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Spatial distribution of dental caries among preschool children in Canoas, Southern Brazil

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ABSTRACT

The aims of this study were to analyze the spatial distribution of dental caries among preschool children and create equiprobable scenarios of its occurrence in the city of Canoas, Southern Brazil. Trained, calibrated dentists examined 1,100 children enrolled at public preschools to determine dental caries experience following World Health Organization criteria. The ArcGis 10.0 Geographic Information System was used to analyze spatial and non-spatial data. Geostatistical Modeling Software was used in geostatistical analyses to detect spatial continuity and create maps using stochastic simulation. Overall prevalence of dental caries was 25% with intra-urban differentials in distribution. The findings enabled the generation of 100 equiprobable scenarios and maps with the best and worst scenarios. The highest concentration of dental caries occurrence was found in the western portion of the city, while the lowest probability of occurrence was found in the northern and southern portions. Identifying spatial inequalities in health conditions and visualizing them through the creation of maps can help to qualify and organize public health interventions and provide information to gain better understanding of the influence of the surrounding environment on adverse health conditions.

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Keywords: *Dental Caries; Child, preschool; Spatial Analysis.*

Distribuição espacial de cárie dentária em crianças pré-escolares de Canoas, sul do Brasil

RESUMO

O objetivo do estudo foi analisar a distribuição espacial de cárie dentária entre crianças pré-escolares e criar cenários equiprováveis da ocorrência deste agravo na cidade de Canoas, sul do Brasil. Exame clínico para detecção da experiência de cárie dentária de acordo com o critério da Organização Mundial da Saúde foi realizado por cirurgiões-dentistas treinados e calibrados em uma amostra de 1.100 crianças matriculadas em escolas de educação infantil. Utilizou-se o Sistema de Informação Geográfica ArcGis 10.0 para a inserção de dados espaciais e não espaciais. O programa GeoMS foi utilizado nas análises geoestatísticas para a detecção da continuidade espacial e construção de mapas através da simulação estocástica. A prevalência de cárie dentária foi 25%, com diferenciais intra-urbanos na sua distribuição. Os resultados permitiram a construção de 100 cenários equiprováveis e de mapas com os melhores e piores cenários no município. Uma maior concentração de ocorrências foi encontrada na região oeste da cidade, enquanto que as regiões norte e sul tiveram a menor probabilidade de ocorrência de cárie dentária. A identificação de desigualdades espaciais em condições de saúde e a sua visualização por meio de mapas pode auxiliar na qualificação e organização de intervenções de saúde pública, assim como fornecer subsídios que ajudem no entendimento da influência do meio ambiente sobre as condições adversas de saúde.

Palavras chave: *Cárie dentária; Pré-escolar; Análise espacial.*

INTRODUCTION

Dental caries is the most prevalent adverse oral health condition in childhood and is considered a public health problem[1]. This condition is associated with pain as well as functional and esthetic problems, and has negative impacts on quality of life, social interactions and psychological well-being[2,3].

Although the oral health status of preschoolers has improved considerably over the past decade, oral health problems and treatment needs are distributed unevenly, with greater concentration in a small portion of the population, reflecting a “polarization process”[4,5]. In addition, social inequalities in oral health have been reported as widespread around the world, with people at the lower end of the socioeconomic scale bearing a greater burden of adverse health conditions than those who are socioeconomically privileged[6,7]. The apparent tendency toward the concentration of adverse health conditions in poor urban areas has been denominated "intra-urban differentials in health" in the literature[8].

Inequalities in oral health have been described as a major challenge for public health authorities, and knowledge of the contextual factors involved is the new paradigm of epidemiology[1,9,10]. Thus, understanding the geographic distribution of adverse health conditions is fundamental to decision-making in epidemiological surveillance systems[11].

The Geographic Information System is a central tool in studies that evaluate the geographic distribution of adverse health conditions, enabling the collection, storage, visualization and analysis of spatial data[11-13]. In turn, geostatistical modeling enables the quantification of the spatial continuity of a given disease and the creation of probability maps for its occurrence through interpolation models and stochastic simulations[14]. In the last decade, health studies have used geostatistics to characterize the spatial distribution of malaria[15], cancer[16,17] and the association between air pollution during pregnancy and low birth weight[18].

In dentistry, few studies have used spatial analysis of information due to a lack of methodological knowledge, deficiencies in cartographic representations and the expense of equipment and software. Thus, only a few studies have used spatial analysis of dental caries[8,10,11,19-21]. Moreover, no study was found in the literature employing this method on a large sample of preschool children in a developing country.

The aim of the present study was thus to identify the spatial distribution of dental caries among preschool children and create equiprobable scenarios of the occurrence of this condition in the city of Canoas in southern Brazil.

MATERIAL AND METHODS

Subjects and study design

This cross-sectional study is part of a larger project of which the aim is to evaluate oral health status among preschool children in the city of Canoas, southern Brazil[2,5]. A total 1316 male and female children aged 0 to five years, enrolled at all public preschools, were examined. According to data provided by the Canoas Municipal Secretary of Education, the source population consisted of 1732 children.

Data collection

Six dentists who had undergone training and calibration exercises collected the data by means of a questionnaire on demographics (age and sex) and socioeconomic characteristics (household income and mother's schooling) administered to parents/guardians at the preschool, and a clinical examination of the preschoolers to determine dental caries experience. Children were examined at the preschool while lying on desks under natural light. Teeth were brushed and dried with gauze, after which a visual clinical examination was performed, following the criteria of the World Health Organization for the diagnosis of decayed (including only cavitated lesions), missing and filled teeth (dmft)[22]. Intra- and inter-examiner reliability for dental caries were assessed using weighted Kappa statistics in two dental examinations performed 10 days apart on 40 children aged 2-5 years. Inter-examiner reliability ranged from 0.83 (95% CI 0.71-0.95) to 1.00 and intra-examiner reliability ranged from 0.93 (95% CI 0.86-1.00) to 1.00.

Data analysis

The ArcGIS 10.0 Geographic Information System was used to integrate the tabulated and spatial data and perform the geoprocessing procedures. Each participant's address was manually georeferenced on a map of the municipality (Fig. 1). The reference datum was the South American Datum of 1969, with the Universal Transverse Mercator projection system on Zone 22 South. The shapes with street names, addresses, neighborhood limits and municipal limits were provided by the Canoas Geoprocessing Institute. The exploratory statistical analysis of the data and the study of the spatial distribution of dental caries based on the creation of variograms were performed using the Geostatistical Modeling Software on the individual level as well as with aggregated data. Dental caries was defined as an indicator variable: $I(X) = 1$: with dental caries; and 0: without dental caries.

Neighborhood was the spatial aggregation unit and the geographic coordinate for the aggregated data by neighborhood was determined by calculating the centroid of the spatial location of all children residing in the same neighborhood. The probability of the occurrence of the outcome per neighborhood was adjusted using the direct adjustment rate, which enabled comparison of populations with different structures (age and number of individuals)[23]. After determining the spatial pattern of dental caries, interpolation was performed using Ordinary Kriging for the estimation of dental caries experience in non-sampled locations. Data simulation was performed using Direct Sequential Simulation for the identification of the best and worst equiprobable scenarios for the occurrence of dental caries. The Mann-Whitney test was used to compare the socio-economic level of the families (with and without location) based on household income and mother's schooling, with the level of significance set at 5% ($p < 0.05$).

Ethical aspects

This study was approved by the Human Research Ethics Committee of the Lutheran University of Brazil under process number 2010-056H. All participants' legal guardians signed a statement of informed consent prior to the data collection process.

RESULTS

The final sample comprised 1110 children aged zero to five years, 566 boys (51%) and 544 girls (49%), who were residents of 16 neighborhoods in the city of Canoas. Incomplete information provided by the parents/guardians during interviews and areas not officially registered with the City Hall determined the non-identification of 206 (15%) addresses. No significant difference in household income ($p = 0.383$) or mother's schooling ($p = 0.683$) was found between the located and non-located families.

The prevalence of dental caries (dmft ≥ 1) was 25%, with a range of 6.6 to 68.4% among the different neighborhoods. Fig. 2 shows the distribution of the children based on place of residence and dental caries experience.

The variograms in the individualized analysis revealed no spatial continuity in dental caries. However, the omnidirectional variogram in the analysis of aggregated data per neighborhood demonstrated a spatial pattern in the occurrence of this condition. Thus, a spherical model was adjusted with a range of 4534 meters.

Based on the variogram modeling, data were interpolated using Ordinary Kriging, which allowed the estimation of mean outcome for each location. The Direct Sequential Simulation generated 100 equiprobable scenarios which were equally representative of the outcome. Each simulation provided a single value for each location, representing a possible exposure measure and reproducing the histogram and variogram of the experimental data.

The variance in the set of values from the simulation represents the uncertainty associated with each simulation. In Fig. 3, regions with warmer colors represent areas of greater uncertainty in the simulation. These areas were those with no sampling and those with very different dental caries prevalence rates, demonstrating validity in the results indicated by the simulation.

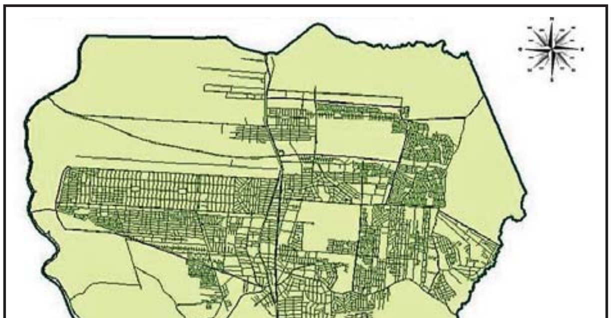

Fig. 1: Cartographic representation of the city of Canoas, southern Brazil.

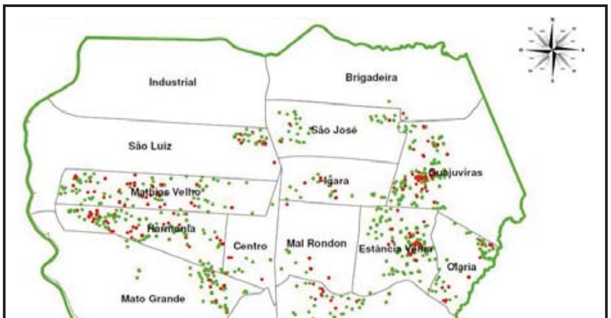

Fig. 2: Georeferencing of residences of children analyzed.

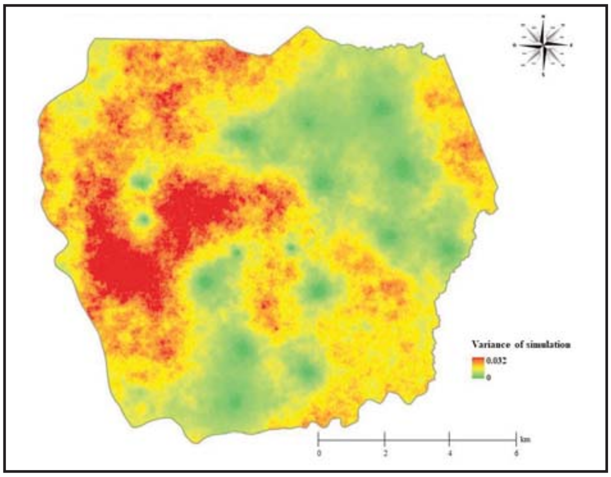

Fig. 3: Degree of uncertainty in the rates of dental caries experience simulated for each surface.

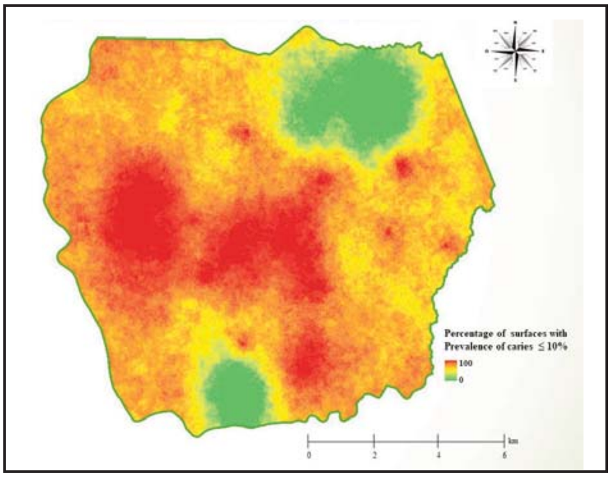

Fig. 4: Map of surfaces with lowest simulated rates of probability of dental caries.

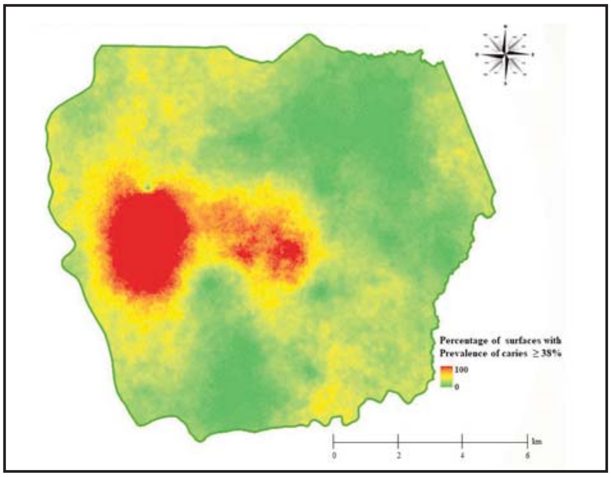

Fig. 5: Map of surfaces with highest simulated rates of probability of dental caries.

From the set of simulated maps, the distribution of probability values of dental caries prevalence was determined for each point on the map. These local distributions were divided into quintiles. The map of the 1st quintile (Fig. 4) shows that the northern and southern portions of the city had the lowest probability of dental caries occurrence, as represented by the coldest color (green). In the map of the last distribution quintile, the portions with the warmest colors are located in areas of the western periphery of the city and partially in the central region of the city, representing 1/5 of the sample and corresponding to a higher prevalence rate (38%; Fig. 5).

DISCUSSION

The spatial analysis of the distribution of dental caries among preschool children in the city of Canoas indicated the occurrence of intra-urban differentials, with the highest concentration of cases in the western portion of the city. This is the first study to investigate the spatial distribution of dental caries among a large sample of preschool children in a developing country. The findings demonstrate the importance of spatial analysis in understanding the polarization process of adverse health conditions and identifying more vulnerable groups.

Identifying spatial inequalities and visualizing them on maps enables health services to be qualified and organized. In addition to optimizing the allocation of financial and human resources based on the characteristics of each geographic area, this process is essential for guiding interventions aimed at reducing inequalities[11,13,24,25].

Certain features of the present study should be highlighted. The use of geostatistical modeling in the interpolation of data on dental caries enabled the probabilistic modeling of the uncertainty of the rate smoothing. Other studies estimate health data using different methods that incorporate the geographic position of the outcome, but without presenting the degree of uncertainty in the estimate[8,11,14].

The spatial continuity pattern of dental caries was only detected with the aggregated data. This was expected due to the behavioral diversity that may result in significant differences in caries experience among children who reside near each other. It is also important to stress that the geographic coordinate for the aggregated data per neighborhood was determined based on the spatial location of all children in a given neighborhood, like a gravity center, and not through the geographic centroid of the neighborhood. Thus, the geographic location closest to the location of the study population was used.

Ordinary Kriging was used as the interpolation method. It differs from other interpolation methods in the manner in which the weights are attributed to different samples. In this case, the weights of an estimator are determined based on the spatial covariance obtained through the modeling of experimental variograms, thereby providing unbiased estimates with minimal variance[14]. Thus, this method enabled greater confidence in the estimation of the area with the greatest probability of the occurrence of dental caries: the westernmost periphery of the city. Other studies have used different estimation methods to detect geographic differences in oral health conditions in different populations[8,11].

Simulation models were also employed in the present study. Unlike estimation models, simulation models do not deliver the most probable image of the characteristics of an outcome, but rather, a setof equiprobable images with the same spatial variability depicted by the experimental data, thereby determining spatial uncertainty[14,16,18]. Methods that consider the degree of uncertainty in statistical models are important to the analysis of health data[16,18]. One map was thus created with the points of the lowest prevalence rates (up to 10%), representing the 1/5 of the distribution with the best oral health status, and another was created with points of the highest prevalence rates (> 38%), representing the 1/5 of the distribution with the worst oral health status. These maps reveal that the distribution of dental caries in the city of Canoas was unequal in the regions analyzed.

Although dental caries occurrence in Canoas appears to be related to socio-environmental features, with higher prevalence rates in areas with substandard living conditions, this study did not directly clarify mechanisms by which such disparities are generated. The socioeconomic gradient in children's oral health has been demonstrated in the individual and contextual level[26]. However, the mechanism underlying (socioeconomic) inequality in health is often complex[27,28]. There is further scope for evaluating the role of contextual and compositional factors that may explain inequalities in children's oral health[29].

As a reflection of socioeconomic conditions and subject to both social and political inequalities, the surrounding environment exerts an influence on the living conditions of its inhabitants. The evidence that inequalities in health have a spatial dimension is well established. There is growing understanding of the role that location plays in influencing individual and familial levels of exposure to health risks as well as opportunities for being healthy[30].

Geographic aspects may be related in different ways to aspects of oral health. Examples of these geographic aspects include location and forms of access to dental services, location of social equipment (schools, community centers and recreational areas), local infrastructure which can provide wellbeing (basic sanitation, electrical energy and public security) and the entire social support network.

The present study has some limitations that should be analyzed. The first is the lack of data on the location of all the preschool children, which is a common problem in developing countries, especially in communities with low socioeconomic levels. However, the likelihood of selection bias is low, since no significant difference was found in the socioeconomic level between the analyzed and non-analyzed children. Another limitation is the cross-sectional design, which does not allow conclusions to be drawn regarding the cause-and-effect relationship between exposure and outcome.

The present findings demonstrate the importance of identifying inequalities in the spatial distribution of diseases and visualizing this distribution on maps. Such visual resources enable a broader understanding of health data, which may help public administrators to plan health strategies in a given area. Further studies are needed to identify the contextual factors involved in the distribution of diseases. Instrumentalization through spatial epidemiology improves the ability of healthcare professionals and public health authorities to design, conduct and evaluate public health interventions.

The implementation of health promotion strategies based on changes in behavior has proven to be limited[29]. The present findings demonstrate 'upstream' structural and environmental risks, which may simultaneously serve as common causes for a variety of adverse health outcomes[5,30-32]. There is growing consensus that oral health measures should be included in general health programs[33]. From the standpoint of public health, the common risk approach appears to be the most effective strategy. In conclusion, the use of geostatistical methods to create equiprobable scenarios enabled the detection of areas with greater probability of dental caries in the study population. Such methods may help establish appropriate interventions and resource allocation, as well as improve our understanding of the influence of the surrounding environment on health status.

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