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Measles-Related Complications in Young Pregnant Women in Kyrgyz Republic

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ABSTRACT

Background: Measles infection during pregnancy poses risks to maternal and fetal health. This study compares clinical outcomes, complications, and immunological markers between vaccinated and unvaccinated pregnant women aged 18-29 years.

Methods: A total of 36 pregnant women (18 vaccinated, 18 unvaccinated) aged 18-29 with confirmed measles infection were retrospectively analyzed. Clinical severity, infectious complications, obstetric outcomes, hematological parameters were compared. Additional cytokine profiling and anti-measles IgG levels were assessed in healthy individuals from the general population (n=127) with subsequent evaluation of these parameters in 39 non-pregnant vaccinated women aged 20–29 years to assess immunity against measles.

Results: No significant differences were observed in the severity of disease, frequency of infectious complications, or obstetric outcomes between vaccinated and unvaccinated women. Immunological analysis revealed higher IFN-γ and IL-4 levels in IgG-positive non-pregnant women, suggesting preserved cellular and humoral immunity. IgG-negative women (10.3%) showed markedly reduced cytokine responses.

Conclusion: Measles vaccination performed according to the national immunization schedule of Kyrgyz Republic did not significantly reduce clinical severity or complications during pregnancy in this cohort. Moreover, reduced IFN-γ and IL-4 in IgG-negative individuals indicate waning immunity, supporting the need to revise the immunization schedule and implement measles revaccination prior to pregnancy, as well as to include measles antibody testing in routine pregnancy screening in Kyrgyz Republic.

KEYWORDS: measles, pregnancy, vaccination, immunity, IFN-γ, IL-4, obstetric outcomes, seronegativity

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INTRODUCTION

Measles remains a major public health threat because this historical viral disease reappears after multiple years of vaccine development and immunization efforts. The disease spreads rapidly which makes it serve as a sign that healthcare systems and vaccination programs need improvement [1]. The European and Central Asian Region has experienced its highest measles case numbers since the late 1990s based on recent epidemiological data. The WHO and UNICEF reported 127350 measles cases in 2024 throughout this region which represented thirty percent of worldwide measles cases that year [2]. The three countries of Kazakhstan and the Russian Federation and the Kyrgyz Republic face major measles outbreaks while Kyrgyzstan recorded a doubling of cases between 2023 and 2024. The Kyrgyz Republic has recorded 7985 new measles cases during the first half of 2025 while 30% of these cases involved infants who are not yet eligible for vaccination which demonstrates the critical role of maternal antibody protection [3]. The changing epidemiological patterns show that measles continues to spread while affecting different age groups and risk groups including women of childbearing age. The increasing number of measles cases among women

who are pregnant creates major risks for their health and the health of their unborn babies [4]. The unique immunological changes of pregnancy create different host responses to infections which can result in more severe measles disease outcomes. The general decrease in measles cases during pregnancy in various countries has not eliminated the risk for unvaccinated women and those whose immunity has decreased [5]. Outbreaks in regions with inconsistent vaccine coverage have consequently led to a growing number of infections among young adults, including expectant mothers. Measles infection in pregnant women creates two major health risks because it leads to maternal pneumonia and increased illness rates and results in negative pregnancy results including miscarriage and preterm birth and intrauterine fetal death [6]. The growing measles disease burden in Kyrgyzstan requires more research about measles effects on pregnant women because current studies from Africa and Asia show severe outcomes but no specific data exists for Central Asia. The absence of research on clinical and immunological characteristics of pregnant women with measles in Central Asia specifically Kyrgyzstan creates a major knowledge gap which supports the need for targeted studies [7]. This study aims to address this gap by examining the clinical and immunological characteristics of vaccinated and unvaccinated pregnant women under the age of 29 who developed measles in Kyrgyzstan. By analyzing differences in disease manifestation and immune responses, this research provides context-specific insights into the interaction between measles infection, vaccination status, and maternal health outcomes. Unlike general epidemiological surveillance, this work narrows its focus to a highly vulnerable subgroup, thereby highlighting the dual significance of vaccination in both preventing infection and mitigating its severity when it occurs. The research provides essential evidence to enhance immunization approaches by focusing on women who are pregnant or will become pregnant. The study provides essential data for improving immunization methods which target women who are pregnant or will become pregnant. The research establishes both the local impact of measles during pregnancy and new knowledge about preventive healthcare methods and maternal immunity and public health needs in the region.

METHODS

2.1 Study Design and Setting

The study used a retrospective observational design to evaluate the medical aspects and birth-related factors and immune system responses of measles infections in pregnant women. The research team conducted this study at multiple healthcare facilities throughout the Kyrgyz Republic during 2023 through 2025. This research study received approval from the institutional review board of the **International Higher School of Medicine, Bishkek, Kyrgyzstan and was performed in line with the principles of the Declaration of Helsinki [8].** The researchers protected patient privacy through data anonymization while focusing on medical records that contained all necessary documentation for analysis.

2.2 Study Population

The study population consisted of 36 pregnant women under the age of 29 who were diagnosed with measles. Diagnosis was confirmed through the detection of measles-specific IgM antibodies using enzyme-linked immunosorbent assay (ELISA). Based on vaccination history, participants were divided into two groups: vaccinated women (n = 18) and unvaccinated women (n = 18). Two control groups were established to determine baseline immunological values. The first group consisted of 127 healthy people aged 18–29 years who showed no signs of recent infection and were part of the general population. The second group consisted of 39 non-pregnant women between 18 and 29 years old who had received measles vaccination. The combined groups enabled researchers to study pregnant women both against each other and against non-pregnant healthy individuals.

2.3 Data Collection

Clinical data were extracted retrospectively from medical records and encompassed the severity of measles infection, the occurrence of infectious complications, obstetric outcomes such as miscarriage and preterm delivery, and relevant hematological parameters. The researchers collected immunological data from serum samples which included both disease-related and overall immune system markers. The protection status. The researchers analyzed cytokine profiles through IL-4 and IFN-γ concentration measurements researchers used anti-measles IgM and IgG antibody tests to determine both infection presence and immune. The laboratory team performed all immunological tests using ELISA kits which followed the manufacturer's established protocols. The researchers presented their results as IU/ml for antibody titers and pg/ml for cytokine concentrations. The laboratory team conducted duplicate tests to boost precision while following standardized procedures which reduced inter-assay variability.

2.4 Statistical Analysis

IBM SPSS Statistics Version 26.0 (IBM Corp., Armonk, NY, USA) was used to analyze the data. Categorical variables were indicated as frequencies and percentages, whereas continuous variables were shown as mean ± standard deviation or median with interquartile range. The independent t-test for continuous variables and the chi-square test for categorical data were used to compare groups. P-values less than 0.05 were regarded as statistically significant.

RESULTS

The study revealed that pregnant women between 18 and 29 years old contributes to the large portion of measles cases. The reproductive age group of 18 to 29 years old in Kyrgyzstan includes most women who start having children during this time. The high number of cases among this age group points to weak immunity which might stem from irregular vaccination patterns throughout past years. The gaps in immunity develop because people lack equal access to scheduled vaccinations and because they move between places or do not understand the necessity of getting booster shots.

The pregnant women who show susceptibility to measles infection probably lack proven protective antibodies when they become pregnant. The mother faces health risks from measles infection but the baby faces additional dangers because pregnancy-related measles complications lead to negative birth results. The research results demonstrate that Kyrgyzstan needs to enhance measles immunity protection for all women who can become pregnant. The process requires healthcare providers to check vaccination

records during reproductive health check-ups and to perform blood tests for measles antibodies during antenatal care when necessary and to deliver focused vaccination programs across both urban and rural areas. The population needs better immunity protection because it directly protects both mothers and their newborns from measles complications which occur during pregnancy.

3.1 Disease Severity and Associated Complications among Study Groups

Severity	Vaccinated (n=18)	Unvaccinated (n=18)	p-value
Moderate	8	7	
Severe	10	11	1.000
Laryngitis	5	1	0.45
Bronchitis	1	2	0.45
Pneumonia	3	4	1.00
Enteritis	3	8	1.00
UTI	0	1	1.00

Among the 36 pregnant women with confirmed measles, 18 had a history of vaccination and 18 were unvaccinated (Table 1). In the vaccinated group, 8 women (44.4%) experienced a moderate course of illness, while 10 (55.6%) had severe disease. In the unvaccinated group, 7 women (38.9%) had moderate severity, and 11 (61.1%) presented with severe illness. Statistical analysis using the chi-square test revealed no significant difference in disease severity between the two groups ($p = 1.000$).

Analysis of infectious complications revealed no statistically significant differences between vaccinated and unvaccinated pregnant women with measles (table 1). Laryngitis occurred in 5 vaccinated patients (27.8%) versus 1 unvaccinated patient (5.6%) ($p = 0.45$). Bronchitis was reported in 1 vaccinated (5.6%) and 2 unvaccinated women (11.1%) ($p = 0.45$), while pneumonia was observed in 3 vaccinated (16.7%) and 4 unvaccinated patients (22.2%) ($p = 1.00$). Enteritis occurred in 3 vaccinated (16.7%) and 8 unvaccinated women (44.4%) ($p = 1.00$). Only one case of urinary tract infection (5.6%) was documented among unvaccinated women ($p = 1.00$). These findings revealed no significant difference in infectious complications between vaccinated and unvaccinated pregnant women. However, there was a slight tendency toward increased incidence of enteritis among unvaccinated patients, which is consistent with data from measles cases in the general population.

3.2 Obstetric Outcomes by Vaccination Status

Table 2. Obstetrics Outcomes Among Women with Measles

Outcome	Vaccinated (n=18)	Unvaccinated (n=18)	p-value
Miscarriage	8	9	
Missed Abortion	4	7	
Preterm Delivery	2	1	
Full-Term Delivery	4	1	0.229

There were no statistically significant differences in obstetric outcomes (table 2) between vaccinated and unvaccinated pregnant women with measles ($p = 0.229$). Miscarriages were recorded in 8 vaccinated (44.4%) and 9 unvaccinated women (50.0%). Missed abortions occurred in 4 vaccinated (22.2%) and 7 unvaccinated (38.9%) individuals. Preterm deliveries were observed in 2 vaccinated (11.1%) and 1 unvaccinated woman (5.6%). Full-term deliveries were more frequent in the vaccinated group, reported in 4 cases (22.2%) compared to 1 case (5.6%) in the unvaccinated group. These results suggest a tendency toward better obstetric outcomes in vaccinated women. However, adverse outcomes, including miscarriages, missed abortions, and preterm deliveries, were observed in 14 out of 18 cases, indicating a high risk of complications regardless of vaccination status.

3.3 Hematological Parameters by Vaccination Status

Table 3. Laboratory Parameters in Pregnant Women with Measles

Parameter	Vaccinated	Unvaccinated
Erythrocytes ($\times 10^{12}$/L)	3.8	3.6
Hemoglobin (g/L)	112.5	119.8
Leukocytes ($\times 10^{9}$/L)	6.4	5.4
Platelets ($\times 10^{9}$/L)	176.3	165.4
ESR (mm/h)	20.1	14.5

Comparative analysis of hematological parameters between vaccinated and unvaccinated pregnant women revealed slight variations without clinical significance (table 3). The mean erythrocyte count was 3.8×10^{12}/L in the vaccinated group and 3.6×10^{12}/L in the unvaccinated group. Hemoglobin levels were slightly lower among vaccinated women (112.5 g/L) compared

to unvaccinated women (119.8 g/L). Leukocyte counts were higher in the vaccinated group (6.4 × 10⁹/L) than in the unvaccinated group (5.4 × 10⁹/L). Platelet counts were also higher in the vaccinated group (176.3 × 10⁹/L vs. 165.4 × 10⁹/L). Erythrocyte sedimentation rate (ESR) was elevated in vaccinated women (20.1 mm/h) compared to the unvaccinated group (14.5 mm/h). These differences, however, were not statistically significant and may reflect variations in individual inflammatory responses.

Immunological Assessment and Age-Related Variations in Measles Immunity

Table 4. Immunological Profile of Healthy Individuals from General Population (A) and Vaccinated Non-Pregnant Women Aged 18–29 Years (B)

Table 4.A

Group	IgG (IU/ml)	IL-4 (pg/ml)	IFN-γ (pg/ml)
18–29 y.o. (n=85)	5.60	1.20	1.10
30–39 y.o. (n=11)	4.70	1.40	0.70
>40 y.o. (n=31)	4.80	1.30	0.80

Table 4.B

Group	IgG (IU/ml)	IL-4 (pg/ml)	IFN-γ (pg/ml)	
Women 18–29 y (IgG^+) n=35	2.90	1.70	1.60	
Women 18–29 y (IgG^-) n=4	0.062	1.40	0.50	10.3%

A thorough immunological evaluation was performed on 127 healthy individuals from the general population (see table 4A) and an additional 39 vaccinated, non-pregnant women aged 20–29 years (refer to table 4B), categorized according to their measles-specific IgG status. In a study involving 85 healthy participants aged 18 to 29 years, the average concentration of anti-measles IgG fell within the established normal range (>0.12 IU/mL), yielding a mean value of 5.60 IU/mL. The 30–39 and ≥40 age groups showed identical patterns through their IgG level measurements which reached 4.40 IU/mL and 4.80 IU/mL respectively. The IgG levels of healthy non-pregnant women between 18 and 29 years old averaged at 2.90 IU/mL which indicated lower immunity compared to other women of the same age group. Interestingly, 10% of these women exhibited IgG levels that fell below the protective threshold of 0.12 IU/mL (0.062). The findings indicate that individuals in the 18–29 age group may face a heightened susceptibility to measles infection.

Interferon-gamma (IFN-γ) and interleukin-4 (IL-4) are crucial cytokines that illustrate the equilibrium between Th1 and Th2 immune responses. The immune system depends on IFN-γ to activate macrophages and boost cellular immunity which protects against viruses. The study revealed that IgG-positive women aged 18-29 years showed higher IFN-γ levels which indicated their cells maintained measles immunity. The absence of IgG in women led to a threefold reduction in IFN-γ levels which might indicate weakened Th1-based cellular antiviral defense. The study demonstrates how vaccine immunity weakens in particular young adult women which posing significant health risks during pregnancy or in the event of measles outbreaks. The results demonstrate the need of routine blood tests to check immunity levels in women of childbearing age who show no IgG antibodies.

3.5 Gestational Stage and Outcome Variations in Measles-Affected Pregnancies

Table 5: Pregnancy Outcomes by Trimester (n=36)

Pregnancy Outcome	Trimester I (0–13 weeks)	Trimester II (14–27 weeks)	Trimester III (≥28 weeks)	Total
Full-term delivery (FTD)	0	3	3	6
Preterm delivery (PD)	0	0	2	2
Spontaneous abortion (SA)	9	8	0	17
Missed abortion (MA)	0	7	4	11

The pregnancy results from Table 5 demonstrate significant variations between different pregnancy stages of the 36 participants. The chi-square test ($\chi^2 = 22.32$, $p = 0.0011$) indicates that these differences were statistically significance. The first and second trimesters were for 49% of spontaneous abortions yet the third trimester showed no cases of abortion.

The majority of missed abortions occurred during the second trimester while the third trimester reported fewer cases. The preterm deliveries occurred exclusively in the third trimester while full-term deliveries happened in both the second and third trimesters. The study results demonstrate that the timing of measles exposure during pregnancy determines pregnancy outcomes for Kyrgyz women thus requiring enhanced maternal vaccination programs.

DISCUSSION

The findings provide a comprehensive overview of measles immunization and maternal–fetal outcomes, within the Kyrgyz context. In our study cohort, vaccinated and unvaccinated pregnant women were virtually indistinguishable: the severity of measles showed no divergence ($p = 1.000$) infectious sequelae were comparable across groups (all $p > 0.05$) and key obstetric endpoints—such as full-term delivery—were likewise overlapping ($p = 0.229$). Consequently once measles infection occurs during pregnancy, a prior vaccine dose seems to offer a if any cushion, against adverse clinical consequences. These findings line up with study of Amanatidou, Evropi et al. (2022), showing that even though vaccination has driven down infection rates breakthrough cases, among the vaccinated can still lead to complications [9] [10].

Our laboratory data further illustrate important immunological subtleties. In women ESR and leukocyte counts were modestly higher which may point to a vigorous immune response when infection strikes. For women who tested IgG-positive we observed elevated IFN-γ and IL-4 aligning with intact cellular immunity; by contrast IgG-negative participants showed lower cytokine levels suggesting a possible decline or lack of immune memory. Study by Pooley, Nick et al. (2023) explore into what protect us have found that while vaccine-induced antibody levels and cellular responses can linger the link, between those markers and real-world protection, against breakthrough infection is anything but straightforward and appears to shift as more time passes since vaccination [11]. While the analysis did not uncover any significant outcome differences linked to vaccination status, in pregnant women the markedly stronger immunological profile seen in vaccinated non-pregnant women hints that the hormonal and immune shifts of pregnancy may reshape how immunity presents itself. In the Kyrgyz context a recent seroprevalence survey reported an average measles IgG seropositivity of 78.9 % (95 % CI 77.9–79.9) and susceptibility rates that remain above the thresholds needed for herd immunity. These observations underscore the need to factor in ecology, vaccination histories and the complications of gestational immunodynamics. Ultimately this investigation will show the significance the demand, for prospectively structured research within Kyrgyz-Republic cohorts to untangle the interaction between vaccine-induced immune memory, physiological changes during pregnancy, and measles infection outcomes. A deeper understaning of these dynamics will be critical, for refining immunisation strategies and safeguarding both mothers and their infants.

FUTURE RECOMMENDATIONS

To strengthen measles control and improve maternal–fetal outcomes in Kyrgyzstan, the following recommendations are proposed:

5.1 Longitudinal Cohort Studies: Set up a network of multicenter, prospective studies to map how long measles-vaccine-induced immunity lasts and how effective it is, in women and women of age [12] [13].

5.2 Maternal Immunization Assessment: We should start screening both before a woman becomes pregnant and during pregnancy. Any IgG-negative women can be identified and offered a booster dose whenever it's needed [14] [15].

5.3 Cytokine and Immune Memory Profiling: Integrate cytokine and IgG profiling into public-health surveillance would enable an assessment of immune-response quality, after vaccination [16] [17].

5.4 Public Health Awareness: Elevate the vigor of public-health campaigns that underscores the role of booster vaccinations and the necessity of seeing the immunization process through, to its end with an emphasis, on rural and underserved territories [18] [19].

5.5 Policy-Level Integration: Collaborate with Kyrgyz health authorities to embed measles immunity monitoring, into the nation's immunization and reproductive-health policies [20] [21].

CONCLUSION

This study compared measles infection during pregnancy among women aged 18 to 29 years and found no significant differences between vaccinated and unvaccinated groups in disease severity, complications, or pregnancy outcomes. The results were remarkably consistent: disease severity, the frequency of complications and pregnancy outcomes showed no difference between the two groups. This suggests that a prior vaccine dose may not confer protection, against the effects once infection occurs during pregnancy. A deeper immunologic look revealed that some vaccinated non-pregnant women possessed either low or undetectable measles-specific IgG antibodies and their cytokine responses IFN-γ were noticeably weaker. This may reflect an waning of immunity, among women of age even for those with documented vaccination histories. Such findings underscore the need to revisit immunization policies, perhaps by adding routine antibody testing during pregnancy and offering booster shots to women whose immunity falls short. Strengthening defenses could help blunt the health hazards associated with measles infection, in pregnancy. Nonetheless the modest sample size limits how broadly these results can be applied and reduces the ability to detect differences. Larger, multi-institutional studies are essential to validate these results, better understand how well the vaccine works during pregnancy and informing public-health policies on measles booster shots for adults.

Conflicts of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Ethical Approval: This study was reviewed and approved by the IRB of International Higher School of Medicine, Bishkek, Kyrgyzstan and was performed in line with the principles of the Declaration of Helsinki.

Data availability statement: The data supporting the findings of this study are available upon reasonable request with corresponding author.

REFERENCE:

1. D. V. Parums, "A Review of the Resurgence of Measles, a Vaccine-Preventable Disease, as Current Concerns Contrast with Past Hopes for Measles Elimination," *Med. Sci. Monit. Int. Med. J. Exp. Clin. Res.*, vol. 30, pp. e944436-1-e944436-10, Mar. 2024, doi: 10.12659/MSM.944436.
2. "Measles Cases in European Region Highest in More Than 25 Years | Infectious Diseases | JAMA | JAMA Network." Accessed: Nov. 12, 2025. [Online]. Available: https://jamanetwork.com/journals/jama/article-abstract/2833101
3. "A chance to catch up: how Kyrgyzstan is fighting measles." Accessed: Nov. 12, 2025. [Online]. Available: https://www.who.int/europe/news-room/photo-stories/item/a-chance-to-catch-up--how-kyrgyzstan-is-fighting-measles
4. A. Khalil, A. Samara, C. Campbell, and S. N. Ladhani, "Pregnant women and measles: we need to be vigilant during outbreaks," *eClinicalMedicine*, vol. 72, p. 102594, Apr. 2024, doi: 10.1016/j.eclinm.2024.102594.
5. R. Ragusa *et al.*, "Measles and Pregnancy: Immunity and Immunization—What Can Be Learned from Observing Complications during an Epidemic Year," *J. Pregnancy*, vol. 2020, p. 6532868, Aug. 2020, doi: 10.1155/2020/6532868.
6. A. Khalil, A. Samara, C. Campbell, and S. N. Ladhani, "Pregnant women and measles: we need to be vigilant during outbreaks," *EClinicalMedicine*, vol. 72, p. 102594, June 2024, doi: 10.1016/j.eclinm.2024.102594.
7. A. SUVANBEKOV, G. KITAROVA, J. A. REYER, and N. HAMAJIMA, "PROGRESS TOWARD MEASLES ELIMINATION IN KYRGYZSTAN," *Nagoya J. Med. Sci.*, vol. 77, no. 1–2, pp. 179–188, Feb. 2015.
8. World Medical Association, "World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects," *JAMA*, vol. 310, no. 20, pp. 2191–2194, Nov. 2013, doi: 10.1001/jama.2013.281053.
9. E. Amanatidou *et al.*, "Breakthrough infections after COVID-19 vaccination: Insights, perspectives and challenges," *Metab. Open*, vol. 14, p. 100180, Mar. 2022, doi: 10.1016/j.metop.2022.100180.
10. M. Antonelli *et al.*, "Risk factors and disease profile of post-vaccination SARS-CoV-2 infection in UK users of the COVID Symptom Study app: a prospective, community-based, nested, case-control study," *Lancet Infect. Dis.*, vol. 22, no. 1, pp. 43–55, Jan. 2022, doi: 10.1016/S1473-3099(21)00460-6.
11. N. Pooley *et al.*, "Durability of Vaccine-Induced and Natural Immunity Against COVID-19: A Narrative Review," *Infect. Dis. Ther.*, vol. 12, no. 2, pp. 367–387, Feb. 2023, doi: 10.1007/s40121-022-00753-2.
12. L. M. Nic Lochlainn *et al.*, "Immunogenicity, effectiveness, and safety of measles vaccination in infants younger than 9 months: a systematic review and meta-analysis," *Lancet Infect. Dis.*, vol. 19, no. 11, pp. 1235–1245, Nov. 2019, doi: 10.1016/S1473-3099(19)30395-0.
13. A. Alam, M. F. Siddiqui, N. Imam, R. Ali, Md. Mushtaque, and R. Ishrat, "Covid-19: current knowledge, disease potential, prevention and clinical advances," *Turk. J. Biol.*, vol. 44, no. 3, pp. 121–131, June 2020, doi: 10.3906/biy-2005-29.
14. "Guidelines for Vaccinating Pregnant Women | Pregnancy & Vaccines | CDC." Accessed: Nov. 12, 2025. [Online]. Available: https://www.cdc.gov/vaccines-pregnancy/hcp/vaccination-guidelines/index.html
15. M. Arora and R. Lakshmi, "Vaccines - safety in pregnancy," *Best Pract. Res. Clin. Obstet. Gynaecol.*, vol. 76, pp. 23–40, Oct. 2021, doi: 10.1016/j.bpobgyn.2021.02.002.
16. "Profiling IgG and IgA antibody responses during vaccination and infection in a high-risk gonorrhoea population | Nature Communications." Accessed: Nov. 12, 2025. [Online]. Available: https://www.nature.com/articles/s41467-024-51053-x
17. M. F. Siddiqui, "IoMT Potential Impact in COVID-19: Combating a Pandemic with Innovation," in *Computational Intelligence Methods in COVID-19: Surveillance, Prevention, Prediction and Diagnosis*, vol. 923, K. Raza, Ed., in Studies in Computational Intelligence, vol. 923. , Singapore: Springer Singapore, 2021, pp. 349–361. doi: 10.1007/978-981-15-8534-0_18.
18. M. A. P. Sáfadi, "The importance of immunization as a public health instrument," *J. Pediatr. (Rio J.)*, vol. 99, no. Suppl 1, pp. S1–S3, Dec. 2022, doi: 10.1016/j.jped.2022.12.003.
19. D. M. Vittrup, S. Charabi, A. Jensen, and L. G. Stensballe, "A systematic review and meta-analysis of adverse events following measles-containing vaccines in infants less than 12 months of age," *Vaccine*, vol. 47, p. 126687, Feb. 2025, doi: 10.1016/j.vaccine.2024.126687.
20. "Kyrgyzstan and Global Partners Unite to Strengthen Vaccine Access for Every Child." Accessed: Nov. 12, 2025. [Online]. Available: https://www.unicef.org/kyrgyzstan/press-releases/kyrgyzstan-and-global-partners-unite-strengthen-vaccine-access-every-child
21. A. Y. Popova *et al.*, "Collective Immunity to the Measles, Mumps, and Rubella Viruses in the Kyrgyz Population," *Vaccines*, vol. 13, no. 3, p. 249, Mar. 2025, doi: 10.3390/vaccines13030249.