Portuguese Older Population Mortality: Spatiotemporal Analysis by Cause of Death and Sex

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Abstract There are indications that the Portuguese population is aging uneven [6]. Considering this fact, it is proposed to identify mortality patterns and regional differences among the older Portuguese population (65 or more years). The study of the spatiotemporal distribution is essential to the understanding of dynamics and emergent trends, regarding mortality in older people, and to promote the health of an aging population. It is applied Spatial Scan Statistics [9], a methodology for detecting space-time clusters. These techniques have a long tradition in Spatial Epidemiology and the advantages of its application to increase knowledge in public health are particularly recognized [3, 11]. Stochastic space-time or time processes are used, according to the level of available geographical disaggregation data, to describe the mortality rates of the older Portuguese population (from 1992 to 2006) associated with Neoplasms and Diseases of the Circulatory System. Statistically significant space-time clusters are identified, from an analysis similar and independent for different age groups, by sex and cause of death. Those space-time units represent the simultaneous occurrence of high mortality rates in different regions of the Portuguese mainland.

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1 Introduction

In Portugal, like in most European countries, the older population doubled in the last four decades of the twentieth century and is still increasing [7]. This phenomenon seems determined to continue and it is expected that the proportion of people aged 65 years, or more, will double again in forty years — reaching 40 per cent of the population in almost all territory [5].

Population aging is becoming a very pertinent issue, in several and different contexts. The study of mortality at older ages is having a rising impact, particularly on population projections and analysis of social-economic impacts resulting of the changes in the classical population structure and from the extending of life.

There are many studies on health care in Portugal. Some characterize mortality trends, at a subnational level, using classical statistical techniques [10]. Considering spatiotemporal analysis, there are also recent studies [11, 12] about the incidence of some particular diseases on Portuguese population using clusters detection methods. Now we propose to apply them to the mortality rates associated with two leading cause of death diseases.

Knowing that older population is not distributed equally throughout the country, what are the mortality trends and regional differences? The aim of this work is to identify where and when the high mortality rates occur simultaneously in the different regions of the Portuguese mainland. For this purpose, it is intended to identify spatiotemporal clusters for the occurrence of deaths per year and geographic unit, by sex and age. The secondary objective is to model the death rates time series in aged regions, to estimate future regional trends by cause of death. Moreover, this approach also allows us to understand if patterns, by cause of death, come from the variability between regions or from temporal variations within causes.

2 Methodology

At first, it was used a descriptive analysis to characterize the mortality rates by cause of death, age group, sex and region. Then, to identify homogenous space-time areas, we applied a space-time scanning method, Spatial Scan Statistic, proposed by [9] and widely distributed in Public Health [2, 3, 8]. Thus, the present study can be considered part of the vast area of Spatial Epidemiology — geography of the causes of death. In order to verify the stability of identified space-time clusters between age groups, by cause of death and by sex, contingency tables were analyzed, considering a referential age group. Finally, time series models were applied in some specific areas, relating major causes of death and time correlated units.

3 Case Study

Mortality death rates of Portuguese older population are described and used to give a general idea of leading causes of death in Portugal at a subnational level. For this purpose it is intended to identify spatiotemporal clusters for the occurrence of deaths from 1992 to 2006. The space-time referential is defined by NUTIII (Portuguese territorial units for statistical purposes) per year and the analysis are done by age group and sex for two specific causes of death: Neoplasms and Diseases of the Circulatory System. Usual 5 years age groups were used for individuals aged 65 and over. Annual data — number of deaths of the older Portuguese population — by NUTIII, cause of death, age group and sex, as well as estimates of the average subnational resident population for the selected time period, were provided by INE.

3.1 Main Causes of Death in Portugal

A first descriptive analysis is done to establish regional differences. These occur only occasionally, by sex, especially in the age group 65 to 69 years (to simplify, we use age 65–69) and 85 or more years (idem, 85+). Considering the major causes reviewed, we chose the two leading causes of death to study: Diseases of the Circulatory System (CIRS) and Neoplasms (NEO). Considering the age 65–69 as the referential group for the mortality tendency study among the older population, we describe it now.

In general, there´s a greater range in mortality rates by cause of death on males comparing to females. For CIRS, there´s a larger range in mortality rate values for males, predominantly in the Northern and Central regions. In the South, on the contrary, the range is larger in NEO deaths rates (particularly on females, these two causes have similar statistics). The maximum rates are associated to males and divided by the two dominant causes of death, with major dispersion in CIRS. In Fig. 1, we illustrate (on the right side) regional death rates for age 65–69, where, according to preliminary analysis, there are, among the older population, major differences by both cause of death and sex.

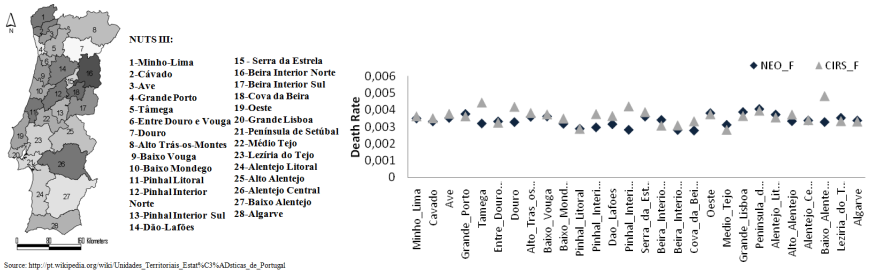

Fig. 1 Average Mortality Rate by Cause of Death (on the right) and Portuguese NUTIII (on the left)), Females, Age 65–69 (1992–2006)

As we can see, the dominance of the deaths from NEO and CIRS among females aged 65 to 69 is confirmed. CIRS are, overall, the dominant cause, although overlapping (*Minho-Lima* or *Algarve*) or even occasionally being exceeded (*Grande Lisboa* or *Médio Tejo*), in certain regions, by NEO. Still, in some regions, we can identify a gap between the two dominant causes (*Tâmega* or *Baixo Alentejo*).

3.2 Clusters identified by Cause of Death, Age and Sex

Clusters were identified for all age groups, for both males/females, and for the two selected causes of death, through retrospective analysis, assuming a Poisson distribution for death occurrences. We use circular windows in the scan (cylinders in the space-time), up to 50 per cent of the population at risk, looking for high values clusters. The statistical significance of the test was determined by the Monte Carlo method. All clusters have shown a p-value less than 0.001. Fig. 2 shows the results for deaths from CIRS on males (gray scale identifies the secondary clusters 2 and 3 — most likely as dark gray, while the main cluster (1), in this case only temporal, is shown in the lower right of each map).

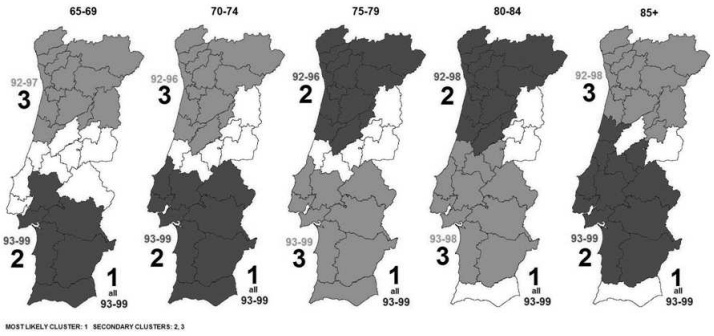

Fig. 2 Identified Clusters for CIRS: Males, per Age

For deaths associated with CIRS, three clusters were identified by age group. The main (or most likely) cluster — a temporal cluster —, is common to all ages in the period from 1993 to 1999, throughout the territory; the other two space-time clusters (secondary clusters) divide the territory roughly in half, from North to South. The results point to a lack of spatial variation in the Portuguese mainland. Comparing to other groups, there are differences in the ages 75–79 and 80–84 (reversal of primary and secondary clusters), with no practical impact: test statistic values are similar and with p-values less than 0.001.

In Table 1, we can see that the identified clusters in Fig. 2 present identical Observed/Expected ratios, for cluster 1, in all age groups. For clusters 2 and 3, the ratios show some minor differences, more obvious in age 85+.

Table 1 Clusters Statistics for Deaths from CIRS, Males, Age 65–69

Cluster	Time	Observed	Expected	Obs./Exp.
1	1993–1999	13462	11183.70	1.20
2	1993–1999	6218	4819.99	1.29
3	1992–1997	5370	4209.07	1.28

Some important questions arise from the initial data analysis and clusters identification: will the spatiotemporal units' behavior differ by age group and sex in NEO deaths? Is there a pattern to mortality trend of the older Portuguese?

Well, for CIRS deaths (now for females), the patterns are similar. We can only point that the clusters are more restricted, geographically, when compared with males (especially aged 75 and over). As for NEO deaths, we identified spatiotemporal clusters, for all ages, on both males and females. The clusters are also located in North and South of the country, mainly associated with the metropolitan areas of Lisbon and Oporto. On males aged 85+ and females aged 65–69 there´s a single spatiotemporal cluster in the Lisbon region. Also on females aged 70–74 it was identified a cluster that covers the entire South of the country. The following section attempts to keep answering the previous questions.

3.3 Comparative Analysis by Cause of Death, Age and Sex

To understand if the identified clusters are stable in space-time regarding the reference age group, contingency tables were built by cause of death and sex. Through the sum of its diagonals we can measure the clusters proportion (Cluster (C) and No Cluster (NC)), which remains constant (in each cell, we have number of events/number of possible cases to 15 years and 28 regions, corresponding to 420 units). We consider that the higher the ratio (see lower right corner of the Table 2) the greater the spatiotemporal coincidence in mortality rates among ages. Table 2 also shows comparisons between baseline age 65–69 and age 70–74, for deaths from CIRS on males. The overall results are shown in Fig. 3.

Table 2 Crosstabs for Clusters Identified by Cause of Death and Age (Males)

$SCIR_M$		Age 65–69		
		C	**NC**	
Age 70–74	**C**	0.495	0.002	
	NC	0.495	0.002	
				0.995

On males, the clusters identified for deaths from CIRS remain substantially constant in the two age groups analyzed in Table 2. That is, both the regions identified as clusters or the regions which remained unidentified maintain the same proportion. For death from NEO we see a slight decrease (0.933) in this ratio. These indicate, in general, when comparing ages 65–69 to 70–74, a small space-time variability to high rates of mortality.

In Fig. 3 we present the trend progression, of spatiotemporal patterns, identified for the two selected causes of death, by sex and age. As mentioned above, the higher the values of space-time correlation between each one of the groups on analysis and the reference group (values between 0 and 1), the greater the stability of the clusters identified by cause of death for the older Portuguese population.

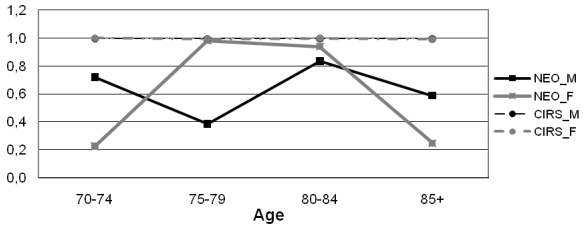

Fig. 3 Stability of Spatiotemporal Clusters Identified by Cause-of-Death, Age and Sex

The clusters from CIRS show no significant differences in each age for the reference group. Under these conditions, stability is maximum (the space-time overlap of clusters is almost total in all ages), that is to say, the clusters are almost defined in the same way. Minimal differences occur on females in the ages 75–79 and 85+. For the NEO deaths clusters, the pattern differs by sex and age, with large fluctuations. Differences are larger in ages 70–74 and 85+ for females. For males, the major oscillations occur mainly between age 75–79. Thus, if one considers the entire older population, there is less stability in clusters defined related to this cause of death.

Analyzed the oscillations by cause-of-death, age and sex, it is now possible to identify the clusters that remained constant in the reviewed time period (see Fig. 4).

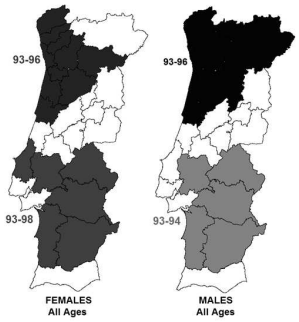

Fig. 4 Homogeneous Spatiotemporal Units: Deaths from CIRS

In the identified units, we highlight the correlation of large spatiotemporal clusters, for deaths from CIRS in all ages. For clusters from NEO deaths, there is a spatiotemporal correlation by sex. Space-time units are centered in the Lisbon and Oporto metropolitan areas which cover, globally, no more than two age groups of the older population on females (ages 70 to 79) with in a one year temporal period (the same for males, in all ages in a two years period).

3.4 Analysis of Time Series

To complement the spatiotemporal analysis, we applied the classical techniques of time series analysis (methodology of Box and Jenkins) to determine whether there are temporal association in each region, by cause of death. To illustrate it, a more detailed analysis was made for the regions of the country especially critical regarding the aging population process. Among these regions, we considered the death rates from NEO on both males (M) and females (F) aged 65–69 in *Alentejo Central*. The fitted models for the differenced data of males (Y_t^M) and females (Y_t^F) are, respectively, an ARIMA(2,1,0) and an ARIMA(3,1,0) model in the form

$$Y_t^M = -0.845Y_{t-1}^M - 0.868Y_{t-2}^M + \varepsilon_t^M \quad \text{and} \quad Y_t^F = -0.767Y_{t-3}^F + \varepsilon_t^F \,,$$

with ε_t^M and ε_t^F sequences of i.i.d. normal random variables with $\sigma_\varepsilon^M = 0.000351$ and $\sigma_\varepsilon^F = 0.00343$.

After fitting the models, we checked if they were appropriate: they were statistically significant and valid (considering the usual criteria of stability associated with the adjustment of such models and the study of error term). The models also explains, reasonably, the variability of the series. Considering the long-term forecasts, Fig. 5 shows a low negative trend for males and a oscillatory behavior on females.

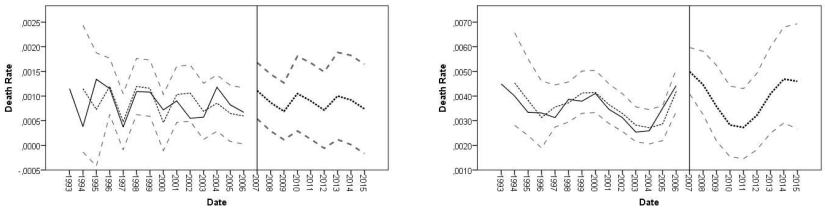

Fig. 5 Fitted Models and Forecasting for NEO Mortality Rates: *Alentejo Central*, Males (on the left) and Females (on the right) – death rate forecast (dashed and bold) and bounds of the 95 per cent confidence interval (dashed grey) on the right side of the vertical bar

As for deaths from NEO (considering *Alentejo Central* region), the data doesn't show any temporal correlation. For that reason, in this region and for this age group, we can conclude that the temporal patterns of these death causes are different.

4 Conclusions and Discussion

This article has explored differences in causes of death among Portuguese older population, at a subnational level. Temporal and spatial statistically significant clusters were identified for a high number of deaths, for the Portuguese mainland, by sex, age and cause of death, from 1992 to 2006. Although spatial clustering is evident for the whole time period, time clustering is also shown. Whereas Spatial clusters

are evident on secondary clusters, the most likely cluster contains all regions of Portuguese mainland on most cases.

Identified clusters from Neoplasms are associated to metropolitan areas (in this case on the coast). Considering this cause of death, identified clusters are distinct by sex and age group. As for mortality rates for Diseases of the Circulatory System seem to be mostly related to the North/South division and identified clusters are similar by sex and age group.

The dynamics of each cause of death is distinct in the studied period. However, it was possible to identify space-time homogeneous units (in terms of the expected number of mortality rates), but with different temporal patterns.

Finally, since this is an introductory work to the application of the methodology to Portugal's demographical data, further developments, like testing other variables or using method alternatives, regarding results assessment, are being prepared.

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