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ENVIRONMENTAL FACTOR IN THE SPATIAL ANALYSIS OF HEARING IMPAIRMENTS IN RESIDENTS OF THE CHALYABINSK REGION

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Abstract: *The goal of the study was a spatial analysis of the morbidity of hearing loss of various types in the adult population of Chelyabinsk Region and the dependence of the incidence on the environmental issues at the place of residence. The epidemiological issues of the localization of hearing disorders were studied by spatial analysis in the R software environment. The main tasks of the spatial analysis were to produce a visualization, in the form of a point pattern, of the geographical coordinates of the patients' places of residence, evaluate the properties of the spatial process that generates the point pattern, and test the hypothesis about the influence of the environmental situation on the indicator. The existing division into zones with different environmental situations, in general, does not have a statistically significant ($p<0.05$) effect on the ratio of the number of patients with hearing loss to the population of the district. However, statistically significant differences ($p<0.05$) of this indicator were found between areas with a critical and severe environmental situation, as well as between those with a critical and provisionally satisfactory situation. No statistically significant differences were found between the other regions ($p>0.05$).*

Keywords: *spatial analysis, hearing loss and deafness, sensorineural hearing loss, epidemiology of hearing loss, relative incidence, program R, ecological zoning*

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1. INTRODUCTION

Diseases associated with hearing loss and deafness are a serious public health problem [1] and lead to significant costs related to medical care, rehabilitation, and habilitation. Remote technologies can be used to improve the efficiency of medical care [2]. The global rate of disabling hearing loss worldwide increased from 1% of the total population in 1985 to 6.1% of the population by 2018 [3], and for mild and single side hearing loss(SSH) – from 17.2% in 2008 to 18.7% in 2017 [4,5]. A person's place of residence determines the intensity of many factors of hearing disorders and can act as an independent factor or as a confounding variable [6]. Spatial analysis is not often (with rare exceptions [7]) used in otorhinolaryngology. In this work, we studied hearing loss and deafness incidence registered in Chelyabinsk Region, which is known as one of the most environmentally challenged regions in Russia according to the National Environmental Rating of Russia [8](greenpatrol.ru), with a higher population size relative to other regions of the Ural Federal District [9], higher population density, and urbanization.

The goal of the study was a spatial analysis of the incidence of various types of hearing loss (conductive, sensorineural and mixed) in the adult population of Chelyabinsk Region and the dependence of the incidence on the environmental issues at the place of residence.

2. MATERIALS AND METHODS

The material of the research was the depersonalized data of the Regional Hearing Center of the Chelyabinsk Regional Clinical Hospital for the period from 2016 to 2020. The main tasks of the spatial analysis were to visualize the point pattern formed by the geographical coordinates of the places of residence of patients with hearing loss; assess the properties of the spatial process that generates this point pattern; and test the hypothesis about the influence of the environmental situation on the indicator in Chelyabinsk Region.

The main software product applied for solving spatial problems was the R software package, which was used with various libraries for spatial data processing and visualizing (ggplot2, rdal, and others). The data on the territorial division of Chelyabinsk Region (including polygons of municipal districts, districts, roads, etc.) were obtained through the Overpass Turbo service (http://overpass-turbo.eu/) and

exported as GeoJSON files in R. The data on the population of Chelyabinsk Region are obtained from the publications of the Federal State Statistics Service from the website https://chelstat.gks.ru/population [6].

3. THE RESULTS

During the period of 2016-2019, 8,415 people aged 18 years and older applied to surdologists at the Regional Hearing Center. Of all the primary referrals, more than half (57.5%) were patients with bilateral sensorineural hearing loss (H90.3). Regardless of gender, the most common type was sensorineural hearing loss (66.1% cases among women and 76.1% among men), a less common type was conductive hearing loss (21.9% among women, 15.6% among men), and even less common was mixed hearing loss (12% of cases among women, 8.3% among men).

The places of residence of patients who first applied to the regional hearing center were shown on the map as separate blue dots (Fig. 1), which formed a point pattern. The red contours or isometric lines showed areas with the same probable density for the incidence of hearing disorders (the estimate was based on Kernel Density Estimation).

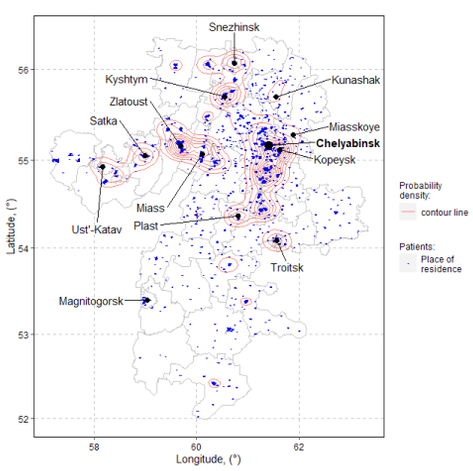

Fig. 1: Evaluation of the probability (probability density) of the appearance of a location on the map (contour lines define areas with an equal probability of the appearance of primary patients with hearing loss)

There are several fairly large areas, with large cities and settlements, where the highest density of cases of primary visits with hearing loss is observed: 1) Ust-Katav, Trekhgorny, Bakal, Satka; 2) Zlatoust, Miass, Chebarkul; 3) Chelyabinsk, Kopeysk, Korkino, Yemanzhelinsk, Krasnogorsky, Yuzhnouralsk, Plast; 4) Troitsk. The intensity of new hearing loss cases in these areas is directly related to the population size.

The risk of new hearing disorders occurrence was presented as the ratio of the number of primary patients with hearing loss to the population of the district, NHLD. The darker the area (Fig. 2), the more intense the risk of the occurrence of new hearing loss cases and initial patient visits to the Regional Hearig Center. The highest values of the indicator were observed in Plastovsky and Chesmensky Districts.

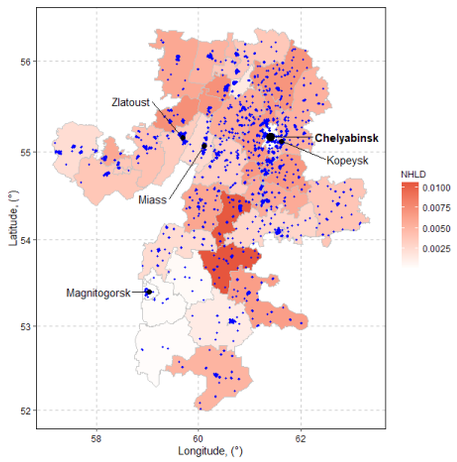

Fig. 2: Intensity of the risk of primary treatment in different districts of the Chelyabinsk region (ratio of the number of primary patients with hearing loss to the population of the district, NHLD)

The testing of the hypotheses about the influence of environmental stress, which has a known spatial form shown on the map, on the point pattern was performed with the environmental zoning of Chelyabinsk Region based on the data published by A. Levit [10]. The following areas were identified in the region: those with a relatively satisfactory environmental situation (on the diagrams, they are marked „Rel. Sat. ES"); with a severe environmental situation („Sev. ES"); with a critical environmental situation („Crit. ES"); with an environmental crisis („E. Crisis") (Fig. 3).

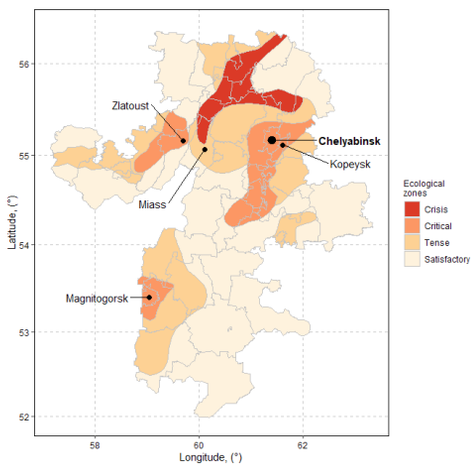

Fig. 3: Ecological map of the Chelyabinsk region (according to A. Levit)

In the area of an environmental crisis, the median (as well as the 1st and 3rd quartiles (Q1; Q3)) of the NHLD indicator was 1.65×10^{-3} (0; 9.01×10^{-3}), in the critical zone: 6.74×10^{-3} (5.81×10^{-5}; 8.82×10^{-3}), in areas with a severe environmental situation: 1.72×10^{-3} (0; 5.08×10^{-3}), and in provisionally satisfactory areas, 1.15×10^{-3} (0; 2.59×10^{-3}).

The hypothesis of equal NHLD in the four ecological zones of Chelyabinsk Region was tested with the Kruskal-Wallis statistical criterion. The null hypothesis was that different samples were taken from the same distribution, or from distributions with the same medians.

The null hypothesis was not refuted by the results of the calculations, the value of the Kruskal-Wallis chi-squared criterion being 6.6803, df = 3, p-value = 0.08282. Therefore, it can be concluded that the existing division into zones with different environmental situations does not have a statistically significant ($p<0.05$) effect on the ratio of hearing loss cases to the population of the zone.

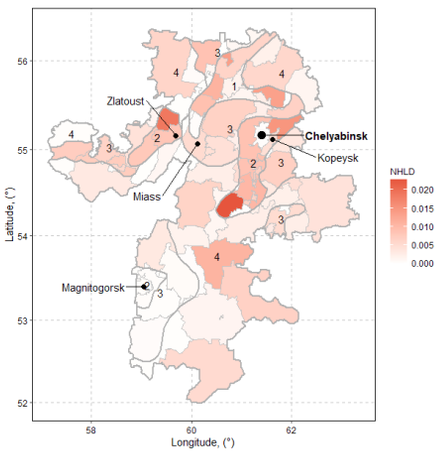

Fig. 4: The ratio of the number of patients with hearing loss to the population in different ecological zones of the administrative districts of the Chelyabinsk region (NHLD indicator). The numbers indicate the ecological zones: 1 - „Crisis", 2 - „ Critical", 3 - „Tense", 4 - „Conditionally satisfactory"

To clarify which environmental zones have statistically significant differences in terms of the indicator, a statistical test was conducted based on the Wilcoxon signed-rank test. The figure shows a chart of scope, or a box plot of the NHLD indicator in areas with different environmental situations and the p-value for pairwise comparisons between individual zones and for all types of zones as a whole. Statistically significant differences ($p<0.05$) of this indicator were found between areas with a critical and severe environmental situation, as well as between those with critical and provisionally satisfactory situation. No statistically significant differences were found between the other regions ($p>0.05$).

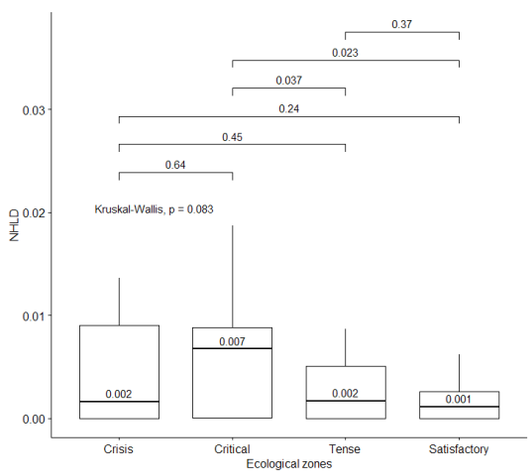

Fig. 5: Diagram of the range of the indicator of the ratio of the number of primary patients with hearing loss to the population of the territory. (Box boundaries are the first and third quartiles (25th and 75th percentiles, respectively); the line in the middle of the box is the median (50th percentile).

At the top of the diagram, horizontal lines connect the groups that are compared in pairs. The number shown on the horizontal lines is the p-value according to the Wilcoxon signed-rank test criterion. The P-level obtained by the Kruskal-Wallis test is 0.083.

4. CONCLUSION

The intensity of new cases of hearing loss and deafness is directly related to the population size in the area. There are several fairly large areas that combine large cities and localities, for which the indicator of probability of primary visits with hearing loss has the highest density. In general, the existing division of Chelyabinsk Region into zones with the different environmental situation does not have a statistically significant ($p<0.05$) effect on the ratio of the number of primary patients with hearing loss to the population of the district (NHLD). However, statistically significant differences ($p<0.05$) of this indicator were found between areas with a critical and severe environmental situation, as well as between those with a critical and provisionally satisfactory situation. No statistically significant differences were found between the other regions ($p>0.05$).

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