

Aim of the study: In this study, we present the results of the interrelation between population density and cancer incidence in the Province of Opole, Poland.

Material and methods: The material included demographic data from the Statistical Office in Opole and oncology information obtained from the Cancer Registry in Opole – both research series encompass the five-year plan (years 2006–2010). A geostatistic analysis was performed using a spatial model (called the conditional autoregressive model). Based on the spatial regression coefficients, the strength of the relationship was measured in male and female populations, respectively. The statistical computations were performed in the Bayesian Inference Using Gibbs Sampling (BUGS) platform based on the so-called Markov Chain Monte Carlo (MCMC) technique.

Results: The data presented in the study indicate that relative risk of cancer is higher within urban than in rural areas; an increase in population density of a thousand people per sq. km results in a 13% increase in risk of cancer among men and 16% increase in this risk for women.

Key words: population density, cancer, spatial modeling, relative risk, interrelation.

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Interrelation between population density and cancer incidence in the province of Opole, Poland

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Introduction

The population density across continents and countries is the effect of centuries-old environmental, economic and cultural processes. Following epidemiological analyses, specialists found that residents of different regions of the world suffer from certain types of malignant tumors at different frequencies [1]. This is the result of genetic, environmental, and infrastructure risk factors [2–4].

Today, the highest population density in the world is in China, in the Macau region (over 20 people per sq km). Analysis of cancer incidence in that region shows that among men the most common cancers are lung (25.2%), liver (16.1%) and stomach cancer (15.6%), whereas among women they are lung (15.6%), breast (15.1%) and stomach cancer (9.8%). Data regarding areas of the lowest population density, which are Australia and Oceania (4 people per sq km), indicate that the most common cancers among men are prostate (31.2%), colorectum (12.8%), and melanoma (10.5%), while among women they are breast (28.1%), colorectum (13.7%), and malignant melanoma (10.0%) [1].

There are other sources indicating that people who live in industrial regions of Asia suffer from colon cancer relatively less frequently, and that among Japanese people stomach cancer is the most often reported type [5]. On the other hand, since the 1970s the incidences of colon cancers, gallbladder, kidney, breast and cervix uterus cancers have increased in Shanghai, and the rates of these malignancies in the city are higher than in rural areas [5]. In terms of migration, Asian people who have moved to the United States of America acquire the same patterns of cancer incidence as Americans [5].

The common risk factors that influence regional differences in cancer incidence rates also include infrastructural causes, i.e. access to medical practices, prevention programs, screening tests, and especially quality of treatment [2]. These therapeutic aspects are increasingly emphasized in contemporary public health issues and they are subjects of various epidemiological analyses. American findings on prostate cancer show that e.g. access to health care can influence the mortality rates due to the disease, which are as high as 10–30% [6].

When considering local determinants of cancer morbidity, one cannot attempt not to consider the impact of civilization-related stress on occurrence of the disease, especially in case of urban areas, where stress seems to be more present. There is a relatively small number of scientific publications available that are focused on this issue (i.e. [7]), possibly due to difficulties in explaining its detrimental effect on health and its relation to cancer. However, the most often measurable was the effect of stress on cancer incidences among Holocaust survivors [8]. The control group in this analysis was the Jewish population, who migrated from Europe to Palestine before the

outbreak of World War II. Following the obtained results, exposure (Holocaust), compared with non-exposure, was associated with a statistically significantly increased risk for all-site cancer, all birth cohorts, and both sexes [8].

In this study, we consider the interrelation between the cancer incidence and population density in the province of Opole at the level of administrative units (Fig. 1).

The aim of the analysis was to estimate a possible statistical impact of the secondary factor, namely population density, on the relative risk of cancer in the region.

Material and methods

The material included demographic data from the Statistical Office in Opole and oncology data obtained from the Cancer Registry in Opole – both research series encompass the five-year plan (years 2006–2010). Within this period, a consecutive downward trend in the number of residents in the region was noticed, both male and female (from 503 969 in 2006 to 497 521 in 2010 for males, and from 537 972 to 531 064 for females). In the discussed five-year time span in the Province of Opole the total 17 890 cancer cases (all cancers combined) were registered as 9079 in the male population, and 8811 in the female population (based on Student's *t*-test for dependent samples, no statistical difference in age of cancer patients is observed between urban and rural areas).

In this study, a geostatistic analysis was conducted using a spatial model, called the conditional autoregressive model [9]. Strength of the relationship between population density and cancer incidence was estimated following

the spatial regression coefficients. All statistical computations were performed in the BUGS platform [10]. Based on the initial “burn-in” 1000 samples and the following 10,000 “production run” cycles of the Gibbs sampler, an equilibrium state of streams of values was established via an examination of within-chain statistics available in the software.

Results

The geographical distribution of average population density in the Province of Opole in the years 2006–2010 is shown in Fig. 2.

In Fig. 2, as expected, evident differences can be observed between urban and rural areas.

The spatial regression coefficients obtained on the basis of data are reported in Table 1.

The data presented in Table 1 indicate that relative risk of cancer (all cancers combined) is higher in urban than in rural areas, i.e. there is a positive and statistically significant correlation between number of residents in the presented area and cancer incidence; an increase in population density of 1000 people per sq. km results in $(\exp(0.00012)^{1000} - 1) * 100\% \approx 13\%$ growth in risk of cancers in men and $(\exp(0.00015)^{1000} - 1) * 100\% \approx 16\%$ increase in this risk in women. Spatial models of relative risk in male and female populations are shown in Figures 3 and 4.

Based on the administrative map (Fig. 1) and thematic maps (Figs. 3 and 4) it can be observed that in the most densely populated centers of the region, such as Ozimek (approx. 2840 people per sq km), Brzeg (2330), Kluczbork



Fig. 1. Administrative map of the Province of Opole (with description of main cities)



Fig. 2. Population density in the Province of Opole (2006–2010)

Table 1. Spatial regression coefficients

Population/Parameter	Regression coeff.	Stand. dev.	Cred. 95% int.	<i>p</i> -value
Males	0.00012	0.00003	(0.00007, 0.00018)	< 0.0001
Females	0.00015	0.00003	(0.00009, 0.00021)	< 0.0001

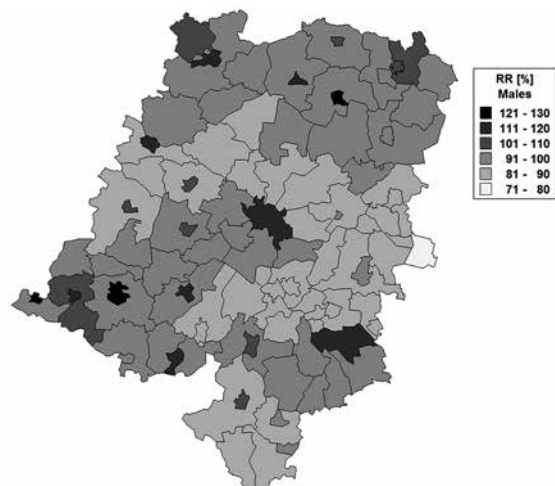


Fig. 3. Spatial model of relative risk (all cancers combined) in males in the Province of Opole (2006–2010)

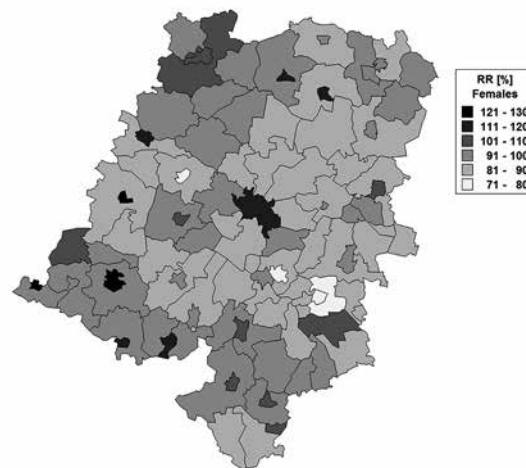


Fig. 4. Spatial model of relative risk (all cancers combined) in females in the Province of Opole (2006–2010)

(2030), and Nysa (1690), the highest incidence rates, both among men and women, were estimated; in some cases those rates exceeded the average cancer incidence level reported in the region being as high as 30%. In two of the biggest cities of the the Province, namely, in Opole and Kędzierzyn-Koźle an increase in cancer risk was observed, as well. Administrative units with the lowest relative risk of cancer were localized in rural areas mainly (compare with Fig. 1).

Discussion

The demographic factor discussed in this paper, namely, population density alone, does not cause the analyzed diseases, yet it can be used as a reliable background for the oncological situation in a given region. It should be noted that the relationship between cancer development and population density was mentioned in the scientific literature several times [11, 12]. It is worth referring to one of the latest findings which relate to the subject [13]. It indicates that there is a strong link between population density and bladder cancer incidence rates, both in men and women. Within urban areas, the risk of bladder cancer was increased by 30% vs. less densely populated regions. In view of the indications described above, real and alleged causes of this epidemiologically diagnosed phenomenon should be investigated.

It appears that broader access to health services in large centers of population and in large cities, and consequently the possibility of performing diagnostic and screening tests, results in increased detection of oncologic diseases; the number of hospitals, outpatient clinics and other health centers equipped with appropriate medical equipment is much higher within urban vs. rural areas, which is why it is easier to diagnose a given disease in an urban region. However, a question arises when approaching a situation in which patients have full access to means of transport and relatively short distances to health care centers, like in Poland, where the most remote villages are generally within a distance of several kilometers away from district towns. Are then population issues the only

premise of observed epidemiological facts? Admittedly, scientific reports do not leave any doubt that environmental degradation in urban areas has a negative influence on cancer registers [14, 15]; on the other hand, in this particular case of Kluczbork, it is hard to determine an exact and significant discrepancy in air quality between the city and surrounding villages. It is possible that we are seeing a manifestation of civilization stress in our health. It is difficult to unequivocally answer the queries stated above; thus the authors of this paper will stop at the confirmed correlation between demography and epidemiology.

In conclusion, from the geostatistical point of view, population density can be considered as a significant secondary predictive factor of cancer risk. Within the studied area, the Province of Opole, Poland, this relationship is proven to exist yet its mechanisms have not been explained, and authors of this paper have suggested co-existence of its elements only.

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