• SPECIAL ARTICLE •

Incidence and Mortality of the Leading Cancer Types in Puerto Rico: 1987-2004

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Background: Cancer remains one of the leading causes of morbidity and mortality worldwide and is the second cause of death in Puerto Rico (PR). This article describes the incidence and the mortality from cancer in PR for the period of 1987 to 2004.

Methods: We analyzed data from the PR Central Cancer Registry and the PR Demographic Registry from 1987-2004, for the leading cancer types in men and women in PR. Age-adjusted incidence and mortality rates were estimated by sex, municipality, health region and primary site and were age-standardized to the 2000 PR population.

Results: Incidence rates for overall cancer remained constant in men and increased in women (APC=0.6%, p<0.05), while mortality rates decreased (APC=-1.0%) for both sexes. A significant increase was observed in the cancer incidence rates for colorectal cancer in men, while in women, an increase in breast, colorectal, and corpus and uterus cancer was observed. Mortality rates decreased for most of the major cancers types in both sexes, except for colorectal cancer in men which showed a significant increase (p<0.05).

Conclusion: The most important cancer types in PR (prostate, breast, colorectal, and lung) for both incidence and mortality are susceptible to primary prevention (eliminating or reducing risk factors) or to secondary prevention (early diagnosis) strategies. Our results are essential for the development of cancer prevention and control strategies in the Island. [*P R Health Sci J 2010;3:317-329*]

Key words: Cancer, Incidence, Mortality

Cancer remains one of the leading causes of morbidity and mortality worldwide (1), being a major public health problem in both industrialized and developing countries (2-3). Worldwide, the most common cancers in terms of incidence are lung (12.3%), breast (10.4%), and colorectal (9.4%), while the most common causes of death due to cancer are lung (17.8%), stomach (10.4%) and liver (8.8%) cancers (4). Currently, one in four deaths worldwide is attributed to cancer (4). In Puerto Rico (PR), cancer has been the second leading cause of death, after heart disease, for more than 40 years (4-5), and accounted for 16.6% of all deaths in 2004 (4-5). Cancer mortality trends in the last years have approximated those of the leading cause of death, cardiovascular disease. This was ocurred primarily given the decrease in deaths from cardiovascular disease, that have resulted given the reduction in the prevalence of some risk factors and advances in treatment (6-7).

During the second half of the last century, the incidence of cancer in PR increased dramatically; however, rates seem to have begun to stabilize in more recent years (8-9). Previous studies in the 1970's and 1980's showed a lower incidence of total cancer in persons residing in PR as compared with the general population in the United States (US) (8) and to Puerto Ricans (10) living in the continental US. Recent studies show similar patterns for selected cancer types (11-14). However, the incidence from infection related cancers such as stomach, liver and cervical is higher in PR than in the US (12). Also, contrary to the US,

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these cancer types also rank among the leading cancer sites in incidence and mortality (8, 11, 15-16).

The PR Central Cancer Registry (PRCCR) is the fourth oldest population based cancer registry in the world (8, 17) and collects information on cancer in PR since 1951. The PRCCR is part of the National Program of Cancer Registries (NPCR) administered by the Centers for Disease Control and Prevention (CDC). As with any other surveillance system, the PRCCR is responsible for generating data on cancer burden for the Puerto Rican population, as the collection, analysis and dissemination of health information are important components of public health surveillance systems (18). Given that the last official report of the PRCCR regarding cancer burden in PR was published in 1991 (9), this special article describes the incidence and mortality data for cancer in PR for the period of 1987 to 2004. In addition, we assess differences in cancer incidence and mortality by sex, municipality and health region. This information is important to identify changes in cancer occurrence in PR and to guide the development of future interventions aimed at diminishing the burden of the disease in our population.

Methods

Data Sources

Cancer statistics from 1987 to 2004 were obtained from the PRCCR (19). Data for the incidence analysis (overall) included all malignant cancers, and *in situ* cases for urinary bladder, except squamous and basal cell carcinomas of the skin and *in situ* tumors of the uterine cervix, which were excluded. For specific cancer types, incident tumors were classified by primary site and histology according to the International Classification of Diseases for Oncology, third edition (ICD-O3) (20). To be eligible for the analyses, cancer cases had to meet the following inclusion criteria: 1) be incident cancer cases, 2) diagnosed in residents of PR at the time of diagnosis, and 3) have information on age and type of diagnostic confirmation. Cancer mortality data (overall and for specific cancer types) was obtained from the PR Department of Health as reported on death certificates enacted by the Division of Statistical Analysis, Auxiliary Secretariat for Planning and Development (21). This database includes all deaths in which the underlying cause of death in the death certificate is a malignant tumor, according to the International Classification of Diseases (ICD-9 and ICD-10).

Statistical Analysis

To assess cancer trends, the age-standardized incidence (ASI) and the age-standardized mortality (ASM) rates, per 100,000 persons, were computed by sex, using the 2000 population of PR as the standard population (22). Overall cancer trends, for both ASI and ASM, were computed from 1987 to 2004, and the annual percent changes (APC) of these rates were estimated using the weight least squares method (23). Distribution of the top ten leading cancer sites, for both new cases and deaths, were calculated by gender and restricted to the 2000-2004 period. Based on these results, cancer trends from 1987 to 2004 were also computed for the five leading cancer sites, for both ASI and ASM, for men and women.

Cancer ASI's and ASM's rates were also computed for the five leading sites, by municipality, from 2000 to 2004. Based on these results, geographical distribution maps, by municipality, were prepared using ArcView software. To assess differences by health (24) regions (Figure 1) of the top five leading cancer sites for incident cases and deaths, age-standardize rate were calculated as follows:

$$ASR_i = \sum_{j=1}^{18} w_j \frac{\sum_{k=2000}^{2004} d_{ij}^k}{\sum_{k=2000}^{2004} n_{ij}^k},$$

where w_j is the proportion of persons in the *j*-th age group of the standard population (PR 2000), d^k_{ij} is the number of cases (new cases or deaths) in the *j*-th age group for the *i*-th health region in the *k*-th year, and n^k_{ij} is the population in the *j*-th age group of the *i*-th health region in the *k*-th year. Then, the ratio of two standardized rates $\left[ASR_{Region\ i} \Big/ ASR_{PuertoRico} \right]$ were estimated with 95% confidence intervals (25), to assess significant differences by health region. This ratio was denoted as Standardized Rate Ratio (SRR) for both incidence and mortality. The statistical analyses were performed using the SEER-Stat program version 6.4.4 (Surveillance Research Program) and STATA version 10.

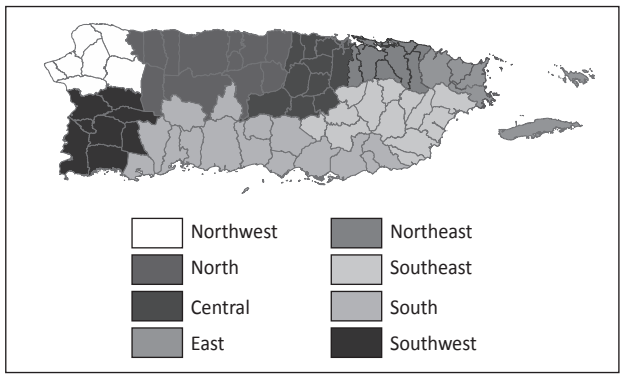

Figure 1. Puerto Rico Health Regions and Sub Regions

Results

Age-standardized incidence and mortality trends of total cancer in Puerto Rico (1987-2004)

In recent years, there has been a constant increase in the number of cancer cases reported to the PRCCR (data not

shown). A total of 6,843 cases of invasive cancer were reported to the registry in 1987 as compared with 11,232 in 2004. For the whole study period (1987-2004), an average of 9,367 cases was reported annually to the registry. In average, 56.3% of cancer cases diagnosed during 1987-2004 were in men and 43.7% were in women. Incidence rates increased from 242.8 per 100,000 in 1987 to 267.2 per 100,000 in 2004. The ASI for overall cancer showed a slight increasing trend in males (APC=0.3%) and in females (APC=0.6%, p<0.05) during this period (Figure 2).

Regarding mortality, there has also been a slight increase in the number of reported cancer deaths in PR (Figure 2). A total of 3,675 deaths due to cancer were reported in 1987 as compared with 4,807 in 2004. For the complete study period (1987-2004), an average of 4,390 deaths due to cancer were reported annually. In average, 58.2% of overall cancer deaths during 1987-2004 were in men and 41.8% were in women. A slight decrease was observed in cancer mortality rates, from 133.3 per 100,000 in 1987 to 113.0 per 100,000 in 2004 (data not shown). However, the ASM showed a decreasing trend both in males (APC=-1.0%) and in females (APC=-1.0%) during the same period. The male to female ratio was similar for both ASI and ASM; males showed a higher risk than females (Figure 2).

Distribution of the leading cancer types in incidence and mortality in Puerto Rico (2000-2004)

Figures 3 and 4 present the leading 10 cancer types in men and women in Puerto Rico, in terms of incidence and mortality for the period of 2000-2004. The five leading cancer sites in incidence accounted for two-thirds of overall cancers in males as follows: prostate (38.1%), colorectal (12.9%), lung and bronchus (6.7%), oral cavity and pharynx (4.6%) and urinary bladder (4.1%). Whereas the five leading cancers in incidence accounted for 61% of overall cancers in females: breast (31.9%), colorectal (14.1%), corpus and uterus (6.8%), lung and bronchus (4.4%) and cervix uteri (3.9%) (Figure 3).

Meanwhile, during 2000 to 2004, the five leading cancers in mortality accounted for 58.2% of overall cancer deaths among males: prostate (18.9%), lung and bronchus (14.6%), colorectal (11.6%), liver and intrahepatic bile duct (6.9%) and stomach (6.2%) cancer. Whereas among females the five leading cancers in mortality accounted for half (52.4%) of overall cancer deaths: breast cancer (17.8%), colorectal (13.0%), lung and bronchus (10.5%), liver and intrahepatic bile duct (5.7%) and stomach (5.4%) cancer (Figure 4).

Age-standardized incidence and mortality trends of the leading cancer types in Puerto Rico (1987-2004), by sex

Among males, prostate and colorectal cancers had the highest ASIs during 1987-2004, both of them showing a moderate increasing trend (APC=1.9% and APC=2.1%, respectively). For colorectal cancer, the increase was statistically significant (p<0.05). However, for males, oral cavity and pharynx cancer showed the highest decreasing trend (APC=-3.5%, p<0.05), followed by lung and bronchus (APC=-1.4%, p<0.05) (Figure 5). Meanwhile, among females, the highest ASIs were found for breast and colorectal cancers, both of which showed a moderate increasing trend (APS=1.7% and APC=1.7%, respectively, both statistically significant). However, cancer of the corpus and uterus, not other specified (NOS), showed the highest increasing trend (APC=2.1%, p<0.05) (Figure 5), while cervical cancer showed a significant reduction (APC=-2.1%, p<0.05).

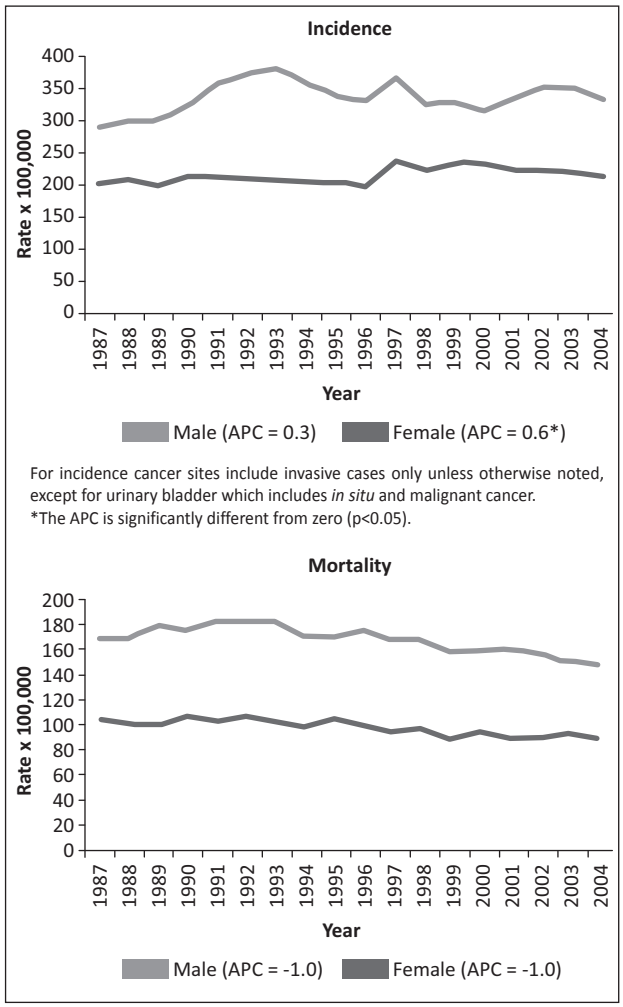

Figure 2. Age-standardized Incidence and Mortality Trends, All cancer by Sex, Puerto Rico 1987-2004. (Rates are per 100,000 and age standardized to 2000 population for PR.)

Among males, the highest ASMs were found for prostate and lung and bronchus cancers during 1987-2004, showing a decreasing trend (APC=-0.1%, p<0.05 and APC=1.0%, p<0.05, respectively). However, stomach cancer showed the largest decrease in trend (APC=-4.1%, p<0.05), while colorectal cancer showed the highest increasing trend (APC=1.9%, p<0.05) (Figure 6). Among females, the highest ASMs were for breast

and colorectal cancers during 1987-2004. Both of these cancers showed minimal changes: breast cancer showed a decrease in trend (APC=-0.3%), while colorectal showed an increase (APC=0.2%), neither one was statistically significant. However, stomach cancer showed a statistically significant decreasing trend (APC=-2.8%, p<0.05) (Figure 6).

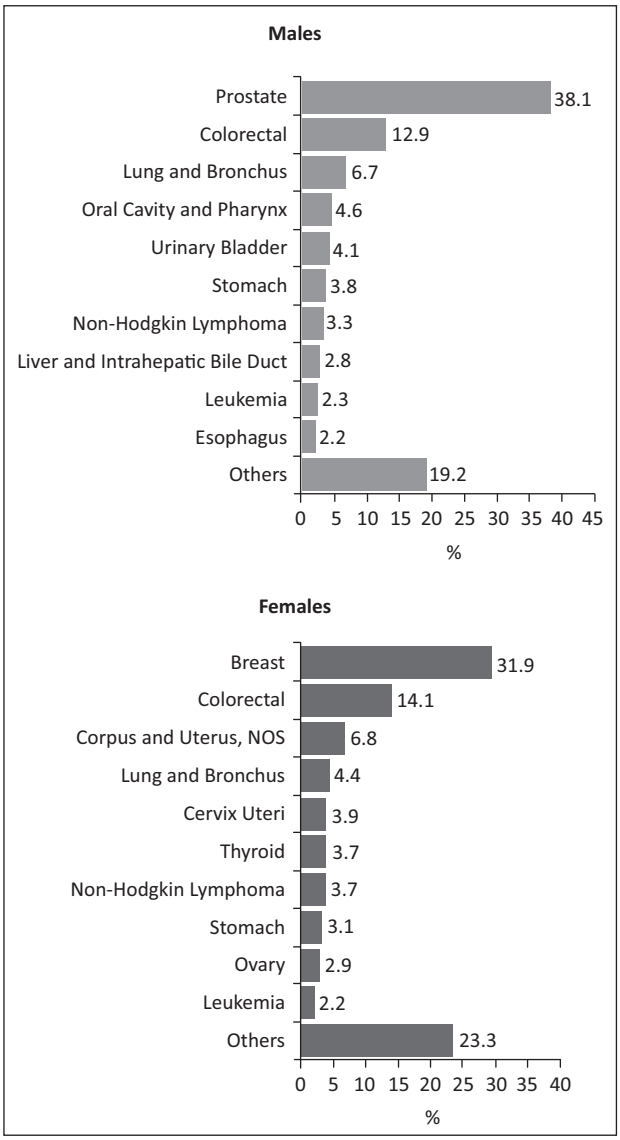

Figure 3. Cancer Incidence Distribution by Sex, Puerto Rico 2000-2004. (Cancer sites include invasive cases only unless otherwise noted, except for urinary bladder that includes *in situ* and malignant cancer).

Age-standardized incidence and mortality rates of the leading cancer types in Puerto Rico (2000-2004), by geographic distribution.

Municipality

The majority of the municipalities in PR with the highest incidences rates of overall cancer in men stretch out from the center toward the east of the Island, in a band from the north coast to the south coast, whereas those municipalities with the lowest rates extend from the center to the northwest of the Island. In females, the distribution of overall cancer incidence shows a more homogeneous pattern throughout the Island (Figure 7).

Municipalities with higher mortality rates for overall cancer in males are found in the southeast corner of the Island and the island municipality of Vieques. However, the vast majority of municipalities with the lowest mortality rates for overall cancer extend from the south coast to the northwest corner of the Island. In contrast, for females, the distribution of overall cancer mortality is homogeneous (Figure 8) without a discernible pattern.

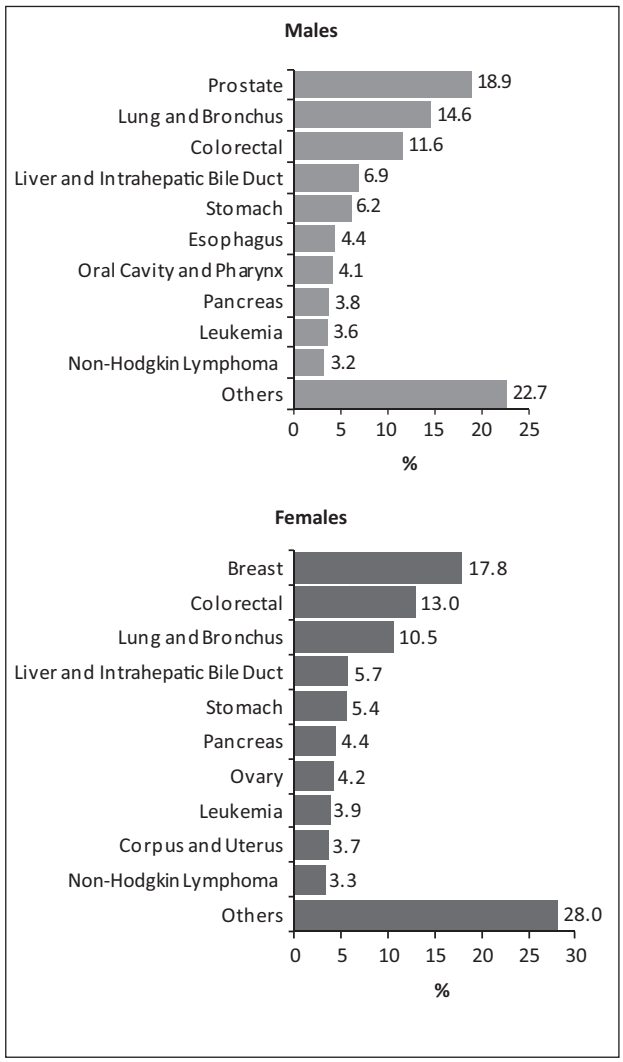

Figure 4. Cancer Mortality Distribution by Sex, Puerto Rico 2000-2004

The specific cancer ASIs by municipality, for each sex, showed a diversity of patterns during 2000 to 2004. For overall cancer among males, the municipalities with the highest rates were: Santa Isabel (441.5 x 100,000), Guayama (418.4

x100,000) and Aibonito (397.4 x100,000). For prostate cancer, the municipalities with the highest ASI rates were: Santa Isabel (190.7 x100,000), Maunabo (185.6) and Guayama (176.9 x 100,000), while the highest ASI rates for colorectal cancer were found in Santa Isabel (62.1 x 100,000), Aibonito (59.7 x 100,000) and Barranquitas (59.0 x 100,000) (Figure 7).

Among females, for overall cancer the municipalities with the highest ASI rates were Rincón (274.6 x 100,000), Aibonito (251.8 x100,000) and Lajas (248.3 x100,000). The ASI rate for breast cancer were highest for the municipalities of Rincón (116.2 x100,000), Guayanilla (86.4 x100,000) and Bayamón (83.2 x 100,000), while the highest ASI rates for colorectal cancer were found in the municipalities of Adjuntas (46.7 x 100,000), Coamo (45.4 x 100,000) and Orocovis (41.0 x 100,000) (Figure 7).

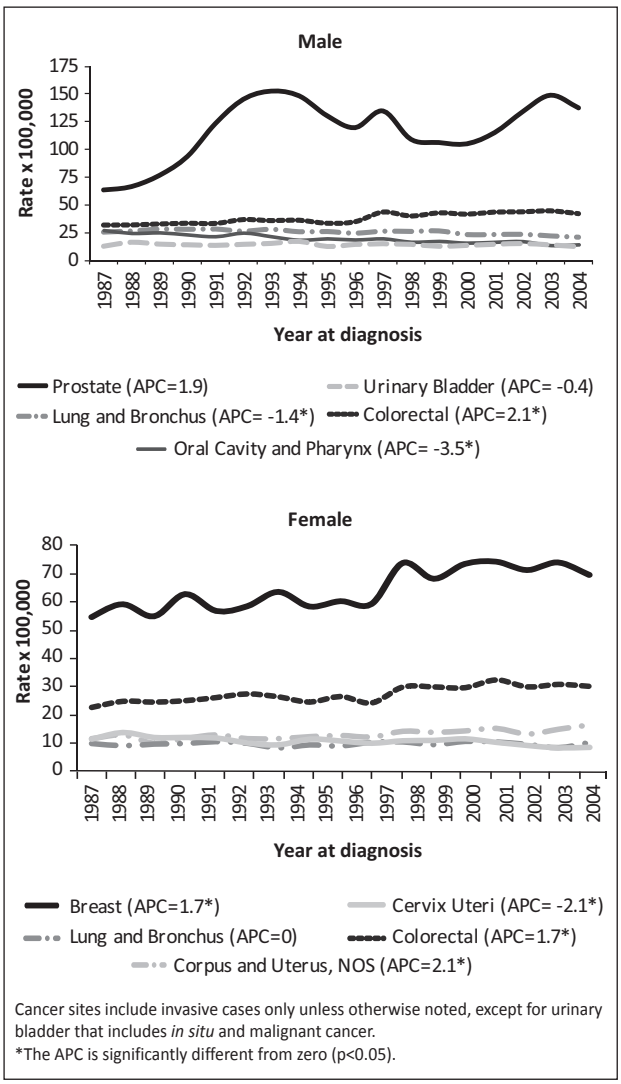

Figure 5. Age-standardized Incidence for the five leading cancer sites, by Sex, Puerto Rico 1987-2004. (Rates are per 100,000 and age standardized to 2000 population for PR).

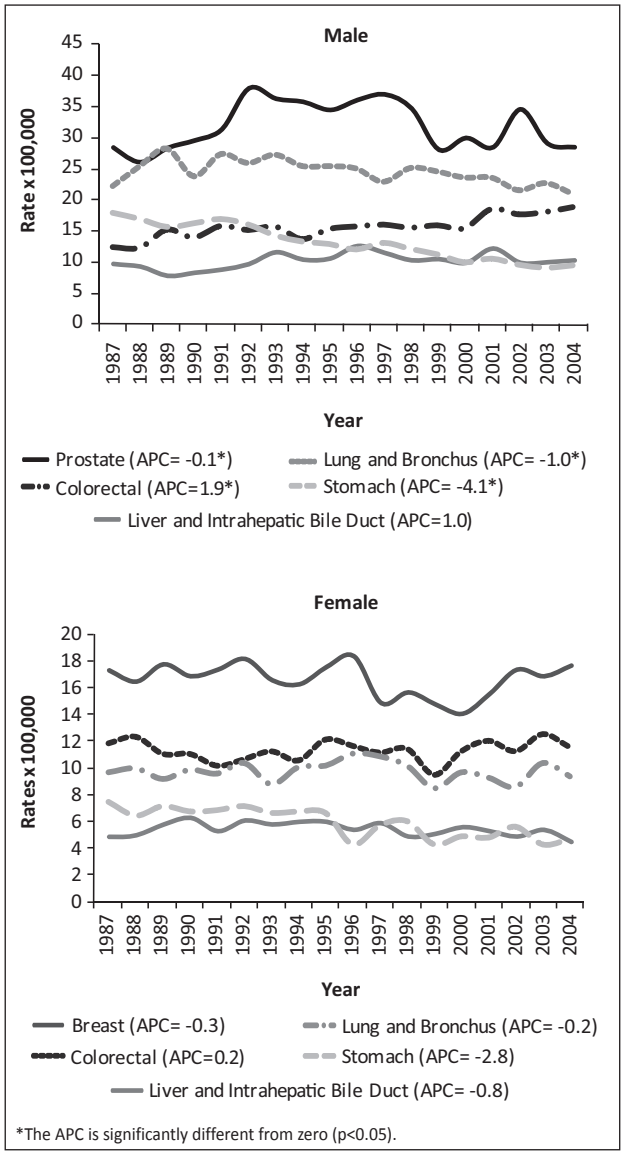

Figure 6. Age-standardized Mortality for the five leading cancer sites, by Sex, Puerto Rico 1987-2004 (Rates are per 100,000 and age standardized to 2000 population for PR).

The overall cancer ASMs by municipality for each sex also showed different patterns from 2000-2004. Among males, for overall cancer mortality, the municipalities with the highest rates were Guayama (225.2 x 100,000), Vieques (224.0 x100,000) and Santa Isabel (217.2 x100,000). The ASM rates for prostate cancer, were higher in the municipalities of Vieques (78.2 x100,000), Maunabo (62.0 x100,000) and Arroyo (57.9 x 100,000), while the highest ASM rates for lung and bronchus cancer were found in Comerío (43.7 x 100,000), Culebra (36.8 x 100,000) and Salinas (35.2 x 100,000) (Figure 8).

Among females, for overall cancer mortality, the municipalities with the highest rates for overall cancer were Comerío (112.3 x 100,000), Ceiba (110.5 x100,000) and Lajas

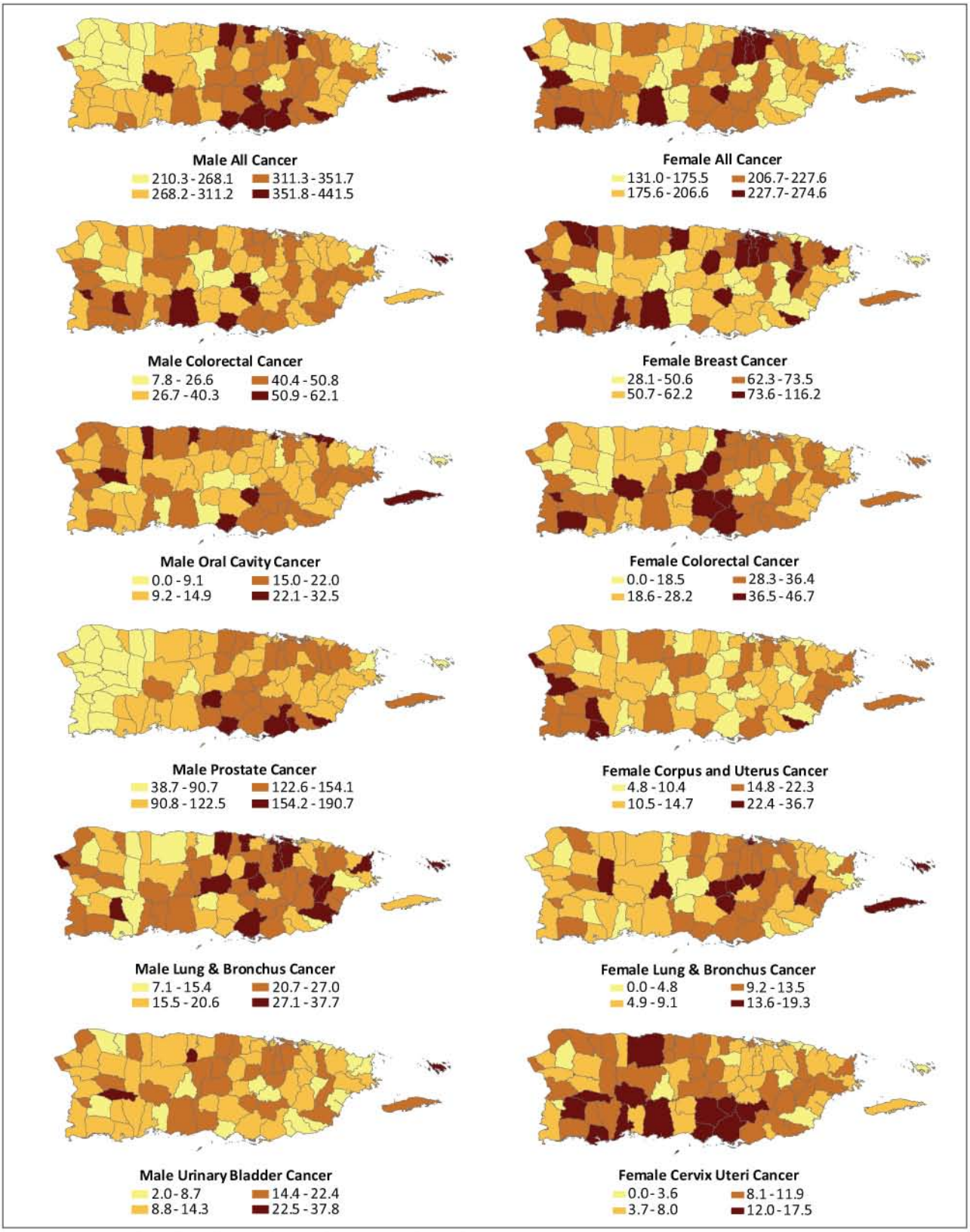

Figure 7. Age-Standarized Incidence of Cancer by Municipality and Sex: Puerto Rico, 2000-2004.
Rates are per 100,000 and age standardized to 2000 population for PR.

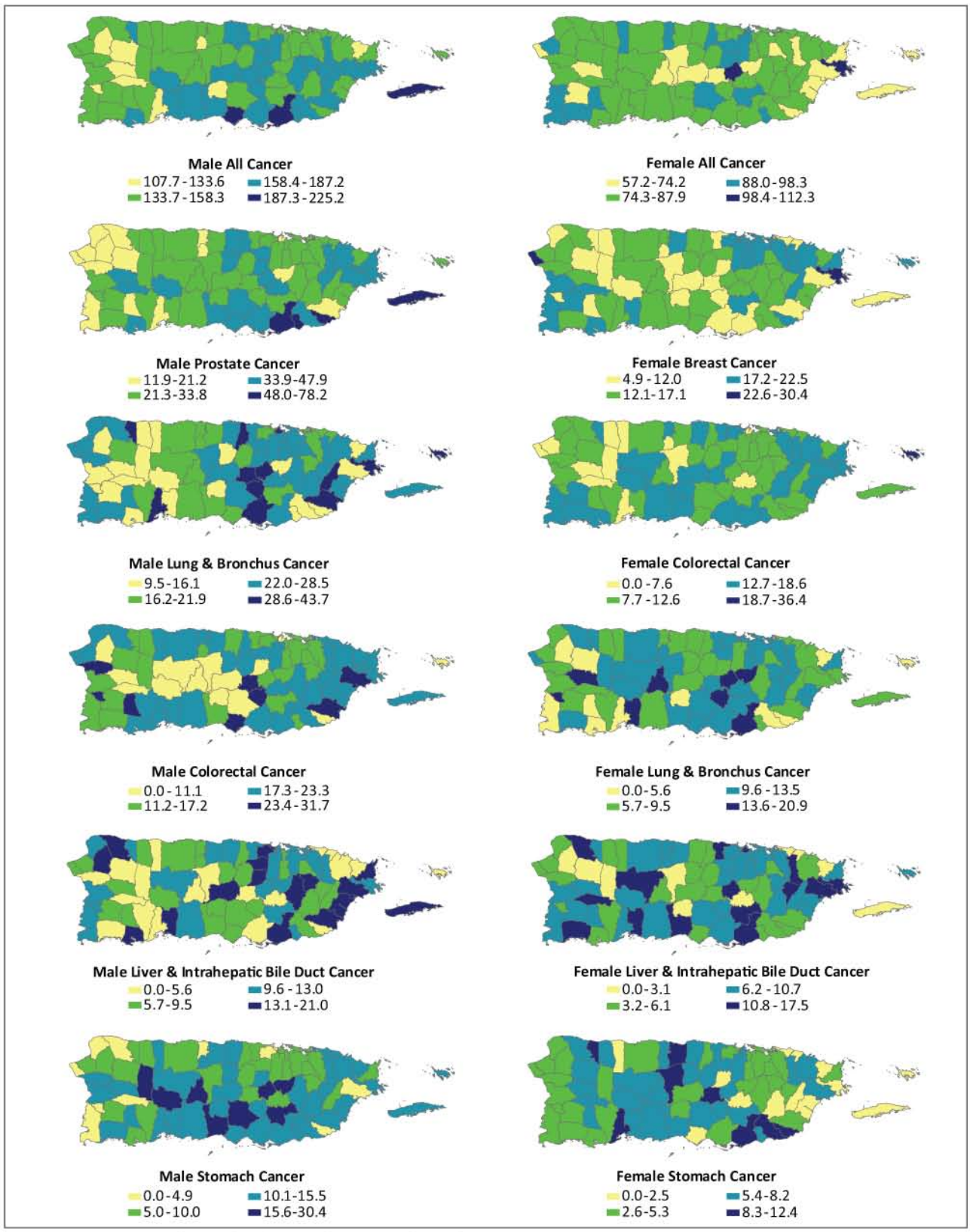

Figure 8. Age-Standarized Mortality of Cancer by Municipality and Sex: Puerto Rico, 2000-2004.
Rates are per 100,000 and age standardized to 2000 population for PR.

(106.6 x100,000). The highest ASM rates for breast cancer were found in the municipalities of Ceiba (30.4 x100,000), Rincón (25.3 x100,000) and Peñuelas (22.5 x 100,000), while the ASM rates for colorectal cancer were highest in Culebra (36.4 x 100,000), Juncos (18.6 x 100,000) and Fajardo (17.9 x 100,000) (Figure 8).

Health Regions

The ASIs for prostate cancer by health region among males showed different pattern from 2000-2004. The Northeast health region showed the highest rate (137.8 x 100,000), representing a significant 7% excess as compared with the risk for PR (SRR: 1.07; 95%CI: 1.03, 1.01). The Northwest health region showed the lowest rate (71.5 x 100,000), representing a significant reduction as compared with the risk for PR (SRR: 0.56; 95%CI: 0.51, 0.61) (Table 1). Among females, the ASIs for breast cancer by health region showed different pattern from 2000-2004. The Northeast health region showed the highest rate (77.1 x 100,000), representing a significant 8% excess as compared with the risk for PR (SRR: 1.08; CI 95%: 1.03-1.13). The Southwest health region showed the lowest rate (58.5 x 100,000), representing a significant reduction as compared with the risk for PR (SRR: 0.82; 95%CI: 0.76, 0.88) (Table 1).

The ASMs for prostate cancer by health region among males showed a different pattern from 2000-2004. The East health region showed the highest rate (39.7 x 100,000), representing a significant 31% excess as compared with the risk for PR (SRR: 1.31; 95%CI: 1.08, 1.57). The Northwest health region showed the lowest rate (18.3 x 100,000), representing a significant reduction as compared with the risk for PR (SRR: 0.60; 95%CI: 0.50, 0.73) (Table 2). Among females, the ASMs for breast cancer by health region showed different pattern from 2000-2004. The Northeast health region showed the highest rate (20.4 x 100,000), representing a significant 25% excess as compared with the risk for PR (SRR: 1.25; CI 95%: 0.99-1.56). The North health region showed the lowest rate (13.8 x 100,000), representing a significant reduction as compared with the risk for PR (SRR: 0.85; 95%CI: 0.72, 0.99) (Table 2).

Discussion

As in any complete surveillance program, the principal objective of the PRCCR is to disseminate its data for the prevention and control of cancer in PR. With this aim, this manuscript from the PRCCR presents for the first time in the past 19 years a scientific overview of the cancer burden in PR in recent years. Our results

Table 1. Age-standardized Incidence (ASI) of the five leading cancer sites, by Health Regions for Each Sex: 2000-2004**

MALES

Health Region	Prostate		Colorectal		Lung and Bronchus		Oral Cavity and Pharynx		Urinary Bladder	
	ASI	SRR (95%CI)	ASI	SRR (95%CI)	ASI	SRR (95%CI)	ASI	SRR (95%CI)	ASI	SRR (95%CI)
Puerto Rico	128.5	1.00	43.4	1.00	22.5	1.00	15.5	1.00	14	1.00
Northwest	71.5	0.56 (0.51-0.61)*	35.0	0.81 (0.70-0.92)*	21.3	0.94 (0.79-1.12)	16.4	1.06 (0.87-1.29)	12.6	0.90 (0.71-1.12)
North	105.8	0.82 (0.77-0.87)*	38.6	0.89 (0.80-0.98)*	17.9	0.79 (0.68-0.92)*	16.9	1.09 (0.93-1.28)	13.8	0.99 (0.83-1.17)
Central	122.8	0.96 (0.91-1.01)	41.6	0.96 (0.87-1.05)	23.9	1.06 (0.94-1.20)	13.6	0.88 (0.75-1.02)	14.2	1.01 (0.86-1.18)
East	113.1	0.88 (0.79-0.98)*	38.8	0.89 (0.74-1.06)	23.9	1.06 (0.84-1.33)	11.9	0.77 (0.55-1.05)	10.5	0.75 (0.52-1.05)
Northeast	137.8	1.07 (1.03-1.12)*	40.7	0.94 (0.87-1.01)	25.0	1.11 (1.01-1.22)*	14.8	0.96 (0.85-1.09)	14.7	1.05 (0.93-1.19)
Southeast	120.2	0.94 (0.89-0.99)*	40.6	0.94 (0.85-1.02)	23.1	1.02 (0.90-1.16)	14.6	0.94 (0.81-1.10)	12.2	0.87 (0.73-1.03)
South	131.1	1.02 (0.97-1.07)	46	1.06 (0.97-1.15)	20.4	0.91 (0.79-1.03)	15.3	0.99 (0.85-1.14)	12.8	0.92 (0.77-1.08)
Southwest	80.7	0.63 (0.58-0.68)*	44.1	1.02 (0.90-1.14)	20	0.89 (0.74-1.05)	15.9	1.03 (0.84-1.25)	13	0.93 (0.75-1.15)

FEMALES

Health Region	Breast		Colorectal		Corpus and Uterus, NOS		Lung and Bronchus		Cervix Uteri	
	ASI	SRR (95%CI)	ASI	SRR (95%CI)	ASI	SRR (95%CI)	ASI	SRR (95%CI)	ASI	SRR (95%CI)
Puerto Rico	71.6	1.00	30.8	1.00	15.3	1.00	9.6	1.00	9.0	1.00
Northwest	70.8	0.99 (0.91-1.08)	24.5	0.80 (0.68-0.92)*	13.4	0.87 (0.71-1.06)	6.6	0.68 (0.51-0.91)*	7.6	0.85 (0.64-1.11)
North	64.3	0.90 (0.84-0.97)*	22.3	0.72 (0.64-0.82)*	12.8	0.83 (0.71-0.98)*	8.2	0.85 (0.69-1.04)	10.1	1.12 (0.93-1.35)
Central	72.4	1.01 (0.95-1.07)	31.4	1.02 (0.93-1.12)	12.8	0.83 (0.72-0.96)*	10.1	1.05 (0.89-1.24)	7.0	0.78 (0.64-0.95)*
East	64.7	0.90 (0.80-1.02)	26.4	0.86 (0.70-1.04)	16.3	1.07 (0.82-1.37)	7.6	0.79 (0.53-1.13)	7.4	0.82 (0.54-1.19)
Northeast	77.1	1.08 (1.03-1.13)*	30.1	0.98 (0.91-1.05)	14.6	0.95 (0.85-1.06)	10.5	1.09 (0.96-1.25)	6.8	0.76 (0.65-0.90)*
Southeast	58.5	0.82 (0.76-0.88)*	26.2	0.85 (0.76-0.94)*	12.8	0.83 (0.72-0.97)*	11.2	1.17 (0.99-1.38)	8.6	0.96 (0.79-1.15)
South	64.0	0.89 (0.84-0.96)*	33.1	1.07 (0.98-1.18)	15.1	0.99 (0.86-1.13)	8.1	0.84 (0.70-1.01)	10.8	1.21 (1.02-1.42)*
Southwest	70.4	0.98 (0.90-1.07)	32.5	1.05 (0.93-1.19)	21.3	1.39 (1.18-1.62)*	8.3	0.87 (0.68-1.10)	9.3	1.04 (0.80-1.33)

Cancer sites include invasive cases only unless otherwise noted, except for urinary bladder that include in situ and malignant cancer.
* Significantly different from Puerto Rico ($p<0.05$).
**ASI per 100,000. 95%CI: Confidence intervals with 95% (Tiwari method).

Table 2. Age-standardized Mortality (ASM) of the five leading cancer sites, by Health Regions for Each Sex: 2000-2004**

MALES

Health Region	Prostate		Lung and Bronchus		Colorectal		Liver and Intrahepatic Bile Duct		Stomach	
	ASM	SRR (95%CI)	ASM	SRR (95%CI)	ASM	SRR (95%CI)	ASM	SRR (95%CI)	ASM	SRR (95%CI)
Puerto Rico	30.3	1.00	22.2	1.00	17.8	1.00	10.5	1.00	9.6	1.00
Northwest	18.3	0.60 (0.50-0.73)*	22	0.99 (0.83-1.17)	18.2	1.02 (0.84-1.23)	10.1	0.97 (0.75-1.24)	6.0	0.62 (0.44-0.85)*
North	28.7	0.95 (0.84-1.07)	19.3	0.87 (0.75-1.00)	16.6	0.93 (0.79-1.09)	8.5	0.81 (0.64-1.00)*	10.6	1.10 (0.90-1.34)
Central	30.8	1.02 (0.91-1.14)	24.3	1.09 (0.97-1.23)	18.4	1.03 (0.90-1.18)	12.1	1.16 (0.97-1.37)	8.9	0.93 (0.76-1.13)
East	39.7	1.31 (1.08-1.57)*	23.7	1.07 (0.84-1.34)	18.9	1.06 (0.81-1.37)	9.9	0.94 (0.65-1.32)	10.4	1.08 (0.75-1.53)
Northeast	31.1	1.03 (0.94-1.12)	24.4	1.10 (0.99-1.21)	16.5	0.93 (0.82-1.04)	11.2	1.07 (0.92-1.23)	7.9	0.83 (0.69-0.98)*
Southeast	30.8	1.02 (0.91-1.13)	23.7	1.07 (0.94-1.20)	19.3	1.08 (0.94-1.24)	12.4	1.18 (0.99-1.40)	11.1	1.15 (0.96-1.38)
South	35.8	1.18 (1.07-1.31)*	19.8	0.89 (0.78-1.01)	19.1	1.07 (0.94-1.23)	8.9	0.85 (0.69-1.03)	12.5	1.30 (1.09-1.54)*
Southwest	25.0	0.83 (0.71-0.96)*	18.8	0.85 (0.71-1.01)	16	0.90 (0.74-1.08)	8.9	0.85 (0.65-1.10)	9.3	0.97 (0.74-1.24)

FEMALES

Health Region	Breast		Lung and Bronchus		Colorectal		Liver and Intrahepatic Bile Duct		Stomach	
	ASM	SRR (95%CI)	ASM	SRR (95%CI)	ASM	SRR (95%CI)	ASM	SRR (95%CI)	ASM	SRR (95%CI)
Puerto Rico	16.3	1.00	11.7	1.00	9.5	1.00	5.1	1.00	4.8	1.00
Northwest	13.3	0.81 (0.66-0.99)*	8.7	0.80 (0.60-1.04)	7.5	0.74 (0.57-0.95)*	5.0	0.97 (0.69-1.35)	4.6	0.94 (0.65-1.33)
North	13.8	0.85 (0.72-0.99)*	10.8	0.97 (0.79-1.17)	9.2	0.93 (0.77-1.10)	5.3	1.04 (0.79-1.33)	5.4	1.11 (0.85-1.43)
Central	17.2	1.05 (0.93-1.19)	11.8	1.04 (0.88-1.23)	9.8	1.01 (0.87-1.18)	6.0	1.18 (0.94-1.45)	5.7	1.19 (0.95-1.48)
East	20.4	1.25 (0.99-1.56)	14.9	0.78 (0.52-1.12)	7.4	1.27 (0.96-1.65)	4.9	0.97 (0.58-1.51)	3.6	0.74 (0.41-1.25)
Northeast	19.1	1.17 (1.06-1.29)*	11	1.06 (0.93-1.21)	10	0.94 (0.83-1.06)	4.5	0.88 (0.72-1.06)	3.9	0.80 (0.65-0.98)*
Southeast	15.2	0.93 (0.81-1.06)	11.6	1.13 (0.95-1.33)	10.7	1.00 (0.85-1.16)	5.0	0.97 (0.76-1.23)	4.3	0.89 (0.68-1.15)
South	14.7	0.90 (0.78-1.03)	13.5	0.99 (0.83-1.18)	9.4	1.16 (1.00-1.34)	5.1	1.00 (0.79-1.27)	6.4	1.33 (1.07-1.64)*
Southwest	15.8	0.97 (0.81-1.15)	13	0.90 (0.70-1.14)	8.5	1.11 (0.91-1.35)	6.0	1.17 (0.87-1.56)	4.6	0.95 (0.68-1.32)

* Significantly different from Puerto Rico ($p<0.05$).
**ASM per 100,000. 95%CI: Confidence intervals with 95% (Tiwari method).

show that cancer continues to be a disease of great impact in the Puerto Rican population (15). From 1987-2004, the number of incident cases and deaths from the disease increased, highlighting the increased burden of cancer in terms of total number of cases. Meanwhile, incidence trends of the disease during this period also increased, particularly in women, whereas mortality trends showed non-significant decreases in both sexes. The overall increase in cancer incidence in women reflects, in part, the substantial increases of breast, colorectal and corpus and uterus cancer, which represent more than half of women cancers in PR. The observed pattern in women has also been attributed to the combined effect of earlier detection (through cancer screening) and improved treatment of the leading cancers in women (breast and colorectal cancer) (26).

Our results also show that in PR cancer is more frequent in men than women. This finding is consistent with historical data for PR (8) and with data for the US and European countries (27). Some differences could be hormonally related, but there are probably also explained by the higher prevalence of high risk behaviors in men, including smoking and drinking, and in some cases, differences in occupational exposures and access to health services in these groups (28). Our results also document that the most important cancer types in incidence in males in PR were: prostate, colorectal, and lung and bronchus, while in females were: breast, colorectal, and corpus and uterus, NOS. For mortality, the most important cancers in males were: prostate, lung and bronchus, and colorectal, while in females were: breast, colorectal and lung and bronchus. These principal cancers in men in PR are strongly related to tobacco use, western diet, and physical inactivity, while in women the most common cancers are related to western diet, physical inactivity and some reproductive factors. Thus, these results support the notion that as our population acquires western lifestyles, cancer risk is likely to follow those of industrialized societies (10-11, 13, 29). Despite the fact that Puerto Ricans living in PR do not live physically in the continental US, they have gradually experienced an acculturation process due to their political and socio-economical relationships with the US which began in 1898 (8, 13).

Regarding tobacco consumption, particularly three of the leading cancer types in men in terms of incidence (lung, oral cavity and pharynx, and urinary bladder) are all strongly associated with cigarette smoking, supporting the relevance of continued smoking cessation interventions in our population, as these cancers are important in both incidence and mortality. Smoking is in fact associated with increased risk for at least

15 cancer types (27), and accounts for at least 30% of overall cancer deaths and 87% of lung cancer deaths (27). Population-based data from the Behavioral Risk Factor Surveillance System (BRFSS) on the prevalence of cigarette use among adults in PR is only available since 1996, showing a decreasing trend over the last decade from 14.5% in 1996 to 11.7% in 2008 (30). Given that historical data on tobacco consumption in PR is scarce, and given that the latency period (time between exposure and disease development) is long for these diseases (31-32), we cannot hypothesize if historical reductions in tobacco consumption in PR may partially account for the decreasing trends observed for some of these cancer types in men in our study. Nonetheless, the low prevalence of smoking in Puerto Ricans (11.7% vs 18.4% in US) may explain, in part, the lower incidence rate of lung cancer in PR (16.3 per 100,000) as compared with the US previously documented (60.7 per 100,000) (30, 32). In addition, differences in radon exposure in these populations may also explain the lower burden of lung cancer in PR as compared to the US. Exposure to radon is the second leading cause of lung cancer after smoking and it is the primary cause of lung cancer among non-smokers (33). The World Health Organization (WHO) indicates that radon causes up to 15% of lung cancers worldwide (33). Radon exposure in PR is low because there are few emission sources, particularly given our tropical climate, which allows the construction of residential living to be more ventilated throughout the year, thus, avoiding the accumulation of gas (radon) within the structures and thereby reducing its indoor concentrations (34).

Regarding obesity and physical activity, some of the most common cancer types identified in men (colorectal) and women (breast and corpus and uterus) in PR are also strongly associated to these behaviors (35-36), and have in fact increased during the last years in our population. These patterns could be related to the high prevalence of overweight and physical inactivity in PR. According to the BRFSS, the prevalence of overweight and obesity (BMI: 25.0 – 99.8 kg/m2) in PR is in average 63.9% (for the period of 2003 to 2008), while only 32.7% of the population report participation in moderate-intensity activities for 30 minutes on five days per week or vigorous-intensity for at least 20 minutes on three days per week (30, 37). The prevalence of overweight and obesity in PR increased by 19.4% from 1996 to 2008, while the prevalence of moderate-intensity activities for 30 minutes on five days per week or vigorous-intensity for at least 20 minutes on three days per week decreased by 30.4% from 2001 to 2007 (30).

As previously mentioned, our results also showed that cancer types related to hormonal and reproductive factors, such as breast and corpus and uterus cancer are also common in Puerto Rican women, and have increased during the last years. Important changes in hormonal and reproductive factors experienced in PR over the last decades, such as parity and age at menarche (38-39), can be a possible explanation for the observed increasing trends. For example, a reduction has occurred in the fertility rate (6.4 children in 1932 to 2.1 children in 1998) in PR (40-42); whereas the median age at menarche has decreased in young Puerto Rican women (13.2 years: 1935-1939 to 12.7 years: 1965-1967) (40-42). Nonetheless, the fact that no population-based data on historical use of hormone therapy has been published, limits our ability to hypothesize on the impact of hormone therapies on cancer incidence trends such as endometrial cancer, in our population (14).

Infections with several viruses and bacteria have been associated to the development of various cancer types (43). Nearly 17.8% of the global cancer burden is attributable to infections agents (44); with a higher percentage in developing countries (26.3%) than in developed countries (7.7%) (4). The principal infectious agents associated with cancer morbidity worldwide are Helicobacter pylori (H. pylori), human papilloma viruses (HPV), and hepatitis B (HBV) and hepatitis C viruses (HCV), associated to stomach, cervical and oral cancer, and liver cancer, respectively (12, 44). Our study shows that contrary to patterns in the US, cancers related to infections are among the leading cancer types in men (oral, stomach, esophageal) and women (cervix) in PR in terms of incidence (44). This is consistent to previous reports (8, 17, 45) that document that during the 1950's, cancers related to infection (stomach, esophageal, and oral cancer in men and cervical and stomach cancer in women) were also among the most common in PR, and to studies that have documented that the burden of various infection related cancers (oral, cervical, stomach and liver cancer) is higher in PR than among NHW in the US (12, 32). Our study also documents that consistent to previous reports (8, 11-12, 15-16, 45), the incidence and mortality trends of several infection related cancers is decreasing in PR. These decreases may be related to the control of certain disease-causing pathogens, changes in other disease risk factors (i.e. reduction in the alcohol and tobacco consumption), to the socio-economic and demographic changes in the last decades (increases socioeconomic status and educational levels) (46), and increased access to health care (30).

The three most common cancer types in men and women in PR (prostate, breast and colorectal cancer) are susceptible to screening, and thus to screening bias and potential overdiagnosis (47). Early detection of cancer or cancer screening refers to the application of strategies to determine whether cancer or pre-cancerous cells are present in a person that does not show signs or symptoms of the disease (18). The goal is to detect cancer in early stages before symptoms develop when the disease can be treated more effectively, improving health outcomes. Even though no structured island wide prostate, breast and colorectal cancer screening program has ever been established in PR, BRFSS data has helped monitor screening behaviors in PR since 1996. For prostate cancer, our results showed that during the early 1990's, the incidence of prostate cancer increased substantially in PR. This increase can be mainly explained by

the introduction of prostate-specific antigen (PSA) screening (48), which may have resulted in overdiagnosis of cases. Recent data from the BRFSS shows that men in PR have a higher percentage of prostate cancer screening (65.6% in 2008) than the US median (54.8% in 2008) (30). The fact suggests that lack of screening is not an issue in our population and may explain the observed increasing trend of the disease (increased diagnosis of cases) as well as the slight decreasing mortality trend (early detection of the disease). Nonetheless, given that prostate cancer is by far the leading cancer type among men in PR, further research is warranted regarding disease risk factors in our population.

For breast cancer, an increase in the number of women who have ever had a mammography in PR in the last decades could partially account for the increases in incidence and the decrease in mortality observed in PR during the study period. According to the BRFSS, in 1996, 61.4% of Puerto Rican women aged 50+ had had a mammogram within the past two years (49). This percent increased to 78.5% in 2008, surpassing the 70% target established by Healthy People 2010 (44). Nonetheless, the proportion of women aged 40+ who have had a mammogram in the US has remained consistently higher than in PR (69.5% in 1996 to 76.0% in 2008) (30). Meanwhile, for colorectal cancer, our results showed that increases in the incidence and mortality trends have been observed for men and women in our population. This gradual increase in colorectal cancer trends may be, in part, also due to changes in lifestyles and use of screening tests. Even though the use of screening tests decreases the risk of death from colorectal cancer, in PR the use of colorectal cancer screening remains well below that of the mainland (44). Even though the prevalence of persons who have had a colonoscopy or a sigmoidoscopy in PR has increased (from 28.4% in 1997 to 42.3% in 2008), its use is low when compared to that of the US (62.2 % in 2008) (50), supporting the need for interventions that promote colorectal cancer screening in PR.

Regarding geographic distribution, our results show that the distribution of cancer incidence is heterogeneous throughout the extension of the Puerto Rican archipelago. Differences in lifestyle and environmental exposures throughout the island, as in access to care, could account for some of these geographic differences. In terms of health care access, although more than 90% of the Puerto Rican adult population has any kind of health care coverage (30), access is influenced by many circumstances, including the location of healthcare facilities, availability of medical providers, and out-of-pocket costs, among other factors (51, 52). In PR, two healthcare systems co-exist; the private system covered by private health insurers and Medicare (parts A and B), and the public system (called *Reforma*) serving, more than half of the Island population, which earnings are up to 200% of the local poverty level. Although *Reforma* is administered by a single government agency and ruled by Law No. 72 (1993), there are different insurance companies serving the eight health regions of PR creating a heterogeneous model of health services. Thus, differences in health care coverage throughout PR may explain some of the differences observed in the incidence and mortality of cancer around the Island. Also, it is not surprising that the incidence of prostate, breast and colorectal cancer follow the geographical distribution of the location of healthcare providers. As a matter of fact, the majority of mammography facilities, urologists and gastroenterologists are clustered in and around the San Juan Metropolitan Area, creating "big pockets" of municipalities without adequate access to care (53). For example, higher incidence rates of prostate cancer are observed in the eastern half of the Island, were more than 65% of providers are located (24). One explanation for this fact is that in PR, a Certificate of Need and Convenience (CNC) is required to establish a health facility.

Finally, differences in the exposition to environmental risk factors across the municipalities of PR could explain, in part, the observed geographic variations in the incidence and mortality cancer rates (30, 54) observed in this study. As an example, the Environmental Protection Agency (EPA) has identified 36 specific spots of contamination due to environmental neglect in PR (55), these areas are defined by the EPA as superfunds (a superfund site is an uncontrolled or abandoned place where hazardous waste is located, possibly affecting local ecosystems or people). Twenty eight percent of superfunds in PR are located in municipalities identified in our study as having high cancer mortality. As an example, in 2005, EPA added portions of the island of Vieques to the Superfund National Priorities List (NPL). Research data suggests that areas of Vieques may be contaminated by solid and/or hazardous waste resulting from decades of military activity (including training exercises, equipment maintenance, supply storage and waste disposal) in this municipality (55). These factors may partially explain the higher rates in cancer incidence and mortality observed in Vieques in the current and previous studies (56-57) as compared to other municipalities in PR, although barriers in access to care in this municipality may also be a contributing factor for the excess in mortality.

Recommendations and Conclusions

This is the first report of the PRCCR that summarizes the current burden of the leading cancer types in PR in recent decades. The most important cancer types in PR (prostate, breast, colorectal, and lung) for both incidence and mortality are susceptible to primary prevention (eliminating or reducing risk factors) or to secondary prevention (early diagnosis) strategies. Estimates have indicated that as much as 50% or more of the cancer incidence can be prevented through smoking cessation and improved dietary habits, such as reduction of fat consumption and increase in fruit and vegetable consumption (27, 44), and through cancer screening (18, 58). Thus, public health interventions in PR should target population changes in the prevalence of these behaviors and in the increase of cancer

screening practices. Our results also showed differing patterns of disease occurrence by sex and geographic region in the Island that warrant further elucidation, and that are essential for the identification of public health priorities for cancer prevention and control in PR. This data should be utilized by the PR Cancer Control Plan (53) for the development of cancer control strategies and for the planning of cancer related health services in PR. Further research is required to analyze the distribution of cancer incidence (and its relation with disease risk factors and screening) and mortality (and its relation to health services access) in PR, as well as the reasons for the observed disease trends. These studies should explore risk factors for disease occurrence (by cancer type) among Puerto Ricans, including the influence of genetics and acculturation.

Resumen

Introducción: El cáncer sigue siendo una de las principales causas de morbilidad y mortalidad a nivel mundial y es la segunda causa de muerte en Puerto Rico (PR). Este artículo describe las tasas de incidencia y de mortalidad por cáncer en PR durante el periodo 1987-2004. Métodos: Se analizaron los datos de incidencia del Registro Central de Cáncer de PR y los datos de mortalidad del Registro Demográfico de PR para los años 1987-2004 de los principales tipos de cáncer en hombres y en mujeres en PR. Se calcularon las tasas de incidencia y de mortalidad estandarizadas por edad de los principales tipos de cáncer, estas fueron estimadas por sexo, municipio, y región de salud; y se estandarizaron por edad a la población de PR 2000. Resultados: Las tasa de incidencia de cáncer en general se mantuvo constante en los hombres y se observó un leve aumento en las mujeres (PCA=0.6%, $p < 0.05$), mientras que la tasa de mortalidad se redujo (PCA =-1.0%) para ambos sexos. Se observó un aumento significativo en las tasas de incidencia de cáncer colorrectal en los hombres, mientras que en las mujeres, se observó un aumento en la incidencia de cáncer de mama, colorrectal y cuerpo del útero. Las tasas de mortalidad disminuyeron para la mayoría de los tipos de cáncer importantes en ambos sexos, excepto para el cáncer colorrectal en los hombres el cual mostró un aumento significativo ($p < 0.05$). Conclusión: Los tipos de cáncer más importantes en PR (próstata, mama, colorrectal y pulmón) tanto para la incidencia como para mortalidad son susceptibles a la prevención primaria (eliminación o reducción de factores de riesgo) o para la prevención secundaria (diagnóstico temprano). Estos resultados son esenciales para el desarrollo de estrategias de prevención y de control de cáncer en la Isla.

Acknowledgements

This work was supported, in part, by the National Program of Cancer Registries (NPCR) of the CDC, Grant #1U58DP000782-02 and by the following grants from the National Institute of Health: Training in Computational Genomic Epidemiology of Cancer (National Cancer Institute [NCI] 5R25CA094186-08), the NCI Grant U54CA96297 for the University of Puerto Rico / University of Texas M. D. Anderson Cancer Center, Partnership for Excellence in Cancer Research, and the RCMI Program Grant G12RR03051 from the University of Puerto Rico. The authors thank Natalia Torres Berríos (Department of Biostatistics and Epidemiology, Graduate School of Public Health, Medical Sciences Campus, University of Puerto Rico) for her collaboration in the technical review of this paper.

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