STANOVNIŠTVO, 2022, 60(1), 1-17
Research paper

Submitted: 06 Jun 2022 | Revised: 01 Jul 2022 | Accepted: 04 Jul 2022
https://doi.org/10.2298/STNV2201001L
UDC 519.246.8:[616-036.2:314.117.15-053](497.11)
First Online: 29 Jul 2022

A population-based spatio-temporal analysis of the early COVID-19 dynamic in Serbia

Suzana Lović Obradović [1] **Hamidreza Rabiei-Dastjerdi** [2] **Stefana Matović** [1]

1 Geographical Institute "Jovan Cvijić" SASA, Belgrade, Serbia
2 School of Computer Science and CeADAR, University College Dublin (UCD), Dublin, Ireland

Correspondence
Suzana Lović Obradović, Research Associate, Geographical Institute "Jovan Cvijić" SASA, Belgrade, Serbia.

Email:
s.lovic@gi.sanu.ac.rs

Abstract

The COVID-19 pandemic escalated in almost all parts of the world over a very short period of time. The speed of the spread was determined by the degree of mobility of the population, while the risk of severe illness or death depended on the population's demographic characteristics, population health status, and the capacity of the health system to treat patients. This paper aims to assess spatio-temporal patterns of patients with COVID-19 in Serbia at the early stage and whether these patterns are linked to valid public health measures that were enforced during this period. The study adopted the local Moran's index to identify the spatial grouping of the number of infected at a municipality level and joinpoint regression analysis to identify whether and when statistically significant changes occurred to the number of infected by gender and age groups, and to the number of deaths in the entire population. The results show the polarisation of the spatial grouping of the number of infected. Considering the change in the trend in the number of infected between genders, no significant difference was noticeable. When the age-gender categories of infected were examined, the differences became more significant. In addition, changes in the trend were associated with the tightening or loosening of public health measures.

KEYWORDS

COVID-19, local Moran's index, Joinpoint regression analysis, gender-age differences, Serbia

1 INTRODUCTION

The global COVID-19 pandemic was declared not long after the Chinese Centre for Disease Control and Prevention announced that it had registered a new disease: coronavirus disease 2019 (COVID-19) caused by the novel coronavirus (SARS-CoV-2) (European Centre for Disease Control and Prevention 2020). The trend of the pandemic's spread was conditioned by the geographical proximity of the outbreak area. At the level of individual countries, it was conditioned by the mobility of the population. Characteristics of the population, such as age, gender, and health status, further conditioned pandemic outcomes. The speed of the spread of the virus was controlled by various preventive and restrictive public health measures (lockdown, work from home, schools and kindergartens closure, etc.). Their tightening or loosening followed a change in the number of infected and dead, the number of hospitalised, the number of people on respirators, etc.

The first measures aimed at preventing the spread of the pandemic in Serbia were announced shortly after the country's first case of COVID-19 was identified on 6 March 2020. The Serbian government issued a decision declaring the COVID-19 disease caused by the SARS-CoV-2 virus a contagious disease on 10 March. Five days later, on 15 March, Serbian authorities declared a national state of emergency. The main goal of public health measures was to reduce the number of infected so that the number of patients requiring hospital treatment would not be higher than the available capacity. Some of the measures included the prohibition of gathering in public places indoors, occasional lockdowns, closing shopping malls, cafes, and restaurants, and suspending teaching in educational institutions. The last measure in most cases covered the population under the age of 19. Special prohibition was applied to people aged 65 and over in urban areas and those aged 70 and over in rural areas, for which the measure of complete quarantine was applied. The economically active population aged 20 to 64 had the highest degree of freedom of movement. Many people in this category worked in jobs for which there were no prohibition measures or limited working hours, e.g., food stores, grocery stores, delivery, and certain private companies (Lović Obradović et al. 2021). The measures were tightened or loosened in line with the epidemiological situation at the time of decision-making. The state of emergency was lifted on 6 May 2020 after a decision by the National Assembly.

This paper aims to evaluate the spatial disparities, temporal trends, and significant changes in the COVID-19 pandemic in Serbia, with a particular focus on the differences between the gender and age structure of the infected population in the early stage, from 15 April to 9 June 2020 (56 days). The paper also aims to link these changes to the dynamics of the public health measures adopted to combat COVID-19. The research is based on the assumption that the tightening of measures will cause a decrease in the number of infected and dead, while their easing will cause an increase.

2 LITERATURE REVIEW AND BACKGROUND

The COVID-19 pandemic has caused changes in all spheres of people's lives. Certain studies have focused on changes in the tourist sector (Božović et al. 2021; Lagos et al. 2021) and hospitality (Demirović Bajrami et al. 2021). Some pa-

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pers deal with changes in the education system (Daniel, 2020; Kuleto et al. 2021). Demographers have been researching changes in mortality (Marinković and Galjak 2021a, 2021b; Modig et al. 2021) and migration patterns (Lukić and Predojević-Despić 2021; Podra et al. 2021; Šantić et al. 2021).

Given the relevance of the ongoing COVID-19 pandemic, numerous studies have focused their research on outbreak trends using joinpoint regression analysis (Ajbar et al. 2021; Ashworth et al. 2021; Chaurasia and Singh 2020; Simetin et al. 2021). The particular importance of the results of these studies is that the dates when the statistically significant changes in the trends were identified (decreasing or increasing) were compared with the changes in public health measures that preceded (in a period of two weeks or more), and which could in some way affect those variations.

A study conducted in Saudi Arabia showed that restricting domestic travel did not significantly affect the change in the number of infected people (Ajbar et al. 2021). The exception to this was the partial lifting of lockdown, after which the number of infected increased. The authors further state that in contrast to this, other measures–such as the mandatory wearing of masks, the closure of the public sector, and the closure of schools—had a more significant role in the fight against the pandemic. The results obtained by Siqueira et al. (2020) showed that the lockdown had an impact on the reduction of the mortality rate in Spain, since the decreasing trend was recorded two weeks after the lockdown came into effect. Chaurasia and Singh (2020), who analysed the trend in daily reported confirmed cases of COVID-19 in India, came to different conclusions. They found that the nationwide lockdown did not significantly affect the increasing number of infected cases. Authors further claim that there is no empirical evidence that loosening measures (economic reopening) caused an increase in confirmed cases. Another study conducted in East Texas county showed that after loosening measures and reopening, followed by another reopening, the number of infected increased (Le et al. 2021). However, after that, the number of infected trended downwards, which the authors attribute to people wearing facemasks in business and social settings. Simetin et al. (2021) used joinpoint regression analysis to assess the COVID-19 mortality temporal trend in Croatia. After obtaining the relevant results, the authors compared them with the time of closing and reopening of schools. They conclude that there is no correlation between these two phenomena. Al Hasan et al. (2021) noticed that the proclamation of the state of emergency had different outcomes in different parts of Japan. Fourteen days after the proclamation, a containment trend was recorded in Osaka. At the same time, there was an increasing trend in Tokyo, which authors linked to the previous return of travellers from European and American countries, which were considered hotspots at that time, since those counties had high per capita infection rates.

The relatively few studies in Serbia focus on the demographic characteristic of the infected population and their spatial grouping (Lović Obradović and Matović 2020; Lović Obradović et al. 2021) considering the importance of physical proximity in transmitting the virus. Demographic characteristics of the population are a significant factor in their vulnerability to COVID-19 (Klempić Bogadi 2021; Liu et al. 2020; Naqvi 2020), but the literature dealing with this issue in Serbia is very scarce.

Trends in the number of infected people were not uniform across the entire population, but varied within the different demographic categories. Therefore, identifying the spatial disparities and trend of the number of the infected, particularly the trend among different age and gender categories, is necessary for defining targeted protection measures accordingly.

3 DATA AND METHODS

3.1 STUDY AREA

Serbia is located in the southeastern part of Europe in the centre of the Balkan Peninsula. Nowadays, Serbia is a medium-size developing European country characterised by population decline due to multi-decade negative natural increases and a high emigration rate (Tadić and Manić 2022). According to data from the Statistical Office of the Republic of Serbia (2021), the estimated population in the middle of 2020 was 6,899,126. There were slightly more females (51.3%) than males (48.7%). When it comes to the age structure, the population under 19 made up 19.4% of the total population (male – 20.5%, female – 18.4%), and the cohort aged 20–64 made up 59.5% (male – 60.9%, female – 58.1%), while the population aged 65 and over made up 21.1% (male – 18.6%, female – 23.5%).

3.2 DATA

This study covers the Republic of Serbia's population, not including the population of Kosovo and Metohija, the territory under United Nations Security Council Resolution No. 1244/99. The daily data on the number of infected and dead with COVID-19 (by country) were obtained from the World Health Organization (2020). The data on the age and gender of the infected population in Serbia from 15 April to 9 June 2020, at the state and municipality level, was obtained from the Open Data Portal (2020). For each infected person, data on gender, age, place of residence, and the date when the disease was identified was available. For the paper's purposes, data was grouped into three age groups: 0–19, 20–64, and aged 65 and over, for both male and female groups. Age groups were defined according to the proposed measures of the COVID-19 Infection Disease Crisis Response Team. To gain insight into relative numbers, we computed precise rates, specifically the number of infected people by gender and age (per 100,000 population of the cohort). This is shown in Table 1. The research period was defined based on the availability of data. Namely, daily data on the gender and age structure of the infected is available only for the stated period of 56 days. The age structure and gender of the infected population from 6 March to 13 April are also available, but information on when the case was recorded is not available.

3.3 SPATIAL AUTOCORRELATION ANALYSIS

To assess local variations and statistically significant groupings of the number of infected per 100,000 population of the municipality from 15 April to 9 June, this paper adopted a local indicator of spatial autocorrelation, the local Moran's index (Anselin 1995). The analysis was performed in version 2.5 of ArcGIS Pro (Esri 2020). Outputs of the statistics are the local Moran's index values, *Z*-score, and *p*-value. The local Moran's index ranges from –1, when it shows

https://doi.org/10.2298/STNV2201001L

a highly negative spatial autocorrelation, to 1, which indicates a high positive spatial autocorrelation. *Z*-score and *p*-value determine the statistical significance of spatial grouping (95% confidence level). A high positive *Z*-score indicates the feature belongs to the cluster and a high negative to the outlier. Two types of clusters can be formed: high-high (high values are surrounded by high values) and low-low (low values are surrounded by low values). There can also be two types of outliers: high-low (high values are surrounded by low) and low-high (low values are surrounded by high) (Esri 2022).

The local Moran's index equation (1) is given as:

$$I_i = \frac{x_i - \bar{X}}{S_i^2} \sum_{j=1, j\neq 1}^{n} w_{i,j}(x_j - \bar{X}) \qquad (1)$$

Where x_i is an attribute for feature ***i*** (the number of infected per 100,000 population of a municipality), $\bar{X}$ is the mean of the corresponding attribute, w_{ij} is the spatial weight between features *i* and *j* (we used contiguity edges corners, suitable for polygon feature classes, to define each feature's neighbourhood), and

$$S_i^2 = \frac{\sum_{j=1, j\neq 1}^{n} (x_j - \bar{X})^2}{n-1} \qquad (2)$$

In equation 2, *n* represents the total number of units, i.e., municipalities (Mitchell 2015).

3.4 TEMPORAL TREND

The change in the trend of the number of infected (total population and by gender-age groups) and the number of deaths over a specific time period, as well as the change percentage, were evaluated using Joinpoint Trend Analysis Software, Version 4.9.0.0 (Statistical Methodology and Applications Branch, Surveillance Research Program, National Cancer Institute 2021). This software is open-source and was designed and developed by Kim et al. (2000). The software is primarily designed to analyse trends in cancer mortality rates, but it can also be used to study the temporal evolution of various phenomena. The main task of the software's algorithm is to assess changes in recent trends, i.e., whether a multi-segment line better describes a trend than a straight line does (Rafiemanesh 2015). The trend can increase if the output value is positive or decrease if the output value is negative, and it's defined by the slope direction. A statistically significant change in the slope is marked by a joinpoint. The change between two successive joinpoints is measured using the daily percentage change (DPC), since the daily interval is in the time-series data. Other interval options for the time range, such as monthly, annual, and further, can be used.

We performed a logarithmic transformation to compare trends among different age groups (assuming the different values of the DPC for different age categories) and constant variance (homoscedasticity) as the option that assumes the random error in the regression model. The DPC was calculated using the natural log-linear model with a 95% confidence interval (CI). Considering that the number of data sets is 56, we set in advance five as the maximum number of joinpoints, according to the algorithmic recommendations. We then used the Monte Carlo permutation test, proposed by Kim et al. (2000), to find the line that best fits each segment. The selected statistic determines the final number of joinpoints. The number of permutations was set to 4,499 (as the minimum recommended and the default number of permutations), and the overall significance level was 0.05.

4 RESULTS

In Serbia, 7,142 people were infected and 165 died in the analysed period, from 15 April to 9 June 2020. The highest number of infected in one day (445) was recorded on 17 April, and the highest number of deaths (9) on 15 April.

The gender-age structure of the infected population and the specific rate of infection by age and gender (per 100,000 inhabitants of age group) are shown in Table 1. There is a slight difference between the number of infected females (3,700) and males (3,422). The lowest number of the infected total population is in the cohort under the age of 19 (495, male – 249 and female – 246). The age-specific rate shows that for every 100,000 inhabitants aged 0–19, 36.9 inhabitants of the same age group are infected. The largest number of infected is in cohort 20–64: 5,009 (male – 2,496, female – 2,603). Given that this is the most populous cohort in the population, the value of the age-specific rate is 124.3. Out of a total of 1,456,175 people aged 65 and over, 1,558 inhabitants were infected in the observed period (the age-specific rate is 103.5).

The value of Moran's I (as a global indicator of spatial autocorrelation) of 0.31 suggests positive spatial autocorrelation, indi-

Table 1 Age and gender structure of population infected with COVID-19

Gender	0–19 Number of infected	0–19 Population	0–19 Specific rate
Male	249	690,527	36.1
Female	246	650,567	37.8
Total	495	1,341,094	36.9
Gender	**20–64 Number of infected**	**20–64 Population**	**20–64 Specific rate**
Male	2,496	2,045,602	122
Female	2,603	2,056,255	126.6
Total	5,099	4,101,857	124.3
Gender	**65+ Number of infected**	**65+ Population**	**65+ Specific rate**
Male	697	624,177	111.7
Female	851	831,998	102.3
Total	1,548	1,456,175	106.3
Gender	**Total number of infected**	**Total population**	**Total specific rate**
Male	3,442	3,360,306	102.4
Female	3,700	3,538,820	104.6
Total	7,142	6,899,126	103.5

Note: The data in the table is calculated based on information obtained from Open Data Portal (2020)

https://doi.org/10.2298/STNV2201001L

cating the clustered nature of the number of infected per 100,000 population in the municipality. The results of the local Moran analysis of the number of infected per 100,000 population of the municipality from 15 April to 9 June 2020 indicate the spatial grouping of values (Figure 1). A distinct polarisation in the number of infected

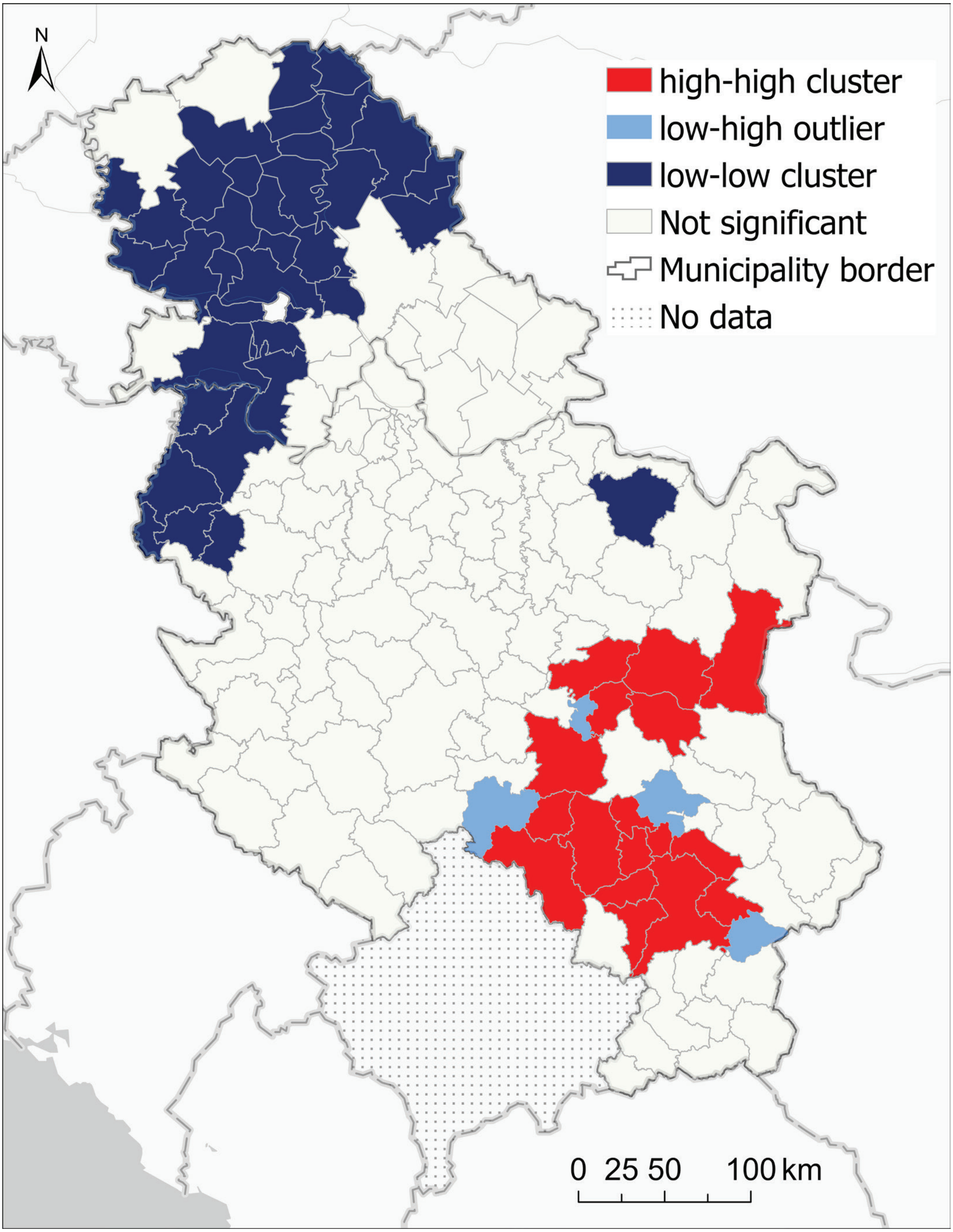

Figure 1 Local Moran cluster and outlier map of the number of infected per 100,000 population of a municipality.

between the north and the south of the country is evident. In Figure 1, gray indicates municipalities with low numbers of infected per 100,000 population municipality, and the surrounding municipalities also have low values. Therefore, low-low clusters are formed and can be noticed in the northern and north-western parts of the country. The black area specifies high-high clusters. Municipalities characterised by high numbers of infected per 100,000 population and their neighbours that also have high values are located in the southeastern part of Serbia. An outlier low-high area (vertical lines) is detected on the periphery of the high-high cluster.

The joinpoint regression analysis of daily new cases (Figure 2) revealed shifts in decreasing and increasing trends. One joinpoint is identified, and a statistically significant change occurred on the 48th day (1 June) from the beginning of the study period. The trend of decrease (48 days), with DPC = –5.21, was represented for a much longer period than the period of increase (six days), with a somewhat sharper slope (DPC = 16.11).

When it comes to temporal trends of new deaths from COVID-19, the joinpoint regression analysis suggests that there were two statistically significant changes, i.e., two joinpoints. A slight increase, with DPC = 0.94, can be seen from 15–30 April (16 days), following the period of decrease with two sharp (DPC = –7.49) and slight decrease (DPC = –0.17) slopes. The second joinpoint is on the 40th day (24 May). Unlike the previous parameter (new cases), the decrease period occurred much earlier time (Figure 3).

The joinpoint regression analysis results indicate that there is a different trend in the number of infected people according to selected age groups (Figure 4). In the youngest cohort, under the age of 19, the results show two joinpoints, when a statistically significant change in the trend of the number of infected occurred. The decreasing trend lasted 44 days (28 May). Within this period, one long-term decreasing trend was recorded (from 15 April to 25 May) with DPC = –4.33, while the second short-term decreasing trend lasted for the next three days (DPC = –37.37). From the 44th day to the end of the period, an increasing trend in the number of infected is noticeable, with DPC = 20.83. In the working-age (20–64) cohort, one joinpoint was detected on the 47th day, i.e., 31 May. Until that date, a decreasing trend (DPC =

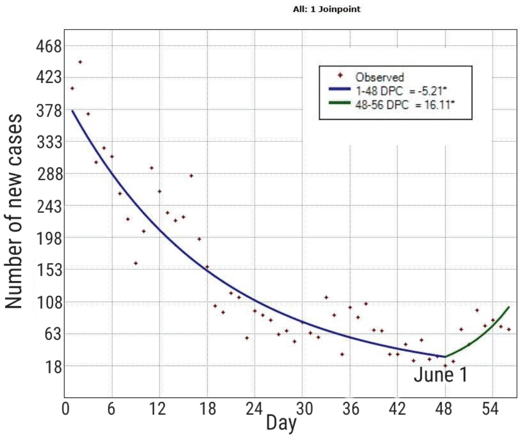

Figure 2 Joinpoint regression analysis of daily new cases.

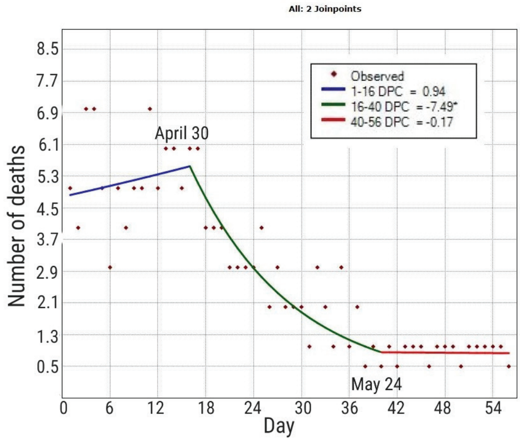

Figure 3 Joinpoint regression analysis of daily new deaths.

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–4.91) was detected, followed by an increasing trend, with DPC = 13.78. Two joinpoints were also detected in the population aged 65 and over, the first on the 47th day (31 May) and the second on the 50th day (3 June). A decreasing trend characterises the first and third segments, with DPC = –6.62 and DPC = –14.83, respectively. Between these two periods there are three days of increase with a very sharp slope (DPC = 61.79).

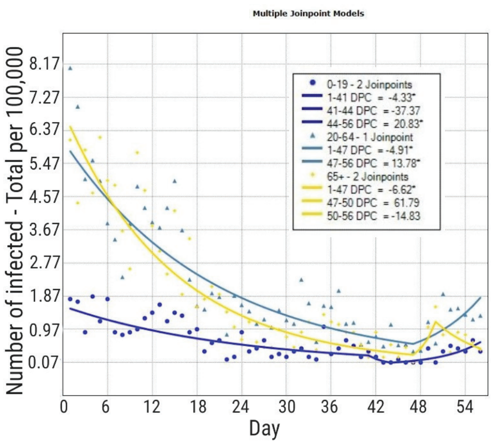

Figure 4 Joinpoint regression analysis of the total population infected with COVID-19 by age group.

To assess whether there are certain disparities within the cohort, differences in gender trends among three cohorts were analysed. Figure 5 displays the decreasing trend of infected females aged 0–19 years until the 46th day (30 May) of the studied period. DPC has a value of –3.71. In the following period, there was an increase in the number of infected females of the specified age, so an increase with APC = 9.19 is noticed. Regarding the trend of infected women aged 20 to 64, one joinpoint is indicated, which means the trend was segmented into two periods. The first decreasing period (the first 48 days, until 1 June) with DPC = –4.58 lasted longer. Then, a shorter increasing period with DPC = 13.53 occurred. As for the oldest cohort of females aged 65 and over, one joinpoint is identified. The difference is that this cohort shows a decreasing trend throughout the period, but intensity varied. After a slightly sharper decrease until the 29th day with DPC = –8.60, a milder decline (DPC = –0.75) followed over the next 27 days. The statistically significant change in trend happened on the 29th day (13 May).

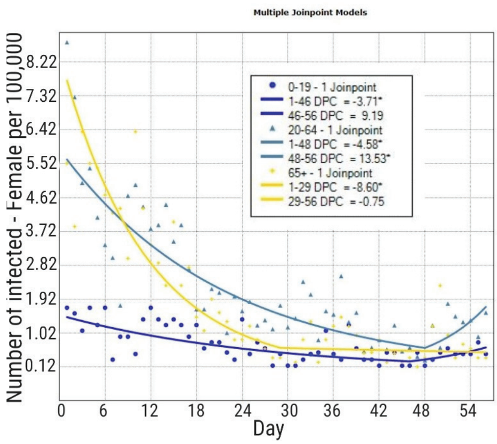

Figure 5 Joinpoint regression analysis of the female population infected with COVID-19 by age groups.

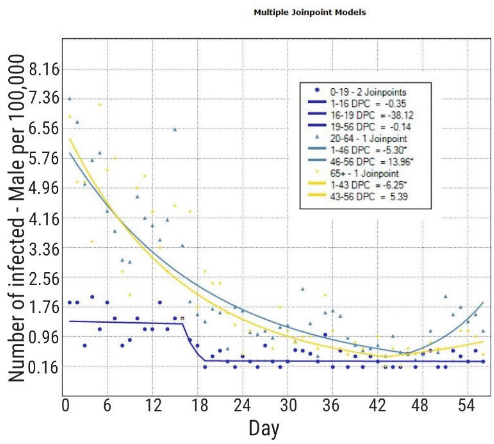

Figure 6 Joinpoint regression analysis of the male population infected with COVID-19 by age groups.

The trend in infected males aged 0–19 showed an uneven decreasing trend in the studied period. Joinpoint regression analysis identified two joinpoints, which means that there are three segments with different characteristics. Mild slopes characterise the first and third segments; DPC in the first segment (up to the 16th day, 30 April) is –0.35, while in the second (from the 19th to the 56th day, 3 May to 9 June), it's –0.14. The sharpest slope was recorded in the three days from the 16th to the 19th day (30 April to 3 May), when the DPC was –38.12. In a significantly longer number of days during the studied period (first 46 days), a decreasing trend was noticed in the cohort aged 20–64, DPC = –5.30. After that detected joinpoint, an increasing trend followed (DPC = 13.96). According to the results of joinpoint regression analysis, infections within the male population aged 65 and over showed a decreasing trend until the 47th day (31 May) of the period (DPC = –6.25). This was followed by an increasing trend, with DPC = 5.39 (Figure 6).

5 DISCUSSION

This study investigates the spatial disparities and temporal trend of the COVID-19 pandemic in Serbia based on the number of infected people and their demographic characteristics (age and gender) in the early period, from 15 April to 9 June 2020, using the local Moran's index and joinpoint regression analysis. In addition, changes in trends are considered in the context of the public health measures enforced at that time. The main findings are summarised as follows.

The number of infected people in the early phase of the COVID-19 pandemic in Serbia was not uniform, but is characterised by distinct spatial differences. Municipalities in the south and southeast of Serbia are characterised by higher relative values of infections than municipalities in the north. In this regard, measures to combat the spread of the pandemic should not be uniform at the national level. In favour of this is the claim by Šantić and Antić (2020), who state that the nationwide lockdown did not take into account the spatial disparities in the number of infected and dead at lower territorial levels.

The change in the trend in the total number of infected was recorded on 1 June, when a decreasing trend replaced the increasing one. Namely, starting on 27 April 2020, decisions to relax the measures took force. One of the first measures was the reopening of cafes (with working hours until 10 pm and with 50% capacity). This was followed by the reopening of hairdressers, beauty salons, and gyms (4 May). The reopening of shopping centres and restarting of normal public transport in the most populated cities (Belgrade and Niš) happened on 11 May, the same day when kindergartens, schools, and extended school stays started working again. Entering Serbia without a polymerase chain reaction (PCR) test or quarantine was possible from 22 May. All these weakened measures have led to an increase in social interaction between people and their close contacts. Studies conducted by Siqueira et al. (2020) and Le et al. (2021) have also confirmed the impact of easing measures on increasing the number of infected people, while Chaurasia and Singh (2020), Ajbar et al. (2021), and Simetin et al. (2021) found the opposite; the easing of measures did not significantly affect the change in the number of infected people. Previous research has shown that interpersonal distance, which is violated in this case, was very important for reducing the number of infected in the early phase of the COVID-19 pandemic (Andersen 2020).

Regarding the trend of the number of deaths, a statistically significant change occurred on 30 April, when a decreasing one replaced the increasing trend in the num-

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ber of deaths. The maximum number of deaths in one day was nine, recorded at the beginning of the observed period. In the following period, that number varied from zero to six. The trend in the number of deaths did not follow the change in the trend of the number of infected.

The differences in the number of infected people between the genders are insignificant, although some studies indicate significant differences in gender vulnerability (Betron et al. 2020; Capuano 2020; Kim et al. 2021). The differences between the age groups are more pronounced. In a study, Lović Obradović et al. (2021) found slightly more infected women than men in the first two months of the pandemic in Serbia (from 6 March to 6 May, 2020). The results also showed a marked difference in the number of infected among different age groups in the same period.

Concerning the trend of the number of infected by age groups, cohorts 0–19 and 20–64 recorded a decreasing trend until the end of May, and then an increasing period emerged, while the oldest cohort, aged 65 and over, after decreasing and increasing, recorded a decreasing trend at the end of the observed period. Namely, measures aimed at combating the spread of the pandemic were largely targeted at the oldest population, given the fact that early research indicated higher vulnerability and higher mortality rates among elderly people (Naqvi 2020). Another reason is that the majority of people aged 65 and over are retired. Therefore, their degree of mobility is reduced to a minimum. Apart from the fact that this cohort is the oldest, they also might have a higher degree of self-discipline. When it comes to the trend of the number of infected among the youngest population, an increase was recorded on 28 May, 17 days after kindergartens, schools, and extended school stays reopened. Given that the incubation period of the virus is 14 days, this increase may be related to the relaxation of this measure. However, the results do not match the findings for Croatia, where Simetin et al. (2021) found no correlation between schools' dynamics and the number of infected. Despite research showing that children have been shown to suffer from COVID-19 to a lesser extent (Lee et al. 2020), the results of a survey conducted in Serbia in April 2020 showed that respondents believe that it was necessary to close kindergartens and schools to prevent further transmission of the virus, which would endanger the health of the elderly population (Cvetković et al. 2020). The 20–64 cohort, on the other hand, had the highest degree of freedom of movement during the state of emergency, but also after its termination and the loosening of measures. And while the "work from home" rule was applied to a large number of industries, certain occupations required going to work every day. In some companies (e.g., banks), the number of workers was in line with the size of the company's premises (limits on the number of employees based on the size of the space in which they work). On the other hand, many companies and stores worked at full capacity. Earlier research (Lović Obradović et al. 2021) showed that this cohort had the largest share in the number of infected in the first two months (this period broadly encompassed the duration of the state of emergency) of the pandemic in Serbia, from 6 March to 6 May (72.98%), and that more intensified social interaction resulted from more contacts.

By examining the trend between the genders within the same cohorts, it can be concluded that certain overlaps and differences in trends are presented. In females aged 0–19 and 20–64, the reversal of the decreasing trend is noticeable, at the end of May and the beginning of June, respectively. The oldest cohort recorded a varying intensity of decline across the entire observed period. The youngest cohort of males recorded a decrease in the number of infected during the whole study period, while in the other two cohorts (20–64 and 65 and over), the trend of increase since the end of May is noticeable. Thus, the trend of infected women aged 0–19 and men aged 65 and over followed a similar trend. Also, there is a similarity between the trends in terms of the number of infected women and men aged 20–64. Namely, public health measures were targeted at certain age categories rather than genders.

6 CONCLUSION

This study provides a comprehensive assessment of the spatial inequalities and the trend in the number of infected in the early phase of the COVID-19 pandemic in Serbia by gender and age. This study shows the importance of using spatial analyses and joinpoint regression analysis in identifying trends and significant changes (joinpoints) and quantifying these changes. Our findings highlighted that the spatial distribution and the trend in the total number of infected in the early phase were not uniform. Comparing the trends with the measures that preceded them, our results suggest that the number of COVID-19 patients varied according to the tightening or loosening of public health measures. The increasing trend was noticeable during and shortly after the lifting of the state of emergency. In addition, the study has revealed the unequal spatial distribution of the number of infected, which indicates that it was necessary to determine targeted public health measures at the lower territorial (municipality) level. More precisely, it is necessary to intensify them in areas with a higher number of infected and reduce them in areas with a smaller number of infected.

Using the available data, a deeper demographic analysis was performed in this paper, the results of which indicated different temporal dynamics of the number of infected among different age-gender categories. Evaluating changes in the trends of the number of infections or deaths according to these groups can be a guideline towards formulating targeted prevention measures aimed at groups with an increasing trend. At the same time, measures can be loosened in groups with a decreasing trend. Therefore, these findings can provide valuable information to decision-makers and public health policymakers as a guideline for future targeted measures to prevent or mitigate the spread of the COVID-19 pandemic. In that case, other social systems would be allowed to function undisturbed.

6.1 LIMITATION AND FUTURE RESEARCH

Data on the COVID-19 pandemic in Serbia is updated daily; data on the confirmed cases, deaths, mortality ratio, total number of tested people, people tested in the past 24 hours, cases confirmed in the past 24 hours, deaths in the past 24 hours, hospitalised, and patients on ventilators forms part of the daily report. This data refers to the territory of Serbia. More detailed daily data containing demographic (gender and age) and spatial (place of residence) characteristics of the population are available for a limited period. Therefore, our research was limited to a shorter period, during which we were able to detect sta-

https://doi.org/10.2298/STNV2201001L

tistically significant changes in age-gender specific data. In that sense, the results obtained in this study are an incentive to make data on the demographic, spatial, and other relevant characteristics of the population who have contracted or died from COVID-19 in Serbia publicly available to the scientific community.

Future research will analyse data from a longer period of time to link certain events to changes in trends in the later period, thus indicating in which direction public health policies should aim. Considering that the identification of spatial patterns and causes of spread is very important when studying infectious diseases (Lović Obradović et al. 2020), future research would be supplemented using spatial analysis, provided that information on location is available. Therefore, information at the local level would be obtained, which would directly aid the creation of targeted public health policies.

ACKNOWLEDGMENT

Hamidreza Rabiei-Dastjerdi is a Marie Skłodowska-Curie Career-FIT Fellow at the UCD School of Computer Science and CeADAR (Ireland's National Centre for Applied Data Ana-lytics & AI). Career-FIT has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No. 713654.

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How to cite: Lović Obradović, S., Rabiei-Dastjerdi, H., & Matović, S. (2022). A population-based spatio-temporal analysis of early COVID-19 dynamic in Serbia. *Stanovništvo*, 60(1), 1–17. https://doi.org/10.2298/STNV2201001L

Prostorno-vremenska analiza dinamike pandemije COVID-19 u ranoj fazi u Srbiji na osnovu polno-starosne strukture obolelog stanovništva

Pandemija COVID-19 eskalirala je u gotovo svim krajevima sveta u veoma kratkom periodu. Brzina širenja pandemije bila je determinisana stepenom mobilnosti stanovništva, a rizik od težine oboljenja i smrtnosti bio je uslovljen demografskim karakteristikama i zdravstvenim statusom stanovništva, kao i kapacitetima zdravstvenog sistema za lečenja pacijenata.

Ovaj rad ima cilj da proceni prostorno-vremenske obrasce stanovništva obolelog od bolesti COVID-19, prema polnoj i starosnoj strukturi, u Srbiji u ranoj fazi, kao i to da li su ti obrasci povezani sa merama javnog zdravlja koje su bile na snazi u tom periodu. S ciljem utvrđivanja lokalnih varijacija i statistički značajnog prostornog grupisanja broja obolelih na 100.000 stanovnika opštine u periodu od 15. aprila do 9. juna, korišćen je lokalni indikator prostorne autokorelacije — Lokalni Moran indeks. Analiza statistički značajne promene trenda broja obolelih (u ukupnom stanovništvu i na osnovu polno-starosne strukture), kao i broja umrlih u istom periodu, procenjeni su pomoću Joinpoint softvera za analizu trenda. Takođe, identifikovan je trenutak kada se statistički značajna promena u trendu dogodila i kvantifikovana je u procentima.

Rezultati su pokazali da postoji izrazita polarizacija prostornog grupisanja broja obolelih od bolesti COVID-19 u ranoj fazi. Tako, primetno je prostorno grupisanje opština sa višim relativnim vrednostima broja obolelih na jugu i jugoistoku, dok se klaster opština sa nižim vrednostima zapaža na severu Srbije. Promena u trendu broja obolelih, u smislu zamene opadajućeg trenda rastućim, usledila je nakon odluke o popuštanju mera (ponovno otvaranje kafića, restorana, frizerskih salona, teretana, tržnih centara itd.), što je uslovilo povećanu interakciju među stanovništvom. Kada je u pitanju promena trenda broja obolelih među polovima, nisu identifikovane značajne razlike. Međutim, prilikom istraživanja promena trenda prema starosnoj strukturi obolelog stanovništva, razlike su izraženije. Rastući trend broja obolelih starosne grupe do 19 godina usledio je nešto više od dve nedelje nakon ponovnog otvaranja vrtića, osnovnih i srednjih škola, kao i produženog boravka. Sličan trend zabeležen je i kod stanovništva starosti od 20 do 64 godina. Kohorta radno sposobnog stanovništva imala je najveći stepen slobode kretanja za vreme vanrednog stanja, ali i nakon njegovog ukidanja (6. maj). Kod stanovništva starijeg od 65 godina primetna je smena opadajućeg, rastućeg i, na kraju analiziranog perioda, ponovo opadajućeg trenda. Dobijeni nalazi mogu pružiti značajne informacije donosiocima odluka i kreatorima politike javnog zdravlja i poslužiti kao smernica za buduće ciljane mere ka određenim područjima i starosnim kategorijama stanovništva pri sprečavanju ili ublažavanju širenja pandemije COVID-19.

Ključne reči:

COVID-19, Local Moran Indeks, Joinpoint regresiona analiza, polno-starosne razlike, Srbija