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REVISTA IBERO-AMERICANA DE SAÚDE E ENVELHECIMENTO
REVISTA IBERO-AMERICANA DE SALUD Y ENVEJECIMIENTO

SPATIAL ANALYSIS TECHNIQUES APPLIED TO THE CHARACTERIZATION OF ELDERLY POPULATION FOR THE PLANNING OF NURSING CARE

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VOL. 2 N.º 3 DECEMBER 2016

ABSTRACT

Goal: The study proposes a methodology to characterize geodemographic aspects causing constraints on the geographical accessibility of nursing care in one of the most aging regions of Portugal, using Geographic Information Systems. The proposed work analyzes data from population censuses of elderly people. Spatial statistical techniques, in addition to the classical statistical techniques, are used. **Methods**: The spatial autocorrelation of some demographic indexes values is studied, in order to characterize statistically the presence of clusters of elderly people in the study area, using the Global Index Moran. The clustering of high and low values for each of the indexes is also statistically characterized, using the calculation of GI* statistics. **Findings**: Areas envisaging a more frequent usage of nursing cares are identified. **Conclusions**: The study calls for the necessary programmatic management of material and human resources in nursing, considering the possibility of minimizing the effects caused by the heterogeneous aging of the population.

Keywords: Nursing Care; Elderly; spatial statistics; geographic information systems.

INTRODUCTION

The Portuguese population is getting older[1,2]. In the past fifty years (from 1960 to 2011), the percentage of Portuguese people with 65 years old and older changed from 7.8% of the total population to about 19%, showing a growth of 4.5% per year. European estimates indicate for Portugal an increase rate of the elderly population at about 3.5% per year, until 2060[3].

The Region of Alentejo has the most elderly population in the country, with more than 178 elderly people (65 and over) per 100 young people (aged 0-14). The Region named "Baixo Alentejo" (RBA), a sub-region of the previous one, covers an area of 8.544.6 km^2, corresponding to 10.8% of the national territory and it has a population density of about 14.7 hab/km^2. The average area of the several Parish councils that compose the RBA is of 102.9 km^2 (which is above the national average of Parish councils, notably 21.7 km^2). The RBA is the largest in the country, as well as it is the one that has the most elongated shape, thus comprising the largest linear distance between two points.

The ageing of the population is associated with greater longevity and, consequently, a greater prevalence of chronic diseases, multi-morbidity and varied functional changes, resulting in a more complex health care needs for the elderly people. However, increased health

care needs have increased demand for health services, and the use of these health services usually depends on the availability and accessibility of available health resources[4].

According to Santana[5], one of the foundations for the usage of health services and one of the guarantors of equity in the access to those services is "accessibility", which is structured in two dimensions: (i) the "organizational accessibility", which covers the demand for services by a population vulnerable to their need for care; (ii) the "geographical accessibility", which includes, among other issues, the influence of distance and travelling time spend to access for health care services. These two dimensions interrelate themselves, which allows realizing: (i) the capability to produce services and to fulfil the health needs of a given population; (ii) getting the best fit degree between the needs of the elderly population, the services and the resources being used[6]. Therefore, by confronting the distances between the health services and the elderly population with their chances/capability to move across the territory, we can detect possible inequalities between the geographical distribution of the elderly population and their need for health services along the territory[7].

The Portuguese Observatory of the Health Services estimate that for the 3 869 188 households there is 110 355 people with self-care deficit in homes, with 43.9% being bedridden people. These people represent a total of 53 160 hospitalizations cases and about 129 508 emergency servicing cases[8]. This scenario reveals that elderly people present a weakened health status and a self-care deficit, with greater difficulties in accessing health services autonomously, quickly and effectively, become more vulnerable compared to other age group.

According to Gruneir et al.[9], the elderly are the ones that use emergency services (ES) more often than any other age group, and the emergency services crowding is a widespread and growing problem, due to the increase of the elderly population. Elderly are fragile people, presenting functional impairments, multimorbidity and a significant prevalence of chronic conditions, which decompensate easily and frequently receive health care in a fragmented, reactive and episodic way at ES. The literature review made by the authors, which included 55 research studies conducted in Canada, the United States, Europe, Asia, Australia and Israel, allowed verifying that the demand for the SU by the elderly was considered unavoidable, as well as unique and feasible when an acute health event occurred, because the informal caregiver was not able to react to the need of care at home, especially since the complex health care needs of the elderly have not previously been fulfilled by means of an adequate continuity of caring, which lead to an health acute crisis episode. According to the same authors, there are two main reasons for the use of ES by the elderly more often than any other age group: (i) the first refers to injuries caused by falls; (ii) the second refers to problems related to the need of self-care, as in case of dehydration, mal-

nutrition and malaise. It is also mentioned that functional impairments, together with the lack of support in self-care, are the main driver of the incidence of SU visits by the elderly people, a scenario that is most noticeable for those with 75 or more years old.

According to the guidelines issued by the Director General for Health (DGS) in Portugal, focusing more specifically on the geographical accessibility, a priority dimension stated by the World Health Organization, the SU should be strategically located in order to maintain equity on the need for those services by the population. In relation to the travel time using ground transportation to access for the SU, it should not exceed one hour[10].

Thus, this study aims to report the difficulties of geographical access to the SU at the only existing District Hospital at the RBA, confronting the location of the elderly population with the travel time to the SU, identifying situations of vulnerability in terms of geographical accessibility. The following steps are considered:

i. To describe the population aging evolution in RBA in a geographic environment, using some demographic indices that best characterizes the elderly population;

ii. To identify the type of geographic pattern (aggregate) of population aging (dispersed, random or clustered), describing it quantitatively/qualitatively using spatial statistics techniques;

iii. To describe (in a geographical environment) the location of the only hospital located at the RBA – José Joaquim Fernandes Hospital (HJJF);

iv. To register in a map, the travel times from the clusters of elderly population to the HJJF, using network analysis techniques;

v. To confront the geographical pattern of population aging with the times to the HJJF, using spatial / descriptive statistic techniques.

METHODS

In this study, all the people with 65 years old or older (elderly) that live in the RBA were considered. The selected area, namely the RBA, is represented by 83 polygons, each identifying a Parish (a sub-area of the RBA). The geographical representation of the Parishes was obtained from the Official Administrative Map of Portugal (Carta Administrativa Oficial de Portugal – CAOP), where the administrative limits of the Parishes of Portugal territory is registered[11].

In order to describe the population aging evolution in a geographic environment, the following demographic indexes are used, each one referred to the Portuguese Population Censuses of 1991, 2001 and 2011, since they are those used by the Statistics Portugal Institution (Instituto Nacional de Estatística – INE) in the characterization of demographic aging, namely:

i. Old-age dependency ratio (Índice de Dependência de Idosos – IDI) – the ratio of the number of persons with 65 years old and older to the number of persons from 15 to 64 years old;

ii. Ageing index (Índice de Envelhecimento – IE) – the ratio of the number of persons with 65 years old and older to the number of persons with age between 0 to 14 years old;

iii. Longevity index (Índice de Longevidade – IL) – the ratio of the number of oldest old persons (with 75 years old and older) to the number of persons with 65 years old and older.

The demographic indexes are represented in a geographic environment in nine cartograms (three demographic indexes obtained in the three demographic censuses), using the aforementioned geographical representation of the Parishes of RBA. To describe the evolution of population aging using a geographic environment, for each demographic index, the geographic mean centers (GMC) are calculated, followed by the analysis of the linear distances between the three *gmc* obtained for each demographic index.

The type of global geographical pattern (dispersed, randomized or clustered) exhibit by the geographic distribution of values of each demographic index, in each demographic census, is identified by analyzing the similar / dissimilar values corresponding to each Parish (calculation of the spatial global autocorrelation coefficient), relative to a certain geographical neighborhood (first-order adjacency is adopted, since it is most often used for data referring to geographic entities of polygon type). The metric used is the Global Moran's I Index. (GMI), since it is the most often used to estimate the global geographic pattern of georeferenced data. After that, in order to identify the existence of local geographic patterns, the local statistics G* (or Getis-Ord Gi* statistic) is used (according to the mathematical formulation developed by Getis and Ord), since it is also the most used for this type of calculations[12].

The ES of the HJJF is characterized geographically as a point, superimposed on the same cartogram where the RBA is represented. Subsequently, using the existing road network at RBA, the minimum travel times (in minutes) between the centroid of each Parish and the ES is computed, simulating the usage of ground transportation. Based on the results

obtained, a cartogram is done, assigning to each Parish the respective minimum time spend in each travel.

By overlapping the two above-mentioned cartograms, the first which refers to the description of demographic aging and the second presenting the minimum travel times (a method commonly referred to as mapping overlay), the vulnerable population is identified in terms of geographic accessibility, i.e. the one that is the oldest and simultaneously spend more than 60 min of travel time (reference value stated in the guidelines issued by DGS).

All data are processed using a Geographic Information Systems (GIS), namely the ESRI ArcGIS environment, version 10.2, since it constitutes an adequate computational environment for the processing of spatial data. These systems incorporate spatial statistics analysis techniques (analysis of geographic patterns/clusters, determination of an optimal path between two sites, among other types of techniques), which are very useful for generating simulations of real world phenomena[13].

RESULTS

The first three lines of Figure 1 show the cartograms that represent the geographic distribution of the IDI, IE and IL indexes. An irregular distribution of IDI and IE values is observed, with the concentration of high and low values to the south and north of the RBA, respectively. Regarding IL, there is no asymmetry of the geographical distribution of the values for this index.

The last line of Figure 1 shows the results obtained for the *gmc* calculation (only the results for the IE and IL indexes are represented, since the ones related to the IDI index are similar to those obtained for the IE index), represented on an enlarged scale when compared to the above cartograms of the same figure (based on the administrative boundary of the Municipality of Beja, which is approximately central at the RBA and it corresponds to the administrative division hierarchically above of the Parishes), for a better visual comparison between the different centers obtained. On an short analysis of the results obtained, it can be seen that the geographic mean centers of the IE index present an irregular spatial distribution (the centers exhibit an higher distanced between each other), when compared with the centers of the IL (the three centers are close each other). The distribution of *gmc* for the IDI index is also irregular, but less pronounced in relation to those of IE, since the Euclidean distance between the three *gmc* is lower for the IDI index, when compared to the distances between the three *gmc* referred to the IE index.

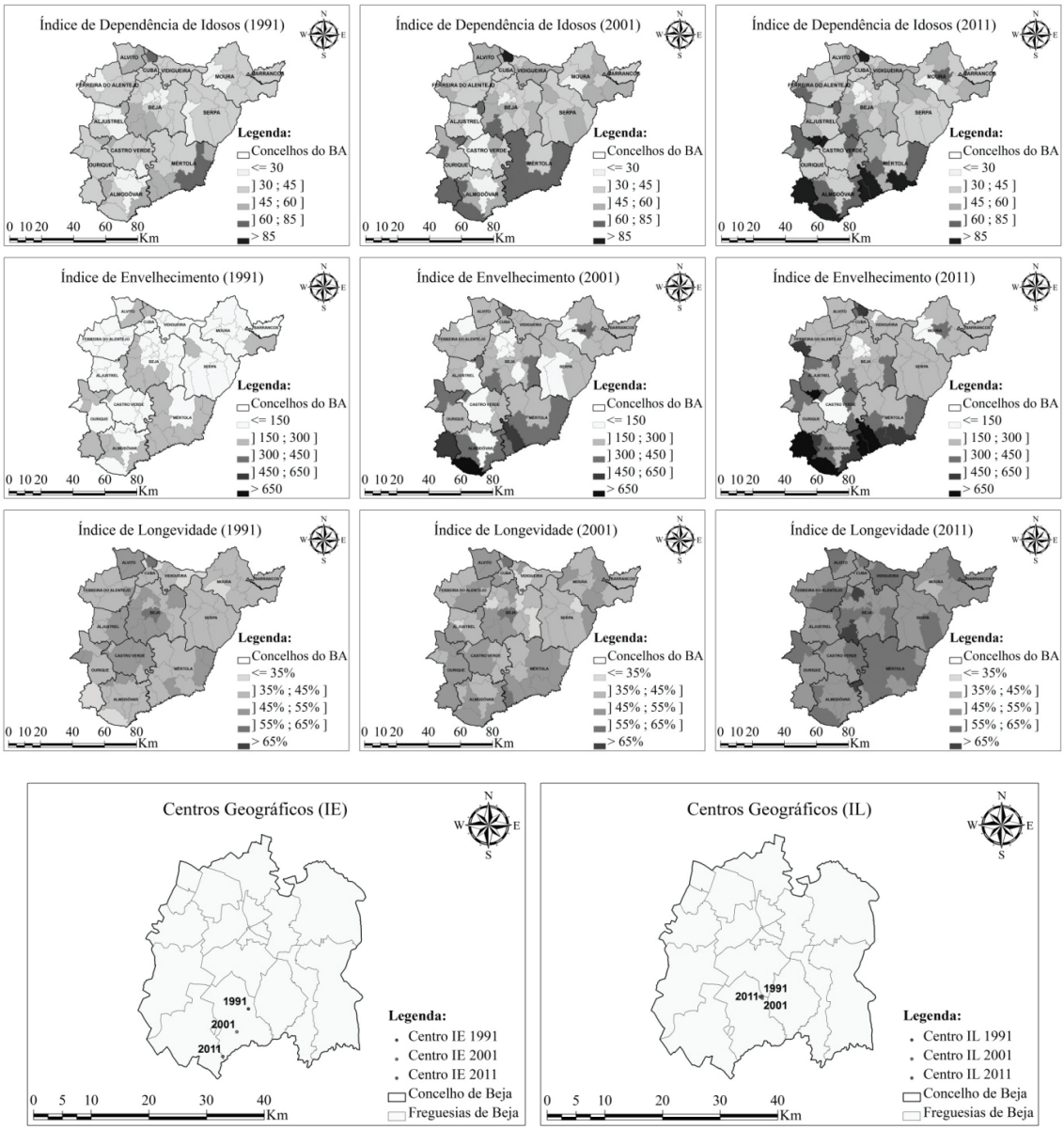

Figure 1 – Cartograms of the IDI, IE and IL indexes for the 1991, 2001 and 2011 population censuses (first three lines) and the representation of geographical mean centers for IE and IL (last line).

In relation to the overall quantitative measure that is used to characterize the geographic pattern presented by the geographic distribution of index values, Table 1 lists the results obtained for the GMI index, respective *Z-score* and *p-value*, for each demographic index and by population censuses. The results show values statistically significant of a geographic pattern considered as clustered for the values of the IDI and IE indexes (null hypothesis is rejected, since *p-value* is always less than 0.001 and simultaneously IGM>0, for the three population censuses), whilst the spatial distribution of IL index values is classified as random (the null hypothesis cannot be rejected for the three censuses, since *p-value*>0.05).

Table 1 - Spatial autocorrelation values for IDI, IE and IL indexes.

	Date of the Census	GMI	$Z\text{-}_{score}$	*p-value*
IDI	1991	0.33	5.01	< 0.001
	2001	0.28	4.18	< 0.001
	2011	0.34	5.19	< 0.001
IE	1991	0.33	5.00	< 0.001
	2001	0.33	5.10	< 0.001
	2011	0.38	6.20	< 0.001
IL	1991	0.04	0.83	0.41
	2001	0.10	1.59	0.11
	2011	-0.06	-0.71	0.48

In relation to the quantitative measure of local geographic patterns of the indexes values (determination of hot and cold spots), referred to the Gi* statistics, it can be seen through the analysis of the results presented in Figure 2 that the Parishes located mainly to the South of the RBA have a local concentration of high values of IDI and IE indexes (statistically significant since *Zs*>1.96). On the other hand, it is interesting to note that this orientation, majority in direction to the south of the RBA, is the same as the one obtained by a line that contains the three *gmc* calculated for the IE index (see last line of cartograms represented in Figure 1, whose result is similar for the case of IDI). In relation to the IL index, the location of clusters of high values (hot spots) and low values (cold spots) varies significantly on the RBA.

Figure 3 shows a map of the geographical distribution of travel times in minutes, between the centroid of each Parish and the ES of the HJJF, based on the existing road network at RBA, simulating the usage of ground transportation. In a short analysis of the results, 14 Parishes (17%) present travel times higher than 60 minutes, which characterizes a poor geographic accessibility, according to Remoaldo (optimal accessibility up to 30 minutes; good accessibility between 31 and 45 minutes, average accessibility between 46 and 60 minutes, poor accessibility with travel time over 60 minutes)[14].

The linear association between the indexes (IDI, IE and IL) and the travel time (the independent variable) was measured based on the Spearman's correlation coefficient (computed using SPSS software, version 22), whose results are listed in Table 2 (all values were obtained for *p-value*<0.05). On the analysis of the values achieved, it can be seen that the

linear association between the travel times for the IDI and IE indexes increased along the three decades (1991, 2001 and 2011). For the IL index, there is no linear association statistically significant with the travel times.

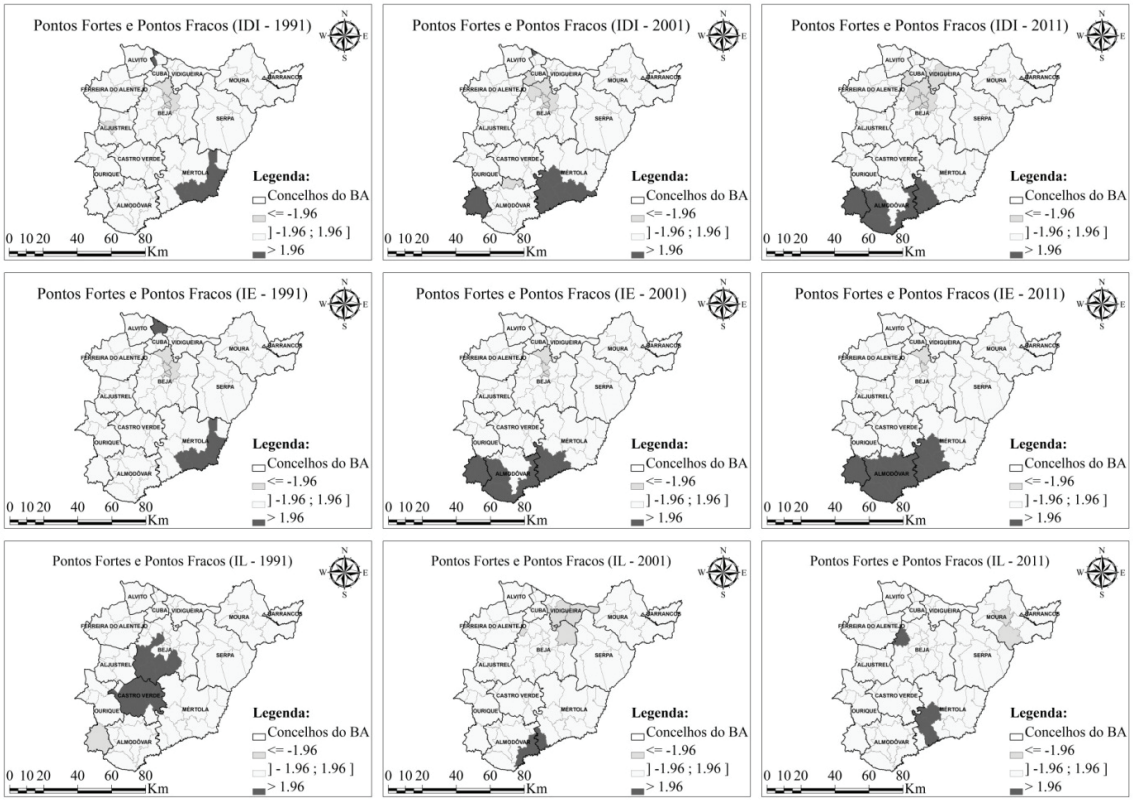

Figure 2 – Cartograms representing the hot (dark) and cold (less dark) spots, based on the values of Z-*score* of Gi* statistics for the IDI, IE and IL indexes.

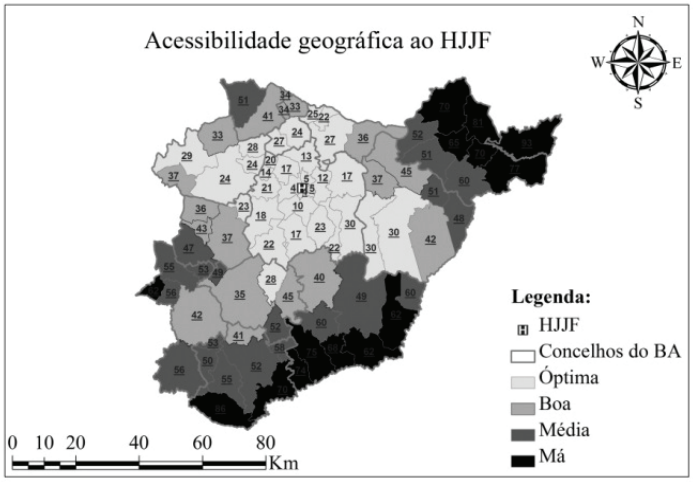

Figure 3 – Cartogram representing the travel times in minutes between the Parishes centroids and the location of the ES at the HJJF.

Table 2 - Spearman's correlation coefficient between the Parishes centroids and the location of the ES at the HJJF.

Date of the Census	IDI	IE	IL
1991	0.327	0.342	-0.222
2001	0.456	0.495	0.234
2011	0.525	0.502	-0.068

DISCUSSION

Results presented in previous section of this paper shows that the RBA undergoes a delicate, worrying and heterogeneous socio-demographic situation of population aging. The scenario obtained here points out to an inequality in the way that elderly people are distributed along the study area. Regarding the IL, there is no asymmetry on the spatial distribution of values for this demographic index, meaning that longevity is widespread along the entire study area, which leads to a reflection about the need for reallocating the necessary health resources to be made available to the elderly population, focusing on the chronic diseases, as well as developing synergies between the need for health care of the this age group and the health resources made available. It is necessary to promote a range of health care services suitable, as most as possible, to the needs of the elderly people, to be provided in their homes, allowing to reduce the geographic access inequalities found in this study area, considered mostly rural and potentially identified as the place of residence of the elderly population with less access to health care services, in addition to the fact that the RBA integrates a public transportation network considered to be scarce and inefficient[5].

The increasing of all indexes considered in this paper (statistically significant along the three population censuses) shows a pronounced aging occurring at the RBA, due to a pronounced decrease of the young and active people. The decrease of these two important age groups is more obvious for the Parishes that are located at south of the study area, as can be seen by the location of the hot spots obtained based on the calculation of Gi* statistic, as shown in Figure 2.

The three *gmc* for IE index present significant distances between each others (see last line in Figure 1, as well as for IDI index), which reveals some heterogeneity on the geographi-

cal distribution for the young and active people when compared to the geographical distribution for the elderly people. Since the elderly tend to consume more health care resources when compared to other age groups, it is expected that there will be a greater pressure of the complexity requirements and quality of health care services for the Parishes at south of RBA, which are signaled as "Hot Spots" in Figure 2, following the same direction of a line that joins the respective geographic mean centers. The travel times increase (see Figure 3), as well as the IDI and IE demographic indexes values also increase, for the Parishes far from the HJJF. Some studies state that the percentage of use some health services (for example, ambulatory care services and hospital emergencies) decrease when the distance from the hospital unit increases[5].

The linear correlation, statistically significant, between the IDI or IE indexes values and the travel times, presupposes the worsening of the socio-demographic inequality scenario on the RBA, i. e. if the elderly people tend to stay in their homes, it is assumed that there is a higher restriction of geographical (or physical) accessibility in relation to the ES of HJJF.

CONCLUSIONS

The analysis of spatial data, in addition to the exploratory analytical techniques, as it is done in this paper, allows for a more detailed strategy for the adequate planning of health care needs that should be provided to the elderly people, as well as to evaluate the relationship between the health care providers and the location where the elderly live, over a geo-socio-demographic environment, to promote the desired equity in health. Since health is the result of a delicate balance between the biological, psychic, social and spiritual aspects of a person, we cannot accept that the health policies being adopted are not correlated, i.e. that the complementarity actions that enable the elderly people to get the access of health services that promotes their quality of life specifically where they live (in their homes) must be taken into account.

The time that elderly spend in a hospitalization episode is decreasing, which leads to early emergencies with people at home still recovering from their illnesses or, in case of a terminally ill person totally dependent on caregivers of the same age, exhausted and unprepared to respond to the needs of the dependent person mainly due to the lack of monitoring of the elderly people, as well as the poor qualification of the respective caregiver. Thus, we are facing in a scenario where the number of elderly people in homes is increasing, with their health condition characterized by dependence on self-care and where a substantial

part of health care will continue to be provided by the family caregivers, at home during a long period of time. Petronilho states that; "regarding the preparation on returning to their homes, we found that in the majority of cases, these relatives are not prepared to adequately respond to the care needs of dependent relatives members, in a family context, as they need to develop a new role".

The results of the present study point outs to the importance of proximity care, because the use of emergency services is not a solution, either in terms of solving the health problems of the elderly people as mentioned in Grunier et al.[9], or in terms of the geographical accessibility to the same services (the latter dimension studied in this article).

Nursing is a profession in the scope of health policies, which contributes to the design of new health interventions, aiming to shift health caring of elderly people to their homes (the place where they live), proposing interventions that enable the implementation of a network of proximity caring, allowing the elderly to live at their homes with quality of life. We believe that the Portuguese Network of Continuing Integrated Care (Rede Nacional de Cuidados Integrados – RNCCI) is a very important health resource for the entire population, which increases the accessibility to health care services and protect the most fragile people, by favoring proximity health care. The RNCCI is the main stream of continuity caring with special emphasis on Integrated Continuing Care Teams (Equipa de Cuidados Continuados Integrados – ECCI), given the nature of their mission, notably emphasizing a greater proximity on supporting families after returning to homes of their relatives dependents, thus revealing an opportunity for nurses to demonstrate their social utility, thus leading to greater gains in health and being closer to families with relatives dependents.

A health policy reflected on the real needs of the elderly people, its epidemiological profile and the specific features of the territory, enabling the elderly to live in a better health state, will contribute to a lower usage of health services and may lead to a reduction of health costs.

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