# Comparative Longterm Mortality Trends in Cancer vs. Ischemic Heart Disease in Puerto Rico

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**Objective: Although contemporary mortality data are important for health assessment and planning purposes, their availability lag several years. Statistical projection techniques can be employed to obtain current estimates. This study aimed to assess annual trends of mortality in Puerto Rico due to cancer and Ischemic Heart Disease (IHD), and to predict shorterm and longterm cancer and IHD mortality figures.**

**Methods: Age-adjusted mortality per 100,000 population projections with a 50% interval probability were calculated utilizing a Bayesian statistical approach of Age-Period-Cohort dynamic model. Multiple cause-of-death annual files for years 1994-2010 for Puerto Rico were used to calculate shortterm (2011-2012) predictions. Longterm (2013-2022) predictions were based on quinquennial data. We also calculated gender differences in rates (men–women) for each study period.**

**Results: Mortality rates for women were similar for cancer and IHD in the 1994-1998 period, but changed substantially in the projected 2018-2022 period. Cancer mortality rates declined gradually overtime, and the gender difference remained constant throughout the historical and projected trends. A consistent declining trend for IHD historical annual mortality rate was observed for both genders, with a substantial changepoint around 2004-2005 for men. The initial gender difference of 33% (80/100,00 vs. 60/100,000) in mortality rates observed between cancer and IHD in the 1994-1998 period increased to 300% (60/100,000 vs. 20/100,000) for the 2018-2022 period.**

**Conclusion: The APC projection model accurately projects shortterm and longterm mortality trends for cancer and IHD in this population: The steady historical and projected cancer mortality rates contrasts with the substantial decline in IHD mortality rates, especially in men. [*P R Health Sci J 2017;36:55-60*]**

*Key words: Mortality, Cancer, Ischemic heart disease, Puerto Rico*

Heart disease and cancer are the leading causes of death worlwide and have been the two leading causes of death in Puerto Rico since 1953 (1). Specifically for cancer and ischemic heart disease (IHD), mortality data may reflect the impact of access and use of medical services and lifestyle behaviors. Although current mortality data are a uniform and fundamental source of demographic, geographic, and cause-of-death information for health assessment, resources allocation, and social and economic planning and monitoring purposes, their availability can be delayed several years due to its cumbersome data collection and validation processes. When this is the case, population-based projections of mortality data can provide reliable and consistent quatitative information on current and future mortality trends. This fact is particularly important for Puerto Rico because the United States Census Bureau publishes annual intercensal estimates for the population of Puerto Rico by age and sex since 2000. The objective of this study is two fold: first to assess the historical trends of mortality due to cancer and IHD; and second, to predict shorterm and longterm cancer and IHD mortality figures in the Puerto Rican population for quinquennials 2013-2017 and 2018-2024.

## Methods

We utilized the direct standardization method to obtain standardized mortality rates (2). Mortality data were standardized using the United States 2000 standard population, which allows for the comparison of trends in cancer and ischemic heart disease mortality in Puerto Rico with mortality

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trends in the United States. Thus, we utilized the National Center for Health Statistics (NCHS) multiple cause-of-death files for Puerto Rico and the United States 2000 population to age-adjust the mortality rates per 100,000 population (3). Specific for Puerto Rico, the authors calculated the population mortality rate estimates by age and sex from the following sources: a) for years 1994 to 1999 the population was estimated by linal interpolation from the 1990 and 2000 census counts (4); b) for years 2010 to 2012 from the Annual Estimates of the Resident Population by Single Year of Age and Sex for the United States, States, and Puerto Rico Commonwealth: April 1, 2010 to July 1, 2013 (5). For years 1994 – 1998, the International Classification of Disease 9th Edition (ICD-9) codes 140 – 239 were selected for neoplasms, and codes 410-414 were selected for IHD. For all other years, the ICD 10th Edition (ICD-10) codes C00-D48 were selected for neoplasms and codes I20-I25 were selected for IHD. IHD represents a subcategory of conditions that are part of heart diseases, a broader spectrum of diseases of the circulatory system. Age-adjusted mortality per 100,000 population projections with a 50% interval probability were calculated utilizing a Bayesian statistical approach of Age-Period-Cohort dynamic model for longitudinal data, (6,7) utilizing the NCHS multiple cause-of-death files for years 1994-2010 for Puerto Rico. Shortterm (2011-2012) forecasts were based on annual data and longterm (2013-2022) forecasts were based on quinquennial data. In addition, we calculated gender differences in rates (men–women) for each study period. Age stands for the age band at death; Period stands for the calendar year at death; and Cohort stands for the year of birth. As an hypothetical situation: If a person dies at age 65 in the running period (1994-2012) then his cohort is from 1929–1947. We fit and predicted mortality for annual data and made the model more robust by introducing the scaled beta of the second kind distribution for the variances as described in the section below (8,9). We validated the model using cross-validation methods.

### Model definition

The model can be stated as Poisson likelihood:

$$y_{\{a,t\}} \sim Pois(\mu_{\{a,t\}})$$

$$\log(\mu_{\{a,t\}}) = \phi_a + \Theta_t + \alpha_c + \lambda_0$$

Where $\mu_{\{a,t\}}$ is the expected occurrence in each age band $(a)$ and period $(t)$ . The cohort is expressed in terms of $a$ and $t$ as c = 5 ∗ (18 - $a$) + $t$. Note that term $\lambda_0 \sim N(0,1)$ is an measurement error.

### Bayesian hierarchical model for parameter priors

Here we use autoregressive priors on the parameters, as an example we present those for Θ.

RW2: *Linear Time Trend*: As a detailed explanation of the linear thends incurred in our calculations we state as follows:

$$\Theta_t \mid \Theta_{t-1}, \Theta_{t-2} \sim N(2\Theta_{t-1} - \Theta_{t-2}, \tau).$$

Note that $\tau$ is precision, reciprocal of Variance and that RW2 has a local time linear trend.

$$\Theta_t - \Theta_{t-1} = \Theta_{t-1} - \Theta_{t-2} + \epsilon$$

The value of $\tau$ is important in the convergence of the MCMC and the random $\epsilon \sim N(0,1)$.

We propose the use of the Scaled Beta2 probability distribution, (9)

Taking the precision $\tau = \frac{1}{\sigma^2} \sim ScaleBeta(p, q, \beta)$:

$$p(\tau \mid p, q, \beta) = \frac{\Gamma(p+q)}{\Gamma(p+q)} \frac{1}{\beta} \left(\frac{\tau}{\beta}\right)^{p-1} \left(1 + \frac{\tau}{\beta}\right)^{-p+q}$$

Replacement of the usual vague Inverted Gamma distribution by a ScaleBeta, leads to more stable inference and accelerated in convergence of the MCMC implementation such as Gibbs sampler. All the code were implemented using WinBUGS and R.

### Age-standardized rates

For purpose to compare with the population of the US Census Bureau 2010 a standard incidence (mortality) measure is included ahead. A natural age standardized measure is the weighted arithmetic mean across the age bands. We will call the new parameter $\widehat{\lambda_t}$ defined as

$$\widehat{\lambda_t} = E_t(\lambda\{a,t\}) = \sum_{t=1}^{A} \lambda_{i,t} \frac{P_i}{\Sigma_{i=1}^{A} P_i}$$

In the calculations the $P_i$ :1,…,18, represents United State Census 2000 Population counts. *NOTE*: However there may be huge variations with age, this is a weighed mean useful for comparisons.

The Florida Interantional University and the University of Puerto Rico Ethics Committee have approved this study.

## Results

Table 1 and Table 2 show gender age-adjusted mortality historical annual fitted data from 1994 to 2012 along with the 50% prediction intervals for 2013 and 2014, for cancer and IHD, respectively. The historical age-adjusted mortality trend for men with cancer (Figure 1) shows a slight but consitent decline overtime (195.3/100,000 in 1994 to 159.0/100,000 in 2012) and even lower rates in the predicted 2014 (158.2/100,000). This is in contrast to the substantial overall decline in the age-adjusted mortality trend for men with IHD during the same period (178.4/100,000 in 1994 to 88.5/100,000 in 2012), and to a further lower rate (76.9/100,000) in 2014. In addition, the trend presents a remarkable changepoint reduction of 12.1/100,000 in just one year from 147.4/100,000 in 2005 to 135.3/100,000 in 2006.

An overall decreasing trend of age-adjusted mortality in women from the beginning of the study period in 1994

**Table 1**. Gender trends of age-adjusted historical annual fitted data (1994-2012) and 50% prediction intervals (2013-2014) for Cancer

| Year | Men | 50% Lower Limit | 50% Upper Limit | Women | 50% Lower Limit | 50% Upper Limit | Men – Women Difference |
|---|---|---|---|---|---|---|---|
| 1994 | 195.3 | | | 113.7 | | | 81.7 |
| 1995 | 195.3 | | | 113.1 | | | 82.1 |
| 1996 | 195.5 | | | 110.5 | | | 85.0 |
| 1997 | 192.4 | | | 107.9 | | | 84.4 |
| 1998 | 190.4 | | | 106.9 | | | 83.5 |
| 1999 | 186.9 | | | 105.0 | | | 82.0 |
| 2000 | 183.4 | | | 103.6 | | | 79.8 |
| 2001 | 181.2 | | | 101.3 | | | 79.9 |
| 2002 | 176.1 | | | 101.0 | | | 75.0 |
| 2003 | 171.1 | | | 102.4 | | | 68.7 |
| 2004 | 169.1 | | | 101.3 | | | 67.8 |
| 2005 | 166.6 | | | 99.3 | | | 67.3 |
| 2006 | 164.9 | | | 98.1 | | | 66.8 |
| 2007 | 163.9 | | | 97.4 | | | 66.5 |
| 2008 | 163.9 | | | 96.6 | | | 67.3 |
| 2009 | 162.4 | | | 95.5 | | | 66.9 |
| 2010 | 161.4 | | | 95.9 | | | 65.5 |
| 2011 | 160.6 | | | 96.4 | | | 64.2 |
| 2012 | 159.0 | | | 97.9 | | | 61.1 |
| 2013 (predicted) | 159.0 | 155.2 | 163.1 | 99.4 | 96.4 | 102.8 | 59.6 |
| 2014 (predicted) | 158.2 | 152.2 | 164.8 | 100.7 | 96.3 | 107.2 | 57.5 |

**Table 2**. Gender trends of age-adjusted historical annual fitted data (1994-2012) and 50% prediction intervals (2013-2014) for Ischemic heart disease

| Year | Men | 50% Lower limit | 50% Upper limit | Women | 50% Lower limit | 50% Upper limit | Men – Women difference |
|---|---|---|---|---|---|---|---|
| 1994 | 178.4 | | | 120.0 | | | 58.3 |
| 1995 | 172.9 | | | 116.7 | | | 56.2 |
| 1996 | 172.0 | | | 115.0 | | | 57.1 |
| 1997 | 172.4 | | | 112.0 | | | 60.4 |
| 1998 | 171.5 | | | 107.9 | | | 63.6 |
| 1999 | 162.8 | | | 103.2 | | | 59.6 |
| 2000 | 157.5 | | | 99.0 | | | 58.5 |
| 2001 | 156.7 | | | 97.9 | | | 58.8 |
| 2002 | 149.3 | | | 95.5 | | | 53.7 |
| 2003 | 147.4 | | | 94.8 | | | 52.5 |
| 2004 | 147.8 | | | 91.2 | | | 56.5 |
| 2005 | 147.4 | | | 85.6 | | | 61.7 |
| 2006 | 135.3 | | | 79.6 | | | 55.6 |
| 2007 | 125.3 | | | 72.9 | | | 52.4 |
| 2008 | 115.0 | | | 67.5 | | | 47.4 |
| 2009 | 108.3 | | | 63.9 | | | 44.4 |
| 2010 | 100.3 | | | 60.7 | | | 39.6 |
| 2011 | 95.5 | | | 57.9 | | | 37.6 |
| 2012 | 88.5 | | | 53.9 | | | 34.6 |
| 2013 (predicted) | 81.9 | 78.2 | 87.4 | 50.7 | 48.4 | 52.3 | 31.2 |
| 2014 (predicted) | 76.9 | 70.4 | 83.8 | 46.8 | 43.6 | 49.9 | 30.1 |

(113.7/100,000) to the last year of historical data in 2012 (97.9/100,000) is observed in Figure 1. However, the predicted rates slightly increase in 2013 (99.4/100,000) and in 2014 (100.7/100,000). Women with IHD show similar downward historical annual fitted data trends in age-adjusted mortality from 1994 (120.0/100,000) to 2012 (53.9/100,000), and in the predicted 2014 rate (46.8/100,000).

For cancer, the age-adjusted rate difference between genders (men minus women) utilizing annual historical fitted data declined by approximately 25% during the study period from 81.7/100,000 in 1994 to 61.1/100,000 in 2012, and to 57.5/100,000 in the predicted 2014 (Figure 2 and Table 1). For IHD, the age-adjusted rate difference between genders utilizing also annual historical fitted data decreased by approximately 41% from 58.3/100,000 in 1994 to 34.6/100,000 in 2012, and to 30.1/100,000 in the predicted 2014 (Figure 2 and Table 2).

Figure 3 and Table 3 show quinquennial age-adjusted mortality rates for the historical fitted data, stratified by gender and by condition, from 1994 to 2012, and 50% prediction intervals for the 2013 – 2017 and for the 2018 – 2022 periods. Men with cancer show a decline trend in age-adjusted mortality rates from 183.4/100,000 (1998-2002) to 161.4/100,000 (2008-2012), and to 147.6/100,000 in the predicted 2018-2022 period. Men with IHD show a remarkable decline in age-adjusted mortality rates from 159.2/100,000 (1998-2002) to 101.0/100,000 (2008-2012), and to 51.9/100,000 in the predicted 2018-2022 period. Women with cancer show a decline in age-adjusted mortality rates from 103.3/100,000 (1998-2002) to 96.6/100,000 (2008-2012), and to 91.8/100,000 in the predicted 2018-2022 period. Women with IHD show a substantial decline in age-adjusted mortality rates from 100.5/100,000 (1998-2002) to 60.7/100,000 (2008-2012), and to 32.0/100,000 in the predicted 2018-2022 period.

Figure 4 and Table 4 show gender differences (men minus women) of age-adjusted mortality rates and predictions utilizing quinquennial historical data. For cancer, the gender difference decreased approximately 30% from 80.1/100,000 in the 1998-

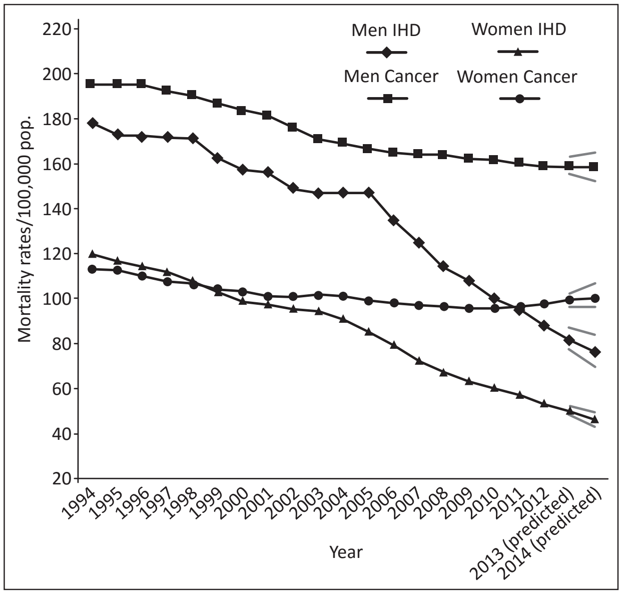


**Figure 1**. Gender trends of Age-adjusted historical annual fitted data (1994-2012) and 50% prediction intervals (2013-2014) for Cancer and Ischemic heart disease.

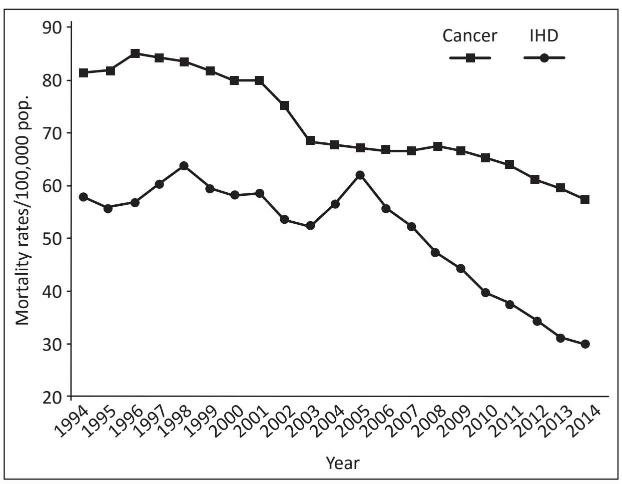


**Figure 2**. Differences (Men minus Women) in Age-adjusted historical (1994-2012) mortality rates and predictions for 2013-2014 for Cancer and Ischemic heart disease based on Annual historical data

2002 period to 55.9/100,000 in the 2018-2022 predicted period, which contrasts with the subtantial 66% gender difference decrease for IHD from 58.7/100,000 in the 1998-2002 period to 19.8/100,000 in the 2018-2022 predicted period.

## Discussion

The historical annual fitted data available for Puerto Rico from 1994 to 2012 show that age-adjusted mortality trends for men declined for cancer and IHD. Age-adjusted mortality rates for women with cancer remained stable and increased slightly during the predicted 2013-2014 period, in contrast to the steady decline trend for women with IHD. A comparison of mortality trends by gender (men vs. men and women vs. women) for cancer and IHD show that, at the beginning of the study period, both conditions had similar mortality rates, but diverge substantially overtime. Driver et al (10) conducted a cohort study among older men in the United States and reported that, after age 80, the incidence of cardiovascular disease continues to increase whereas the incidence of cancer decreases. Findings from this study suggest that a substantial group of individuals suffering from both diseases are diagnosed only at death. However, this cohort study was limited to men and no analysis on age-period-cohort was reported.

Because the largest mortality decline during the study period is observed among IHD, specially for men, and the rather steady trend among women with cancer, it is predicted in both, the annual (2013-2014) and quinquennial periods (2013-2017 and 2018-2022) that mortality rates within each condition, gender differences will decrease and even equalize, and that women with cancer will have higher mortality rates than men and women with IHD. Similar findings have been reported in a recent paper by Townsend et al. on the 2016 epidemiological update of cardiovascular dsease in 53 countries of Europe: The number of deaths from CVD is higher in women (2.2 million) than in men (1.8 million) (11). Most of the countries have experienced substantial decreases in death rates for CVD and CHD since 2003 and a greater number of deaths from cancer than from CVD annually. This transition from CVD to cancer as the most common cause of death for men was first seen in France in 1998 and in Spain in 1999. However, these data lack predicting trends, which the Age, Period, and Cohort models that we present in this study for the Puerto Rican population do.

In conclusion, the flexibility of the APC model accurately predicts cancer and IHD mortality rates in the Puerto Rican

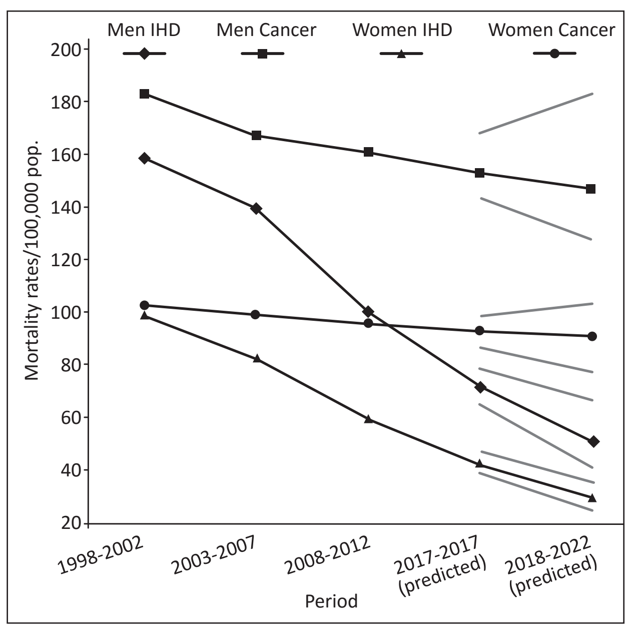


**Figure 3**. Quinquennial age-adjusted mortality rates historical fitted data (1994-2012) and 50% prediction intervals (2013-2022) for Cancer and Ischemic heart disease

**Table 3**. Quinquennial age-adjusted mortality rates historical fitted data (1994-2012) and 50% prediction intervals (2013-2022) for Cancer and Ischemic heart disease

| Period | Men Cancer | +/- 50% Interval | Men IHD* | +/- 50% Interval | Women Cancer | +/- 50% Interval | Women IHD | +/- 50% Interval |
|---|---|---|---|---|---|---|---|---|
| 1998-2002 | 183.4 | | 159.2 | | 103.3 | | 100.5 | |
| 2003-2007 | 167.4 | | 140.4 | | 100.1 | | 84.7 | |
| 2008-2012 | 161.4 | | 101.0 | | 96.6 | | 60.7 | |
| 2013-2017 (predicted) | 153.8 | 10.2 | 72.9 | 7.0 | 93.9 | 6.1 | 43.8 | 4.0 |
| 2018-2022 (predicted) | 147.6 | 19.1 | 51.9 | 9.7 | 91.8 | 13.3 | 32.0 | 6.0 |

*IHD = Ischemic Heart Disease

population, allowing the estimation of time trends in both men and women. The APC model is an essential tool for supporting public health planning and decision-making policies,and for scrutining cancer registries. It is of paramount importance to further research the reasons for the relatively steady age-adjusted mortality trend in women with cancer.

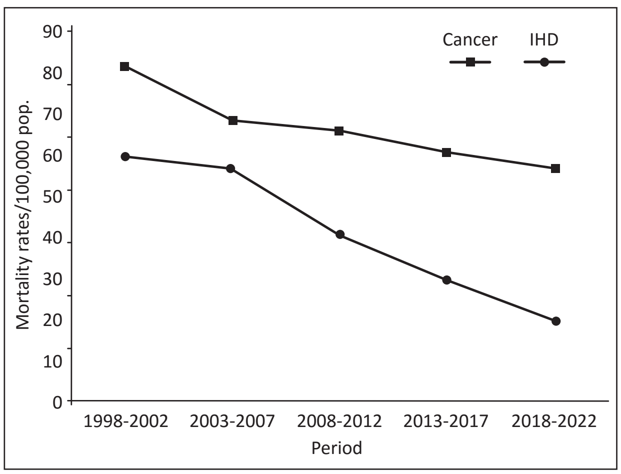


**Figure 4**. Differences (Men minus Women) of age-adjusted historical (1994-2012) mortality rates data and predictions for 2013-2022 for Cancer and Ischemic heart disease based on Quinquennial historical data

**Table 4**. Differences (men minus women) of age-adjusted historical (1994-2012) mortality rates data and predictions for 2013-2022 for Cancer and Ischemic heart disease based on Quinquennial historical data

| | 1998-2002 | 2003-2007 | 2008-2012 | 2013-2017 | 2018-2022 |
|---|---|---|---|---|---|
| Cancer | 80.1 | 67.3 | 64.8 | 59.9 | 55.9 |
| IHD* | 58.7 | 55.8 | 40.2 | 29.1 | 19.8 |

*IHD= Ischemic Heart Disease

## Resumen

Objetivo: Los datos de mortalidad son importantes para evaluar y planear temas relacionados con salud, pero su disponibilidad tiene retraso de varios años. Técnicas estadísticas de predicción pueden emplearse para obtener estimados actualizados. El objetivo de este estudio fue evaluar la tendencia anual de mortalidad en Puerto Rico de cáncer y enfermedad isquémica del corazón, y predecir las tendencias a corto y largo plazo de ambas enfermedades. Métodos: Obtuvimos proyecciones de mortalidad ajustada por edad/100000 habitantes e intervalo de probabilidad del 50% utilizando un enfoque Bayesiano al modelo dinámico Edad-Período-Cohorte (EPC). Las tasas anuales de defunción por causa múltiple para 1994–2010 de Puerto Rico se utilizaron para predecir tendencias a corto plazo (2011–2012). Las predicciones a largo plazo (2013–2022) se basaron en datos quinquenales. Adicionalmente, calculamos diferencias de tasas por género (hombres–mujeres) para cada período. Resultados: La tendencia de mortalidad por cáncer declinó gradualmente. La tendencia de mortalidad por enfermedad isquémica declinó constantemente en ambos sexos, con un cambio sustancial alrededor de 2004–2005 en hombres. La diferencia por género entre cáncer y enfermedad isquémica se incrementó desde 33% (80/100000 vs. 60/100000) en 1994–1998 a 300% (60/100000 vs. 20/100000) en 2018–2022. Conclusión: El modelo EPC permite predecir con mucha precisión las tendencias de mortalidad a corto y largo plazo de cáncer y enfermedad isquémica del corazón en esta población. La relativa estabilidad de las tendencias de mortalidad tanto histórica como proyectada de cáncer en ambos sexos contrasta con la sustancial declinación de mortalidad por enfermedad isquémica, especialmente en hombres.

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