and reporting cancer cases, potentially leading to lower IRs. Additionally, Pramesh et al. (2022) notes that population-based cancer registries are often lacking in African and Asian countries, which contribute to the lower reported rates.

Mortality

In this study, Higher MRs are observed in Poland, South Africa, and South American countries, while lower rates are found in the USA, Singapore, and Korea. According to Goss et al. (2013), the mortality-to-incidence ratios in Latin American regions are nearly twice that of the USA (16). The key factors contributing to this difference could include the low healthcare expenditure, fragmented healthcare systems, and lack of coverage for the poor. In contrast, the USA has one of the highest healthcare expenditures as a percentage of GDP, leading to better cancer prevention and treatment possibilities. Similarly, in Korea, the five-year survival rate improved to over 70% from 2010 to 2014, indicating enhanced health outcomes and improved cancer care (49).

Gender Disparity

The largest gender-based differences in cancer rates are found mainly in European countries, with men more commonly contributing to these disparities. Higher rates among women are only found for breast and endocrine cancers across almost all studied countries. This disparity in Europe might be unexpected. However, according to Gu X et al. (2018), cancer is associated with aging populations and socioeconomic development, which is more prevalent in Western countries. The long-life expectancy in well-developed nations leads to higher possibility of cancer development and thereby overall cancer incidence and mortality, with the gender skew potentially depending on cancer type or the varying impact of high SES (50).

SES and Cancer Trends

This study highlights that a higher HDI, indicative of high SES countries, is linked to narrower gender disparities in cancer. Differences between high SES men and women might be narrower due to greater healthcare expenditure and better health literacy (51–53). Rana et al. (2020) found that 43% of the variation in global health expenditure growth is explained by economic development, suggesting that higher-income countries have increased health expenditure, which enhances access to cancer care and screening programs (52). Higher SES women tend to utilize these facilities more than men, while men are generally riskier in their health-seeking behavior, mitigating the disparity(13).

Education, another aspect of HDI, is associated with increased cancer risks among the less educated. Better education leads to improved health literacy, promoting health-seeking behaviors, especially among high SES women, and better health outcomes due to a better understanding and involvement in cancer care (Holden et al., 2021). Health literacy is linked to the uptake of preventive services, the ability to understand health information, and making informed decisions about care (53). In low SES countries, lower education levels can lead to gender-based differences, as individuals may struggle to manage their health, and women are even less likely to be educated based on labor market participation and empowerment issues (54). Holden et al. (2021) suggest that more research should focus on patient-centered care for those with low literacy to improve health outcomes, especially among low SES women who are more likely to adopt health opportunities but have minimal access in less developed countries (13,53).

This study also highlights that higher GII values, commonly found in less developed countries, are linked to narrower gender disparities in cancer as well. Reproductive health in low SES women, characterized by early childbearing and multiple pregnancies, influences cancer risk (13,55). For instance, breast cancer is more common among high SES women because of late childbearing due to higher education levels and career choices, potentially leading to larger gender-based differences than in low SES countries. Empowerment, or lack thereof, in less developed countries often means women are less educated, have lower labor market participation and thereby limited decision-making power about household resources and their own healthcare (13,56). Low SES men are less likely to attend screening programs or seek treatment, which can further limit low SES women's access to healthcare, narrowing the gender gap (2,14). Additionally, most employed women in Africa and Asia work in the informal sector, earning low incomes and lacking social protection, which increases their dependency (56). The impact of education, labor market participation, and socioeconomic dependency on low SES individuals, especially among women, may lead to narrower disparities. However, registration issues and underreporting in less developed regions should not be overlooked when making this assumption(48,57).

Limitations and strengths

A limitation of this study is the greater inclusion of more developed countries compared to less developed ones. This results in a better representation of the relationship between high SES and gender disparity. Future research should include more lower-developed countries, which are underrepresented here, to maximize external validity and better understand the actual interplay, especially considering the general underreporting of rates from these regions (48,57). Despite the variations in data coverage, this study successfully demonstrates a relation between SES and gender disparity for multiple cancer categories on a global scale.

This study enlightens a largely unexplored dimension by visualizing and identifying gender disparities in cancer using the CI5-XII volume, leveraging the most recent and complete data available. The research methods and regression analysis can be applied in future volumes, and additional SES measures can be incorporated in future studies. Past trends in SES development and cancer can provide valuable insights for policymakers and researchers.

Recommendations based on this study include stimulating health-promoting behaviors among high SES men and both providing and educating about screening and treatment opportunities to low SES individuals, especially women.

Conclusion

Incidence and Mortality

High IRs are mainly found in European countries, while low IRs are common in less developed regions like Africa and Asia. Cancer research primarily focuses on more developed countries. However, due to different healthcare contexts, availability of socioeconomic resources, and the ability to implement interventions, less developed regions struggle to adopt these measures. This leads to lower rates of cancer diagnosis and reporting in these areas. Additionally, high mortality rates are identified in Poland, South Africa, and some South American countries, while lower mortality rates are observed in Iceland, the United States, and parts of Asia. High mortality and thereby poor survival could relate to lower healthcare expenditure, fragmented healthcare systems, and lack of coverage for the poor.

Gender disparity

For most cancer categories, the IRs and MRs in men are higher in European countries, followed by African and Asian countries. Breast and endocrine cancers are an exception to this trend, which are more prevalent among women. Regarding MRs in women, high MRs are primarily found for endocrine and liver cancers in European countries, followed by south American countries.

SES and Cancer Trends

In general, higher HDI or GII is linked to a decrease in MFR, indicating narrower gender disparities in cancer incidence and mortality. In more developed countries, reduced gender differences may result from varying westernization impact, health-promoting behaviors among high SES women, and health literacy. Higher gender inequality, linked to reduced disparity, might be due to early childbearing among low SES women, socioeconomic dependency from lower labor participation, and the riskier health attitudes of low SES men.

To mitigate the gender disparities, clinicians and policymakers should focus on stimulating health-promoting behaviors among high SES men, raising awareness of cancer symptoms and treatment among the less educated, and prioritizing screening programs for low SES individuals, particularly women.

Ethical Approval

Ethical approval was obtained from the Ethics Commission of the Behavioural and Management Sciences Faculty of the University of Twente, in the Netherlands.

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Appendix

Appendix A – Overview Categorized Cancer Types

Cancer Category	Cancer Type	ICD-10 Codes
Head and Neck Cancer	Lip	C00
	Tongue	C01-02
	Mouth	C03-06
	Salivary glands	C07-08
	Tonsil	C09
	Other oropharynx	C10
	Nasopharynx	C11
	Hypopharynx	C12-13
	Pharynx unspecified	C14
Esophageal Cancer	Oesophagus	C15
Stomach Cancer	Stomach	C16
Small Intestine Cancer	Small intestine	C17
Colorectal Cancer	Colon	C18
	Rectum	C19-20
Anal Cancer	Anus	C21
Liver Cancer	Liver	C22
	Gallbladder etc.	C23-24
	Pancreas	C25
Head and Neck Cancer	Nose, sinuses etc.	C30-31
	Larynx	C32
Lung Cancer	Lung (incl. trachea and bronchus)	C33-34
	Other thoracic organs	C37-38
Skin, Bone and Bone Marrow Cancer	Bone	C40-41
	Melanoma of skin	C43
	Other skin	C44
	Mesothelioma	C45
	Kaposi sarcoma	C46
	Connective and soft tissue	C47+C49
Breast Cancer	Breast	C50
Urinary Tract Cancer	Kidney	C64
	Renal pelvis	C65
	Ureter	C66
	Bladder	C67
	Other urinary organs	C68

Skin, Bone and Bone Marrow Cancer	Eye	C69
Brain and CNS cancer	Brain, nervous system	C70-72
Endocrine Cancer	Thyroid	C73
	Adrenal gland	C74
	Other endocrine	C75
Skin, Bone and Bone Marrow Cancer	Hodgkin disease	C81
	Non-Hodgkin lymphoma	C82-86, C96
	Immunoproliferative diseases	C88
	Multiple myeloma	C90
	Lymphoid leukaemia	C91
	Myeloid leukaemia	C92-94
	Leukaemia unspecified	C95
	Myeloproliferative disorders	MPD
	Myelodysplastic syndromes	MDS

Appendix B – MFR Formula

$$MFR = \frac{Incidence\ Rate\ Male}{Incidence\ Rate\ Female}$$

$$MFR = \frac{Mortality\ Rate\ Male}{Mortality\ Rate\ Female}$$

Appendix C – Distribution of MFR worldwide Incidence Dataset

Figure 8: Global Gender Disparity for Brain and CNS Cancer Incidence

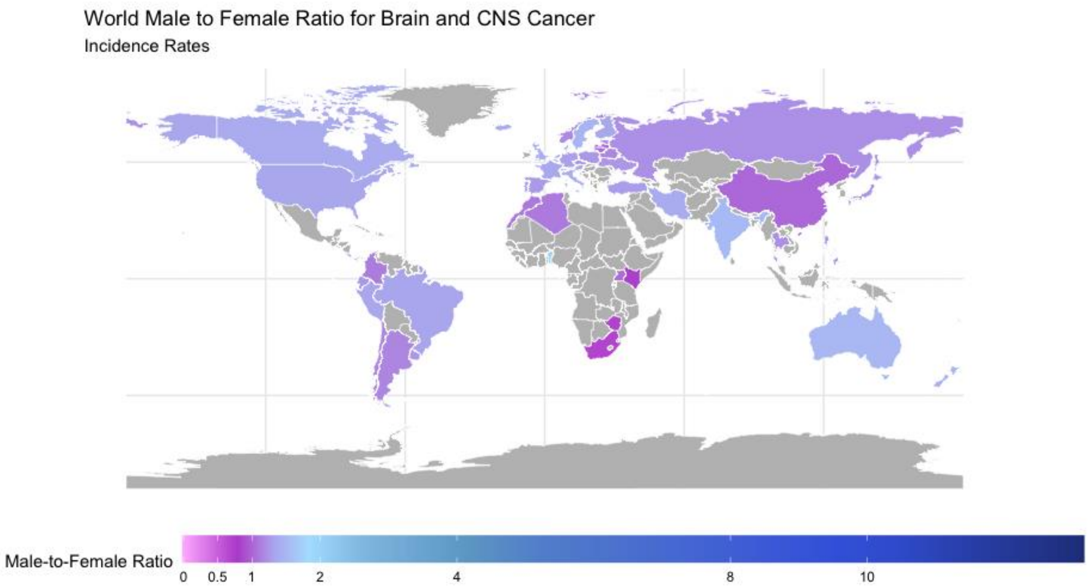


Figure 9: Global Gender Disparity for Breast Cancer Incidence

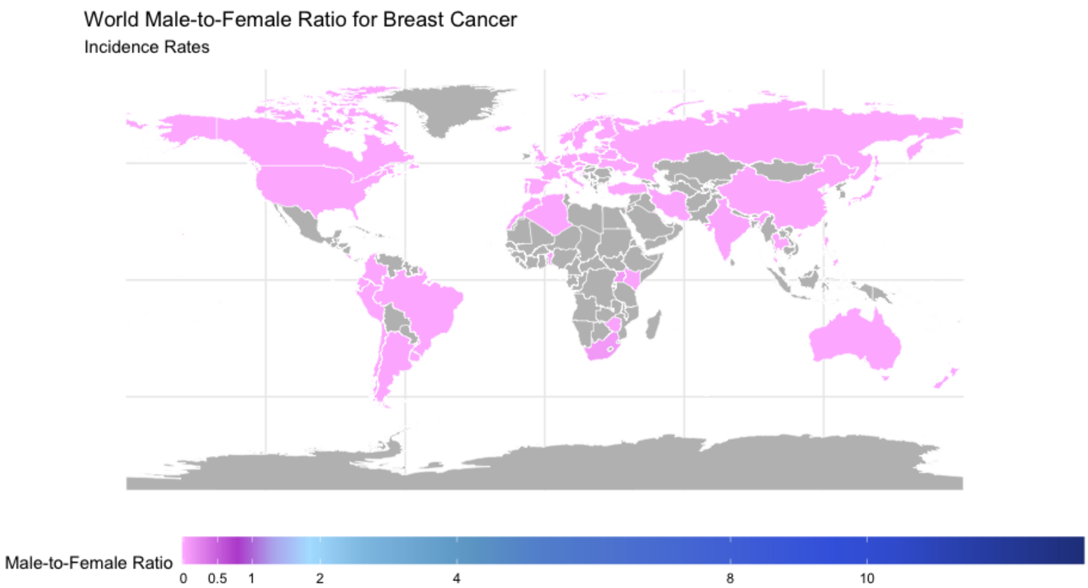


Figure 10: Global Gender Disparity for Colorectal Cancer Incidence

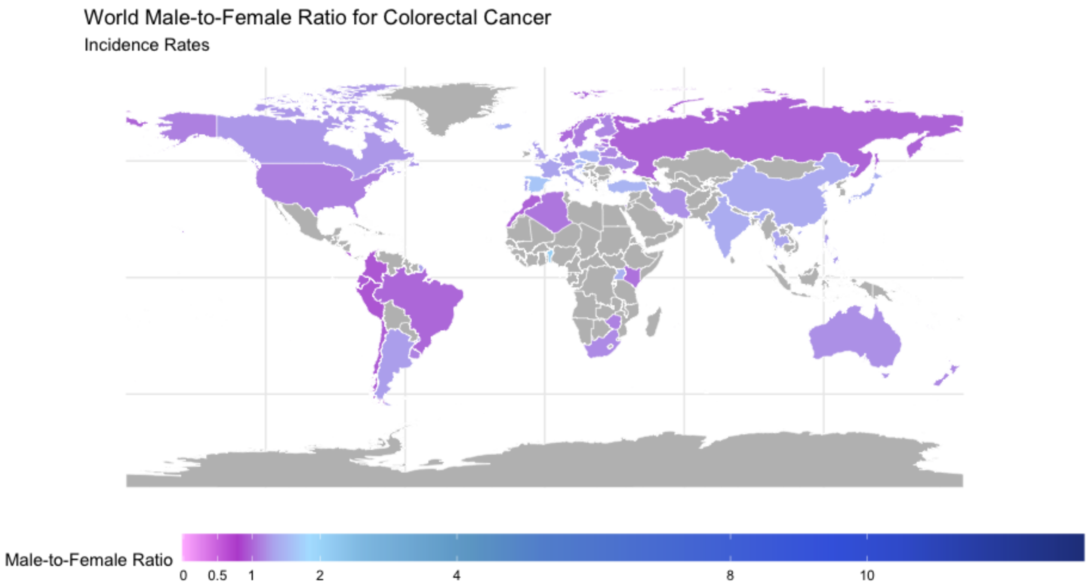


Figure 11: Global Gender Disparity for Endocrine Cancer Incidence

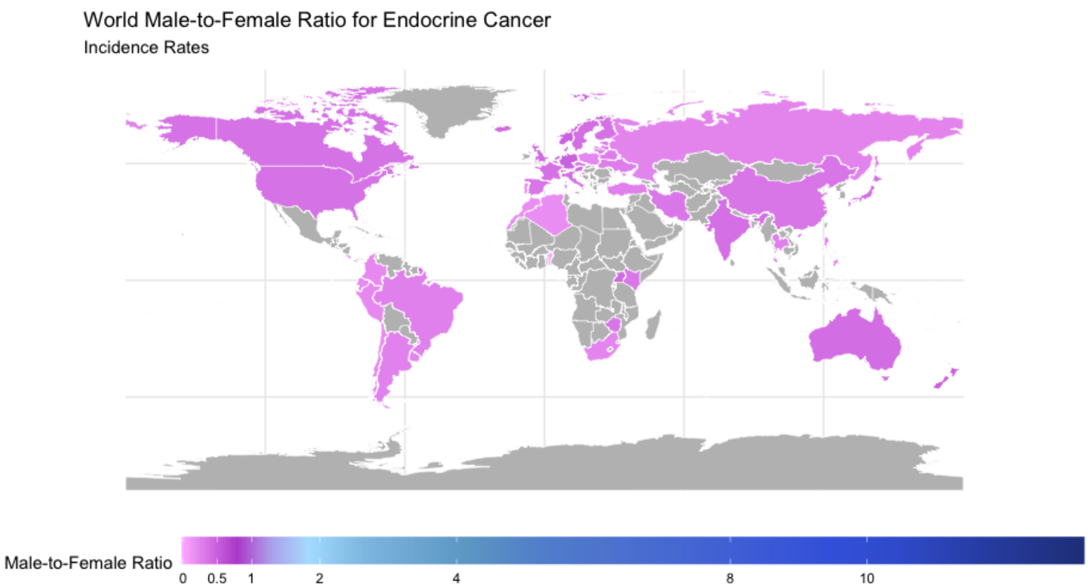


Figure 12: Global Gender Disparity for Esophageal Cancer Incidence

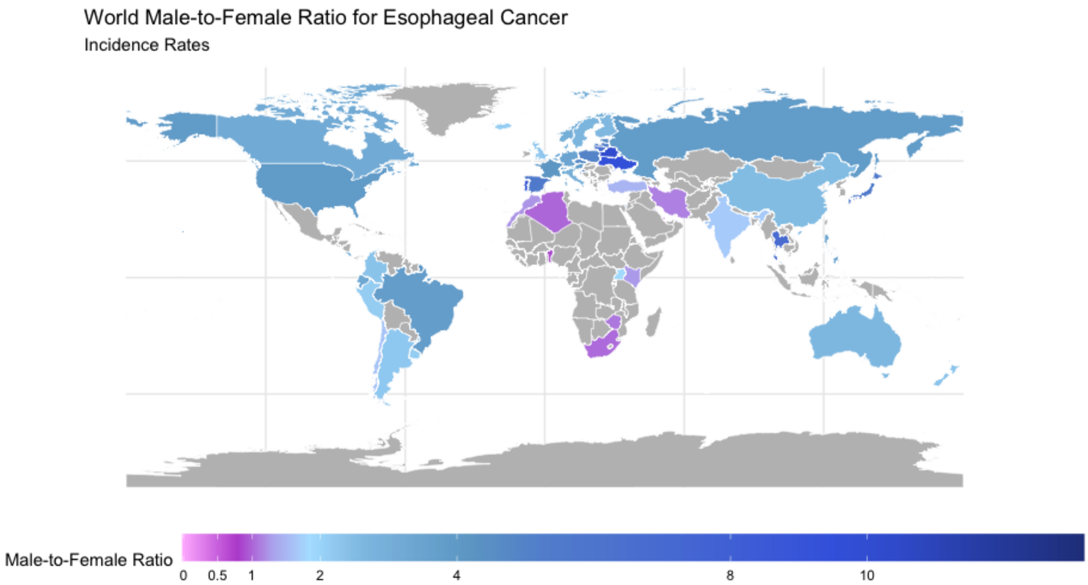


Figure 13: Global Gender Disparity for Head and Neck Cancer Incidence

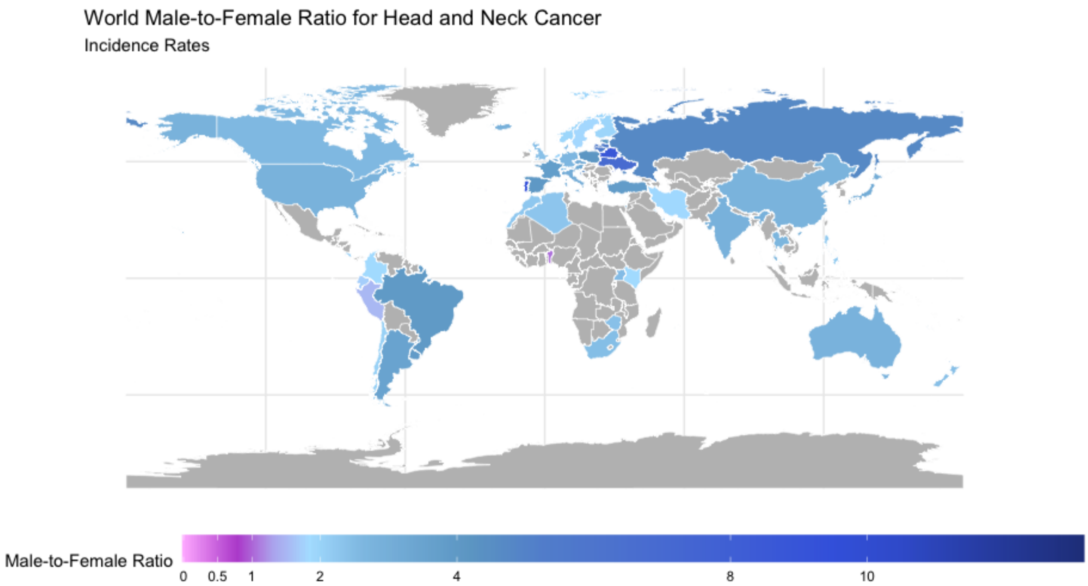


Figure 14: Global Gender Disparity for Liver Cancer Incidence

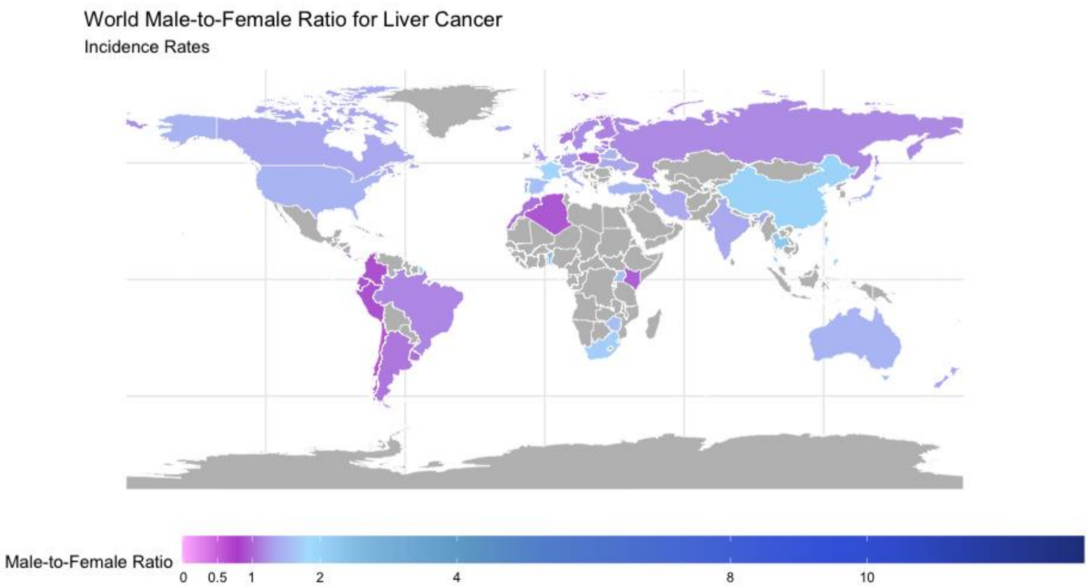


Figure 15: Global Gender Disparity for Lung Cancer Incidence

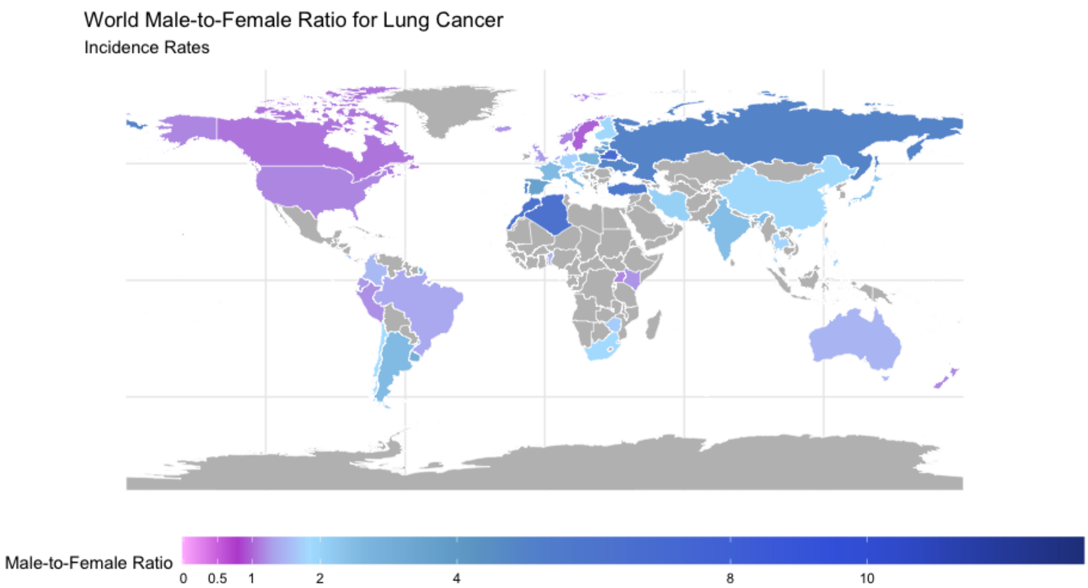


Figure 16: Global Gender Disparity for Skin, Bone and Bone-Marrow Cancer Incidence

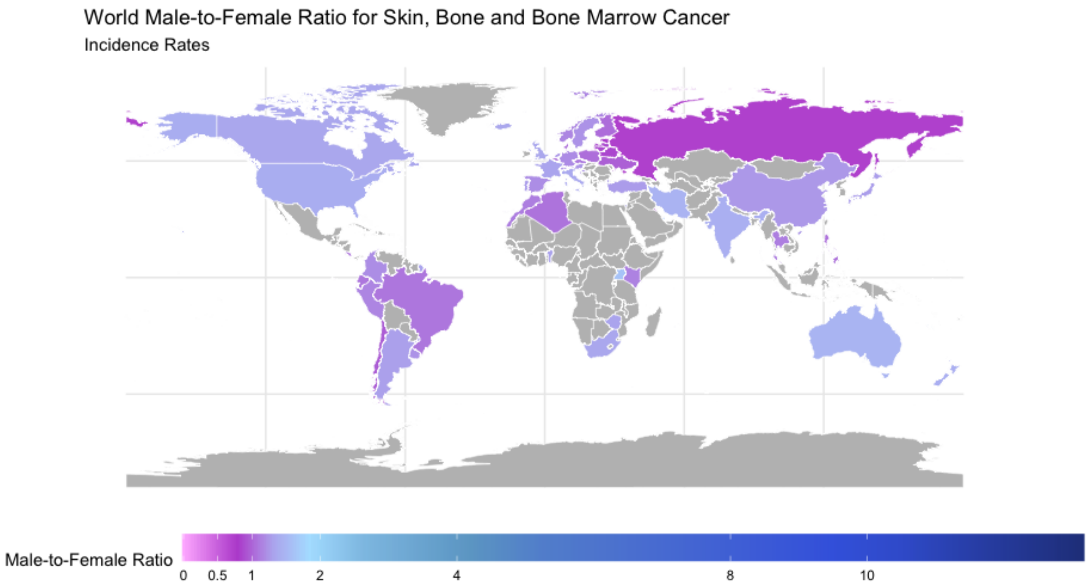


Figure 17: Global Gender Disparity for Small Intestinal Cancer Incidence

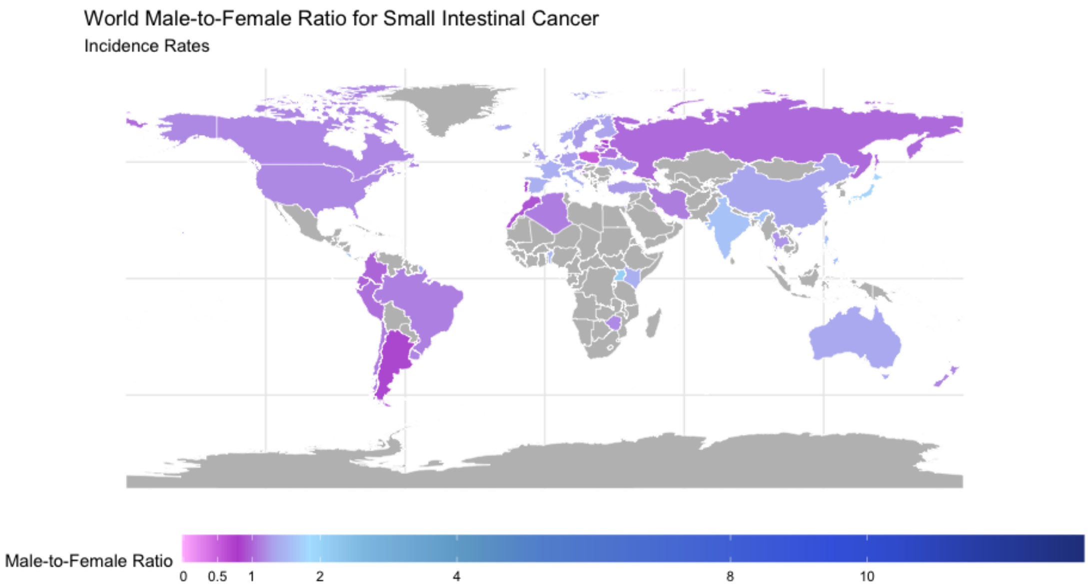


Figure 18: Global Gender Disparity for Stomach Cancer Incidence

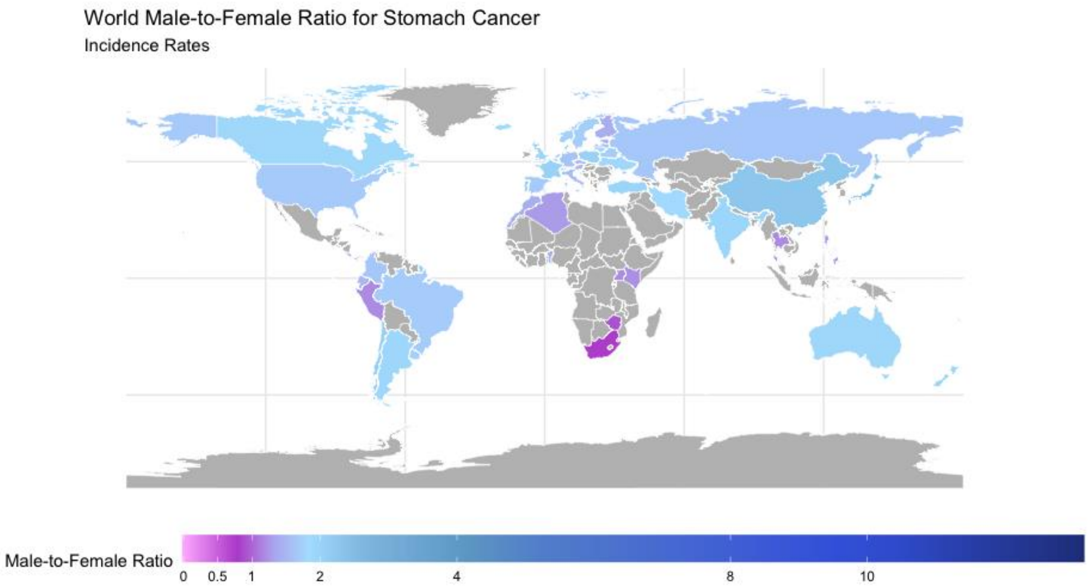
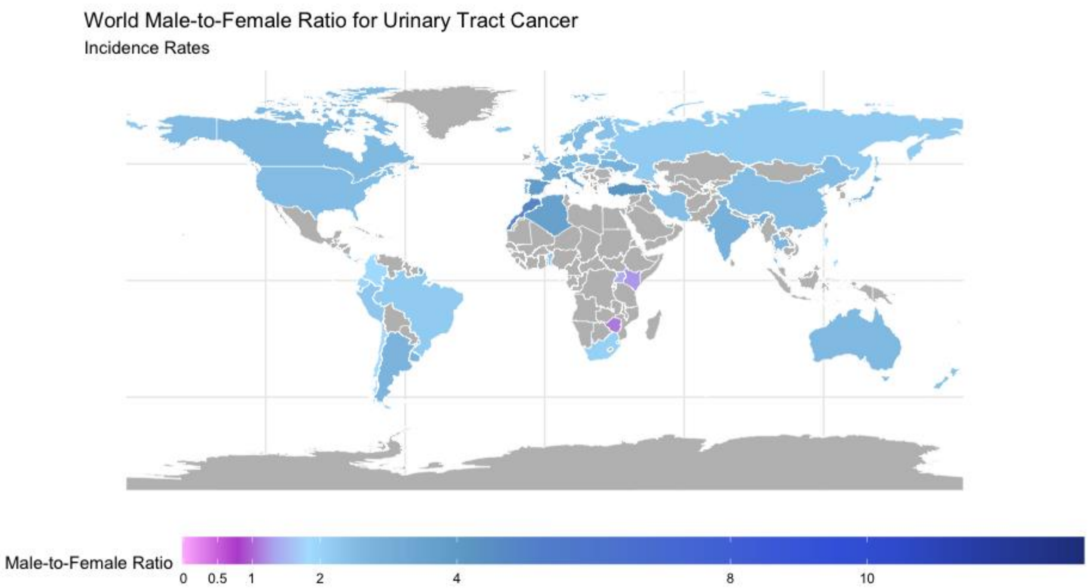


Figure 19: Global Gender Disparity for Urinary Tract Cancer Incidence



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Appendix D – Distribution of MFR worldwide Mortality Dataset

Figure 20: Global Gender Disparity for Brain and CNS Cancer Mortality

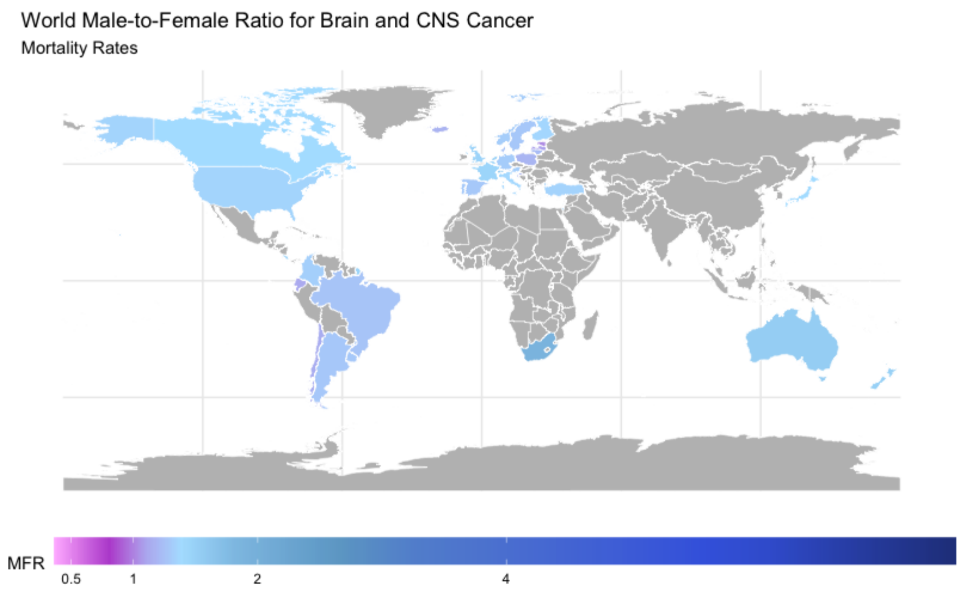


Figure 21: Global Gender Disparity for Colorectal Cancer Mortality

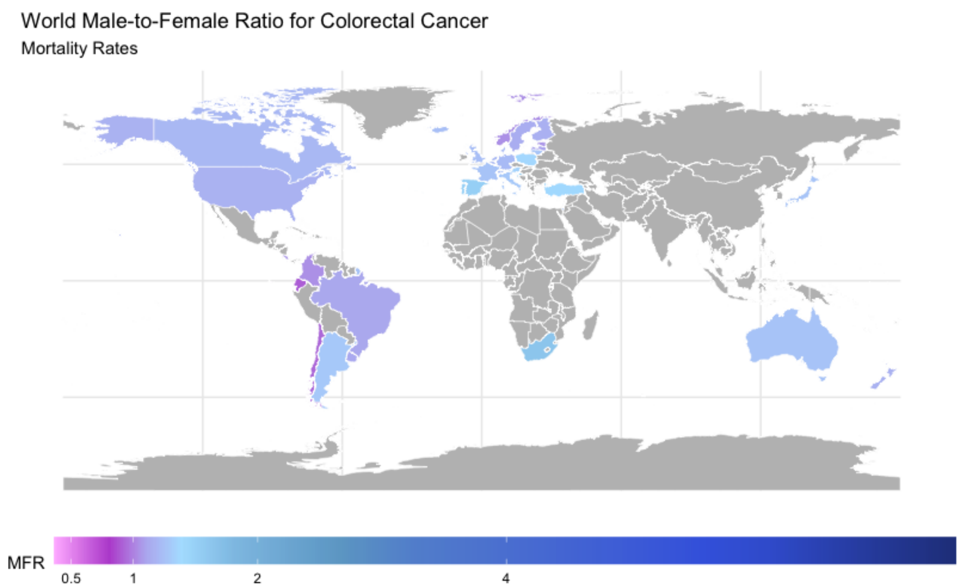


Figure 22: Global Gender Disparity for Endocrine Cancer Mortality

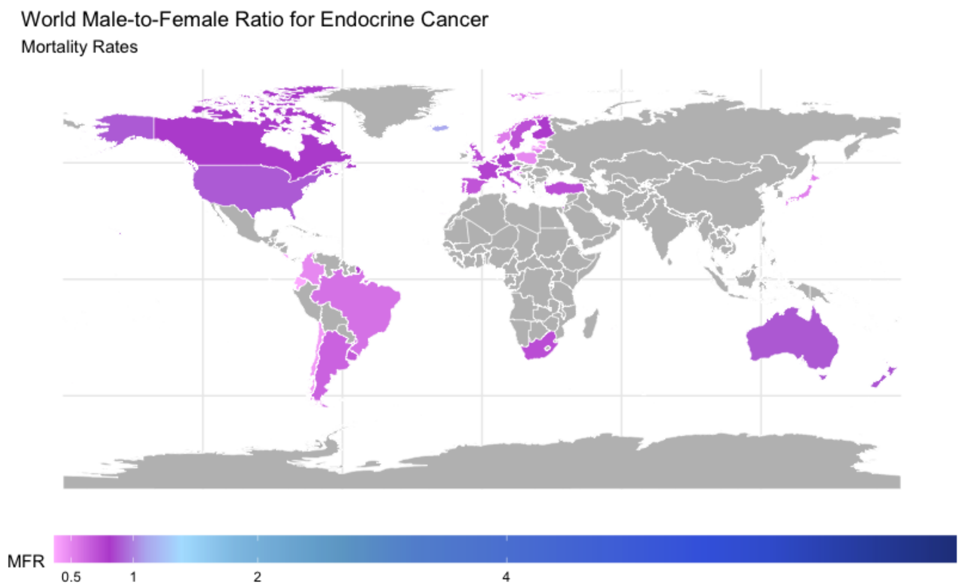


Figure 23: Global Gender Disparity for Esophageal Cancer Mortality

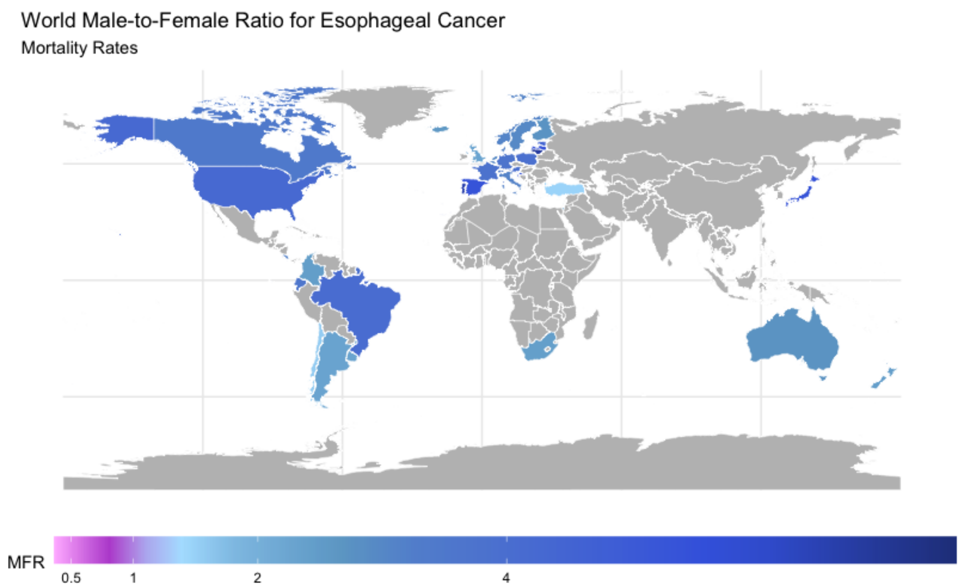


Figure 24: Global Gender Disparity for Head and Neck Cancer Mortality

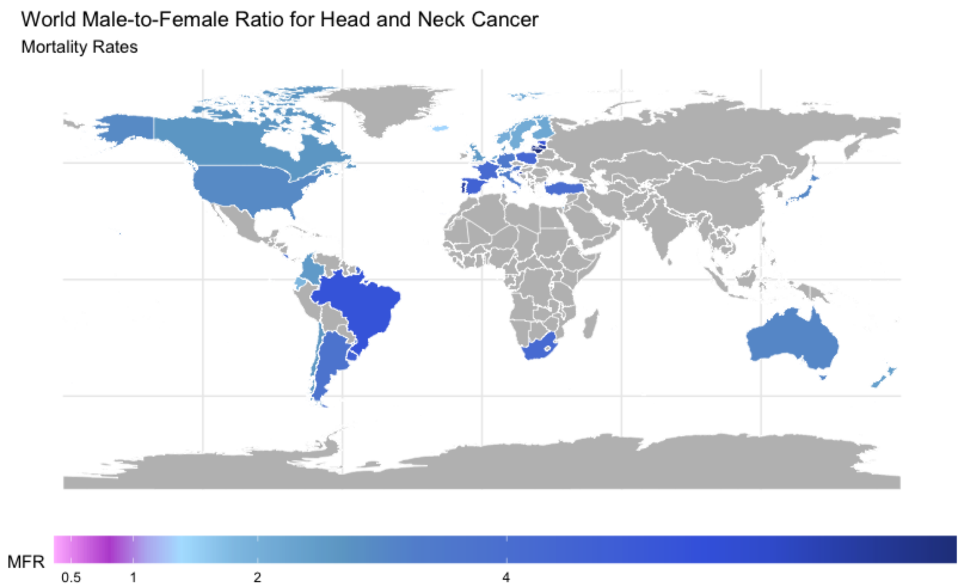


Figure 25: Global Gender Disparity for Liver Cancer Mortality

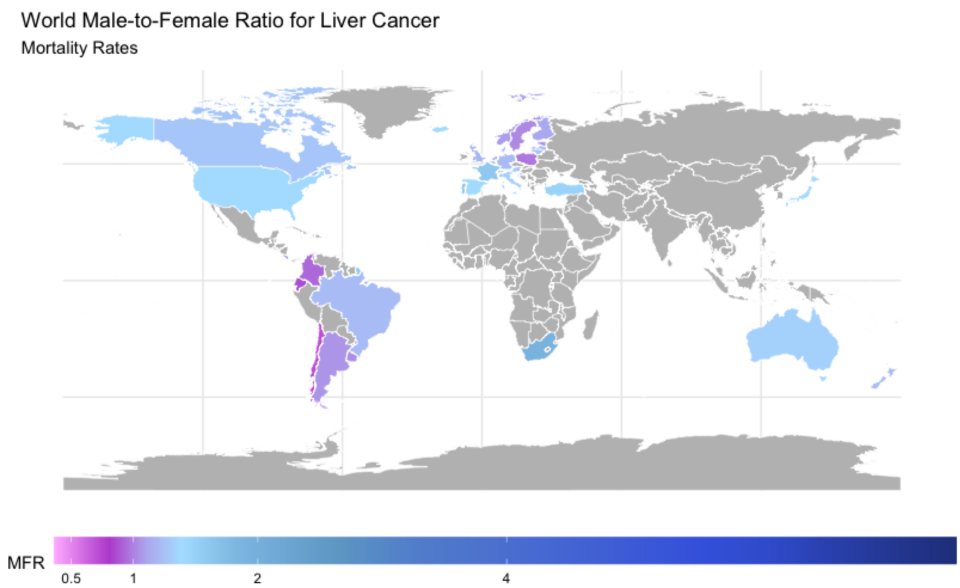


Figure 26: Global Gender Disparity for Lung Cancer Mortality

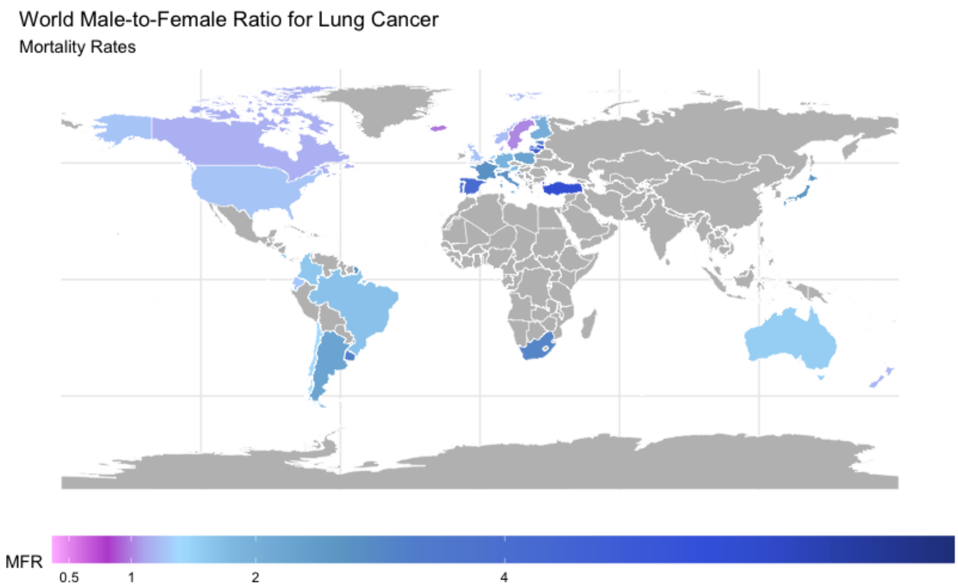


Figure 27: Global Gender Disparity for Skin, Bone and Bone-Marrow Mortality

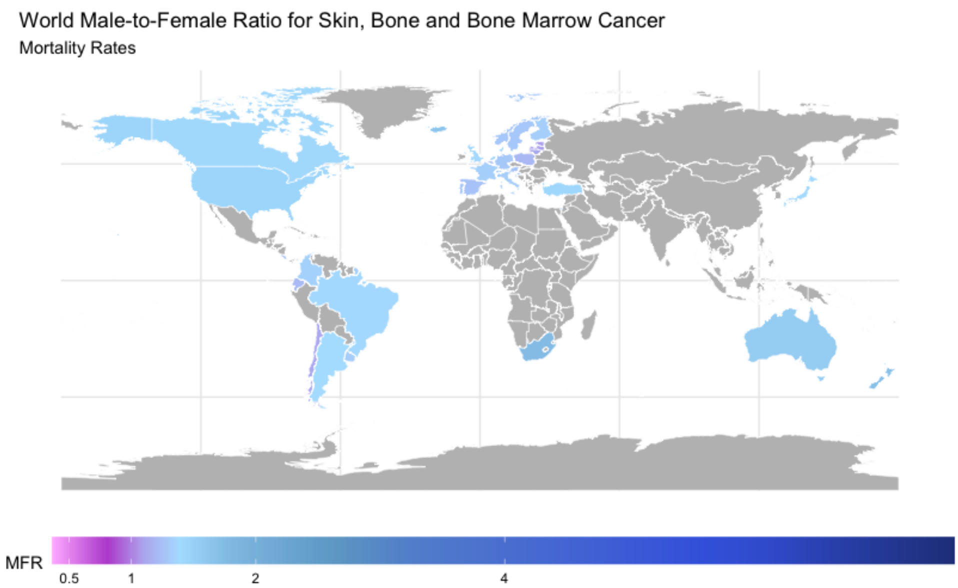


Figure 28: Global Gender Disparity Stomach Cancer Mortality

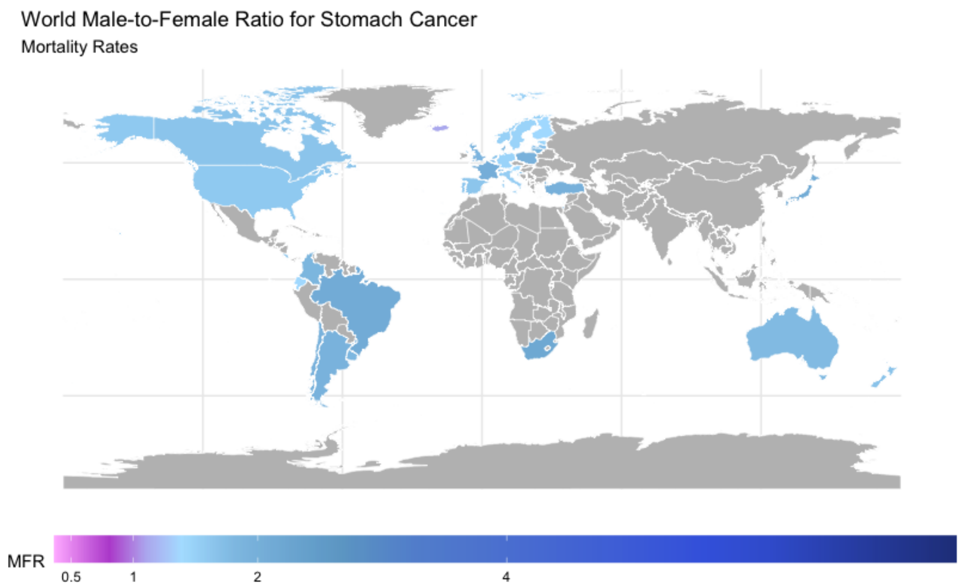
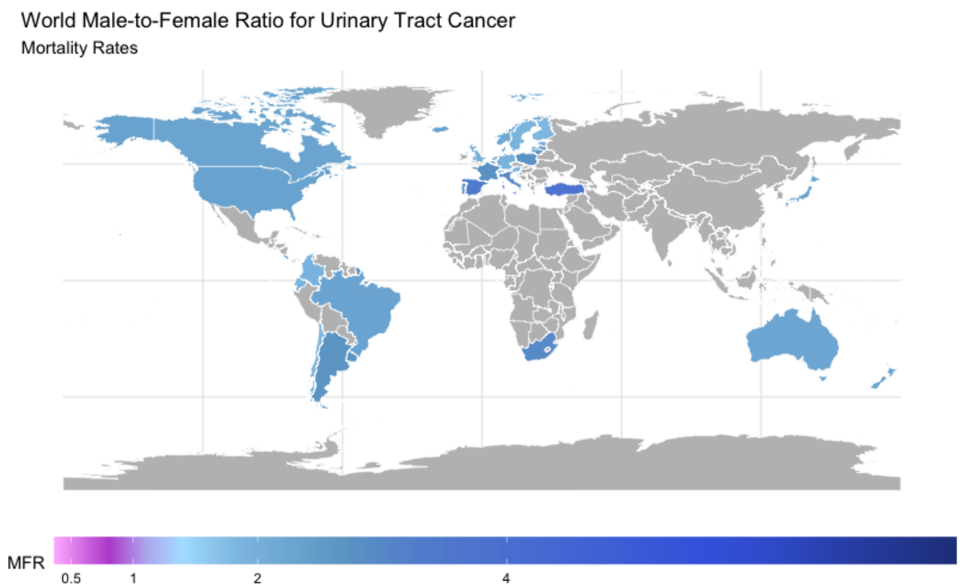


Figure 29: Global Gender Disparity for Urinary Tract Cancer Mortality



Appendix E – Regression Results Age Groups

Cancer Category	20-30 yrs	30-39 yrs	40-49 yrs	60-69 yrs	70-79 yrs	80+ yrs
Brain and CNS	0.969	0.940	0.996	1.068	0.962	1.018
Breast	1.292	0.674**	0.666**	1.733**	2.820**	4.082**
Colorectal	0.732**	0.796**	0.824**	1.207**	1.323**	1.243**
Endocrine	0.769**	0.777**	0.776	1.307**	1.767**	2.298**
Esophageal	0.497**	0.615**	0.835	1.029	0.995	0.741
Head and Neck	0.295**	0.422**	0.698**	1.048	0.961	0.741**
Liver	0.574**	0.804**	0.940**	0.969**	0.908**	0.800**
Lung	0.698**	0.654**	0.939**	1.243	1.389	1.540**
Skin, Bone and Bone Marrow	0.876*	0.899*	1.121*	1.130*	1.353*	1.477*
Small Intestine	0.817	0.863	0.947	1.133	0.989	1.223
Stomach	0.402**	0.579**	0.723**	1.141	1.173	1.103
Urinary Tract	0.557**	0.680**	0.879	1.141	1.247	1.328*

Table 3: Regression analysis of the Male-to-female ratio (MFR) for incidence rates across 12 distinct cancer types, using HDI, GII and age groups as predictor variables. The age group of 50-59 years old is used as a reference. The coefficients must be interpreted relatively. *Note: Bold and asterisks ()* indicate significant values with p<0.001** and p<0.01*.

Cancer Category	20-30 yrs	30-39 yrs	40-49 yrs	60-69 yrs	70-79 yrs	80+ yrs
Brain and CNS	1.009	1.030	1.072**	0.949	0.972	1.018
Colorectal	0.893**	0.777**	0.793**	1.260**	1.293**	1.082**
Endocrine	1.044	0.834**	0.851**	0.889**	0.815**	0.629**
Esophageal	0.382**	0.528**	0.843**	0.968	0.876**	0.630**
Head and Neck	0.327**	0.490**	0.833**	1.078	0.950**	0.660**
Liver	0.733**	0.868**	0.901**	0.956**	0.844	0.713**
Lung	0.670**	0.652**	0.750**	1.243**	1.481**	1.606**
Skin, Bone and Bone Marrow	0.936**	0.927**	0.860**	1.033	1.069**	1.094**
Stomach	0.485**	0.545**	0.762**	1.225**	1.226**	1.041**
Urinary Tract	0.415**	0.581**	0.871**	1.115**	1.101**	1.068

Table 4: Regression analysis of the Male-to-female ratio (MFR) for mortality rates across 10 distinct cancer types, using HDI, GII and age groups as predictor variables. The age group of 50-59 years old is used as a reference. The coefficients must be interpreted relatively. *Note: Bold and asterisks ()* indicate significant values with p<0.001** and p<0.01*.

Appendix F- SES and Cancer Trends: A worldwide Overview

Human Development Index

The scatterplot analysis visualized in Figure 30, demonstrates a positive linear relationship between HDI and MFR in half of the cancer categories, as indicated by the regression slopes. This trend is observed, among others, in brain and CNS, breast, and endocrine cancers. The same pattern holds for the relationship between HDI and MFR regarding mortality trends, for endocrine and skin and bone cancer which exhibits a significant positive linear relationship between HDI and MFR (Figure 31).

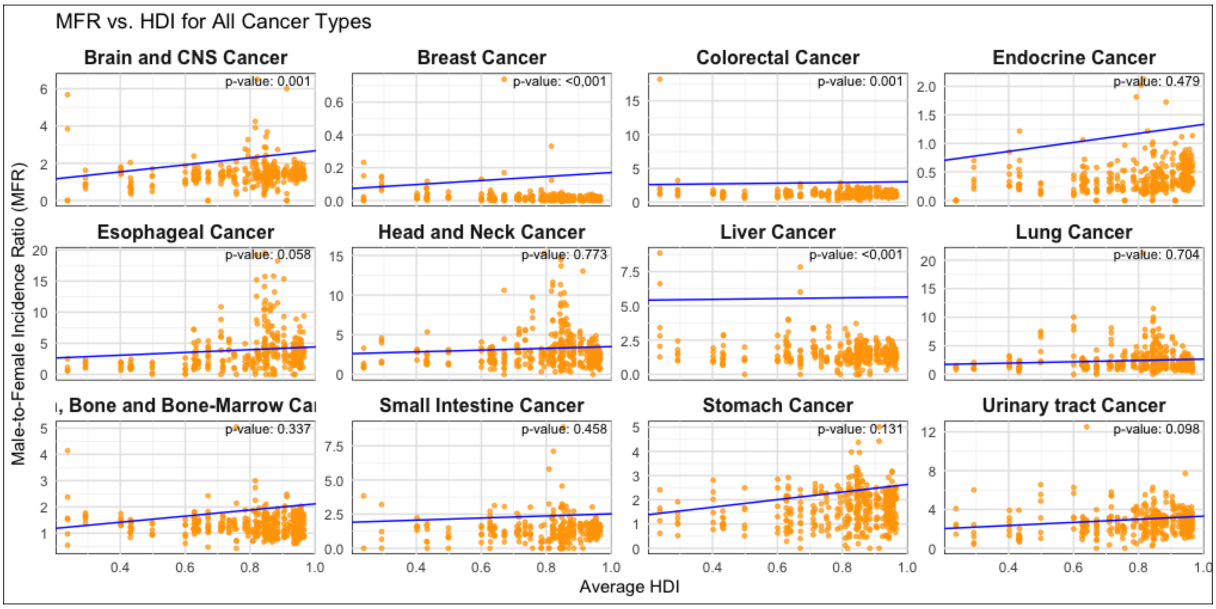


Figure 30: Illustration of the relationship between the Male-to-Female ratio (MFR) and the average Human Development Index (HDI) for various cancer types. Each panel represents individual data points to show the MFR for different countries against corresponding HDI values. The regression line is based on the intercept and regression coefficients of the average GII from the multivariable regression model with corresponding p-values.

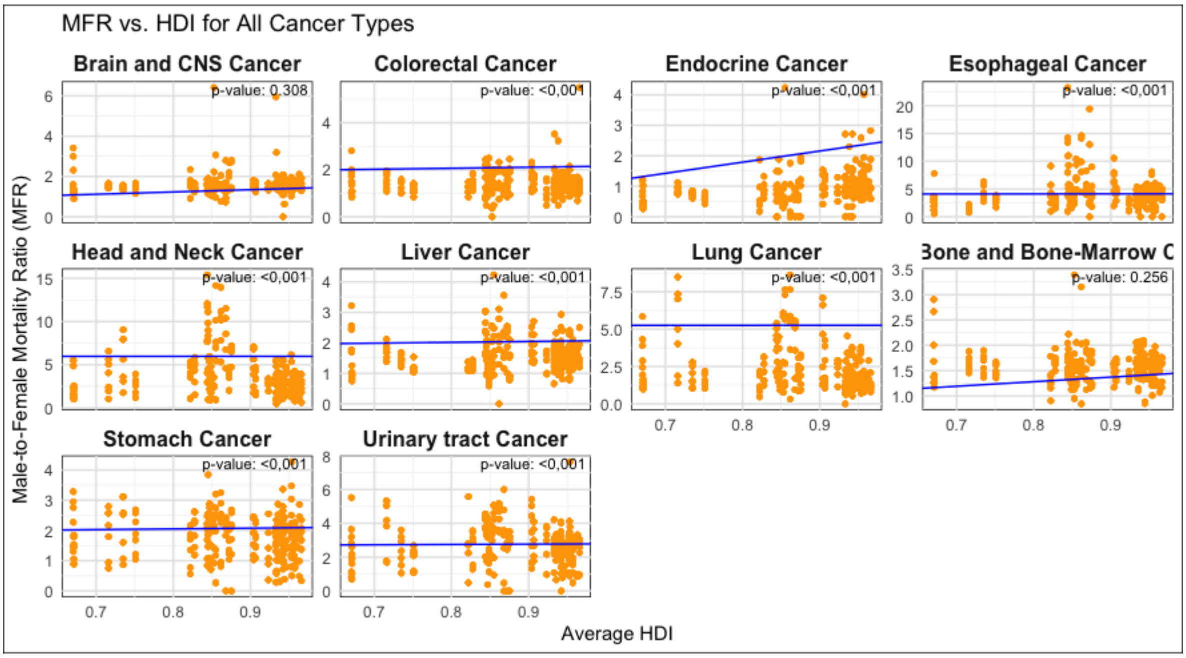


Figure 31: Illustration of the relationship between the Male-to-Female ratio (MFR) and the average Human

Development Index (HDI) for various cancer types. Each panel represents individual data points to show the MFR (mortality) for different countries against corresponding HDI values. The regression line is based on the regression coefficients of the average HDI from the multivariable regression model with corresponding p-values.

Gender Inequality Index

The scatterplot shown in Figure 32 demonstrates a positive linear relationship between GII and MFR for the same categories observed in Figure 30, except for esophageal cancer. Suggesting that as GII increases the MFR rises for brain and CNS, breast, endocrine, skin and bone, and stomach cancers.

In terms of mortality trends, a positive association between rising gender inequality and an increase in the MFR is observed for more than half of the cancer categories (Figure 33, Appendix F). This pattern is evident, for example, in brain and CNS, endocrine, and stomach cancer, aligning with the trends observed in cancer incidence.

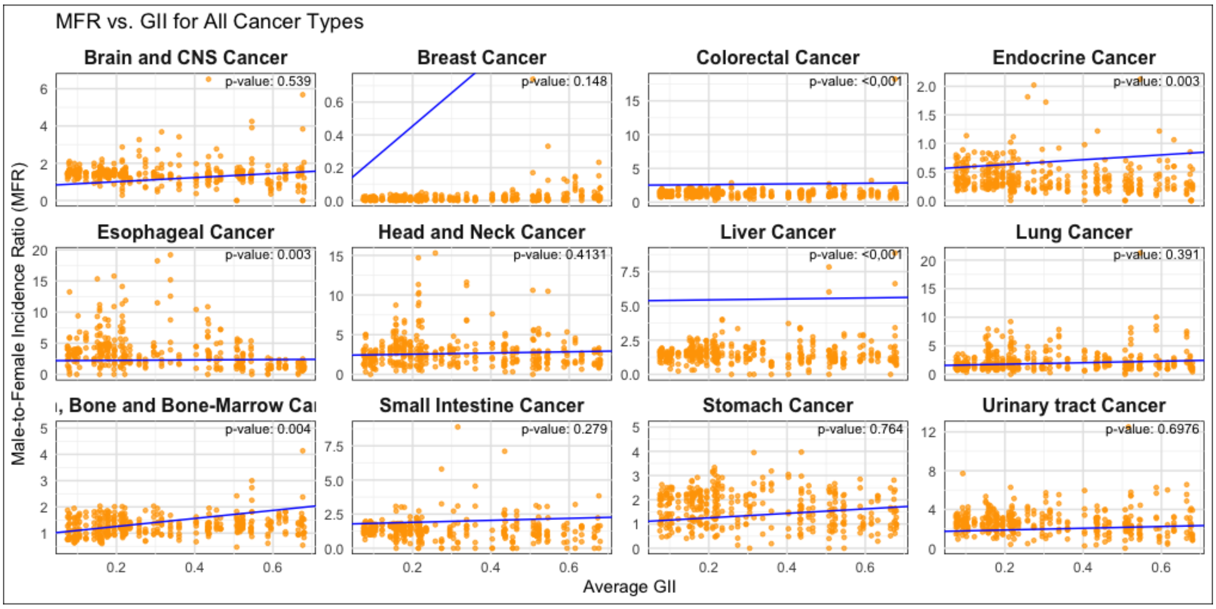


Figure 32: Illustration of the relationship between the Male-to-Female ratio (MFR) and the average Gender Inequality Index (GII) for various cancer types. Each panel represents individual data points to show the MFR for different countries against corresponding GII values. The regression line is based on the intercept and regression coefficients of the average GII from the multivariable regression model with corresponding p-values.

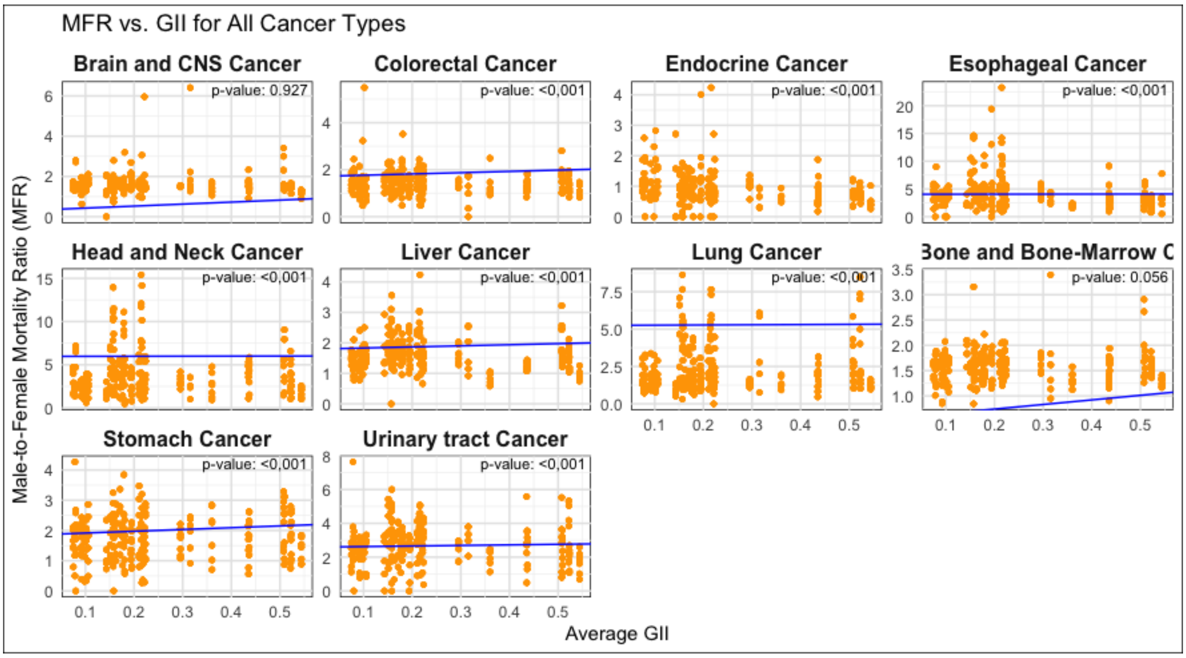


Figure 33: Illustration of the relationship between the Male-to-Female ratio (MFR) and the average Gender Inequality Index (GII) for various cancer types. Each panel represents individual data points to show the MFR (mortality) for different countries against corresponding GII values. The regression line is based on the regression coefficients of the average GII from the multivariable regression model with corresponding p-values.