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Spatial Distribution of Hospitalisations for Cardiovascular Diseases in the Central Region of Asturias, Spain

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Research

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Abstract

Background

Cardiovascular diseases are the leading cause of death worldwide; it is estimated that they cause 17 million deaths annually. In 2019, there were more than 29,000 deaths, and in 2018, ischemic heart diseases cause more than 118,000 hospitalisations in Spain. There is an unevenly distribution throughout the different autonomous communities, being Asturias the community with the highest rate for acute myocardial infarction (AMI) and angina pectoris (AP) of the country. Cardiovascular diseases are related to environmental, socioeconomic and previous medical conditions which result in geographical differences in the incidence of hospital admissions and mortality. To know the distribution of hospital admissions in the central area of Asturias and the existence of spatial patterns or clusters is the goal of this study.

Methods

Urgent hospital admissions for AMI and angina AP in the hospitals of the central area of Asturias were registered, geocoded and grouped by census tracts. Standardised admission ratio, smoothed relative risk and posterior risk probability, together with analysis of spatial clusters between relative risks throughout the study area were calculated and mapped.

Results

Geographical differences were found in the distribution of hospital admissions for AMI and AP in the study area. The cluster analysis indicated aggregates of census tracts with high relative risk values in the northwest region of the study area.

Conclusion

The geographical analysis shows the existence of patterns and spatial aggregations in the incidence of AMI and AP, for men and women, in the central area of Asturias.

Background

Cardiovascular diseases are the leading cause of death worldwide (1). It is estimated that they cause 17 million deaths annually, of which approximately 7.4 would correspond to coronary heart diseases. In the European Union, cardiovascular diseases caused a mortality rate of 63 cases per 100,000 inhabitants in 2017 (2). However, there are large geographical differences throughout Europe, with Spain being one of the countries with a lower rate, i.e., 37 cases per 100,000 inhabitants. In 2019, there were 29,247 deaths from ischemic heart diseases registered in Spain (International Classification of Diseases - ICD10 I20-I25), of which 13,673 were caused by acute myocardial infarction (AMI) (ICD10 I21), and 13,371 by chronic ischemic heart disease (ICD10 I25) (3). Diseases of the circulatory system also cause a high percentage of hospital admissions, reaching 12.5% in 2018 in Spain, only behind respiratory diseases

(13.0%). The data published in Spain for 2018 included 118,464 hospitalisations for ischemic heart diseases, which represented 2.4% of total hospitalisations, and 19.4% among all circulatory diseases. The rate of hospitalisations for ischemic diseases was unevenly distributed in the different autonomous communities, Asturias being the community with the highest rate both for angina pectoris (AP) (57 cases per 100,000 inhabitants) and for AMI (158 cases per 100,000 inhabitants), both above the national average of 31 and 126, respectively, according to the data from 2018 (4).

Cardiovascular diseases are related to: previous medical conditions, such as hypertension, diabetes, overweight or smoking, among others (5–8); socioeconomic conditions, such as deprivation index, and social and geographical scope (9–11); and environmental conditions, especially pollutants such as NO_2 and particulate matter (PM) (12–15). As a result, there have been geographical differences in the incidence of hospital admissions and mortality from heart diseases (16–19).

Geographical information systems and spatial analysis techniques focused on epidemiology help analyse the spatial variable in the geographical context of a disease, so that the analysis can be focused from the spatial distribution of social risk factors and environmental factors that influence health, the existence of geographical trends, and associations or clusters and their influence on the distribution of the diseases (20).

The use of geographical information systems makes it possible to incorporate, within spatial epidemiology, variations in social issues and environmental exposures as factors in the study of risk of hospitalisations and mortality from certain diseases (21). These systems have also been used for the surveillance and monitoring of diseases transmitted by animal vectors or by water (22, 23), modelling the exposure and quantification of environmental pollutants and their influence on health (24–26).

The existence of inequalities in the geographical distribution of diseases plays an important role both for epidemiological research and for public health management services. This way, specifically targeted follow-up campaigns can be created to detect the existence of deficiencies or shortcomings in care networks. Also, measures directed at areas with higher incidence rates of the diseases can be implemented to mitigate environmental effects (27, 28).

The distribution of the population in Asturias has exhibited a clear asymmetry, with a very dense central zone, in comparison to the regional borders. The triangle formed by the three main cities (Avilés, Gijón and Oviedo) concentrates almost 70% of the population of the Autonomous Community in a territory of about 1,000 km^2, i.e., approximately 10% of the area of the region. This is the area where the main roads and industrial sectors are located. Studies conducted in this region, within the framework of the health portal “Air Quality and Health in Asturias”, have revealed a short-term association between admissions for heart diseases and the concentration of pollutants(29–31), especially NO_2 and, to a lesser extent, PM. However, further studies are necessary to determine whether progressive decrease in pollution values would represent lower risks of becoming ill. This way, the goal of the present study was to determine the distribution of hospital admissions for AMI and AP in the central area of Asturias, as well as trends and/or spatial patterns.

Method

Study area and reference population

The study area (Figure 1) comprises eleven municipalities in the central area of the Autonomous Community of the Principality of Asturias, with a total population of 705,968 inhabitants. The 2016 Municipal Register of Inhabitants was used as a reference value. It was the first year of the study sample, obtained from SADEI (Asturias Society of Economic and Industrial Studies). The individuals were categorised by age groups (less than 15; 15 to 39; 40 to 64; 65 to 84; 85 years and over) and sex. The study population corresponded to 67% of the total population of the region (1,042,628 inhabitants in 2016). The four municipalities with more than 50,000 inhabitants in the Autonomous Community were included (Avilés, Gijón, Oviedo and Siero), thus comprising 81.32% of the study population.

Study population

The health data analysed corresponded to unscheduled (urgent) hospital admissions in the hospitals of Avilés (San Agustin University Hospital), Gijón (Cabueñes University Hospital and Jove Hospital), and Oviedo (Asturias Central University Hospital). The study focused on hospital incidence of admissions for AMI and AP. The data were obtained from the Specialised Care Activity Registry RAE-CMBD - Minimum Basic Data Set, corresponding to the period 2016-2018, recorded according to the ICD code (ICD10: I-20 - I-21).

In this registry, each entry corresponded to an admission event, and included a personal identifier for each registry, sex, date of birth, date of admission, and main diagnosis. Through the personal identifier, the residence addresses entered in the SIPRES (Population and Health Resources Identification System) were obtained for their geographical allocations. The ICD10: I20-I21 records were taken from all age groups (less than 15, 15 to 39, 40 to 64, 65 to 84, 85 and over).

Population area and reference cartography

The unit of study was composed of the census tracts (CT) of the municipalities under study (558 CT), obtained from the National Institute of Statistics. Their total reference population was determined through the code of the CT contained in the data set of the Municipal Register of Inhabitants. The CT constituted the most homogeneous units in terms of population, with an average of 1,265 inhabitants for the 558 CT included.

Procedure

The health registry data was geocoded according to the portal level, using the addresses entered in each health event. Geocoding was performed using ArcGis 10.4, based on the cartographies of specific portals of the city councils of Avilés, Gijón and Oviedo, and the cartography of the project 'CartoCiudad' of the National Geographic Institute for the rest of the municipalities. Once the health events were geocoded, they were grouped by CT, disease, sex, and age group.

For each geographical unit (CT), we calculated the standardised admission ratio (SAR), i.e., the quotient between the numbers of observed and expected admissions. The expected admissions for the group of municipalities in the study area was calculated for each sex, using the indirect method of standardisation and the specific rates for age groups in the study period of the central area considered.

Due to the variability of the SAR, resulting from areas with little population or with infrequent health events, it was considered necessary to apply spatial smoothing methods. To that end, the smoothed relative risk (SRR) of admission for AMI and AP was calculated using conditional autoregressive models developed by Besag, York and Mollié (32). They are spatial Poisson models with random effects that take into account the spatial adjacency of the geographical units of the area. Its use is simplified using the Laplace approximation technique to perform Bayesian inference, following the integrated nested Laplace approximation procedure (33,34). Both the SAR and the SRR have been expressed in percentages.

In addition, the posterior risk probability (PP) was calculated, i.e., the probability that the smoothed risk was greater than 100. A PP value ≥0.8 indicated a statistically significant admissions excess (not due to chance). The Stata v14 and R version 3.6.1 programmes were used with the INLA library (R-INLA Project) for calculating the standardised admission ratio, SRR, and PP. The analysis of spatial clusters was performed using the Moran's index, which measures the spatial autocorrelation between the smoothed relative risks throughout the study area, and tries to contrast the null hypothesis of the absence of global spatial autocorrelation (i.e., spatial randomness) *versus* the alternative hypothesis of the existence of spatial autocorrelation.

In a complementary manner, we calculated local indicators in order to detect a possible spatial autocorrelation in a certain subset of spatial units. In this way, an index could be obtained for each spatial unit studied, which made it possible to assess the degree of individual dependence of each spatial unit with respect to the others. To that end, we used the local Moran's statistics, proposed by Anselin (35), whose interpretation is similar to that of the Moran's index, i.e., if it is statistically significant and positive, it allows confirming the presence of a cluster of similar values around the spatial unit 'i'. On the contrary, if it is statistically significant, but negative, there will be a cluster of different values around the n^{th} spatial unit (spatial outliers). The results of spatial autocorrelation at the local level are presented using the local indicators of spatial association (LISA), which used the local Moran's indices calculated for all the assessed spatial units (CT), allowing the geographical determination of spatial groupings (which occurs when a spatial unit that registers a high/low value of the variable is surrounded by spatial units that also register high/low values of that variable, i.e., high-high or low-low) and the spatial outliers, those that arise when a spatial unit with a high value of the assessed variable is surrounded by spatial units in which the variable registers small values or *vice versa*, i.e., high-low or low-high.

Results

The health events geocoded and analysed were 3,218 out of a total of 3,251 contained in the original database, representing 98.99%. Some records (1.01%) were excluded due to the impossibility of spatial determination through the addresses entered. The records corresponded to men (64.42%) and women (35.58%).

The geographical analysis of the SAR (Fig. 2) indicated a dispersed distribution of values above 100 for men, though more concentrated in the north and northwest of the study area. In the case of women, the distribution was similar, without a clear pattern in the distribution; however, there were CT with high SAR values observed in the central zone of the study area. For men, 43.73% of the CT was above a value of 100, and 43.37% in the case of women.

The representation of the smoothed relative risks (Fig. 3) smoothed the standardised admission ratio, thus allowing better spatial analysis of the underlying patterns. For both, men and women, the concentration of values was above 100 in the northwest of the study area, which corresponded to the area of Avilés and neighbouring municipalities, reaching the west of Gijón. Furthermore, in both men and women—especially in the latter—a homogeneous pattern of high risk could also be observed in the central zone, between the municipalities of Siero and Oviedo.

The spatial distribution of the PP (Fig. 4) indicated how the northwest zone contained numerous CT in which the values were greater than 0.8, similar for men and women. In addition, specific areas were observed inside the study area (surroundings of Oviedo and Siero), where these values were also exceeded, confirming the patterns observed in the SRR map. Overall, 19% of the CT regarding men, and 14% considering women exceeded the value of 0.8. It is also worth noting the existence of a wide area of values below 0.2 (low probability of risk) to the east and south of Gijón—more evident in men—and to the south and centre of Oviedo.

The analysis of spatial correlation (Moran's index) indicated that, for both men and women, there was spatial aggregation: $I_{women} = 0.638$ ($z = 26.3$); $I_{men} = 0.838$ ($z = 34.2$). The analysis of LISA, on the other hand (Fig. 5), indicated the areas where the high and low values of incidence of the disease were grouped, making it clear that there were high-value grouping areas in the Avilés region (councils of Avilés, Castrillón, Corvera de Asturias, Illas, and Gozón) in the case of men, extending to Carreño and Gijón for women. In the case of men, the presence of a group of low values in the central and eastern areas of Gijón was notable; however, it was not indicated by the analysis of women, where only some CT were observed in the centre of Oviedo and Gijón under this aggregation.

Discussion

The results of the present study indicated the existence of a clear geographical differentiation in the incidence of hospital admission for AMI and AP in the central area of Asturias. We assessed small geographical units, in this case, CT. The standardised admission ratios assessed indicated a fairly heterogeneous pattern for both men and women. However, a north-south trend could be observed in the grouping of high values, which could be seen more clearly representing the distribution of SRR, eliminating certain relative variability and taking into account spatial adjacency. The maps of SRR illustrate grouping of high values in the CT located in the northwest, more concentrated in men; whereas, in women, there was an aggregation of high values also in the central zone of the area, as well as in the aforementioned northwest zone. The analysis of clusters and spatial aggregation made the described situation become more evident, since the high values were grouped in the CT of Avilés, Castrillón, Carreño, and Gozón, reaching Carreño and the western area of Gijón in the case of women, and also showing a statistically significant correlation in the study area with respect to both sexes.

The area of study is an industrial environment with a dense population. The main cities and industrial areas of the region are structured—especially those next to the estuaries of Avilés (municipalities of Avilés, Corvera de Asturias, Gozón, and Castrillón) and Aboño (between the municipalities of Gijón and Carreño), and the port El Musel (Gijón)—to take advantage of the accesses by sea. Also, there are cities and industrial areas in the central regions of the municipalities of Llanera and Siero, benefiting from the availability of land and good road accesses (36, 37).

On the other hand, it has been documented that, in hospitals of the area, there has been a positive association between unscheduled admissions for AMI and AP in the 2003–2018 study period and the daily mean levels of atmospheric pollutants, especially SO_2. Moreover, the association with PM and NO_2 had also been statistically positive. It is worth noting the association found in Avilés Hospital, located in the aforementioned northwest region of the study area, where the cumulative incidence of hospital admissions for AMI and AP was clearly higher than in the rest of the municipalities of the area, and one of the highest observed in the Spanish health areas as a whole (31).

A consistent number of published scientific studies addressing the spatial distribution of heart disease morbidity have highlighted health inequalities between different geographical areas, similar to the results obtained in the present study. In France, in the Etang-de-Berre region, an excess risk of hospitalisations due to myocardial infarction was detected for both men and women living in districts exposed to atmospheric pollution of industrial origin (38)(Pascal et al., 2013). On the other hand, in Denmark, a more complex pattern was found by studies that assessed the incidence of AMI and social inequalities that were not explained only by differences between social groups (10). This fact is similar to what occurred in the Municipality of Madrid, according to a study that addressed mortality from cardiovascular diseases (39). In addition, some studies have highlighted the impact that traffic and port activities have on air quality, as well as the exposure of the populations to pollutants in urban areas near ports (40), which might also be influencing the central area of Asturias and should be analysed.

The geographical differences found in the distribution of hospital admissions for AMI and AP in the central area of Asturias, both in the reasons for admission, as well as the SRR and the probability of subsequent risk, for men and women, indicated the existence of CT with high risk values, concentrated in the north and northwest of the study area, especially in the Avilés region. The cluster analysis at the local level (LISA) indicated, for both sexes, the existence of aggregates of CT with high relative risk values in the northwest region of the study area, revealing the existence of underlying causes that might be enhancing the risks of admission for heart diseases in this area. This finding should be assessed in detail.

Studies based on spatial inequalities in the incidence of diseases, in this case AMI and AP, offer information on the location of the greatest risks of these diseases, and can contribute to the implementation of public health measures aimed at the prevention and improvement of care in these areas. These measures should include screening and prevention programmes aimed at the population at risk, and increased healthcare resources specifically aimed at these pathologies.

Aggregation by small areas, in this case CT, is used in epidemiological studies (41, 42) to highlight geographical differences in the onset of diseases, the existence of patterns distribution or specific aggregates that may be rooted in socioeconomic differences, the distribution of industrial areas, communication routes, etc. The CT of the study area differed greatly in their size (i.e., large in rural areas and small in urban areas), although the relatively homogeneous reference population allowed reducing the negative effects of using small areas for epidemiological analyses. In addition, their use will make it possible to associate demographic and socioeconomic information linked as variables for the study of the causes or factors that influence the spatial distribution of diseases. The use of a Bayesian model allowed smoothing the population differences found between the CT, and attenuated the existence of disparate incidence rates in small but correlated areas (43, 44).

The use of the last addresses recorded in the health records—as a source of basic information for the present study—to geocode health events could have made it difficult to interpret the results when these addresses were not the usual residences or, even if they were, the addresses did not correspond to the places where the individuals had the greatest exposure to environmental risks (where they spent most of their time). Likewise, the existence of residential centres for older adults may pose a limitation in the interpretation of the results, since the relationship of such centres in the CT was not included in our study, thus being factors that might be affecting the rates of some CT.

The present study revealed the existence of defined patterns and spatial aggregations in the incidence of AMI and AP, for both men and women, in the central area of Asturias. Our work may serve as a basis for studying the epidemiology of cardiovascular diseases in Asturias, and advance knowledge of the causes and risks of admissions for AMI and AP. Therefore, further studies should be conducted in order to analyse these factors together with environmental and/or socioeconomic aspects.

List Of Abbreviations

AMI.- Acute Myocardial Infarction

AP.- Angina Pectoris

ICD.- International Classification of Diseases

PM.- Particulate Matter

CT.- Census Tracts

SAR.- Standardised Admission Ratio

SRR.- Smoothed Relative Risk

PP.- Posterior Risk Probability

LISA.- Local Indicators of Spatial Association

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

The data are not publicly available

Competing interests

The authors declare that they have no competing interests.

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Authors' contribution

I.M.-P.: formal analysis, investigation, methodology, visualization, writing–original draft, writing—review and editing. V.G.-I.: formal analysis, methodology, visualization, writing—review and editing. V.R-S.: conceptualization, supervision, project administration, funding acquisition, writing—review and editing. A.F.-S.: conceptualization, investigation, methodology, project administration, funding acquisition, supervision, writing—review and editing. All authors have read and agreed to the published version of the manuscript.

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Figures

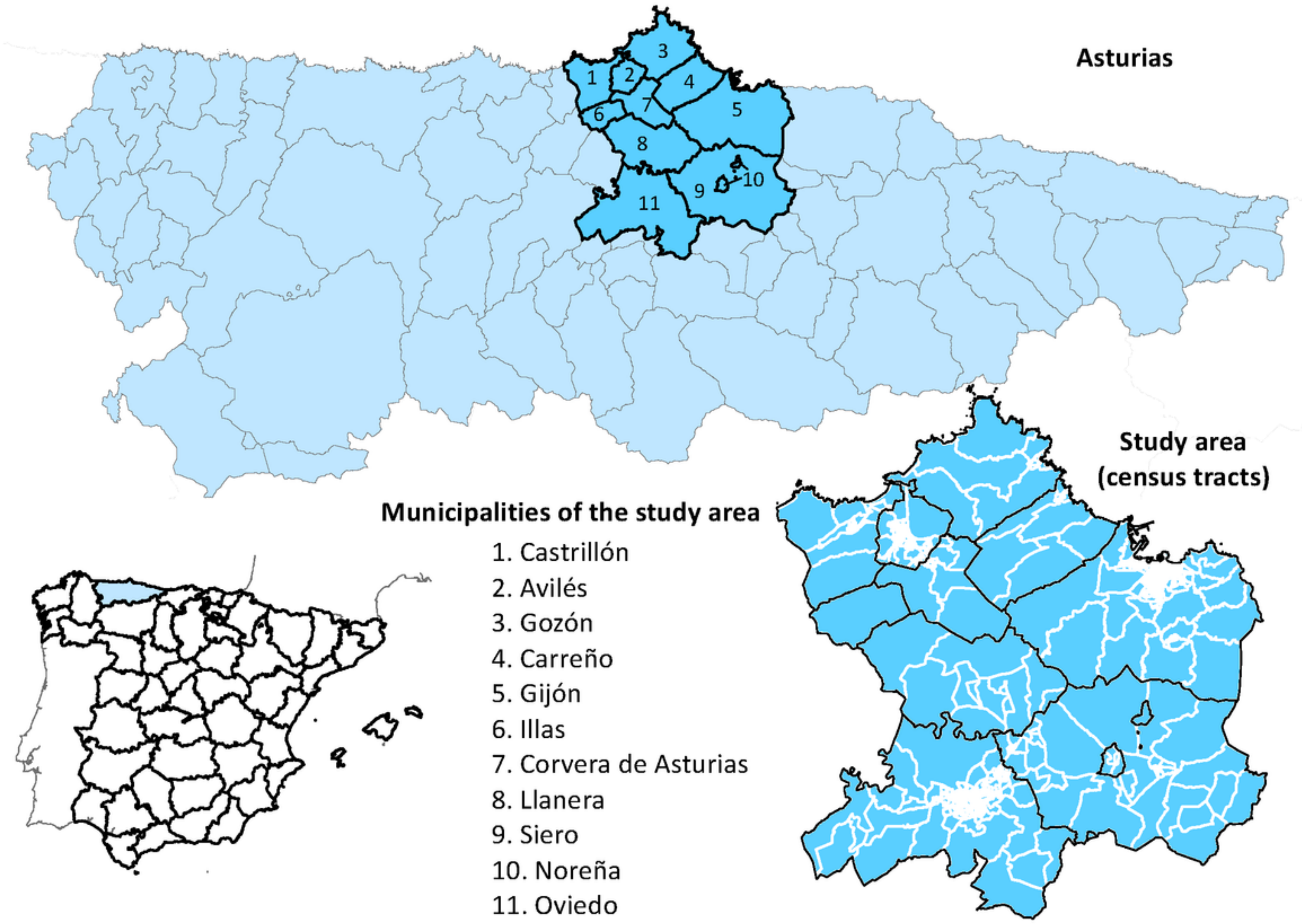

Figure 1

Location of the study area. Asturias is an Autonomous Community of Spain, located in the north of the country. The study area is comprised of eleven municipalities in the central area of the region. The census tracts used for the spatial analysis sum up 558 areas with an average of 1,265 inhabitants.

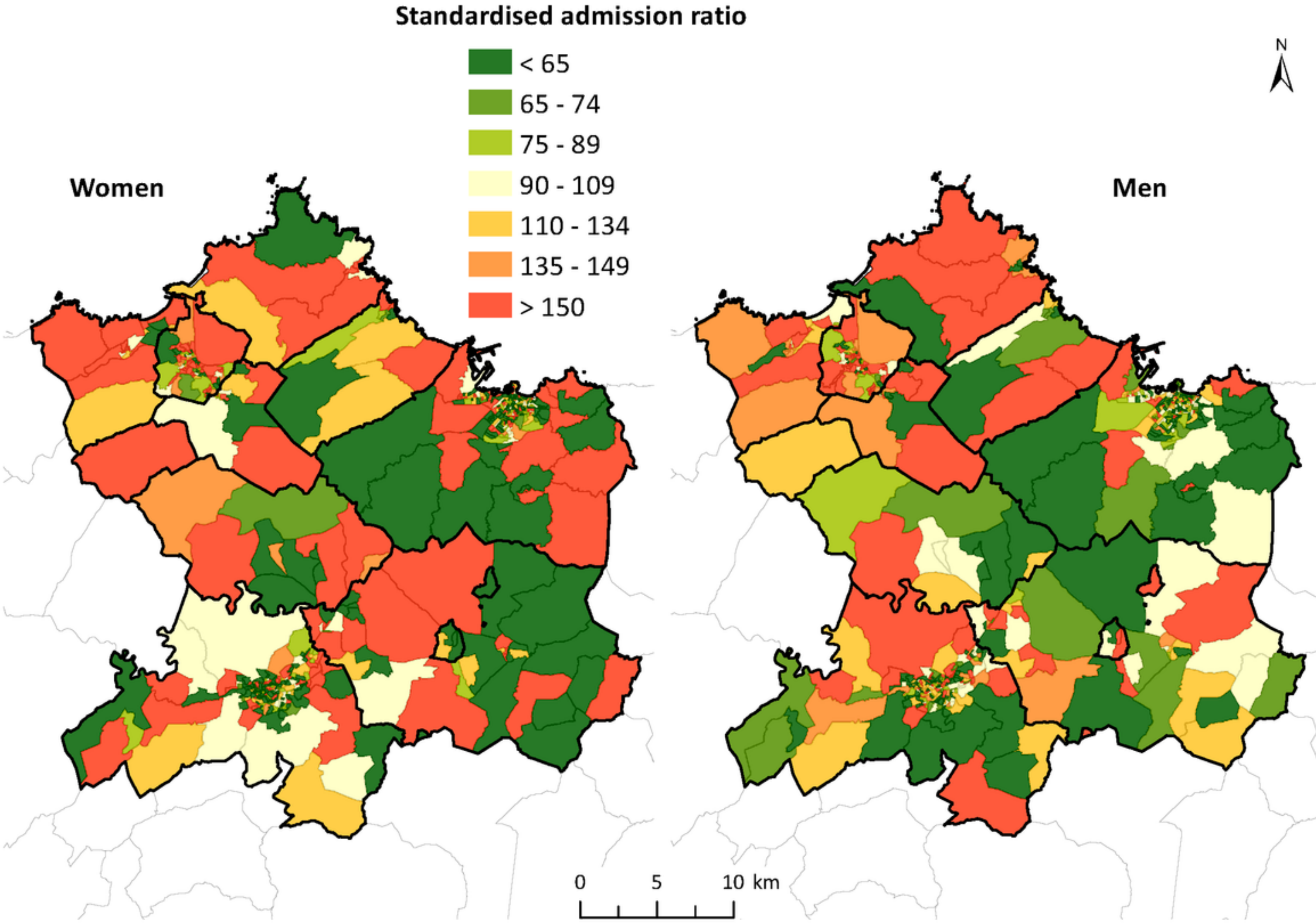

Figure 2

Standardised Admission Ratio for AMI and AP in the study area. The geographical distribution of the Standardised admission ratio shows a dispersed distribution of high values for both men and women, without a clear pattern in the distribution.

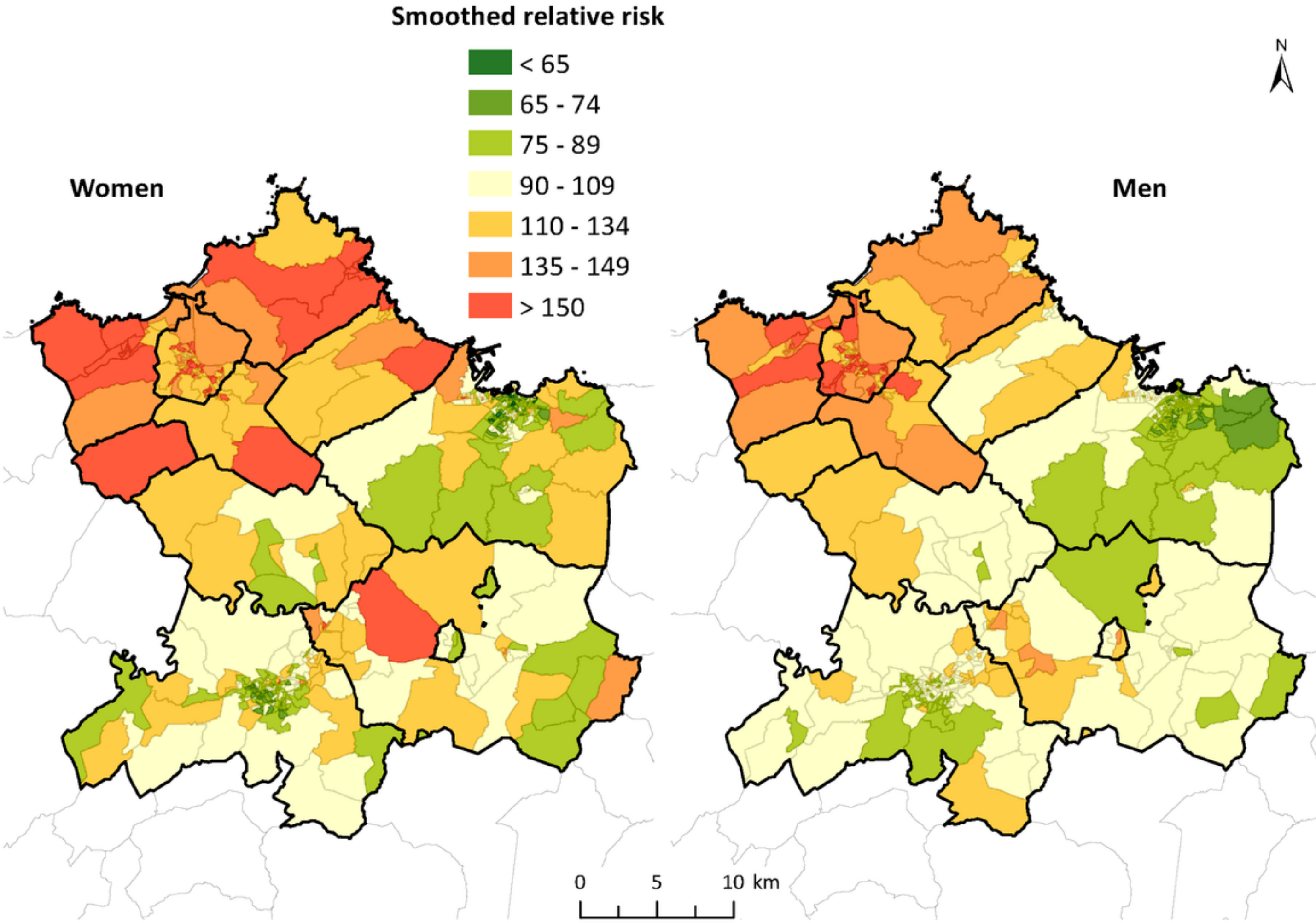

Figure 3

Smoothed Relative Risk for AMI and AP in the study area. The representation of the smoothed relative risks allows better spatial analysis of the underlying patterns. For both, men and women, the concentration of values was above 100 in the northwest of the study area, which corresponded to the area of Avilés and neighbouring municipalities, reaching the west of Gijón. Furthermore, in both men and women—especially in the latter—a homogeneous pattern of high risk could also be observed in the central zone, between the municipalities of Siero and Oviedo

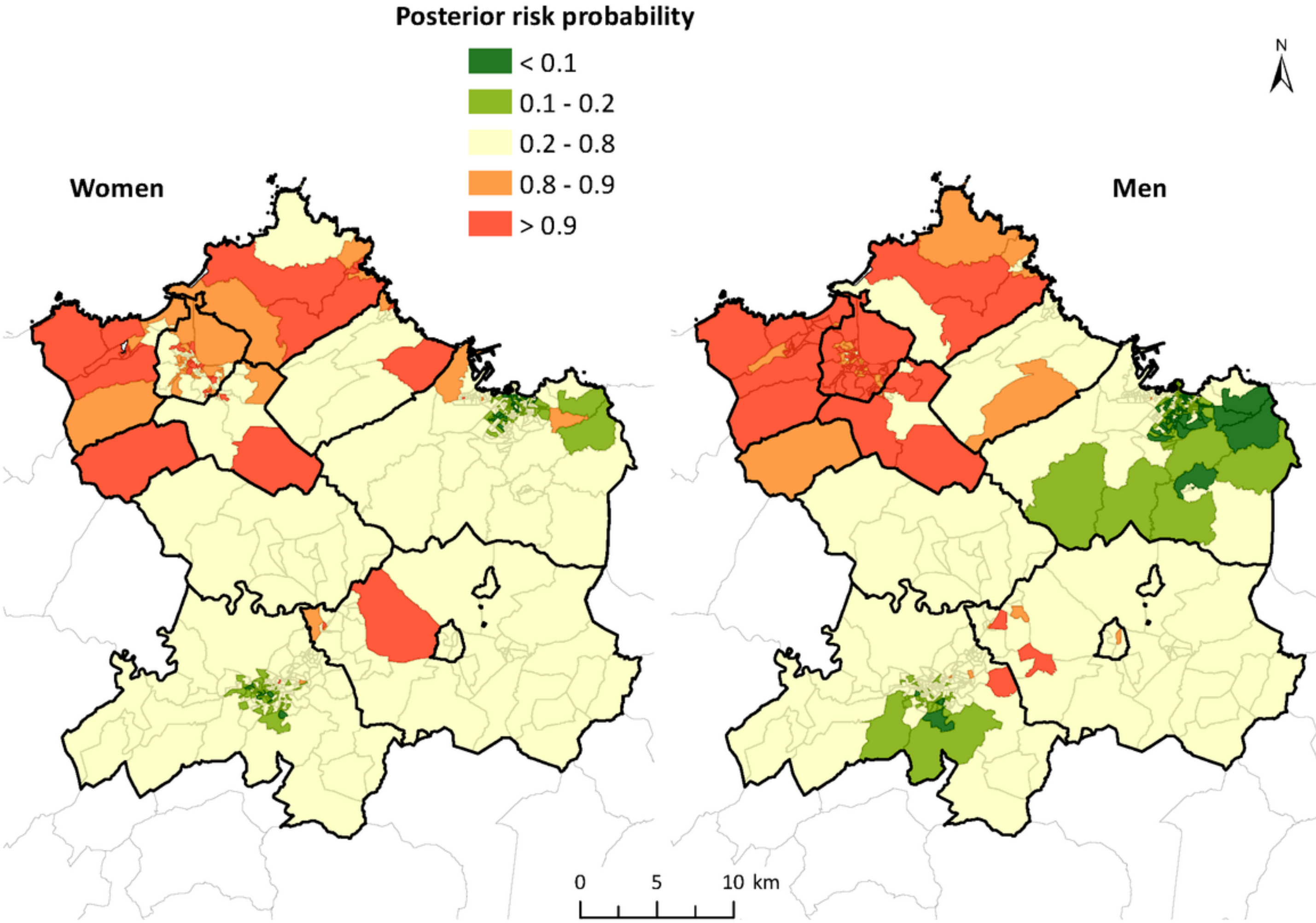

Figure 4

Posterior Risk Probability for AMI and AP in the study area. The spatial distribution of the PP indicated how the northwest zone contained numerous CT in which the values were greater than 0.8, similar for men and women. In addition, specific areas were observed inside the study area (surroundings of Oviedo and Siero), where these values were also exceeded, confirming the patterns observed in the SRR map.

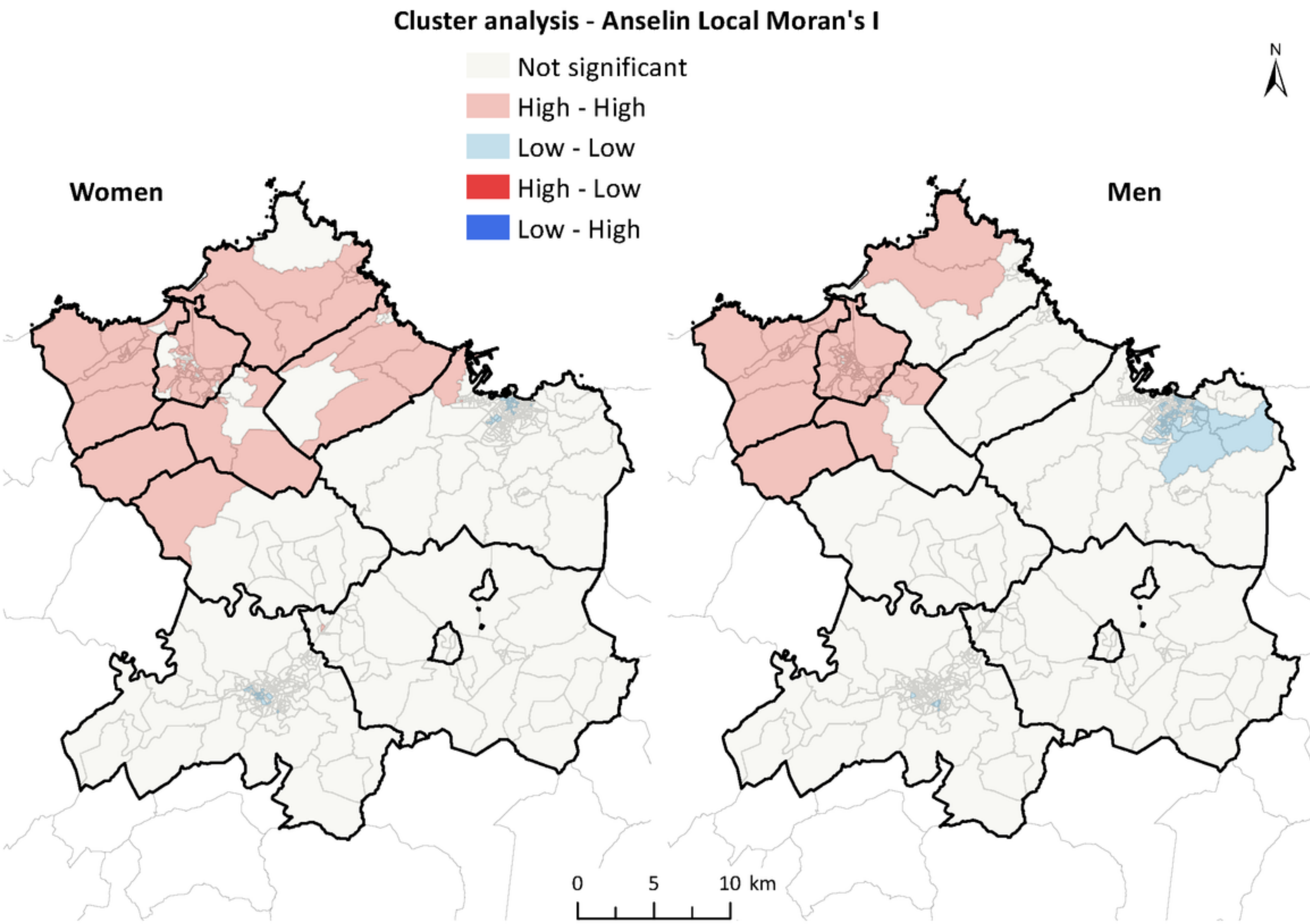

Figure 5

Cluster analysis (LISA) of AMI and AP in the study area. The analysis of LISA indicated the areas where the high and low values of incidence of the disease were grouped. There were high-value grouping areas in the Avilés region (councils of Avilés, Castrillón, Corvera de Asturias, Illas, and Gozón) in the case of men, extending to Carreño and Gijón for women. In the case of men, the presence of a group of low values in the central and eastern areas of Gijón was notable.