ORIGINAL ARTICLE

Annals of Agricultural and Environmental Medicine
www.aaem.pl

A national registry-based study on uptake of the first dose of MMR vaccine in 380 administrative regions in Poland, 2013–2016–2020

Piotr Samel-Kowalik[1,A-F], Mateusz Jankowski[2,E-F], Aneta Tomaszewska[1,A,D-F], Karolina Sobeczek[1,D-F] ✉, Kamil Rakocy[3,B-C,E-F], Bolesław Krzysztof Samoliński[1,E-F], Mariusz Gujski[1,E-F], Jarosław Pinkas[2,E-F], Anastasiia Vatsenko[4,D-F], Filip Raciborski[1,A,D-F]

[1] *Department of Prevention of Environmental Hazards, Allergology and Immunology, Medical University, Warsaw, Poland*
[2] *School of Public Health, Centre of Postgraduate Medical Education, Warsaw, Poland*
[3] *KR Consulting, Warsaw, Poland*
[4] *State Medical University, Poltava, Ukraine*
A – Research concept and design, B – Collection and/or assembly of data, C – Data analysis and interpretation, D – Writing the article, E – Critical revision of the article, F – Final approval of the article

Samel-Kowalik P, Jankowski M, Tomaszewska A, Sobeczek K, Rakocy K, Samoliński BK, Gujski M, Pinkas J, Vatsenko A, Raciborski F. A national registry-based study on uptake of the first dose of MMR vaccine in 380 administrative regions in Poland, 2013–2016–2020. Ann Agric Environ Med. doi: 10.26444/aaem/172887

Abstract

Introduction and Objective. Regular monitoring of the measles, mumps, and rubella (MMR) vaccine uptake quickly exposes immunity gaps in the population. In Poland, the first dose of the MMR vaccine is mandatory for children between 13 and 15 months of life. This study aimed to assess the uptake of the first dose of MMR vaccine in 380 administrative counties in Poland in 2020, as well as to analyze the MMR vaccine uptake trends in 2013–2016–2020.

Materials and method. This study is an epidemiological retrospective national registry-based analysis. Data on mandatory childhood vaccinations in all 380 counties in Poland were collected from the epidemiological reports of the State Sanitary Inspectorate territorial representatives. MMR vaccine uptake was calculated as the percentage of children who received the first dose of MRR vaccine to all children subject to mandatory vaccination in the county.

Results. The uptake of the first dose of MMR vaccine decreased from 99.4% in 2013, to 95.5% in 2016 and 91.9% in 2020. In 2013, 93.2% of countys MMR vaccine uptake level reached the herd immunity level, followed by 77.1% of counties in 2016 and only 38.3% of countys in 2020. In 2020, two counties reached complete (100%) MMR vaccine uptake, and the lowest MMR vaccine uptake was 63.88%. Of the 380 counties in Poland, in 226 (61.1%) the MMR vaccine uptake level was lower than the herd immunity level, and a downward trend was observed. MMR vaccine uptake decreased with an increased number of residents in a county ($r= -0.35$; $p<0.001$).

Conclusions. This study revealed that in 61% of administrative regions in Poland, the MMR vaccine uptake was below the herd immunity level. Regional differences in the MMR vaccine uptake were observed. A significant decrease in MMR vaccine uptake between 2013 – 2020 poses a risk of measles outbreaks.

Key words

Poland, vaccination, regional differences, vaccines, vaccine hesitancy, MMR vaccine uptake, vaccine coverage rate, childhood vaccination

INTRODUCTION

Childhood vaccinations are one of the greatest public health achievements that have led to a reduction in childhood mortality and an improvement in the health status of the global population [1–4]. It is estimated that in the last 20 years, childhood vaccination programmes in low- and middle-income countries have prevented 36 million deaths in children under 5 years of age [2]. The World Health Organization (WHO) estimates that every year 3.5–5 million deaths from infectious diseases like diphtheria, tetanus, pertussis, and measles, are prevented due to the widespread implementation of childhood vaccination programmes [5]. The WHO initiatives like the WHO's Expanded Programme of Immunization (1974) and the Global Alliance for Vaccination and Immunization (2000), led to the eradication of some vaccine-preventable diseases, like smallpox, and a significant reduction in the incidence of diseases such as polio or measles [6]. In numerous countries, national recommendations/programmes on childhood vaccination have been developed [4, 7, 8].

Despite the scientifically proven safety and effectiveness of vaccines, the number of people negating the importance of vaccination, especially childhood vaccination, is increasing worldwide [9–12]. Vaccine hesitancy is defined by the WHO as a 'delay in acceptance or refusal of vaccines despite availability of vaccination services' [5, 10]. Vaccine

✉ Address for correspondence: Karolina Sobeczek, Department of Prevention of Environmental Hazards, Allergology and Immunology, Medical University, Warsaw, Poland
E-mail: karolina.sobeczek@wum.edu.pl

Received: 31.07.2023; accepted: 22.09.2023; first published: 13.10.2023

hesitancy is a global phenomenon [10, 13], and between 2015 – 2017, vaccine hesitancy was reported by over 90% of countries worldwide [13]. The most common reason for vaccine-hesitant attitudes is vaccine safety concerns, but vaccine hesitancy reasons differ by country income level, geographical regions, and socio-demographic factors [13–15].

Measles is a highly contagious viral disease with a basic case reproduction number (R0) of 12–18 [16]. Measles infection usually results in a high fever and rash, but may also lead to serious complications (e.g., blindness, encephalitis, or even death) [16, 17]. Due to its high transmissibility, measles is often considered an early warning indicator for epidemiological surveillance systems [16–19]. Regular monitoring of the measles incidence and the measles, mumps, and rubella (MMR) vaccine uptake, quickly expose immunity gaps in the population [16–19]. MMR vaccine is a safe and effective polyvalent vaccine that protects against measles, mumps, and rubella infections [19].

Between 2019 – 2022 the global proportion of children receiving the first dose of MMR vaccine decreased from 86% to 83% [19]. As of 2022, approximately 22 million children missed the first dose of measles vaccine [19]. The global target for MMR vaccination is to reach a 95% coverage target for the first MMR vaccine before the age of 2 years [19, 20]. Global trends in vaccine hesitancy and disruptions in routine vaccination programmes during the COVID-19 pandemic interrupted the global MMR vaccine uptake [10, 11, 21].

In 2019 (the last year before the COVID-19 pandemic outbreak), the countries of the European Union (EU)/ European Economic Area (EEA) reported 13,199 cases of measles (overall notification rate per 1,000,000 population: 25.4) [22]. The notification rate per 1,000, 000 population varied from 1.6 in Portugal to 298.5 in Lithuania [22]. Poland is an example of a country with a measles notification rate higher than the EU/EAA average (37.5 vs. 25.4) [22].

In line with the national vaccination schedule, 11 different childhood vaccinations (including MMR vaccine) are mandatory in Poland [9]. All children living in Poland are legally obligated to follow the vaccination schedule [23]. Mandatory vaccines are free-of-charge and provided in primary care practices [23, 24]. The recommended time frame for the first dose of the MMR vaccine is between 13 – 15 months of life [9]. A second dose (booster) is recommended for children at the age of 6 years [9]. Vaccine hesitancy and the growing number of refusals of mandatory childhood vaccination poses serious public health concerns in Poland [23–25]. According to the National Institute of Public Health data, the number of exemptions from mandatory vaccination has doubled, from 40.3 thousand refusals in 2018 to 72.7 thousand refusals in 2022 [25].

Characterization of the online public debate on MMR vaccination in Poland published between 2018 – 2020 showed that 48% of postings expressed anti-vaccination trends [24]. Lack of trust in vaccination effectiveness, the belief that immunity can be acquired by natural infection, and fear of side-effects were the most common thesis presented by the MMR-vaccine hesitant individuals [24]. In 2019, 8.5% of parents in Poland declared that they would stop vaccinating their children if the vaccination obligation should be abolished [26].

Epidemiological data on MMR vaccine uptake are usually presented at the national level [22]; however, numerous EU countries reported regional variations in vaccination coverage rates, vaccine hesitancy, and avoidance [19, 27, 28, 29, 30]. Regional data on the MMR vaccine uptake may inform policymakers and public health agencies about the public attitudes toward mandatory childhood vaccination in different administrative regions, and prepare public health interventions targeted at vaccine-hesitant regions / local populations. The territory of Poland is divided into 16 regions called voivodeships – provinces, that are further divided into smaller administrative regions known as countys – counties [31]. There are 380 counties (314 land counties and 66 cities with county status) [31]. Each county is under epidemiological surveillance by the territorial representatives of the State Sanitary Inspectorate. Data on vaccination uptake, vaccination refusal, as well as data on the incidence of infectious diseases and infectious disease-related deaths, are regularly collected and analyzed by the State Sanitary Inspectorate.

Analysis of vaccine hesitancy and avoidance in Poland focused only on province-level data, and there was a lack of epidemiological analysis concerning MMR vaccine uptake in each county territorial representatives.

OBJECTIVE

The aim of the study was to assess the uptake of the first dose of MMR vaccine in 380 administrative regions (counties) in Poland in 2020, as well as to analyze the MMR vaccine uptake trends in 2013–2016–2020.

MATERIALS AND METHOD

Study design. This study is an epidemiological retrospective national registry-based analysis. Data on mandatory childhood vaccinations in each administrative region (province) are collected by the State Sanitary Inspectorate within the Epidemiology Surveillance System in Poland [25]. Data on the uptake of the first dose of MMR vaccine in 380 counties in Poland between 2013 – 2020 were derived from 3,370 reports on mandatory childhood vaccination uptake in counties, submitted by the State Sanitary Inspection to the National Institute of Public Health [22, 25].

In the years 2018–2021 in Poland, there was a marked decrease in the uptake of the first dose of the MMR vaccine, and a slight increase in the uptake of the second dose of the MMR vaccine [22]. Based on the previously published data and epidemiological reports published by the European Centre for Disease Prevention and Control (ECDC), in this study, we analyzed only the uptake of the first dose of the MMR vaccine [19, 20, 22].

Data source. Every child residing permanently in Poland should be vaccinated in accordance with the national vaccination schedule [8]. Data on the mandatory childhood vaccinations are noted in the individual vaccination cards stored in primary care practices. All healthcare facilities that provide childhood vaccinations (mostly primary care practices) are legally obliged to report the mandatory childhood vaccination status of children and adolescents to the State Sanitary Inspectorate representatives [8, 23, 26]. Data from vaccination cards are reported by healthcare facilities on an annual basis according to the template

specified by the Minister of Health (MZ-54 form). The MZ-54 forms contain data on the vaccination status of children and adolescents against infectious diseases covered by the national vaccination schedule. In the MZ-54 form, data are presented separately for each age group (relative to the year of birth) in a given administrative region (county). Data on mandatory childhood vaccination uptake (MZ-54 from healthcare facilities) are collected by the State Sanitary Inspectorate territorial representatives within the counties into one form, representative for the county. Aggregated data are submitted by the State Sanitary Inspectorate territorial representatives to the National Institute of Public Health which aggregates regional data into one national registry on vaccination coverage rates. This registry provides a basis for reports on the health status of the Polish population, health policy planning, as well as international epidemiological surveillance and monitoring carried out, e.g., by the EU public health agencies like the European Centre for Disease Prevention Control (ECDC).

2013 was the first year in which a complete dataset became available, 2020 was the first year of the COVID-19 pandemic in Poland, and 2016 was selected as a comparative value between the first and last year of the analysis.

Measures. Data on the uptake of the first dose of MMR vaccine in 380 counties (all counties in Poland) were analyzed. The total population of administrative regions (counties) included in this study varied from 19,914 to 399,272 for urban-rural areas, and from 35,719 to 1,790,658 for urban areas (the biggest cities with county status). The MMR vaccine uptake rates in the 380 counties were calculated based on the regional reports submitted by the State Sanitary Inspectorate territorial representatives to the National Institute of Public Health. MMR vaccine uptake was calculated as the percentage of children who received the first dose of MRR vaccine in relation to all children subject to mandatory vaccination in a given county (based on vaccination cards stored in healthcare facilities). The MMR vaccine uptake level of 95% or above was considered as the coverage target. Out of the 380 counties, 20 (5% of all counties) with the highest uptake of the first dose of MMR vaccine in 2020, and 20 counties with the lowest MMR vaccine uptake rate were identified.

For each county, an analysis of the MMR vaccine uptake trend in the years 2013–2020 was performed. Population eligible for MMR vaccination in each year was defined based on year of birth. Based on the trend analysis, the counties were divided into four categories:

- Category I – MMR vaccine uptake level lower than coverage target, downward trend (bad trend).
- Category II – MMR vaccine uptake level lower than coverage target, upward trend (improving trend).
- Category III – MMR vaccine uptake level higher than coverage target, downward trend (worsening trend).
- Category IV – MMR vaccine uptake level higher than coverage target, upward trend (optimal trend).

Statistical analysis. Data received from the State Sanitary Inspectorate territorial representatives were transferred into the electronic database. Python software (3.8.8, Python Software Foundation, https://www.python.org/) was used for data integration. Data analysis was performed using the procedures available in the R package (R 4.0.0. Core Team, Vienna 2019). The geographical differences in the MMR vaccine uptake were presented using the QGIS 3.16.16 software (QGIS Geographic Information System. Open Source Geospatial Foundation Project. http://qgis.org). Descriptive statistics (proportions) were used to present the MMR vaccine uptake in the counties. MMR vaccine uptake trends were presented using regression analysis. The Spearman correlation method was used to assess the relationship between the MMR vaccine uptake and the number of residents in the counties. Statistical significance level was set at $p < 0.05$.

Ethics. The study was carried out in accordance with the principles of the Declaration of Helsinki. Epidemiological reports on MRR vaccination status were anonymous and prevented identification of any individual in the study by the research team at any stage of the study.

RESULTS

The uptake of the first dose of MMR vaccine decreased from 99.4% in 2013, to 95.5% in 2016, and to 91.9% in 2020. In 2013, in 93.2% of counties, the MMR vaccine uptake level reached the coverage target, followed by 77.1% of the counties in 2016, and only 38.3% of counties in 2020 (Tab. 1). In 2020, two counties reached complete (100%) MMR vaccine uptake (Tab. 2). The lowest MMR vaccine uptake (63.88%) was reported in Zwoleński county in the Masovian province of east-central Poland (Tab. 2).

Findings from the trend analysis (2013–2020) on uptake of the first dose of MMR vaccine are presented in Figure 1. Out of 380 counties in Poland, in 226 (61.1%) the MMR vaccine uptake level was lower than the coverage target, and a downward trend (Category I) was observed (Fig. 1). In 131 counties (35.4%), MMR vaccine uptake level was higher than the coverage target, and a downward trend (Category III) was observed. Regional differences in MMR vaccine uptake were also observed. Regional differences indicated a clear division of Poland along the north-east and south-west lines, into counties that are above (north-west) and below (south-east) the coverage target area (Fig. 1).

MMR vaccine uptake decreased with the increased number of inhabitants of the county (Fig. 2). The relationship between the MMR vaccine uptake and the population living in the county, as determined by Spearman's rank correlation value was -0.35 ($p<0.001$).

DISCUSSION

This is the first study to assess the MMR vaccine uptake in 380 administrative regions (counties) in Poland. The study revealed a rapid decrease in the uptake of the first dose of MMR vaccine in Poland between 2013 and 2020. The percentage of points where the MMR vaccine uptake by eligible populations exceeded 95% decreased from 93.2% in 2013 to 38.3 of the counties in 2020. Regional differences and clusters were observed in the study. Vaccination policy should include public health interventions targeting regional differences in MMR vaccine uptake and vaccination hesitancy in different administrative regions within the country.

Findings from this study show that since 2013, the MMR vaccine uptake in Poland has been decreasing. The coverage

Table 2. List of 20 counties with the highest or the lowest uptake of the first dose of MMR vaccine in 2020

Counties with the highest MMR vaccine uptake			Counties with the lowest MMR vaccine uptake		
Administrative region	MMR vaccination-eligible population	Vaccine uptake in 2020	Administrative region	MMR vaccination-eligible population	Vaccine uptake in 2020
Kwidzyński county	923	100%	Tarnobrzeski county (Tarnobrzeg city included)	782	85.17%
Białogardzki county	416	100%	Białostoski county (Białystok city included	5,027	84.96%
Radziejowski county	414	99.76%	Przysuski county	299	84.95%
Lidzbarski county	381	99.74%	Ostrowski county	653	84.84%
Zgierski county	1435	99.72%	Wyszkowski county	926	84.77%
Olecki county	292	99.66%	Krośnieński county (Krosno city included)	1,520	84.34%
Aleksandrowski county	456	99.56%	Mielecki county	1,374	84.21%
Leszczyński county (Leszno city included)	1293	99.54%	Łosicki county	290	84.14%
Golubsko-Dobrzyński county	415	99.52%	Rycki county	537	83.61%
Skarżyski county	534	99.44%	Sopot city	244	83.61%
Kętrzyński county	470	99.36%	Płoński county	898	82.52%
Działdowski county	558	99.28%	Chrzanowski county	1,092	82.51%
Brzozowski county	661	99.24%	Lubliński county	1,138	82.25%
Rypiński county	390	99.23%	Łomżyński county (Łomża city included)	1184	82.18%
Sępoleński county	385	99.22%	Kolneński county	334	80.54%
Braniewski county	331	99.09%	Radomski county (Radom city included)	3,508	79.39%
Bieszczadzki county	398	98.99%	Siedlecki county (Siedlce city included)	1,828	78.50%
Leski county	398	98.99%	Łukowski county	1,144	76.49%
Tucholski county	519	98.84%	Tatrzański county	753	73.31%
Szczecinecki county	679	98.82%	Zwoleński county	335	63.88%

Table 1. Uptake of the first dose of MMR vaccine in the counties in Poland, 2013-2016-2020

MMR vaccine uptake	Year of the report					
	2013		2016		2020	
	n	%	n	%	n	%
> 95%	354	93.2	293	77.1	146	38.4
90% - 94.9%	25	6.6	79	20.8	141	37.1
80% - 89.9%	1	0.3	8	2.1	86	22.6
70% - 79.9%	0	0	0	0	8	1.6
< 70%	0	0	0	0	1	0,3

target observed in 2020 was lower than 95%, an observation which is in line with the global observations on decreasing MMR vaccine uptake [19]. Vaccine hesitancy is the most common reason for decreasing MMR vaccine uptake [9–12].

In Poland, the MMR vaccine is mandatory, and the first dose is administered between the ages of 13 and 15 months [8]. The growing number of vaccination refusals observed in Poland in the last decade had an impact on MMR vaccine uptake [25]. Moreover, the COVID-19 pandemic also had a negative impact on vaccination programmes, as some healthcare facilities were temporarily closed and access to healthcare services was limited [21].

Measles is a highly infectious disease, therefore the loss of MMR herd immunity may lead to epidemic outbreaks [16, 18]. Data on the measles incidence between 2020 – 2022 may be misleading, as most of the epidemiological surveillance resources were targeted at COVID-19, and the number of contacts between children was limited due to the temporary closure of schools and restrictions on the work of kindergartens [32].

Since February 2022, Poland has been hosting millions of refugees from Ukraine, mostly women and children [33]. Due to the low MMR vaccine coverage rate (approximately 80%), the measles incidence in Ukraine was one of the largest in Europe [33]. Public health institutions should be actively involved in MMR vaccine promotion among refugees currently staying in Poland.

This study shows that MMR vaccine uptake levels varied geographically. Between 2013 – 2020, the number of counties that reached the coverage target (95% of the eligible population) decreased by more than half. In 2020, the MMR vaccine uptake level was lower than the coverage target, and a downward trend was observed in 61.1% of counties in Poland. MMR vaccine uptake decreased with the increased number of residents in a county. This observation may result from the fact that in small local communities, it is easier to reach the target population with health information. Vaccine hesitancy is a national problem [23, 26, 34]. However, some clusters of counties with a low MMR vaccine uptake were also observed, mainly in south-east Poland. Previously published data showed that most of Poland's young adults lack clearly

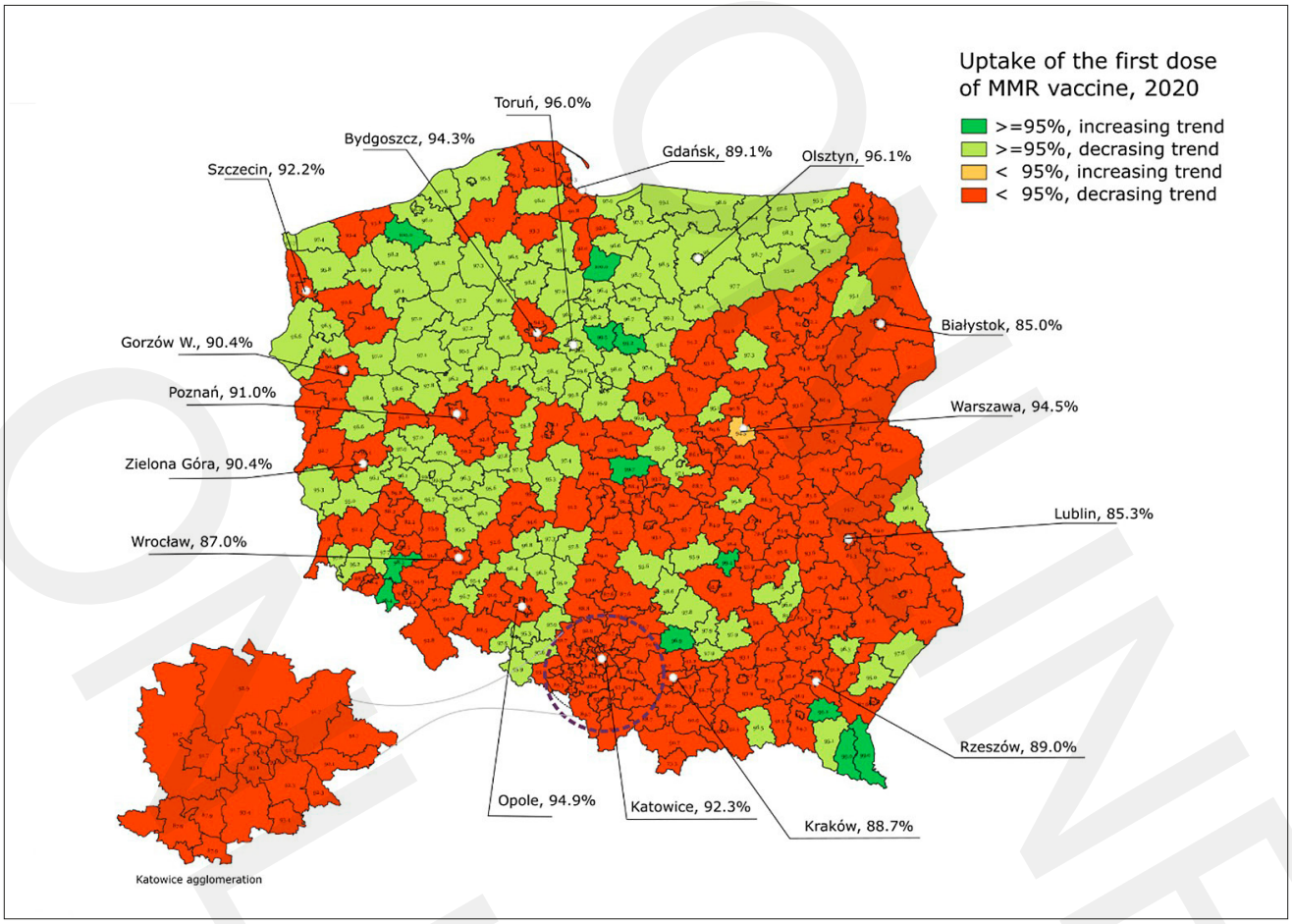

Figure 1. Uptake of the first dose of MMR vaccine – trend analysis 2013–2016–2020.

defined attitudes towards vaccination, and that attitudes towards vaccination can be divided into 6 heterogeneous groups [35]. Further analysis is needed to identify factors associated with vaccine hesitancy in different administrative regions in Poland (especially in south-east Poland). Most of the counties that reached the MMR coverage target were located in north-western Poland. This observation also requires further investigation. Access to healthcare, level of urbanization, as well as the health policy developed by the local government units, should be analyzed to identify factors associated with the higher acceptance of the MMR vaccine in north-western Poland [7, 19, 23, 24].

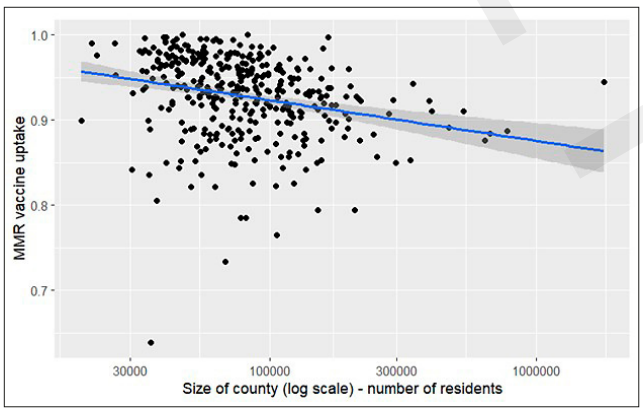

Figure 2. Relationship between the level of MMR vaccination and population living in the county

Previously published data on vaccination coverage and vaccine hesitancy in Poland mostly focused on some local populations (e.g., in a single province) [36–38]. There was a lack of data on vaccination coverage in counties, which limited the possibility of comparing the findings of the current study with other studies.

Implications of the study. The study has several practical implications for healthcare professionals and policymakers in Poland. Data on regional differences in MMR vaccine uptake should be used by policymakers to identify regions with the lowest MMR vaccine uptake, and regions with the highest risk of measles outbreaks. General practitioners and paediatricians working in places with the lowest MMR vaccine uptake should promote vaccinations, and strengthen vaccine confidence levels of the local populations. Regions (counties) with the lowest MMR vaccine uptake should be monitored, and potential violations of the law on mandatory vaccinations should be enforced. Public health institutions should analyze whether the population of unvaccinated children come mostly from one medical facility in the region, and if confirmed, legal action should be taken. Moreover, factors influencing regional differences in vaccination avoidance and acceptance should be analyzed. Currently, there is a lack of one single electronic database and annual reports on vaccination coverage rates and vaccine uptake in the 380 counties in Poland. Since March 2022, vaccination cards have been available in electronic form. There is therefore a need to develop a single standard for collecting,

submitting, and processing vaccination-related data, using digital technologies.

The COVID-19 pandemic evoked disruptions to routine childhood vaccine coverage, therefore the data presented in this study may be used by public health specialists in the further analysis of vaccine hesitancy and MMR vaccine uptake during the COVID-19 pandemic at the regional level [10, 11, 21].

Limitations of the study. This national registry-based study has several limitations. The use of public statistics from national registries is associated with the risk of systematic error. Vaccination cards for children who have changed their place of residence (different county) could result in a delay in the transfer to the new medical facilities. In addition, children who have permanently moved abroad may be reported as having refused the MMR vaccine. However, the influence of the above-mentioned factors on the obtained results should be assessed as marginal. Reports on MMR vaccination in counties, prepared by the State Sanitary Inspectorate territorial representatives, were submitted using a dedicated form, but these documents were filled electronically or handwritten; therefore, optical character recognition software was used during the data management process.

CONCLUSIONS

This study revealed that in 2020, in 61% of the administrative regions (counties) in Poland, the MMR vaccine uptake by the eligible population was below the coverage target (95% of the eligible population). A significant decrease in MMR vaccine uptake between 2013 – 2020 led to a loss of MMR herd immunity, which may later cause outbreaks of infectious diseases. Regional differences in the MMR vaccine uptake were observed.

Local government units should be actively involved in vaccination policy, and regional health policy programmes should include interventions aimed at building trust in vaccines in local communities.

Acknowledgements

This study was carried out as a part of the scientific project funded by the National Centre for Research and Development within the Strategic Program of Scientific Research and Development "Social and economic development of Poland in the conditions of globalizing markets", grant number GOSPOSTRATEG-II/0007/2020-00."

The authors express their thanks to the State Sanitary Inspectorate for the data sharing.

REFERENCES

1. GBD 2020, Release 1, Vaccine Coverage Collaborators. Measuring routine childhood vaccination coverage in 204 countries and territories, 1980–2019: a systematic analysis for the Global Burden of Disease Study 2020, Release 1. Lancet. 2021;398(10299):503–521. https://doi.org/10.1016/S0140-6736(21)00984-3
2. Li X, Mukandavire C, Cucunubá ZM, et al. Estimating the health impact of vaccination against ten pathogens in 98 low-income and middle-income countries from 2000 to 2030: a modelling study. Lancet. 2021;397(10272):398–408. https://doi.org/10.1016/S0140-6736(20)32657-X
3. Chang AY, Riumallo-Herl C, Perales NA, et al. The Equity Impact Vaccines May Have On Averting Deaths And Medical Impoverishment In Developing Countries. Health Aff (Millwood). 2018;37(2):316–324. https://doi.org/10.1377/hlthaff.2017.0861
4. Nandi A, Shet A. Why vaccines matter: understanding the broader health, economic, and child development benefits of routine vaccination. Hum Vaccin Immunother. 2020;16(8):1900–1904. https://doi.org/10.1080/21645515.2019.1708669
5. World Health Organization (WHO). Vaccines and immunization. https://www.who.int/health-topics/vaccines-and-immunization#tab=tab_1 (access: 2023.07.22).
6. Greenwood B. The contribution of vaccination to global health: past, present and future. Philos Trans R Soc Lond B Biol Sci. 2014;369(1645):20130433. https://doi.org/10.1098/rstb.2013.0433
7. Gallagher KE, Kadokura E, Eckert LO, et al. Factors influencing completion of multi-dose vaccine schedules in adolescents: a systematic review. BMC Public Health. 2016;16:172. https://doi.org/10.1186/s12889-016-2845-z
8. European Centre for Disease Prevention and Control (ECDC). Vaccine schedules in all countries in the EU/EEA. https://vaccine-schedule.ecdc.europa.eu/ (access: 2023.07.23).
9. Singh P, Dhalaria P, Kashyap S, et al. Strategies to overcome vaccine hesitancy: a systematic review. Syst Rev. 2022;11(1):78. https://doi.org/10.1186/s13643-022-01941-4
10. The Lancet Child Adolescent Health. Vaccine hesitancy: a generation at risk. Lancet Child Adolesc Health. 2019;3(5):281. https://doi.org/10.1016/S2352-4642(19)30092-6
11. Troiano G, Nardi A. Vaccine hesitancy in the era of COVID-19. Public Health. 2021;194:245–251. https://doi.org/10.1016/j.puhe.2021.02.025
12. de Figueiredo A, Simas C, Karafillakis E, et al. Mapping global trends in vaccine confidence and investigating barriers to vaccine uptake: a large-scale retrospective temporal modelling study. Lancet. 2020;396(10255):898–908. https://doi.org/10.1016/S0140-6736(20)31558-0
13. Lane S, MacDonald NE, Marti M, et al. Vaccine hesitancy around the globe: Analysis of three years of WHO/UNICEF Joint Reporting Form data-2015-2017. Vaccine. 2018;36(26):3861–3867. https://doi.org/10.1016/j.vaccine.2018.03.063
14. Dubé È, Ward JK, Verger P, et al. Vaccine Hesitancy, Acceptance, and Anti-Vaccination: Trends and Future Prospects for Public Health. Annu Rev Public Health. 2021;42:175–191. https://doi.org/10.1146/annurev-publhealth-090419-102240
15. Schuster M, Eskola J, Duclos P, et al. Review of vaccine hesitancy: Rationale, remit and methods. Vaccine. 2015;33(34):4157–4160. https://doi.org/10.1016/j.vaccine.2015.04.035
16. Hübschen JM, Gouandjika-Vasilache I, Dina J. Measles. Lancet. 2022;399(10325):678–690. https://doi.org/10.1016/S0140-6736(21)02004-3
17. World Health Organization (WHO). Immunization coverage. https://www.who.int/news-room/fact-sheets/detail/immunization-coverage (access: 2023.07.22).
18. Bester JC. Measles and Measles Vaccination: A Review. JAMA Pediatr. 2016;170(12):1209–1215. https://doi.org/10.1001/jamapediatrics.2016.1787
19. Di Pietrantonj C, Rivetti A, Marchione P, et al. Vaccines for measles, mumps, rubella, and varicella in children. Cochrane Database Syst Rev. 2021;11(11):CD004407. https://doi.org/10.1002/14651858.CD004407.pub5.
20. World Health Organization (WHO). Measles and rubella strategic framework: 2021–2030. https://www.who.int/publications/i/item/measles-and-rubella-strategic-framework-2021–2030 (access: 2023.07.22).
21. Causey K, Fullman N, Sorensen RJD, et al. Estimating global and regional disruptions to routine childhood vaccine coverage during the COVID-19 pandemic in 2020: a modelling study. Lancet. 2021;398(10299):522–534. https://doi.org/10.1016/S0140-6736(21)01337-4
22. European Centre for Disease Prevention and Control (ECDC). Measles. Annual Epidemiological Report for 2022. https://www.ecdc.europa.eu/sites/default/files/documents/Measles%20Annual%20Epidemiological%20Report%202022%20data.pdf (access: 2023.07.24).
23. Reczulska A, Tomaszewska A, Raciborski F. Level of Acceptance of Mandatory Vaccination and Legal Sanctions for Refusing Mandatory Vaccination of Children. Vaccines (Basel). 2022;10(5):811. https://doi.org/10.3390/vaccines10050811
24. Włodarska A, Raciborski F. Characterisation of the online public debate od MMR vaccine against measles, mumps and rubella on the Polish Internet. Przegl Epidemiol. 2021;75(3):390–401. https://doi.org/10.32394/pe.75.36

25. National Insitute of Public Health, Warsaw, Poland. Waht is the number of vaccination refusal? https://szczepienia.pzh.gov.pl/faq/jaka-jest-liczba-uchylen-szczepien-obowiazkowych/ (access: 2023.07.23).
26. Furman FM, Zgliczyński WS, Jankowski M, et al. The State of Vaccine Confidence in Poland: A 2019 Nationwide Cross-Sectional Survey. Int J Environ Res Public Health. 2020;17(12):4565. https://doi.org/10.3390/ijerph17124565.
27. Spencer CN, Delamater PL. Examining vaccination coverage in Germany: spatiotemporal clustering of MMR coverage, 2008–14. Eur J Public Health. 2020;30(5):993–995. https://doi.org/10.1093/eurpub/ckaa120
28. Bocquier A, Ward J, Raude J, et al. Socioeconomic differences in childhood vaccination in developed countries: a systematic review of quantitative studies. Expert Rev Vaccines. 2017;16(11):1107–1118. https://doi.org/10.1080/14760584.2017.1381020
29. Tabacchi G, Costantino C, Napoli G, et al. Determinants of European parents' decision on the vaccination of their children against measles, mumps and rubella: A systematic review and meta-analysis. Hum Vaccin Immunother. 2016;12(7):1909–1923. https://doi.org/10.1080/21645515.2016.1151990
30. Braczkowska B, Kowalska M, Braczkowski R, et al. Determinants of vaccine hesitancy. Przegl Epidemiol. 2017;71(2):227–236.
31. Statistics of Poland. Administrative division of Poland. https://stat.gov.pl/en/regional-statistics/classification-of-territorial-units/administrative-division-of-poland/#:~:text=As%20of%201%20January%202023%2C%20the%20administrative%20division,gminas%2C%20677%20urban-rural%20gminas%20and%201498%20rural%20gminas%29 (access: 2023.07.23).
32. Chaabane S, Doraiswamy S, Chaabna K, Mamtani R, Cheema S. The Impact of COVID-19 School Closure on Child and Adolescent Health: A Rapid Systematic Review. Children (Basel). 2021;8(5):415. https://doi.org/10.3390/children8050415
33. Jankowski M, Lazarus JV, Kuchyn I, et al. One Year On: Poland's Public Health Initiatives and National Response to Millions of Refugees from Ukraine. Med Sci Monit. 2023;29:e940223. https://doi.org/10.12659/MSM.940223
34. Raciborski F, Samel-Kowalik P, Gujski M, et al. Factors Associated with a Lack of Willingness to Vaccinate against COVID-19 in Poland: A 2021 Nationwide Cross-Sectional Survey. Vaccines (Basel). 2021;9(9):1000. https://doi.org/10.3390/vaccines9091000
35. Raciborski F, Tomaszewska A, Rakocy K, et al. The multidimensional nature of attitudes towards preventive vaccinations – a cross-sectional survey among Poles aged 15–39 years. Int J Occup Med Environ Health. 2023;36(2):214–228. https://doi.org/10.13075/ijomeh.1896.02068
36. Szczupak M, Augustyniak T, Sikorska K. The avoidance of vaccinations among people aged 0–18 years in pomorskie voivodeship in 2000–2017. Przegl Epidemiol. 2020;74(1):109–118. https://doi.org/10.32394/pe.74.08
37. Jędrzejek MJ, Mastalerz-Migas A. Influenza Vaccination Coverage, Motivators for, and Barriers to Influenza Vaccination among Healthcare Workers in Wroclaw, Poland. Int J Environ Res Public Health. 2022;19(3):1586. https://doi.org/10.3390/ijerph19031586
38. Ganczak M, Gil K, Korzeń M, Bażydło M. Coverage and Influencing Determinants of Influenza Vaccination in Elderly Patients in a Country with a Poor Vaccination Implementation. Int J Environ Res Public Health. 2017;14(6):665. https://doi.org/10.3390/ijerph14060665