

## Cancer mortality in Guarapari, Espírito Santo State, Brazil, with areas of high natural radioactivity

Mortalidade por câncer em Guarapari, Espírito Santo, Brasil, em áreas de alta radioatividade natural

Mortalidad por cáncer en Guarapari, Espírito Santo, Brasil, en áreas de alta radiactividad natural

Rafael Gonçalves Ferreira <sup>1</sup>  
Marcio Vinicius de Nardi de Angeli <sup>1</sup>  
Debora Rocha Barboza <sup>1</sup>  
Gustavo de Paula Batista de Carvalho-Silva <sup>1</sup>  
Romildo Rocha Azevedo Junior <sup>1</sup>  
Fausto Edmundo Lima Pereira <sup>1</sup>

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### Abstract

Guarapari, a municipality of the state of Espírito Santo, Brazil, reported higher mortality rates for the most common cancers from 1996 to 2000. This municipality has beaches with high natural radioactivity. To verify whether this excessive cancer mortality rate still exist in Guarapari, mortality rates for all causes, cancers, and the most prevalent cancers in this municipality were studied from 2000 to 2018 and compared with those observed in the state. Data on all-cause mortality, all-cancer mortality, and mortality from cancer of the esophagus, stomach, larynx, trachea, bronchi and lung, prostate, breast, and leukemias were collected in Brazilian Health Informatics Department (DATASUS) from 2000 to 2018. Mortality rates were calculated by direct method. Standardized age-adjusted rates (SAAR) were calculated based on standard of the World Health Organization (WHO) world population. Crude mortality rates were calculated for each municipality and SAAR for the state and nine municipalities where natural radioactivity was evaluated. Mortality rates from all causes, all cancers, and different cancers observed in Guarapari did not differ significantly from those observed in the state or municipalities with more than 100,000 inhabitants. Radioactivity levels and mortality rates showed no correlation in nine municipalities where natural radioactivity was known. In conclusion, results showed that mortality from cancer and all causes in Guarapari did not differ from those observed in the state and that there was no correlation between the levels of natural radioactivity and mortality from cancer in areas where natural radioactivity was evaluated.

Radioactivity; Neoplasms; Mortality

### Correspondence

F. E. L. Pereira  
Rua Ludwick Macal 137, Vila Velha, ES 29102-920, Brasil.  
faustoelpereira@gmail.com

<sup>1</sup> Universidade Vila Velha, Vila Velha, Brasil.



The Espírito Santo State, Brazil, has areas of high natural radioactivity, especially on the beaches of Guarapari, where it is comparable to the locations with the highest natural radioactivity on the planet <sup>1,2,3,4</sup>. Higher mortality rates for esophagus, stomach, lung, and prostate cancer were reported in Guarapari from 1996 to 2001 <sup>5</sup>. To verify whether this excessive cancer mortality still exists in Guarapari, we studied the mortality rates for all causes, all cancers, and the most prevalent cancers (esophagus, stomach, larynx, lung, prostate, breast, and leukemias) from 2000 to 2018, and compared them with rates observed in the Espírito Santo State.

Data from all-cause mortality (International Classification of Diseases – ICD-10: A00-Z99), all-cancer mortality (ICD10: C00-C97), and mortality from cancer of the esophagus (ICD10: C15), stomach (ICD10: C16), larynx (ICD10: C32), trachea, bronchi and lung (ICD10: C33 and C34), prostate (ICD: C61), breast (IC10: C50), and leukemias (ICD10: C91-C95) were collected from the Brazilian Health Informatics Department (DATASUS) <sup>6</sup> from 2000 to 2018. Mortality rates were calculated using the direct method <sup>7</sup>, based on the state's population during the period <sup>8</sup>. Crude mortality rates and age-adjusted rates standardized by the World Health Organization (WHO) world population <sup>9</sup> were calculated. Crude mortality rates were calculated for each municipality, and standardized rates were calculated for the entire state and nine municipalities where natural radioactivity has known values. The comparison of mortality rates observed in Guarapari with that observed in the state was performed by: (a) comparison of crude mortality rates in Guarapari with the average of crude rates observed in the 78 municipalities of Espírito Santo; (b) comparison between the expected and observed values for deaths in Guarapari based on the standardized rate observed for the state; (c) comparison between the averages of the annual mortality rates observed in Guarapari with the rates observed in Espírito Santo. To verify a possible relationship between natural radioactivity and mortality rates, the Spearman's correlation test was performed using data from the nine municipalities with natural radioactivity. Data on natural radioactivity in Espírito Santo were taken from Veiga et al. <sup>3</sup>, which evaluated the radioactivity of the beaches of Espírito Santo, from Marataízes to São Mateus. This study was approved by the Vila Velha University (UVV) Ethics Research Committee.

The results are summarized in Tables 1, 2 and 3. In Guarapari, all-cause mortality rates, all-cancer mortality, and mortality from the malignant neoplasms evaluated did not differ or were lower than expected (Table 1). The differences were significantly lower for all cancers, esophageal cancer, stomach cancer, and prostate cancer (Table 1). The average crude mortality rates from all cancers observed in Guarapari showed no significant difference from the average of the same rates in the 78 municipalities of Espírito Santo (respectively 93.98/100,000, 95%CI: 83.9-102.3 and 89.2/100,000, 95%CI: 85.1-93.3; Mann-Whitney test,  $p = 0.4676$ ). Likewise, the means of standardized mortality rates observed in Guarapari showed no significant difference from those of the state, except for mortality from esophageal cancer, significantly lower in Guarapari (Table 2). There was no correlation between mortality rates and the level of natural radiation in the municipalities where radioactivity was evaluated (Table 3).

The mortality rates observed in Espírito Santo are similar to those of Brazil and the Southeast Region <sup>10,11</sup>. The results showed no excess mortality for cancer in Guarapari in the analyzed period; on the contrary, the number of deaths expected according to the mortality rates for the state was higher than those observed in Guarapari. Mortality rates from all cancers observed in Guarapari did not significantly differ from those observed in other municipalities of Espírito Santo. Although not significant, the mortality rate for all cancer was higher in Guarapari than that observed in the state. However, it was similar to cancer mortality rates observed in eight municipalities with more than 100,000 inhabitants (data not shown). It is known that cancer mortality is higher in the largest urban concentrations <sup>12</sup>, and Guarapari belongs to the metropolitan area of Vitória, where 40% of the state's population lives. Additionally, no correlation was observed between the levels of natural radioactivity and the mortality rates evaluated.

Altogether, these results do not confirm the findings of Veiga et al. <sup>5</sup>. It is difficult to explain this discrepancy because comparing the results was impossible due to the standardization method used by Veiga et al. <sup>5</sup>, which was not clearly described in the paper.

**Table 1**

Mortality rates from cancer in Guarapari, Espírito Santo State, Brazil, from 2000 to 2018: number of observed and expected deaths based on standardized mortality rates.

| Cause of death (ICD-10)   | Observed cases | Expected cases | p-value * |
|---------------------------|----------------|----------------|-----------|
| All-causes (A00-Z99)      | 11,469         | 12,612         | 0.7030    |
| All-cancers (C00-C97)     | 1,913          | 2,129          | 0.0001    |
| Esophageal cancer (C15)   | 98             | 140            | 0.0366    |
| Stomach cancer (C16)      | 155            | 187            | 0.0473    |
| Laryngeal cancer (C32)    | 48             | 58             | 0.7728    |
| Lung cancer (C33 and C34) | 242            | 253            | 0.7097    |
| Prostate cancer (C61)     | 150            | 185            | 0.0071    |
| Breast cancer (C50)       | 134            | 133            | 0.8526    |
| Leukemias (C91-C95)       | 64             | 65             | 0.8110    |

Note: International Classification of Diseases (ICD-10) codes are shown in parenthesis.

\* Chi-squared test.

**Table 2**

Comparison between the mortality rates observed in Guarapari and Espírito Santo State, Brazil, 2000 to 2018.

| Cause of death (ICD-10)   | Guarapari<br>Mean (95%CI) | Espírito Santo<br>Mean (95%CI) | p-value * |
|---------------------------|---------------------------|--------------------------------|-----------|
| All-causes                | 639.4 (614.6-664.2)       | 648.2 (621.0-675.3)            | 0.4044    |
| All cancer (C00-C97)      | 108.4 (102.3-114.1)       | 104.7 (101.4-108.0)            | 0.0703    |
| Leukemias (C91-C95)       | 3.27 (2.48-4.06)          | 3.32 (3.16-3.49)               | 0.9055    |
| Prostate cancer (C61)     | 19.49 (16.11-22.88)       | 18.44 (17.38-19.50)            | 0.5440    |
| Breast cancer (C50)       | 13.28 (10.58-15.97)       | 12.84 (11.85-13.83)            | 0.7098    |
| Stomach cancer (C16)      | 9.52 (7.74-11.30)         | 9.34 (8.70-9.88)               | 0.7798    |
| Esophagus cancer (C15)    | 5.61 (4.50-6.72)          | 6.88 (6.46-7.28)               | 0.0121    |
| Larynx cancer (C32)       | 2.61 (2.12-3.09)          | 2.59 (2.40-2.78)               | 0.9435    |
| Lung cancer (C33 and C34) | 14.57 (11.81-16.52)       | 12.46 (12.10-12.91)            | 0.1397    |

95%CI: 95% confidence interval.

Notes: International Classification of Diseases (ICD-10) codes are shown in parenthesis. The means of mortality rates adjusted for age and standardized by the World Health Organization (WHO) world population are indicated with 95%CI.

\* Mann-Whitney U test.

Some studies showing a relationship between natural radioactivity and cancer conducted in different parts of the world, including Brazil, are criticized because they fail to consider many confounding variables<sup>13</sup>. It is possible that the natural radioactivity on Espírito Santo beaches, particularly in Guarapari, may not be influencing the incidence of cancer. However, there have been reports of chromosomal anomalies in the resident population in Guarapari<sup>14</sup>, although these results were questioned due to the long reading time for cultures of lymphocytes<sup>13</sup>. The gamma radiation emitted by radionuclides occurring on the beaches of Guarapari was at normal levels in homes and high in the sand of the beaches, but within tolerable limits for human exposure<sup>15</sup>. It is also known that urbanization, with building modifications, reduces the population's exposure to natural radiation in regions of high natural radioactivity<sup>16</sup>.

**Table 3**

Correlation between levels of natural radioactivity and cancer mortality (2000 to 2018) in the municipalities of the state of Espírito Santo, Brazil, where natural radioactivity was evaluated.

| Municipalities (Becquerel/kg) | Cancer standardized mortality rate/100,000 inhabitants |         |        |        |           |           |          |        |
|-------------------------------|--|---------|--------|--------|-----------|-----------|----------|--------|
|                               | All types  | Stomach | Larynx | Lung   | Leukemias | Esophagus | Prostate | Breast |
| Guarapari (55,537)            | 93.2   | 9.52    | 2.61   | 14.17  | 3.27      | 5.61      | 19.49    | 13.28  |
| São Mateus (1,671)            | 71.01  | 7.92    | 2.34   | 8.94   | 4.41      | 6.32      | 21.49    | 11.71  |
| Anchieta (1,387)              | 100.83   | 10.73   | 2.14   | 16.08  | 4.16      | 8.03      | 12.49    | 12.36  |
| Serra (1,330)                 | 76.82  | 15.07   | 5.14   | 20.36  | 5.21      | 11.22     | 22.86    | 15.18  |
| Vitória (236)                 | 172.25   | 8.89    | 2.94   | 16.03  | 3.50      | 5.64      | 20.36    | 15.94  |
| Vila Velha (77)               | 109.66   | 7.58    | 2.53   | 20.36  | 5.21      | 5.69      | 18.84    | 16.08  |
| Marataízes (36)               | 83.22  | 6.09    | 1.70   | 10.75  | 2.96      | 5.39      | 14.60    | 7.99   |
| Itapemirim (11)               | 127.96   | 9.18    | 2.76   | 11.48  | 3.34      | 6.15      | 16.14    | 10.27  |
| Piúma (7)                     | 93.33  | 9.98    | 3.05   | 11.33  | 1.11      | 5.96      | 17.2     | 10.92  |
| p-value *                     | 0.2912   | 0.6436  | 0.5517 | 0.7081 | 0.2696    | 0.6777    | 0.2696   | 0.2912 |

Note: the numbers in parentheses indicate the values (Becquerel/kg) of the radioactivity emitted by <sup>232</sup>Th in the sand of the beaches in each municipality (based on Veiga et al. <sup>3</sup>).

\* Spearman's test between natural radioactivity and the mortality rates in each column.

In conclusion, the results show that the natural radioactivity observed on the beaches of Guarapari is not related to higher mortality rates from malignant neoplasms in the local population. In contrast, the observed number of deaths from all cancers and cancer of the stomach, esophagus, and prostate was significantly lower than expected. Mortality rates for all cancers and stomach, esophagus, larynx, lungs, breast, and prostate cancers showed no difference from those observed in the state, except for esophageal cancer, which was significantly lower in Guarapari. Further investigations are necessary to verify factors involved in the lower mortality from esophageal cancer observed in this region.

### Contributors

R. G. Ferreira participated on data collection, assistance with statistical calculations and revised the manuscript. M. V. N. Angeli participated on data collection, assistance with statistical calculations and revised the manuscript. D. R. Barboza participated on data collection, assistance with statistical calculations and revised the manuscript. G. P. B. Carvalho-Silva participated on data collection, assistance with statistical calculations and revised the manuscript. R. R. Azevedo Junior guided and checked all statistical calculations and revised the manuscript. F. E. L. Pereira planned the research and wrote the final article.

### Additional information

ORCID: Rafael Gonçalves Ferreira (0000-0001-8798-0643); Marcio Vinicius de Nardi de Angeli (0000-0001-5093-8329); Debora Rocha Barboza (0000-0001-7264-1622); Gustavo de Paula Batista de Carvalho-Silva (0000-0003-4173-912X); Romildo Rocha Azevedo Junior (0000-0002-5273-6744); Fausto Edmundo Lima Pereira (0000-0001-7471-8742).

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## Resumo

*Taxas de mortalidade maiores para os cânceres mais frequentes foram registradas entre 1996 e 2000 em Guarapari, um município do Espírito Santo, Brasil, onde se localizam praias com alta radioatividade natural. Para verificar a existência desse excesso de mortalidade por câncer em Guarapari, taxas de mortalidade por todas as causas, todos os cânceres e pelos cânceres mais prevalentes no município foram estudadas entre 2000 e 2018 e comparadas com aquelas observadas no estado. Dados de mortalidade por todas as causas, por câncer e por câncer de esôfago, estômago, laringe, traqueia, brônquios e pulmão, próstata, mama e leucemias foram coletados no Departamento de Informática do SUS (DATASUS) de 2000 a 2018. As taxas de mortalidade foram calculadas pelo método direto. As taxas padronizadas ajustadas por idade (TPAI) foram calculadas com base na população mundial padrão da Organização Mundial da Saúde (OMS). Foram calculadas taxas brutas de mortalidade para cada município e as TPAI para o estado e para os nove municípios onde foi avaliada a radioatividade natural. A mortalidade por todas as causas, todos os cânceres e pelos diferentes cânceres investigados em Guarapari não diferiu significativamente daqueles observados no estado ou em municípios com mais de 100 mil habitantes. Não houve correlação entre os níveis de radioatividade e as taxas de mortalidade nos nove municípios onde a radioatividade natural era conhecida. Em conclusão, os resultados mostraram que a mortalidade por câncer e por todas as causas em Guarapari não diferiu daquelas observadas no restante do estado. Além disso, não houve correlação entre os níveis de radioatividade natural e a mortalidade por câncer nas áreas onde a radioatividade natural foi avaliada.*

*Radioatividade; Neoplasias; Mortalidade*

## Resumen

*Las mayores tasas de mortalidad por cáncer se registraron entre 1996 y 2000 en Guarapari, un municipio del estado de Espírito Santo, Brasil, donde existen playas con alta radiactividad natural. Para verificar la existencia de mayor mortalidad por cáncer en Guarapari, se estudiaron las tasas de mortalidad por distintas causas, por los tipos de cáncer y por los tipos más prevalentes en este municipio entre 2000 y 2018, y se las compararon con las observadas en todo el estado. Los datos sobre la mortalidad por distintas causas, por cáncer y por cáncer de esófago, estómago, laringe, tráquea, bronquios y pulmón, próstata, mama y leucemias se recogieron del Departamento de Informática de SUS (DATASUS) sobre el periodo de 2000 a 2018. Las tasas de mortalidad se calcularon utilizando el método directo. Las tasas estandarizadas ajustadas por edad (TEAE) se calcularon con base en las de la población mundial estándar de la Organización Mundial de Salud (OMS). Se calcularon las tasas brutas de mortalidad para cada municipio y las TEAE para el estado y para los nueve municipios donde se evaluó la radiactividad natural. La mortalidad por distintas causas, por los tipos de cáncer y por los diferentes tipos de cáncer investigados en Guarapari no difirió significativamente de la observada en el estado o en los municipios con más de 100.000 habitantes. No hubo correlación entre los niveles de radiactividad y las tasas de mortalidad en los nueve municipios donde existe radiactividad natural. Se concluye que la mortalidad por cáncer y por distintas causas en Guarapari no difiere de los resultados observados en todo el estado. Además, no hubo correlación entre los niveles de radiactividad natural y la mortalidad por cáncer en las áreas donde se evaluó la radiactividad natural.*

*Radiactividad; Neoplasias; Mortalidad*

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