Migration and cancer mortality among Colombian migrants in the USA: a death certification study[1]

Migração e mortalidade por câncer entre os migrantes colombianos nos EUA: um estudo com dados de declaração de óbito

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Abstract

We aim to compare cancer mortality rates of USA Colombian migrants (USA Colombians) to Colombians in their country of origin (CO Colombians). Using Colombian national mortality data and data on cancer deaths among Colombians residing in the states of California, Florida, and New York (USA Colombians) for the period 2008-2012, we estimated sex-specific and age-standardized mortality rates (ASMR), expressed per 100,000 persons. For comparisons between the two populations before and after adjustment for educational level, negative binomial regression models were used to compute Mortality Rate Ratios (MRR). CO Colombians had higher cancer mortality rates compared with USA Colombians (male MRR 1.4 [95%CI: 1.2-1.5], female MRR 1.5 [95%CI: 1.3-1.7]). These differences persisted for most cancers even after adjustment for education. CO Colombians had significantly higher mortality from gastric (MRR 2.6 in males and 2.8 in females) and cervical cancer (MRR 5.0) compared with US Colombians. Educational inequalities in cancer mortality were more pronounced among CO Colombians than among USA Colombians. Lower cancer mortality observed among USA Colombians cannot be attributed to differences in education, an indicator of socio-economic status. Rather, it is likely due to better access to preventive and curative healthcare in the USA.

Keywords: Migrants; Cancer; Colombia; United States; Mortality.

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Resumo

Este estudo teve como objetivo comparar padrões de mortalidade por câncer entre os migrantes colombianos nos EUA e colombianos em sua terra natal. Dados de 2008 a 2012 foram coletados, e foram calculadas taxas de mortalidade por câncer de colombianos residindo em seu país natal e colombianos residindo em Califórnia, Flórida e Nova York, bem como taxas específicas de mortalidade por idade e sexo por cada 100.000 pessoas. Para comparar as duas populações, tanto antes como após a correção para o nível educacional, as razões de taxas de mortalidade (MRR) foram estimadas por modelo de regressão binomial negativa. Foi descoberto que colombianos em sua terra natal apresentam taxas de mortalidade por câncer mais altas quando comparados aos que residem nos EUA (MRR masculino 1,4 (IC 95%: 1,2-1,5), MRR feminino 1,5 (IC 95%: 1,3-1,7)). Essas diferenças persistem para a maioria dos tipos de câncer, mesmo após correção para o nível educacional. Os colombianos apresentaram mortalidade por câncer gástrico (MRR masculino 2,6; feminino 2,8) e cervical (MRR 5,0) significativamente mais alta em comparação com os que residem nos EUA. As desigualdades educacionais na mortalidade por câncer foram mais pronunciadas aqueles que moram em sua terra natal. A menor mortalidade por câncer observada entre os colombianos nos EUA, porém, não pode ser atribuída às diferenças no nível educacional, um indicador de status socioeconômico. Em vez disso, provavelmente ocorre devido à acessibilidade superior aos serviços de saúde preventivos e curativos nos EUA.

Palavras-chave: Migrantes; Câncer; Colômbia; Estados Unidos; Mortalidade

Introduction

Cancer is a disease of growing importance in Colombia. Its incidence patterns are changing, with decreases in important cancers like stomach and cervical cancers, while incidence of breast, colorectal, and prostate cancers is increasing (Sierra, 2016). These changes are both due to population growth and ageing, as well as increases in the prevalence of sedentary lifestyles, overweight status, and changes in fertility patterns, which altogether describe characteristics of the so-called "Western lifestyle." Mortality rates can change over time due to changes in the underlying incidence rates combined with alterations in the prognosis of cancer patients, which depends on accessibility and availability of early detection resources, as well as the necessary diagnostic and treatment facilities (Piñeros, 2013).

Migrants from Colombia to the United States (USA Colombians) carry a large part of their cancer risk with them, including genetic background risk, as well as accumulated risks due to lifestyle factors associated with early life in Colombia. However, they are immigrating to a country with more treatment options and easier access to the latest treatment regimens. Therefore, comparing mortality rates of USA Colombians with their counterparts in their country of origin provides insight into the net effects of changes in lifestyle and, – perhaps most importantly, – the impact of implicit differences in early detection, diagnostic, and treatment options between the two countries.

Colombia has a universal social security care system, which also covers healthcare, to which, during the study period, over 90% of the population was affiliated. The system consists of two main types of financing: subsidized and contributive, persons are affiliated to one or the other based on income. Details of the system and their effect on access to care, with a focus on cancer, is detailed elsewhere (Pan-American Health Organization [PAHO], 2002). In essence, the system covers cancer diagnosis and treatment, but patients often suffer from delays in diagnosis and treatment, and paperwork can be cumbersome (De Vries, 2018). To accelerate diagnosis, some patient may pay for diagnostic workup privately.

The US healthcare system is remarkably different. It does not provide universal coverage (less than 10% of Americans are still uninsured) and can be defined as a mixed system, in which publicly financed government health coverage (e.g., Medicare for those aged 65 and above and Medicaid for those with less economic means) coexists with private insurance coverage obtained primarily by employment, or special forms of public insurance for Veterans and Military Personnel. Health insurance coverage may vary by state, in part because some states, such as New York and California, have expanded Medicaid eligibility under the Affordable Care Act (Obamacare), whereas others, like Florida, have not. Along with access to the healthcare system, cancer mortality patterns also depend on socio-economic status (SES), even though this relationship may vary according to country (Boscoe, 2016a; De Vries, 2015a; Lortet-Tieulent 2020). SES is intrinsically associated with educational level.

We present unique data comparing cancer mortality in Colombia to cancer mortality among USA Colombians who migrated to the USA states of California, Florida, and New York, which together account for 57% of USA Colombians (Lopez, 2010). We aim to provide insight into changes in the epidemiological profile upon migration and evaluate the possible effects of educational level on explaining cancer differences between CO Colombians and USA Colombians.

Methods

This study includes all cancer deaths occurring in Colombia, and among Colombians in the included USA States, as well as their population denominators for the period of 2008-2012. Below, we describe the sources and calculations done on data on individual deaths (participants) and on how population denominators were calculated (population).

Participants

Age- and Sex-specific Colombian mortality data for the period 2008-2012 were obtained from the Colombian Statistics Office (Departamento Administrativo Nacional de Estadística (DANE)) and analyzed using the population sizes for this time period as projected by DANE (2017). Mortality data for Colombian-born individuals with residence in California, Florida, and New York (total population 378,214), hereafter referred to as USA Colombians, were obtained from the California Department of Public Health and the Florida Bureau of Vital Statistics for the period 2008-2012, and from the New York State Department of Health for 2008-2014. Deaths of USA Colombians with a code of residence outside the USA were excluded.

Sex-stratified data were analyzed for all cancers combined (ICD-10 codes C00-C97) and for the following cancer sites, selected based from the top five causes for cancer death by sex in either USA or Colombia, separately: Stomach (C16); Colorectal, including Anus (C18-C21 and C26); Liver (C22); Pancreas (C25); Female Breast (C50); Cervix (C53); Uterus (C54-C55); Ovary (C56); and Prostate (C61).

Population

Data on mid-year population counts by age, sex, and educational level for Colombia (total population 45,483,093) were obtained from the Colombian Demography Health Surveys (DHS) (Profamilia, [2017]), which contain periodical information on the distribution of education by age and sex. These surveys follow the methodology stablished by the United States Agency for International Development (USAID) program worldwide, by collecting, analyzing, and disseminating accurate and representative data on population health (Ministerio de Salud y Protección Social; Profamilia, [2017]).

The resulting proportions of individuals in each educational level were multiplied by the total population numbers per year, age, and sex—obtained from the census combined with statistical projections from DANE—to estimate the annual population size in each educational group. The registration of the Colombian mortality database for 2012 has been shown to coincide with the life-tables derived from the Colombian Censuses by demographic variables such as sex, age, and region of residence (Rodríguez-García, 2017).

For the USA, we used population data from the 5-year 2008-2012 American Community Survey (ACS), selected based on birthplace "Colombia" and residence in California, Florida, or New York by educational level, age, and sex. In addition, for New York 1-year American Community Survey, data were retrieved for 2013 and 2014 (ACS) (Ruggles, 2015). While the population of Colombian-born in the three states in the midyear of 2010 was 378,214, the total population-years of observation in this study amounted to 2,099,053 (Table I).

Table 1 – description of included populations: Number of cancer deaths, person-years and proportion with higher level of education

Country/ US State	Cancer Deaths		Population size (person-years) 2008-2012[a]	
	#	% with higher education	#	% with higher education
USA	2,137	36.3%	2,099,530	46.1%
California	288	51.0%	200,995	57.8%
Florida	1,150	37.1%	1158,265	47.8%
New York	699	28.9%	740,270	40.3%
Colombia	165,222	8.8%	227,415,467	11.9%

[a]New York years: 2008-2014

Analysis

To evaluate the different aspects of cancer mortality patterns of CO Colombians and USA Colombians, the following analyses were performed:

Firstly, using the previously mentioned number of deaths by age, sex, and cancer type, and the population denominators, annualized age-standardized mortality rates (ASMR) were calculated per 100,000 person-years by sex using the Segi Population as the standard population, as is customary in international comparisons.

Secondly, to compare the cancer mortality between the two populations, considering their very different demographic profiles, sex-specific and age-standardized mortality rate ratios (MRR) were used derived from negative binomial regression models with number of deaths as the dependent variable and the natural log of person-years as the offset variable. For these models, we categorized age into three groups: 35-64, 65-74, and older than 75. These age groups were selected to accommodate the common retirement age of 65, using 75+ as the most senior population.

Thirdly, MRRs between CO Colombians and USA Colombians stratified by educational level were computed for comparisons. Educational level was classified as lower education, for high school diploma or less, and higher education, for any college attendance, regardless of degree completion.

Lastly, within-population educational differences were evaluated, computing MRR of lower versus higher education among CO Colombians and among USA Colombians.

This work is a secondary analysis of vital statistics data, with publicly available national Colombian data and the USA Colombians data being provided to the researchers. The project on which this research is framed (see Disclaimer) was approved by the Ethics Committee of the National School of Public Health of the University of Antioquia, and was rated as "without risk," according to the regulations in Colombia on the matter, whereas the study was declared exempt from the USA side (protocol submitted to the University of Nevada Las Vegas Institutional Review Board).

Results

Overall, CO Colombians had higher cancer mortality rates than USA Colombians. A total of 2,137 cancer deaths were recorded among USA Colombians. By cancer site, the largest combined number of deaths was observed for lung (n=322), followed by pancreatic (n=187), female breast (n=182), colorectal (n=176), and stomach cancer (n=154). Furthermore, among USA Colombians, 64% of cancer deaths occurred in those aged 65 and over, whereas only 0.7% of deaths occurred among those under age 35 (Tables I, II). Many USA Colombians had a university degree (36.3%), compared to only 8.8% among CO Colombians (Tables I and II).

Table 2 — Number of deaths, age-standardized cancer mortality rates for US Colombians and Colombia and regression-derived mortality rate ratios

	Number of deaths		Age-standardized mortality rates		Adjusted mortality rate ratios (MRR)	
			US Colombians	Colombia	MRR adjusted for age[a]	MRR adjusted for age and education[a]
	US Colombians	Colombia	ASR (95% CI)	ASR (95% CI)	MRR (95% CI)	MRR (95%CI:)
Males						
Stomach	85	13,709	5.4 (4.3-7.5)	13.1 (12.9-13.4)	2.8 (2.1-3.3)	2.2 (1.8-2.8)
Colorectal	88	6,131	5.5 (4.4-7.7)	5.9 (5.7-6.0)	1.1 (0.9-1.4)	1.2 (0.9-1.5)
Liver	51	3,867	3.3 (2.4-5.4)	3.8 (3.6-3.9)	1.2 (0.9-1.6)	1.1 (0.8-1.6)
Pancreas	91	3,010	5.8 (4.6-8.0)	2.9 (2.8-3.0)	0.5 (0.4-0.7)	0.6 (0.5-0.7)
Lung	150	11,655	9.3 (7.9-11.7)	11.3 (11.1-11.5)	1.2 (1.0-1.5)	1.1 (0.9-1.4)
Prostate	107	12,086	7.0 (5.7-9.3)	10.9 (10.7-11.1)	1.7 (1.4-2.0)	1.6 (1.3-2.1)
All Cancers Combined	907	81,123	60.0 (55.3-65.3)	76.8(76.3-77.4)	1.4 (1.2-1.5)	1.3 (1.1-1.5)
Females						
Stomach	69	8,782	2.5 (1.9-4.4)	6.9 (6.8-7.1)	2.8 (2.2-3.5)	2.5 (2.0-3.2)
Colorectal	88	7,047	3.4 (2.7-5.3)	5.6 (5.5-5.7)	1.8 (1.5-2.2)	1.7 (1.4-2.1)
Liver	55	4,349	2.1 (1.5-4.0)	3.5 (3.4-3.6)	1.8 (1.4-2.3)	1.6 (1.1-2.4)
Pancreas	96	3,549	3.5 (2.8-5.5)	2.8 (2.7-2.9)	0.8 (0.7-1.0)	0.8 (0.7-1.0)
Lung	172	7,883	6.0 (5.1-8.0)	6.4 (6.2-6.5)	1.0 (0.9-1.2)	1.0 (0.8-1.2)
Breast	181	11,400	6.9 (5.9-9.0)	9.6 (9.4-9.7)	1.4 (1.1-1.6)	1.4 (1.1-1.8)
Cervix	35	7,859	1.3 (0.9-3.3)	6.5 (6.4-6.7)	5.0 (3.6-6.9)	3.8 (2.6-5.7)
Uterus	45	2,291	1.8 (1.3-3.8)	1.9 (1.8-2.0)	1.1 (0.8-1.6)	1.0 (0.8-1.4)
Ovary	84	3,639	3.1 (2.5-5.1)	3.1 (3.0-3.2)	0.9 (0.7-1.2)	0.9 (0.7-1.2)
All Cancers Combined	*1,230*	*84,099*	*45.8 (43.2-49.2)*	*68.4 (67.9-68.9)*	*1.5 (1.3-1.7)*	*1.3 (1.1-1.6)*

ASR: Age-standardized mortality rate, standardized to the SEGI world population, expressed per 100,000 person-years[a]: results from negative binomial regression models (see methods section for details), US Colombians are reference group ICD10 codes for the cancer groups: Stomach: C16, Colorectal: C18-C21 and C26, Liver: C22, Pancreas C25, Female Breast: C50, Cervix: C53, Uterus: C54-C55, Ovary: C56, Prostate: C61.

In Colombia, 165,222 cancer deaths were recorded, led by stomach cancer (n=22,491), followed by lung (n=19,538), colorectal (n=13,178), prostate (n=12,086), and female breast cancer (n=11,400). A total of 58.1% of cancer deaths occurred in those aged 65 and over, while 3.1% occurred among those under age 35.

Among males, the overall risk of dying from cancer was 1.4 (95% CI 1.2-1.5) times higher among CO Colombians (vs. USA Colombians). For female sex, this MRR was 1.5 (95% CI 1.3-1.7) (Table II). For cervical and gastric cancer, CO Colombians' risk of dying was 2.5-5.0 times higher than among USA Colombians (MRR cervical cancer 4.97; MRR stomach cancer males 2.63, females 2.79). Smaller mortality excesses in Colombia were observed for prostate cancer in males, and for breast, colorectal, and liver cancer in females (Table II). Other cancers did not display this advantage for USA Colombians; risk of dying was similar between the two populations for liver, colon, and rectal cancers, along with lung cancer in males and ovarian and uterine cancers in females (Table II). Risk of dying from pancreatic cancer was significantly lower among CO Colombians (MRR males 0.54, females 0.82, both sexes $p<0.05$) when compared with USA Colombians.

The models were corrected for educational level since cancer mortality is generally associated with socio-economic status and educational level, and a larger proportion of USA Colombians had higher education when compared with CO Colombians. The results of these adjusted models are described in the final column of Table II. The change in the estimated MRR before and after adjustment was very small; observed patterns remained largely the same. The largest attenuation of differences between USA Colombians and CO Colombians were observed for male lung and female cervical cancers (male lung MRR 1.22 to education-adjusted 1.09; cervix MRR 4.97 to education-adjusted 3.81) (Table II, comparison of final 2 columns).

Regarding the MRR adjusted for educational groups, the ratio between mortality rates of CO Colombians versus USA Colombians were much higher for those with lower education when compared with those with higher education, which was noted for cancers of the stomach, liver, pancreas (females), cervix, and uterus. For other important cancers, such as breast and lung cancer, the MRR was not significantly different between educational levels in both populations (Table III).

Lastly, we evaluated differences in mortality between higher and lower education within the populations of each country (Table IV). Larger educational differences were observed in cancer mortality among CO Colombians than among USA Colombians . For cancers where educational inequalities were observed, mortality was almost always higher for the lower education group, except for male pancreatic cancer, which showed higher rates in the higher education groups of both countries. Breast cancer mortality also tended to be higher in the higher education group, but the difference was not significant.

Table 3 – Cancer Mortality Rate Ratios of low and high educated populations, comparing deaths in Colombia and US Colombians (category of reference)

	Lower Education Level		Higher Education Level	
	MRR	95% CI	MRR	95% CI
Males				
Stomach	2.75*	(2.08; 3.64)	1.51*	(1.07; 2.12)
Colorectal	1.01	(0.77; 1.31)	1.37	(0.97; 1.94)
Liver	1.08	(0.77; 1.51)	1.22	(0.75; 1.98)
Pancreas	0.63*	(0.46, 0.84)	0.54*	(0.40; 0.74)

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Table 3 – Continuation.

	Lower Education Level		Higher Education Level	
	MRR	95% CI	MRR	95% CI
Lung	1.21	(0.94; 1.55)	0.94	(0.71; 1.23)
Prostate	2.05*	(1.58; 2.67)	1.19	(0.90; 1.58)
All Cancers Combined	1.44*	(1.32; 1.59)	1.12*	(1.00; 1.25)
Females				
Stomach	2.87*	(2.15; 3.82)	1.70*	(1.11; 2.60)
Colorectal	1.63*	(1.28; 2.09)	2.09*	(1.35; 3.23)
Liver	1.68*	(1.24; 2.29)	1.20	(0.68; 2.10)
Pancreas	0.74*	(0.59; 0.93)	1.07	(0.69; 1.64)
Lung	0.97	(0.81; 1.15)	0.89	(0.58; 1.38)
Breast	1.40*	(1.16; 1.70)	1.40*	(1.11; 1.76)
Cervix	4.07*	(2.78; 5.94)	3.34*	(1.66; 6.73)
Uterus	1.40	(0.94; 2.09)	0.64	(0.41; 1.00)
Ovary	0.95	(0.72; 1.25)	0.88	(0.62; 1.26)
All Cancers Combined	1.44	(1.34; 1.55)	1.23*	(1.10; 1.38)

*Statistically significantly different from 1 at α 0.05 ICD10 codes for the cancer groups: Stomach: C16, Colorectal: C18-C21 and C26, Liver: C22, Pancreas C25, Female Breast: C50, Cervix: C53, Uterus: C54-C55, Ovary: C56, Prostate: C61.

Table 4 – Mortality rate ratios of low versus high education (category of reference) in Colombia and US Colombians

	Colombians				US-Colombians			
	Males		Females		Males		Females	
	MRR	95% CI	MRR	95% CI	MRR	95% CI	MRR	95% CI
Stomach	1.92*	(1.79; 2.08)	1.85*	(1.67; 2.00)	1.04	(0.67; 1.61)	0.94	(0.55; 1.64)
Colorectal	0.85*	(0.72; 0.99)	1.20*	(1.10; 1.32)	1.16	(0.75; 1.79)	1.54	(0.92; 2.63)
Liver	1.19	(0.95; 1.47)	1.85*	(1.27; 2.70)	1.28	(0.71; 2.33)	1.08	(0.56; 2.08)
Pancreas	0.78*	(0.70; 0.87)	1.05	(0.93; 1.19)	0.63	(0.43; 1.00)	1.47	(0.88; 2.44)
Lung	1.45*	(1.20; 1.67)	1.35*	(1.12; 1.64)	1.08	(0.69; 1.67)	1.02	(0.70; 1.49)
Prostate	1.09	(0.94; 1.27)			0.59	(0.40; 0.86)		
Breast[a]			0.79	(0.61; 1.04)			0.83	(0.61; 1.15)
Cervix			2.94*	(2.50; 3.57)			2.33*	(1.03; 5.26)
Uterus			1.49*	(1.28; 1.75)			0.57	(0.30; 1.09)

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Table 4 – Continuation.

	Colombians				US-Colombians			
	Males		Females		Males		Females	
	MRR	95% CI	MRR	95% CI	MRR	95% CI	MRR	95% CI
Ovary[a]			1.10	(0.19; 6.25)			0.78	(0.48; 1.25)
All Cancers Combined	1.18*	(1.02; 1.35)	1.22*	(1.03; 1.45)	0.88	(0.76; 1.01)	0.95	(0.74; 1.23)

[a]Interpretation requires caution; possible data overdispersion in some age groups in the Colombian data
*statistically significant at α 0.05 ICD10 codes for the cancer groups: Stomach: C16, Colorectal: C18-C21 and C26, Liver: C22, Pancreas C25, Female Breast: C50, Cervix: C53, Uterus: C54-C55, Ovary: C56, Prostate: C61.

Discussion

This unique migrant study comparing Colombians who migrated to the United States (USA Colombians) to their counterparts in Colombia (CO Colombians) shows how different environments affect the risk of dying from cancer. A study has demonstrated population-based incidence rates of cancer substantially higher among USA Hispanics (based on SEER-18 database, with 263 males and 230 females for the period 2008-2012, expressed per 100,000) (Bray, 2017) than in Colombia, where rates were approximately 163-205 and 165-186 for males and females, respectively. The results of our analyses show that, contrary to these described incidence patterns, cancer mortality was higher for CO Colombians than USA Colombians. As we report on mortality rates, it is important to realize that mortality is the net result of risk factors and incidence (risk) of cancer, combined with the probability of dying or surviving from the disease (normally assessed by survival)–the latter being dependent mostly on stage at diagnosis and access to treatment. Therefore, our results may be the result of differences in incidence and/or survival, which are clearly distinct for each studied cancer site based on general knowledge of cancer epidemiology.

Explanation of results

For stomach, liver (females only), and cervix uteri cancer, our findings of higher mortality for CO Colombians are consistent with the expected higher incidence and/or worse prognosis of these cancers in Colombia versus the USA. Particularly for cervical cancer, high incidence and relatively poor survival rates have been documented. Colombia still has to improve coverage of HPV vaccination, the use and quality of cytology, and the access to subsequent diagnostic and clinical care (De Vries, 2018; Murillo, 2016; 2012). Cervical cancer mortality is considered an avoidable disease since a comprehensive early screening program can prevent this cancer from occurring. The expected observation of substantially lower cervical cancer mortality among USA Colombians is likely mostly attributable to a combination of earlier detection and better diagnosis and treatment options for premalignant tumors and cancer early invasive lesions within the USA. The fact that educational differences for this cancer were stronger for CO Colombians than USA Colombians likely reflects lower participation and less access to prevention and early detection services for less educated populations in Colombia (De Vries, 2015a; 2018). However, even among the USA Colombians, important differences in cervical cancer mortality were found according to educational level.

For liver cancer, the higher mortality rates for CO Colombian females, not detected among males, are consistent with results from other studies on Hispanic immigrants' groups in the USA (De Vries, 2015b; Pinheiro, 2017a; Pinheiro, 2016). According to recent studies, in both Florida and New York, the mortality (and incidence) rates of liver cancer in male minorities (but not in females), are clearly related to the higher prevalence of Hepatitis C virus in these populations (Pinheiro et al., 2019; 2020).

The differences in stomach cancer are of complex interpretation. It is generally thought that the risk of developing stomach cancer via infection with

Helicobacter Pylori is determined at a young age (Khan, 1998), when most USA Colombians were likely still living in Colombia—which would indicate that the substantially reduced risk for USA Colombians is likely due to better survival in the USA. Indeed, scarce information on age-adjusted population-based survival shows poorer 5-year survival rates for stomach cancer in Colombian populations, around 17% in Colombia compared to 33% in the United States (Allemani et al., 2018). However, it is also possible that the risk of stomach cancer diminishes after immigration, possibly due to healthier diet, providing better protection against stomach cancer; this lower risk would also result in a lower mortality among USA Colombians.

For unclear reasons, mortality for pancreatic cancer tends to be higher among immigrant populations in the USA compared to their countries of origin and the same happens for USA Colombians when compared with CO Colombians—probably due to higher incidence, since survival is uniformly poor in both countries (Allemani et al., 2018). Prostate cancer mortality was higher in Colombia, but this difference was only statistically significant among low educated men, suggesting possible differences in access to early detection and quality care between the two countries and among the lower education group.

For colorectal, breast, and lung cancer, the observations are contrary to our expectations. We expected a lower mortality from these cancers in CO Colombians due to their lower risk profile and lower incidence rates in Colombia compared to the USA. However, we observed equal or increased mortality rates for these cancers among CO Colombians compared to USA Colombians, particularly among females. Previously observed effects of migration from developing countries to the USA generally show that Hispanics tend to have their cancer risk increased when moving to the USA (Pinheiro et al., 2009), probably due to changes in lifestyle and reproductive factors. However, cancer mortality rates for colorectal, breast, and lung cancers in most Hispanic groups in the USA remains below that of the general USA population, with the exception of cervical, stomach, and female liver cancers (Pinheiro et al., 2017b; 2017c). Thus, while a potential slight increase in incidence of colorectal, breast, and lung cancer among USA Colombians may exist, the observed higher mortality among CO Colombians strongly suggests that better survival rates in the USA can counter that effect.

Survival of colorectal cancer is quite poor in Colombia, with an estimated 34.5% net 5-year survival for colon cancer (Allemani et al., 2018) versus 64.7% in the USA. This difference likely results from late diagnosis and delays in treatment access in Colombia. Although colorectal cancer screening by the fecal occult blood test is reimbursed by the Colombian healthcare system, according to demographic health surveys, only 8.6% of men and 7.1% of women participated in colorectal cancer screening in Colombia. Likewise, a study with a large series of patients presented that the median time between suspicion of colorectal cancer and initiation of radiotherapy was 83 days in Colombia in 2015; for other treatments, the times were longer (Instituto Nacional de Cancerología ESE, 2016). Apart from potential problems with data quality, the only logical explanation for the increased breast cancer MRR in Colombia , is very poor survival, which seems consistent with observations. Population-based 5-year net survival for breast cancer was 72.1% in Colombia versus 90.2% in the USA (Allemani et al., 2018). Moreover, of all cancer patients treated at the Colombian national cancer institute, the proportion of women with stage III or IV has been stable at around 50% over the past 5 years (De Vries et al., 2018). In Colombia, median time, in 2015, for chemotherapy initiation after suspicion of breast cancer was 100 days, and for surgery after initiation, 120 days (Instituto Nacional de Cancerología ESE, 2016). The increased lung cancer MRR among males is most likely attributable to differences in both survival (8.7 versus 21.2 net 5-year survival (Allemani et al., 2018)) and incidence. Since the USA Colombian group is largely composed of highly educated Colombians (Table I), their lower smoking prevalence is expected to result in lower incidence and mortality rates (Macías et al., 2013). Indeed, of all lung cancer deaths among USA Colombians, only 31.4% were highly educated (versus 46.1% of all cancer deaths), and among the CO Colombian deaths, 92.4% of cancer deaths were among the low education group (data not shown).

In order to migrate to the United States from a non-border country like Colombia, one must comply with strong selection criteria, including educational status. Therefore, unlike in native Colombia, many USA Colombians are highly educated (Lopez, 2010). Notably, the higher mortality observed in CO Colombians, when compared with USA Colombians, replicates the cancer immigration experience of another relatively high educated immigrant population, USA Italians, who presented lower mortality rates in the USA than in Italy (Santucci et al., 2022). Conversely, Mexican immigrants, a population with an overwhelming proportion of lower education levels, showed much higher cancer mortality rates in the USA, mostly due to increased incidence rates in the country (Pinheiro et al., 2017c).

To account for the potential confounding of our observed differences in mortality rates by educational status, we adjusted the model for educational level (high versus low education), and most associations persisted despite a general tendency towards a slight reduction in the differences between the two countries.

The MRR for stomach cancer (both sexes), lung (males), and cervical cancer diminished substantially, illustrating the important educational differences that exist for these cancers, and likely reflecting differences in exposure to risk factors and, therefore, incidence rates, along with differences in access to timely diagnosis and treatment (Table II, IV) (De Vries et al., 2015a). The data allowed for stratification by age in broad age groups and educational levels (in two levels), which gives room for residual confounding for these two variables. We performed some sensitivity analyses using different age group stratifications which did not yield a different result. It would be ideal to have smaller subgroups for both variables but the information available combined with the number of cancer deaths did not allow for a more detailed analysis.

Estimates for country-specific educational differences were computed for both countries, even though the results for the USA were somewhat imprecise due to low numbers. Despite this limitation, the population specific MRR by educational level provides insights: the strong disadvantage observed for stomach and cervical cancer in the lower educated groups in Colombia persists among USA Colombians, but to a much lesser extent, indicating more equal access to diagnostic and treatment services in the USA. Educational differences in the USA are pointing mostly towards a disadvantage towards the higher educated for prostate and uterine cancers, most likely due to higher incidence caused by increased risk factors. This pattern for USA Colombians is in clear contrast with observations on non-Hispanic whites in the USA where, for most cancers, higher educational level equates with lower cancer mortality rates (Withrow et al., 2021). Meanwhile, USA Colombians' advantage (lower mortality) among the high education group was only observed for cervical cancer.

Strengths and limitations

The strength of our work is its population-based nature, with mortality data that are complete and of high and moderate quality, for the USA and Colombia, respectively, according to the World Health Organization (WHO) (Piñeros Petersen 2010). The accuracy of the denominators from Colombia may be somewhat uncertain since the last census in Colombia at the moment of analysis had been conducted in 2005, and many changes in society had since facilitated a better life expectancy than initially expected. Unfortunately, we did not have data on the age at migration or the duration of stay in the United States, which could have provided us with additional interesting information. Unfortunately, in this cross-sectional study, we had relatively sparse data on USA Colombians, making it impossible to refine our analyses to deal with changes over time. There is a larger recent immigration in younger age groups, but the observed cancer deaths have probably occurred among earlier immigrants.

Contrary to previous work (De Vries, 2015a; Piñeros Petersen, 2010), we did not apply redistribution methods for ill-defined causes of "uterine cancer" since the margin of error is relatively lower due to improvements in the quality of the data (WHO, 2008; Piñeros Petersen, 2010). It is debatable whether any redistribution would result in under- or overestimation of the comparative ratios between the CO and USA Colombians. Cervical cancer is still a quite common cause of death in Colombia, and it is likely that a substantial part of the "uterine cancer – not specified" cases are cervical cancers, whereas in the USA endometrial cancers are more common and the very few unspecified uterine cancers are less composed of cervical cancer cases.

We did not adjust for the proportion of ill-defined causes of death. However, we can interpret how this lack of adjustment will have influenced our estimates since it is expected that the proportion of such "garbage-codes" was higher for the CO Colombians (Rodríguez-García 2017) than those for the USA Colombians data, considering that the USA National Center for Health Statistics (NCHS) applies the software ACME (Automatic Classification of Medical Entry) to the mortality statistics to improve the quality of the information on causes of death, diminishing the use of unspecified codes. Undertaking this substantial difference of unreliable codes among the USA and Colombian registries, an underestimation of the RRs is more than likely. Therefore, our results represent conservative estimates, and the conclusions of the study do not change.

Conclusion

Overall, the disparities in cancer mortality between populations of CO Colombians and USA Colombians are striking, with higher mortality observed among CO Colombians even after adjustment for educational levels. This is especially intriguing considering previously documented disparities by race/ethnicity in healthcare access in the USA (Boscoe, 2016a; Boscoe, 2016b; Liu; Zhang; Du, 2016; Sakhuja, et al., 2017). However, within the USA, the disparities within each race/ethnicity may be much smaller, as our data confirms for USA Colombians. By contrast, a country like Colombia theoretically provides universal access to preventive and diagnostic care and treatment, but the quality of and real access to these services remain unclear (De Vries, 2018).

Explanations for the observed overall higher cancer mortality among CO Colombians compared with USA Colombians is likely due to the combination of better access to preventative and curative healthcare, and the availability of high-tech treatment options in the USA, especially given that underlying incidence rates are likely higher in the USA, except for cervical and gastric cancer. Therefore, our study provides several interesting conclusions for politicians, decision-makers, and the public in general as the population of a middle-income country like Colombia ages and adopts an increasingly Western-lifestyle, cancer will become an increasingly important health burden. Populational growth and the expected continued increase in population ageing (accelerated due to the ongoing peace-process) will result in a substantial growth in the number of cancer patients (Mendoza et al., 2017). Traditional cancer patterns will shift from infection and poverty-related cancers (stomach and cervical cancers (De Vries, 2015a)) towards breast, colorectal, ovarian, and prostate cancers. Primary prevention will be important to avoid large epidemics of smoking, obesity, and diet-related cancers. The inequalities in access within the USA healthcare system are strong, but even so, educational inequalities in cancer mortality within the group of USA Colombians were much smaller than in CO Colombians, showing ample opportunity for improvement in real access to care in Colombia, a country with "universal" healthcare insurance. Lowering the average cancer mortality rates in Colombia will require a more effective and accessible healthcare system that can identify and address important educational disparities, along with the associated barriers impeding the achievement of healthcare equity for the provision of oncological care in the country.

References

ALLEMANI C et al. Global surveillance of trends in cancer survival 2000-14 (CONCORD-3): analysis of individual records for 37 513 025 patients diagnosed with one of 18 cancers from 322 population-based registries in 71 countries. *Lancet*, London, v. 391, n. 10125, p. 1023-1075, 2018. DOI: 10.1016/S0140-6736(17)33326-3.

BOSCOE, F.P. et al. The relationship between cancer incidence, stage and poverty in the United States. *International Journal of Cancer,* Hoboken, v. 139, n. 3, p. 607-612, 2016a.

BOSCOE, F.P. et al. Public domain small-area cancer incidence data for New York State, 2005-2009. *Geospatial Health*, Pavia, v. 11, n. 1, p. 304, 2016b.

BRAY, F. et al. (Ed.). *Cancer Incidence in Five Continents.* Lyon: International Agency for Research on Cancer, 2017. v. XI. Disponível em: <http://ci5.iarc.fr>. Acesso em: 17 jan. 2023.

INSTITUTO NACIONAL DE CANCEROLOGÍA ESE. *Situación del cáncer en Colombia 2015.* Bogotá: Cuento de Alto Costo, 2016.

DANE – DEPARTAMENTO ADMINISTRATIVO NACIONAL DE ESTADÍSTICA. Proyecciones de población por sexo y edades simples hasta 80 años y más, a nivel nacional y departamental. Periodo 2005-2020. Bogotá, 2017. Disponível em: <https://www.dane.gov.co/files/investigaciones/poblacion/proyepobla06_20/proyecciones-nivel-nacional-departamental-por-sexo-y-edades-simples-hasta-80-anos-y-mas.xls>. Acesso em: 17 jan. 2023.

DE VRIES, E. et al. Trends in inequalities in premature cancer mortality by educational level in Colombia, 1998-2007. *Journal of Epidemiology and Community Health*, London, v. 69, n. 5, p. 408-415, 2015a. DOI: 10.1136/jech-2014-204650

DE VRIES, E. et al. Gastric cancer survival and affiliation to health insurance in a middle-income setting. *Cancer Epidemiology,* [s.l.], v. 39, n. 1, p. 91-96, 2015b. DOI: 10.1016/j.canep.2014.10.012

DE VRIES, E. et al. Access to cancer care in Colombia, a middle-income country with universal health coverage. *Journal of Cancer Policy*, Amsterdam, v. 15, pt. B, p. 104-112, 2018. DOI: 10.1016/j.jcpo.2018.01.003

KHAN, A.R. An age- and gender-specific analysis of H. Pylori infection. *Annals of Saudi Medicine,* Riyadh, v. 18, n. 1, p. 6-8, 1998. DOI: 10.5144/0256-4947.1998.6

LIU, Z.; ZHANG, K.; DU, X. L. Risks of developing breast and colorectal cancer in association with incomes and geographic locations in Texas: a retrospective cohort study. *BMC Cancer,* Thousand Oaks, v. 16, p. 294, 2016. DOI: 10.1186/s12885-016-2324-z

MACÍAS, F. et al. Different patterns by age-group and gender of socioeconomic inequalities in smoking in Colombia. *Nicotine and Tobacco Research,* Oxford, v. 15, n. 10, p. 1745-1755, 2013. DOI: 10.1093/ntr/ntt055

MENDOZA, G. H. et al. El efecto del envejecimiento para la carga de cáncer en Colombia: proyecciones para las primeras cinco localizaciones por departamento y sexo en Colombia, 2020 y 2050. *Revista Colombiana de Cancerología*, Bogotá, v. 21, n. 1, p. 104-112, 2017. DOI: 10.1016/j.rccan.2017.04.002

LOPEZ, G. *Hispanics of Colombian Origin in the United States, 2013.* Statistical Profile. Washington, DC, 2015. Disponível em: <https://www.pewresearch.org/hispanic/2015/09/15/hispanics-of-colombian-origin-in-the-united-states-2013/>. Acesso em: 17 Jan. 2023.

LORTET-TIEULANT J. et al. Profiling global cancer incidence and mortality by socioeconomic development. *International Journal of Cancer*, London, v. 147, n. 3029-3036, 2020. DOI: 0.1002/ijc.33114

MURILLO, R. et al. Approaches to cervical cancer screening in areas with unequal health services: the example of Colombia. *HPV Today,* [s.l.], n. 27, p. 27, 2012.

MURILLO, R. et al. Cervical cancer in Central and South America: Burden of disease and status of disease control. *Cancer Epidemiology*, Amsterdam, v. 44, n. suppl 1, p. S121-S130, 2016.

PAHO – PAN-AMERICAN HEALTH ORGANIZATION. Profile of the health services system of Colombia. Washington, DC, 2002. Disponível em: <https://www.paho.org/hq/dmdocuments/2010/Health_System_Profile-Colombia_2002.pdf> Acesso em: 17 jan. 2023.

PINHEIRO, P. S. et al. Cancer incidence in first generation U.S. Hispanics: Cubans, Mexicans, Puerto Ricans, and new Latinos. *Cancer Epidemiology, Biomarkers and Prevention,* Philadelphia, v. 18, n. 8, p. 2162-2169, 2009. DOI: 10.1158/1055-9965.EPI-09-0329

PINHEIRO, P. S. et al. Black Heterogeneity in Cancer Mortality: US-Blacks, Haitians, and Jamaicans. *Cancer Control,* Thousand Oaks, v. 23, n. 4, p. 347-358, 2016. DOI: 10.1177/107327481602300406

PINHEIRO, P. S. et al. Cancer Mortality in Hispanic Ethnic Groups. *Cancer Epidemiology Biomarkers and Prevention*, Philadelphia, v. 26, n. 3, p. 376-382, 2017a. DOI: 10.1158/1055-9965.EPI-16-0684

PINHEIRO, P. S. et al. High cancer mortality for US-born Latinos: evidence from California and Texas. *BMC Cancer,* Thousand Oaks, v. 17, n. 1, 2017b.

PINHEIRO, P. S. et al. Migration from Mexico to the United States: A high-speed cancer transition. *International Journal of Cancer,* Hoboken, v. 142, n. 3, p. 477-488, 2017c. DOI: 10.1002/ijc.31068

PINHEIRO, P. S. et al. Incidence of etiologic-specific hepatocellular carcinoma; diverging trends and significant heterogeneity by race and ethnicity. *Clinical Gastrenterology and Hepatology,* Amsterdam, 2023. DOI: 10.1016/j.cgh.2023.08.016

PINHEIRO, P.S. et al. Liver cancer: a leading cause of cancer death in the United States and the role of the 1945 -1965 birth cohort by race/ethnicity. *JHEP Reports*, Amsterdam, v. 1, n. 3, p. 162-169, 2019.

PINHEIRO, P. S. et al. The association between etiology of hepatocellular carcinoma and race-ethnicity in Florida. *Liver International*, Hoboken, v. 40, n. 5, p. 1201-1210, 2020. DOI: 10.1111/liv.14409

PIÑEROS PETERSEN, M. *Atlas de mortalidad por cancer en Colombia*. Bogotá. Ministerio de la Protección Social, 2010.

PIÑEROS, M. et al. Patterns and trends in cancer mortality in Colombia 1984-2008. *Cancer Epidemiology,* Amsterdam, v. 37, n. 3, p. 233-239, 2013. DOI: 10.1016/j.canep.2013.02.003

PROFAMILIA. *Encuesta Nacional de Demografía y Salud* (1990, 1995, 2000, 2005, 2010, 2015). Bogotá, [2017]. Disponível em: https://profamilia.org.co/investigaciones/ends/. Acesso em: 17 Jan. 2023.

RODRIGUEZ-GARCIA et al. Estimation of the global burden of disease in Colombia-2012: new methodological aspects. 2017. *Revista de Salud Publica*, Bogotá, v. 19, n. 2, p. 235-240. DOI: 10.11144/Javeriana.rgps18-36.ccmn

RUGGLES, S. et al. *Integrated public use microdata series*: version 9.0 [dataset]. Minneapolis: University of Minnesota, 2015. DOI: 10.18128/D010.V6.0

SAKHUJA, S. et al. Availability of healthcare resources and epithelial ovarian cancer stage of diagnosis and mortality among Blacks and Whites. *Journal of Ovarian Research,* Mobile, v. 10, n. 1, p. 57, 2017. DOI: 10.1186/s13048-017-0352-1

SANTUCCI, C. et al. Cancer mortality in Italian populations: differences between Italy and the USA. *European journal of cancer prevention*, [s.l.], v. 31, n. 4, p. 393–399, 2022. DOI: 10.1097/CEJ.0000000000000712

SIERRA, M.S. et al. Cancer patterns and trends in Central and South America. *Cancer Epidemiology,* Amsterdam, v. 44, n. Suppl 1, p. S23-S42, 2016. DOI: 10.1016/j.canep.2016.07.013.

MINISTERIO DE SALUD Y PROTECCIÓN SOCIAL; PROFAMILIA. *Colombia Encuesta*

Nacional de Demográfia y Salud 2015. Bogotá: Profamilia, 2017. Disponível em: <https://dhsprogram.com/publications/publication-fr334-dhs-final-reports.cfm?cssearch=657727_>. Acesso em: 1 dez. 2023.

WITHROW D et al. Leading cancers contributing to educational disparities in cancer mortality in the US, 2017. *Cancer Causes & Control*, Basel, v. 32, n. 11, p. 1193-1196, 2021. DOI: 10.1007/s10552-021-01471-9.

WHO - WORLD HEALTH ORGANIZATION. *Global Health Estimates*: Life expectancy and leading causes of death and disability. Geneva, 2008. Available at: <http://www.who.int/healthinfo/mortality_data/en/>. Accessed on: 17 Jan. 2023.

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Author's contribution

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