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THE IMPACT OF THE COVID-19 PANDEMIC ON VACCINATION COVERAGE WITH THE MMR VACCINE

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Abstract. Introduction. *Rubella is a viral disease caused by the rubella virus. Together with measles and varicella, it belongs to the group of febrile rashes. Although the clinical course is mild in both children and adults, infection during pregnancy can lead to serious congenital malformations in the fetus. The consequences of such an infection can be blindness, deafness, heart defects in newborns, but also stillbirths. Vaccination against rubella is crucial in medicine and is important for controlling and eradicating the disease. The vaccine mandatorily administered to children in the Republic of Serbia according to the vaccination calendar is the MMR vaccine. The MMR vaccine is a live virus vaccine that is administered to infants after the age of one, i.e., in the second year of life. The booster vaccination is given in the seventh year of life before entering elementary school. Regular vaccinations against this disease are carried out worldwide. This research* ***aimed*** *to analyze the impact of the COVID-19 pandemic on the rubella vaccination rate by following trends in immunization before, during, and after the pandemic.* ***Research Methodology.*** *The research is conducted by analyzing data from official health sources and the immunization database from health institutions and institutions in the period 2014 - 2024 for the territory of the Šumadija District. Descriptive statistics were applied to analyze annual vaccination rates and comparative analysis before, during, and after the Coronavirus pandemic.* ***Results and Discussion.*** *The COVID-19 pandemic led to a different organization in the functioning of the health system, especially primary health care. All of this affected the coverage of vaccinations against infectious diseases, which are legally mandatory according to the vaccination calendar in our country. The analysis of statistically processed data showed a significant drop in the MMR vaccination rate during the COVID-19 pandemic. Before the pandemic, vaccination coverage in the territory of Šumadija District was more than 95%, so immunization with the MMR vaccine was successfully carried out. During and immediately after the Coronavirus pandemic, vaccination coverage was drastically reduced, and it was observed that the COVID-19 pandemic harmed the mandatory vaccination that is applied in our country.* ***Conclusion.*** *It is important to implement a strategy for compensating for missed vaccines through population education and strengthening immunization systems and programs to increase collective immunity and reduce the possibility of rubella epidemics.*

Keywords: *rubella, congenital malformations, MMR vaccine, COVID-19, collective immunity*

1. INTRODUCTION

Rubella is a viral infection classified among the rash fevers. It occurs in both acute and congenital forms. Although the acute form most often presents as a mild illness with a favourable outcome, a short course, and a poorly manifested clinical stage, it carries extremely high epidemiological significance. Congenital rubella is a severe, chronic disease that can cause fetal damage when the mother acquires an acute infection during pregnancy. Notably, infection during pregnancy can result in congenital rubella syndrome (CRS), which may lead to severe fetal malformations and chronic complications, including central nervous system disorders, hearing and vision impairment, and cardiac anomalies [1]. These consequences place rubella among the leading infectious causes of congenital anomalies worldwide [2]. This aspect makes rubella not only a paediatric and infectious disease concern, but also one of the most important issues in perinatal medicine and reproductive health.

The rubella virus belongs to the family *Togaviridae* and the genus *Rubivirus*. Its morphology and pathogenetic mechanisms form the basis for understanding the disease's clinical manifestations and significance. Although it is an RNA virus that in most cases causes a mild infection, especially in children, its teratogenic properties make it one of the most dangerous agents during pregnancy [3]. Infection in a pregnant woman can result in transplacental transmission of the virus and the development of congenital rubella syndrome (CRS), which can have severe and often lifelong consequences for the fetus, and may sometimes be fatal [4].

The pathogenesis of the infection is linked to the virus's ability, after initial replication in the epithelial cells of the respiratory tract and lymphoid tissues, to spread through the bloodstream and penetrate target organs. Numerous seroepidemiological studies indicate

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that a significant proportion of infections are asymptomatic, especially in children, which further complicates disease control and enables silent transmission within the population [5].

The specificity of the virus lies in the fact that, although it does not exhibit a pronounced cytotoxic effect, it disrupts the normal function and development of cells, particularly during organogenesis, resulting in multiple types of fetal damage – from neurological disorders and hearing impairment to cardiovascular and ophthalmological malformations [6].

Diagnosis of rubella is now based on serological evidence of specific IgM and IgG antibodies (haemagglutination inhibition test (HI-Christ's test), neutralisation test, immunofluorescence test, and complement fixation test), which distinguishes between acute infection and acquired immunity [7, 8]. In addition to serology, in some cases of congenital disease, the virus can be isolated from various body fluids and tissues. In addition to serology, in some cases of congenital infection, the virus can be isolated from various body fluids and tissues, confirming its persistence in the early postnatal period. Such findings are important not only for clinical diagnostics but also for epidemiological monitoring and control of disease spread.

There is no specific antiviral therapy for rubella, and in most cases, the disease does not require special treatment. In cases of more severe complications involving the central nervous system, symptomatic measures and corticosteroids are used. At the same time, certain congenital anomalies, such as cataracts, glaucoma, or some heart defects, can be corrected surgically. However, many damages caused by intrauterine infection, such as deafness, visual impairment, or speech disorders, remain permanent and require long-term rehabilitation [9]. The absence of effective therapy and the severity of the consequences of congenital rubella make prevention through vaccination a key challenge and priority in primary health care.

Infection with the rubella virus is accompanied by strong and long-lasting, usually lifelong, immunity. Reinfections are possible in 2–5% of cases. Global experience confirms that only systematic and comprehensive immunisation can achieve long-term protection of the population and prevent new cases of congenital rubella [10].

The MMR vaccine is a live attenuated combination vaccine containing weakened strains of measles, mumps, and rubella viruses, produced by repeated passage of the viruses in cell cultures to reduce virulence while maintaining immunogenicity. Unlike inactivated vaccines, which contain killed microorganisms or their components, the MMR vaccine induces a strong and long-lasting humoral and cellular immune response, similar to that acquired through natural infection [11].

In addition to general contraindications for immunisation, there are specific contraindications for the MMR vaccine. The MMR vaccine must not be administered to individuals with severe immunodeficiency due to malignant disease, antimetabolite therapy, high-dose corticosteroid treatment, alkylating agents, radiation therapy, or other conditions associated with significant immunosuppression. Pregnancy is also a contraindication for the MMR ccine, as it is a live attenuated vaccine [12, 13].

Pregnancy is an absolute contraindication for MMR vaccination due to the theoretical risk of transplacental transmission of attenuated viruses to the fetus. Therefore, it is recommended that women avoid pregnancy for at least four weeks after vaccination. If the vaccine is administered during pregnancy, or if the woman becomes pregnant shortly after vaccination, this alone does not indicate a need for termination of pregnancy, but requires appropriate counselling and monitoring.

Administration of the MMR vaccine is also delayed in individuals who have recently received blood, plasma, or immunoglobulin preparations, because passively transferred antibodies may interfere with the development of an adequate immune response to the vaccine [14]. In individuals with a history of a severe allergic reaction (anaphylaxis) to a previous dose of the MMR vaccine or to any of its components, including gelatin or neomycin, further administration of the vaccine is contraindicated.

Despite the rubella vaccine being part of routine immunisation programmes for decades, immunisation coverage varies between countries and regions, resulting in different levels of protection within the population [15]. These differences necessitate constant monitoring of coverage, analysis of epidemiological trends, and timely recognition of potential risks for the emergence of epidemic outbreaks.

Before the introduction of immunisation in European countries, rubella persisted in an endemo-epidemic pattern, with cyclical increases in incidence every three to five years. Thanks to vaccination, rubella has been eliminated in the USA since 2002 and across the entire continent since 2009 [16].

Between 2013 and 2015, the number of reported rubella cases in Serbia ranged from two to eleven. Ten years earlier, there were many more cases, over three hundred. At the same time, the frequency of this infection at the time of the introduction of the rubella vaccine into the mandatory vaccination programme can only be speculated [15]. For such a mild disease, which can often be asymptomatic and go unnoticed, the only way to assess its prevalence is to examine the state of immunity, both in the past and today. The most important goal is to reduce the number of people affected by this disease, and achieving this certainly requires high coverage of immunisation with the MMR vaccine. The trend of refusing MMR vaccination may jeopardise the progress made [17, 18]. It is considered that, in addition to routine immunisation of children, it is necessary to conduct campaign immunisation of adolescents and adults of both sexes who were not immunised in childhood.

In Serbia, vaccination against rubella has been mandatory since 1993, when the trivalent MMR vaccine was introduced. Three years later, revaccination was introduced, and since 2006, it has been administered before starting school [15].

For all these reasons, rubella remains an infection of exceptional public health importance. Monitoring immunisation, analysing vaccination coverage, and timely detection of seronegative individuals of childbearing age are key tools in the prevention and elimination of the disease [19].

Pregnant women who had been exposed to patients were given ready-made antibodies, but this immunoglobulin protection did not yield convincing results. The experience with vaccinating only girls was also disappointing, as the virus continued to circulate in the population. The victims then became pregnant women who were not vaccinated due to contraindications, as well as some, albeit rare, individuals in whom the vaccine did not provide a satisfactory level of protection. In conditions of high collective immunity, such individuals would have no one from whom to contract the infection, but leaving the male population unprotected exposed them to significant risk. Therefore, only vaccinating all children makes the environment epidemiologically safe.

Riding the wave of efforts to combat measles, significant progress is also expected in the suppression and elimination of rubella. The combined vaccine enables many related activities to be carried out simultaneously. The ambitious adoption of the WHO Global Strategic Plan for Measles and Rubella in 2012 did not result in the expected "transition time" in autumn 2017, and the planned final goal was unlikely to be achieved by 2020 [20].

This paper aims to analyse and compare the coverage of mandatory rubella vaccination, specifically the use of the MMR vaccine, in the Šumadija District. The focus is on assessing changes in immunisation trends across three periods: before the onset of the COVID-19 pandemic (2014–2018), during the COVID-19 pandemic (2019–2020), and after the pandemic (2021–2022).

2. Research Methodology

The descriptive method was used in this research. The analysis is based on data from the annual immunisation reports for the territory of the Šumadija District, prepared by the Kragujevac Institute for Public Health, as well as on official statistics published by the Institute for Public Health of Serbia "Dr Milan Jovanović Batut" [21]. Standard statistical procedures were applied to data processing using SPSS version 23.0 (Statistical Package for the Social Sciences, SPSS Inc., Chicago, IL, USA). A p-value < 0.05 was considered statistically significant. The results are presented in tables and graphs to clearly show the trends and differences in vaccination coverage over the observed time intervals.

3. Results and Discussion

Based on the data in Figure 1, the highest number of people vaccinated with the MMR vaccine in the second year of life was recorded in the municipalities of Knić and Lapovo, where the vaccination rate was 100.00%. This was followed by the municipalities of Aranđelovac, Batočina, and Kragujevac, each with a vaccination rate of 95.00%. In Kragujevac, the largest municipality in the district, vaccination coverage was 95%, which meets the recommendations and target values set by the Ministry of Health. The lowest vaccination rates were observed in the municipalities of Rača (92.00%) and Topola (90.00%).

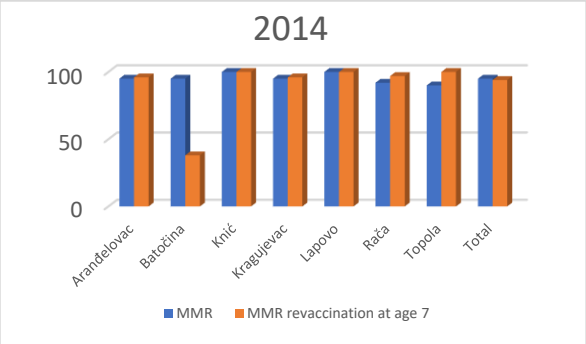

Figure 1. Graphic representation of immunization against rubella in the Šumadija District in the period of 01.01.2014 - 31.12.2014.

Considering the total number of people planned for MMR vaccination (2,486) and the number actually vaccinated (2,353), the vaccination rate in the Šumadija District for 2014 was 95.00%. These results indicate successful implementation of the immunisation programme, but also reveal minor differences between municipalities that require further analysis of potential factors, such as the availability of health services, parental education levels, and the efficiency of local immunisation teams.

Also, the table shows that revaccination with the MMR vaccine was conducted in the Šumadija District at ages 7 and 12. For revaccination at age 7, the total number planned for vaccination was 2,662, while 2,512 were actually vaccinated in the Šumadija District in 2014, resulting in a vaccination coverage rate of 94.00%. The lowest coverage was recorded in the municipality of Batočina, at only 38%, which is concerning.

Particularly troubling is that in this municipality, the number of revaccinated children was less than half of those planned. This may indicate administrative errors in planning, a lack of staff, or low parental motivation to bring children for revaccination, all of which should be further investigated and addressed through targeted interventions. In Kragujevac, the district centre, revaccination coverage at age 7 was 96%, consistent with the district average and representing a positive indicator of successful immunisation in a larger urban area. For revaccination with the MMR vaccine at age 12 in 2014 in the Šumadija District, both the number planned and the number vaccinated were zero. Revaccination at age 12 was not implemented during 2014, as expected according to the immunisation calendar in effect at that time.

In conclusion, MMR vaccination and revaccination coverage in the Šumadija District during 2014 was

satisfactory overall, but there were differences between municipalities that should be examined in more detail. The priority for further action should be to increase coverage in municipalities such as Batočina and Rača, as well as to ensure continuous monitoring and improvement of vaccine availability and public awareness.

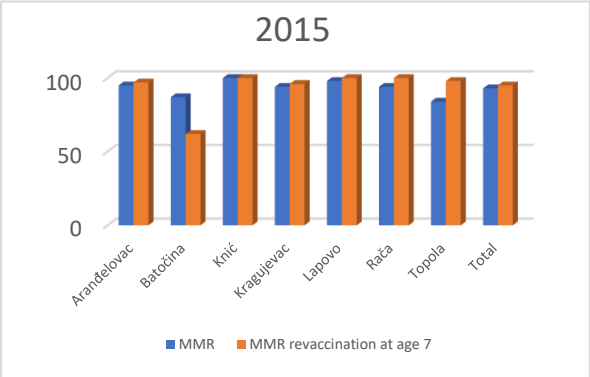

Figure 2. Graphic representation of immunization against rubella on the territory of the Šumadija District in the period of 01.01.2015 - 31.12.2015.

In the Šumadija District, during the period from 01.01 to 31.12.2015, in the municipality of Aranđelovac, 380 out of 400 planned residents were vaccinated, representing 95.00%. In Batočina, 74 out of 85 planned were vaccinated, which is 87.00%, indicating that immunisation was not successfully implemented in this municipality in 2015. In Knić, all 76 planned residents were vaccinated, achieving 100.00% coverage. In Kragujevac, 1,573 out of 1,680 planned were vaccinated, which is 94.00%. In Lapovo, 49 out of 50 planned were vaccinated, representing 98.00%. In Rača, 66 out of 70 planned were vaccinated, which is 94.00%. In Topola, 131 out of 155 planned were vaccinated, which is 84.00%, also indicating that immunisation was not successfully implemented in this municipality, as in Batočina.

Based on these data, the highest percentage of vaccinated people was in the municipality of Knić, at 100.00%, followed by Lapovo at 98.00%, and Aranđelovac at 95.00%. The lowest percentage was in Topola, at 84.00%, and Batočina, at 87.00%. In the Šumadija District in 2015, the overall vaccination rate was 93.00%.

Revaccination of children in their seventh year was also considered. In Aranđelovac, out of 430 planned, 418 were revaccinated, representing 97.00%. In Batočina, 60 out of 96 planned were revaccinated, or 62.00%, indicating that revaccination was not successfully carried out in this municipality in 2015. In Knić, all 101 planned children were revaccinated, achieving 100.00%. In Kragujevac, 1,606 out of 1,670 planned were revaccinated, or 96.00%. In Lapovo, all 58 planned were revaccinated, also 100.00%. In Rača, all 88 planned were revaccinated, again 100.00%. In Topola, 171 out of 175 planned were revaccinated, or 98.00%.

Regarding revaccination, the highest percentage of vaccinated children in the seventh year was recorded in the municipalities of Knić, Lapovo and Rača, at 100%. The lowest percentage was in Batočina, at 62%.

In 2015, data on MMR vaccination and revaccination coverage in the seventh year of life indicated a satisfactory level of immunisation in most municipalities of the Šumadija District. The average coverage for the first dose of the MMR vaccine at the district level was 93%, which is a good result, although significant differences were observed between individual municipalities. While some areas, such as Knić, achieved 100% coverage, others, such as Topola, recorded significantly lower values (84%), indicating the need for additional interventions and education of the population in these areas.

Revaccination with the MMR vaccine in the seventh year of life was, on average, at a high level, with overall coverage of 95% at the district level. However, the situation in Batočina requires special attention, as coverage was only 62%, significantly below the recommended values. These results indicate potential organisational problems or reduced parental trust in the immunisation programme, so the competent authorities should conduct a more detailed analysis of the causes and take appropriate measures to improve coverage.

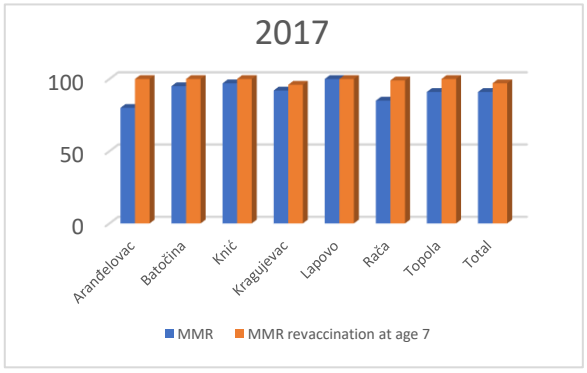

Figure 3. Graphic representation of immunization against rubella on the territory of the Šumadija District in the period of 01.01.2017 - 31.12.2017.

The highest number of vaccinated persons in 2017 was recorded in the municipality of Lapovo, where the vaccination rate was 100.00%. The lowest vaccination rate was in the municipality of Aranđelovac, at 80.00%. Considering the total number of people planned for MMR vaccination (2,682) and the number actually vaccinated (2,432), the vaccination rate in the Šumadija District for 2017 was 91.00%.

Revaccination in the seventh year of life showed a positive trend, with an average coverage of 97%, representing an improvement compared to 2015. In 2017, the revaccination rate for children in the seventh year of life in the municipalities of Aranđelovac, Batočina, Knić, Lapovo, and Topola was 100.00%, meaning all planned individuals were revaccinated. In the municipality of Kragujevac, 1,661 out of the planned 1,730 were revaccinated, which is 96.00%. In the municipality of Rača, 89 out of the planned 90 were revaccinated, which is 99.00%. Taking into account the total number planned for revaccination with the MMR

vaccine in the seventh year (2,603) and the number actually revaccinated (2,533), the revaccination rate in the Šumadija District in 2017 was 97.00%, indicating that revaccination in the seventh year of life was successfully carried out.

These results indicate that, despite a slight decline in primary vaccination, the revaccination system functions efficiently, and trust in the health system has been maintained during the later phase of immunisation.

Rubella, although now suppressed and eliminated in many countries worldwide thanks to successful immunisation programmes, remains a serious and concerning public health problem in many underdeveloped and poor countries. Rubella continues to occur in under-immunised communities where public health awareness is very low, and it can also re-emerge if high vaccination coverage is not maintained. It is important to note that there are many challenges to achieving and sustaining the elimination of rubella.

By its nature, this disease can recur with serious consequences, especially for pregnant women and unborn children. Therefore, it is essential to analyse available data on the implementation of successful vaccination at the municipal, district, and national levels, particularly in the context of unrest, wars, population migration, anti-vaccination movements, poor financial conditions, and the unavailability of many vaccines for purchase [22, 23].

At the beginning of the century, a programme was adopted to reduce the incidence of congenital rubella syndrome (CRS) to below 1:100,000 by the end of the first decade. This goal has been achieved, but maintaining it requires a planned effort to achieve high vaccination coverage at the national level. Despite the availability of the vaccine, immunisation coverage still varies regionally, necessitating continuous monitoring of the epidemiological situation and consistent implementation of national and global vaccination programmes [3].

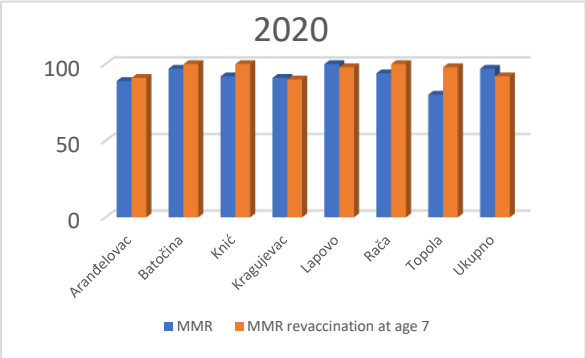

Figure 4. Graphic representation of immunization against rubella (MMR vaccine) on the territory of the Šumadija District in the period of 01.01.2020 - 31.12.2020.

In the Šumadija District, from 1 January 2020 to 31 December 2020, the following vaccination rates were recorded. In 2018, in the municipality of Aranđelovac, 344 out of the planned 383 children were vaccinated, representing 89.00% coverage in the second year of life. In the municipality of Batočina, 80 out of 82 planned were vaccinated, which is 97.00%. In the municipality of Knić, 71 out of 77 planned were vaccinated, which is 92.00%. In the municipality of Kragujevac, 1,776 out of 1,951 planned were vaccinated, which is 91.00%. In the municipality of Lapovo, all 46 planned were vaccinated, which is 100.00%. In the municipality of Rača, 61 out of 65 planned were vaccinated, which is 94.00%. In the municipality of Topola, 123 out of 154 planned individuals were vaccinated, representing 80.00%. This indicates that immunisation was not successfully implemented in this municipality.

Vaccination with the MMR vaccine in the second year of life was very successfully implemented in the municipality of Lapovo, where the vaccination rate was 100.00%. The municipality of Topola had the lowest vaccination rate, at 80.00%. For this calendar year, immunisation was carried out at a rate of more than 95.00%, so it is considered successfully implemented.

Revaccination with the MMR vaccine is carried out in the seventh year of life, before starting school, according to the legally mandatory vaccination calendar applied in the Republic of Serbia. In the municipality of Aranđelovac, 310 out of 340 planned individuals were revaccinated, which is 91.00%. In the municipalities of Batočina and Knić, all planned individuals were revaccinated, which is 100.00%. In the municipality of Kragujevac, 1,605 out of 1,780 planned individuals were revaccinated, which is 90.00%. In the municipality of Lapovo, 46 out of 47 planned individuals were revaccinated, which is 98.00%. In the municipality of Rača, all planned individuals were revaccinated, which is 100.00%. In the municipality of Topola, 151 out of 154 planned individuals were revaccinated, which is 98.00%. In the Šumadija District, out of a total planned 2,539, the number of children revaccinated in their seventh year is 2,330, representing 92.00%.

Data on missed years show that 13 individuals received the first dose in the municipality of Kragujevac. For the Šumadija District, there were a total of 13 such cases in 2020.

The results of MMR vaccination in the Šumadija District for 2020 indicate a satisfactory level of immunisation, particularly for the first dose, which achieved 97% coverage – above the minimum recommended threshold of 95%.

However, it is concerning that revaccination did not reach the same level of success. With overall coverage at 92%, there is room for improvement, especially in larger municipalities where organisation is more complex. The lowest revaccination percentage was recorded in Kragujevac, which has the largest number of planned children. This may indicate challenges in immunisation implementation in urban areas, such as missed appointments, family migration, or increased anti-vaccination sentiment. The standard deviation for vaccination is 6.41, and for revaccination, it is 4.35.

These data indicate a somewhat more uniform coverage of revaccination between municipalities (smaller deviation), while greater variability was observed in vaccination, which may suggest the need for further analysis and interpretation in individual

municipalities, especially in Topola, which has the lowest coverage (80%).

Despite the challenges of 2020 due to the COVID-19 pandemic, these results support the stability of the basic immunisation system, although it is necessary to further strengthen surveillance and strategies to increase revaccination coverage.

Considering the total number of people planned for vaccination with the MMR vaccine in the second year of life (2,459), compared to the number vaccinated (2,314), the percentage vaccinated in the territory of the Šumadija District for 2023 is 94.00%. The highest number of vaccinated individuals was in the municipality of Kragujevac, where the percentage vaccinated was 97.00%. The lowest number of vaccinated individuals was in the municipality of Topola, where the percentage vaccinated was 79.00%. The standard deviation of coverage is 5.33, indicating moderate differences in coverage between municipalities.

A total of 2,517 people were revaccinated in the Šumadija District out of the planned 2,642, which is 95.00%. The highest number of revaccinated individuals was in the municipalities of Batočina, Knić, and Lapovo, where the revaccination rate was 100.00%. The lowest number was in the municipality of Rača, where the revaccination rate was 86.00%. The standard deviation for revaccination was 5.03.

In the municipality of Aranđelovac, 72 people were vaccinated with the first dose, 31 were revaccinated with the second dose, making a total of 103. In the municipality of Knić, 1 person was vaccinated with the first dose, 1 was revaccinated with the second dose, and 1 received both the first and second doses, totalling 3. In the municipality of Kragujevac, 27 people were vaccinated with the first dose and 24 were revaccinated with the second dose, totalling 51. In the municipality of Topola, 1 person was vaccinated with the first dose, making a total of 1. The total number vaccinated with the first dose was 101, revaccinated with the second dose was 56, and 1 person received both the first and second doses.

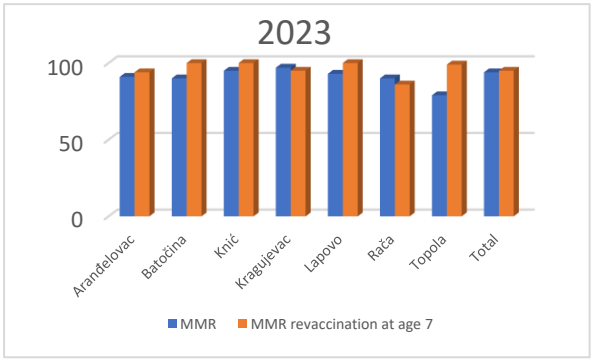

Figure 5. Graphic representation of immunization against rubella (MMR vaccine) on the territory of the Šumadija District in the period of 01.01.2023 - 31.12.2023.

The results show high coverage of vaccination and revaccination with the MMR vaccine in the Šumadija District during 2023, which is in line with WHO recommendations. The WHO defines a coverage target of more than 95% to ensure herd immunity and prevent outbreaks of measles, mumps, and rubella.

Nevertheless, the fact that the coverage of the first dose of vaccine in some municipalities, such as Topola (79%), did not reach the minimum recommended level indicates the need for additional interventions, parental education, and strengthened confidence in immunisation.

Significantly, revaccination achieved higher and more uniform coverage compared to primary vaccination, which may indicate greater commitment and better organised activities by health centres within the school dispensary. This finding may result from better coverage of school-aged children through systematic examinations and organised vaccination in schools, unlike younger children, for whom immunisation depends on parental involvement.

The results also show successful compensation of the vaccination status of children from the missed years, with a total of 158 children vaccinated, indicating appropriate activities by the immunisation teams in the health centres. Such data are encouraging and show that the system is responding to the challenges of unvaccinated and incompletely vaccinated children, which is especially important given the declines in coverage during the COVID-19 pandemic.

Reviewing the data reveals a difference in the total percentage of vaccinated individuals in the period from 2014 to 2023. Immunisation is considered successful for a calendar year if the percentage of vaccinated individuals exceeds 95%.

The analysis of MMR vaccination and revaccination coverage in the Šumadija District before the pandemic (e.g., 2015 and 2017), during the pandemic (2020), and after the pandemic (2023) clearly shows differences reflecting the impact of the global health crisis on the implementation of the Mandatory Immunization Programme.

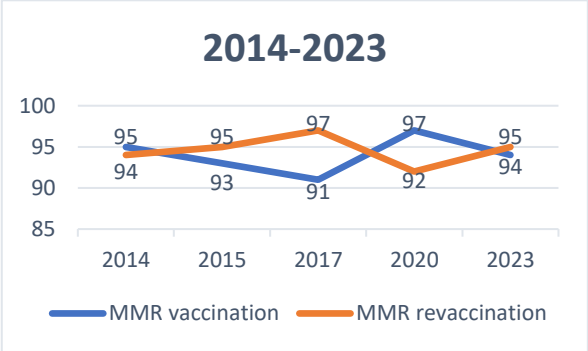

Figure 6. Graphic representation of immunization against rubella (MMR vaccine) in the Šumadija District in the period of 2014 – 2023.

Comparison of the statistical results shows that from 2014 to 2017, MMR immunisation was successfully implemented in the Šumadija District, with vaccination in the second year of life and revaccination in the seventh year. In 2014, 95.00% of children were vaccinated and 94.00% revaccinated. In 2015, 93.00%

were vaccinated and 95.00% revaccinated. In 2017, 91.00% were vaccinated and 97.00% revaccinated.

During the COVID-19 pandemic, vaccination and revaccination rates were lower in the Šumadija District in 2020 and 2021. In 2020, 97.00% were vaccinated and 92.00% revaccinated.

These percentages may appear high, but it is important to note that some municipalities have recorded a drop in coverage below the recommended threshold, consistent with global trends of decreased immunisation coverage during the pandemic due to movement restrictions, overloading of the health system, and reduced access to health services. In 2023, the percentage vaccinated was 94.00%, while the percentage revaccinated was 95.00%.

By observing and comparing data from 2014, 2015, 2017, 2020, 2021, 2022, and 2023, we note that the total number of people vaccinated with the MMR vaccine in the Šumadija District was significantly lower during and after the COVID-19 pandemic. In 2023, the percentage of people vaccinated with the MMR vaccine is gradually increasing.

In the post-pandemic period, in 2023, there is stabilisation and even a slight improvement in coverage, with several municipalities reaching or exceeding the recommended threshold of 95%. Coverage with the first dose of the MMR vaccine and revaccination in the seventh year of life exceeds 90% in most municipalities, and in some reaches 100%. It is particularly encouraging that in 2023, vaccination compensation for missed years was carried out, with a total of 158 children vaccinated, including 56 who received both first and second doses and 1 who was previously completely unvaccinated. This approach to vaccinating children from missed years demonstrates the recovery of the system and its ability to respond to the consequences of the pandemic.

Cumulative data indicate that the COVID-19 pandemic had a negative [24], but time-limited, impact on immunisation coverage, and that effective corrective measures were implemented afterwards. However, observed differences between municipalities persist, indicating the need for continued monitoring and improvement of local immunisation strategies. Based on the available data, it can be concluded that the health system of the Šumadija District showed a relatively high level of resilience and ability to recover after the pandemic, but there is still room for improvement, particularly in targeting populations with lower coverage and strengthening confidence in vaccination.

These results confirm the resilience and capacity of the health system to adapt to crisis conditions [25, 26, 27], as well as the importance of continuous education and monitoring of immunisation and individual immunisation status to maintain high coverage and prevent epidemics of vaccine-preventable diseases [13].

4. Conclusion

The analysis of MMR vaccination coverage in the Šumadija District shows that the COVID-19 pandemic in 2020 harmed the implementation of regular immunisation. In 2020, a decline in vaccination coverage was recorded in most municipalities, most likely as a result of disruptions to health services, parents' fear of visiting health institutions and health centres, and general insecurity caused by the pandemic. Despite this, data from 2023 indicate a significant recovery, with high vaccination rates and successful catch-up for missed years. In conclusion, the COVID-19 pandemic did temporarily threaten routine immunisation, but institutional efforts in the post-pandemic period led to significant recovery and a return to high levels of coverage. Maintaining this trend in the future requires coordination between health institutions, local communities, and the education system.

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