



Microbes and Infectious Diseases

Journal homepage: <https://mid.journals.ekb.eg/>

Original article

Assessment of measles vaccine effectiveness and its correlation with IL-6 and INF- γ in vaccinated children of Thi-Qar Province, Iraq

Abdulrahman Seger Gumar^{*}, Talib Hassan Ali

1- Department of Microbiology, College of Medicine, University of Thi-Qar, 64001, Iraq

ARTICLE INFO

Article history:

Received 8 February 2025

Received in revised form 5 March 2025

Accepted 12 March 2025

Keywords:

Measles vaccine

MMR vaccine

IL-6

INF- γ .

ABSTRACT

Background: Measles is still an endemic disease in Iraq, although it is preventable via vaccination. This study aimed to evaluate the effectiveness of measles vaccine which used in Thi-Qar province, Iraq. **Methods:** The case-control study included 176 children (117 vaccinated and 59 unvaccinated). The ELISA technique was used to detect measles virus IgG in children less than 13 years old. The person's informed consent was obtained. **Results:** The seroprevalence of measles virus IgG was positive in 91 (77.8%) of 117 vaccinated children, whereas 24 (40.7%) of 59 unvaccinated children tested positive showing a significant difference between both groups (p value < 0.001). In the vaccinated group, a significant difference was observed between males and females (p value = 0.028). In contrast, no significant difference was found in the unvaccinated group based on the chi-square test. In addition, this study showed significant differences between the case and control groups (p value = 0.002) and male and female in the case group (p value = 0.016), by using t-test. The results found a weak negative correlation with IL-6 ($r = -0.191$, p value = 0.039), but no correlation with INF- γ ($r = -0.095$, p value = 0.311) by using Pearson correlation. All at a p value < 0.05 . **Conclusions:** Findings of this study revealed that portion of children (22.2%) did not develop immunity against the measles virus. So, there must be increased efforts to achieve maximum immunization coverage, educate population about importance of vaccination, and perform more studies to ensure measles vaccine efficacy.

Introduction

Measles virus (MeV) is a highly infectious virus; It spreads through the respiratory system via respiratory droplets, and humans are the only known MeV reservoir [1, 2]. Wild-type measles virus highly replicates in lymphoid tissue, but the live attenuated MeV vaccine poorly replicates in lymphoid tissue [3]. Acute measles virus infection produces temporary immunosuppression, which is a significant cause of illness and death in children [4].

Indeed, the age of infection by measles varies; In developing countries, measles is frequently found in infants aged 6 months to 2 years, whereas children, adolescents, and young adults who have received vaccinations in developed countries have it. The MeV loses 60% of its infectivity in 3–5 days at room temperature. It has a 2-hour half-life at 37°C and a half-hour at 56°C [5]. Between 2000 and 2020, the annual number of projected measles deaths decreased by 94% saving an estimated 31.7 million lives. To eliminate measles in regions, all children

must receive two MeV vaccine doses under rigorous surveillance, peaking at 86% in 2019 and declining to 84% in 2020 due to the COVID-19 pandemic and vaccine coverage rate decreasing [6, 7].

The MeV vaccination rate was at its lowest level since 2008 in 2022, with approximately 83% of children worldwide receiving one shot by their first birthday through routine health services. Around 22 million infants skipped the recommended measles vaccine in 2022 [8]. The Immunization Agenda 2021–2030 (IA2030) uses measles incidence as a gauge of how effective vaccination programs are [6, 7]. The measles case fatality rate varies based on the epidemiologic setting, ranging from 0.2 to 29.1% [4]. Usually, only one dose of the measles vaccine provides 95% protection against measles, while a second dose boosts the measles vaccine's effectiveness to more than 99% [9]. Because of the widespread use of live-attenuated measles vaccination, the prevalence of measles in wealthy nations has dropped over the last two decades [10]. Measles vaccine side effects are rare and usually self-resolving [11]. Parental vaccine hesitation is one of the key causes of inadequate measles vaccine coverage [12, 13].

In Iraq, MeV remains an endemic disease, primarily due to insufficient vaccine coverage [14]. A study performed in the central teaching hospital of paediatrics in Babylon Province, Iraq, by Mohammed *et al.*, concluded that the measles is still a serious health issue for children [5]. As well as according to a study by Comfort, H., *et al.*, in Iraq, measles incidence was higher in areas with more displaced people even when vaccine coverage was constant, indicating that conflicts fueled the epidemic in ways that vaccine coverage could not control [15]. Despite massive efforts to eradicate measles from Iraq, isolated cases and restricted outbreaks continue to occur. Jawad, A.W., *et al.*, [16].

A study conducted in Thi-Qar Province in 2022 by Harbi, M.R. *et al.*, discovered that the most common reasons for decreasing immunization coverage were a lack of information and attention from parents, as well as child sickness [17]. In addition to the most primary health centres (PHCs), in Thi-Qar Province, particularly those serving remote areas, have a noticeable deficiency in full vaccine coverage due to the fact that most families reside far from PHC centres [18]. Finally, a study was conducted to assess the vaccination coverage

rate (VCR) for children under the age of five in Nasiriya 64001, Iraq, both before and after the COVID-19 pandemic. The VCR for measles decreased significantly (2018: 83.7%, 2019: 69.1%, 2020: 63.6%; p value < 0.001) [19]. This study aimed to evaluate the measles vaccine efficacy in Thi-Qar province, Iraq, and find out the protective level it gives for the target group.

Material and Methods

A case-control study included one hundred seventy-six children's serum or plasma samples whose age is less than 13 years with a history of child immunization status for the measles virus that were collected in Thi-Qar province, Iraq. During the period from 1/9/2023 to 15/1/2024. The vaccinated group count consisted of 117 children (males 68 children and females 49), and the unvaccinated group was 59 children (males 36 children and females 23). The personal information was obtained from parents and primary health centres as well, including age, sex, and vaccination status. The technique used in this research was Enzyme-Linked-Immunosorbent assay (ELISA) to detect the presence of IgG of the measles virus and cytokine levels in clinical samples.

Statistical Analysis: It was done by the IBM SPSS 26 version. Frequency and percentage were used for categorical data (by using the Chi-square test) and mean and standard deviation (SD) for continuous data (by using t-test and ANOVA) in addition to Pearson correlation to assess the associations between variables at a p value less than 0.05.

Ethical approval: The study was conducted in accordance with the ethical principles that have their origins in the Declaration of Helsinki. The committee of researchers at the Thi-Qar Health Directorate (No. 2023/163 on 7/8/2023) has viewed and approved this study. The person's informed consent was obtained.

The limitations: Any doubted case regarding vaccinated status were removed from this study

Results

Demographic Statistic

Comparison between vaccinated and unvaccinated children according to results

This study has shown a significant difference in measles virus IgG between case and control groups (p value < 0.001) by using Chi-square analysis according to results (positive or negative). Positive cases comprise 91 children (77.8%), whereas negative cases comprise 26 children (22.2%) in the vaccinated children (case group). In the unvaccinated children (control group), there were 24 children who tested positive (40.7%) and 35 who tested negative (59.3%) (Table 1).

Comparison between vaccinated and unvaccinated children according to sex and results

According to the current study, the vaccinated group's measles virus IgG levels differed significantly from those of the unvaccinated group when comparing sex and results based on child status (within the same group). The vaccinated group showed a statistically significant difference between males and females for measles virus IgG (p value = 0.028). There was no significant difference between males and females in the unvaccinated group (p value = 0.068) (Table 2).

Estimation of immune parameters

The vaccinated and invaccinated groups.

The current study showed that measles virus IgG levels were significantly higher in the

vaccinated group than in the unvaccinated group by using t-test (p value = 0.002) (Table 3).

The vaccinated group according to sex.

The study showed that the levels of measles virus IgG in the vaccinated group, according to sex, were significantly different for males and females (p value = 0.016) (Table 3).

The vaccinated group according to the doses of the measles vaccine

In this study, levels of measles virus IgG concentration were not statistically different when compared between children who got one dose and those who got two doses (p value = 0.055) after getting the MMR vaccine (Table 3).

The vaccinated group according to the age group.

The vaccinated group's age was split up into five groups. There were no statistically significant differences between the levels of Measles Virus IgG (p value 0.457) (Table 4).

The Pearson correlation between immune parameters.

The parameters in this study have been linked to each other. It was discovered that there were significant differences between measles virus IgG and some cytokines. Measles virus IgG has a significant weak negative correlation with IL-6, but not with INF- γ . The values were for IL-6 ($r = -0.191$; p value = 0.039), and INF- γ ($r = -0.095$; p value = 0.311) (Table 5).

Table 1. The number and percentage of children's results in both groups.

Parameter	Child Status	Positive		Negative		Total		Chi-Square
		No.	%	No.	%	No.	%	
Measles virus IgG	Vaccinated	91	77.8	26	22.2	117	100	CalX2= 23.838 p value $< 0.001^*$
	Unvaccinated	24	40.7	35	59.3	59	100	
	Total	115	65.3	61	34.7	176	100	

* = Significant Difference

Table 2. The number and percentage of results by sex for each group.

Parameter	Child Status	Sex	Positive		Negative		Total		Chi-Square
			No.	%	No.	%	No.	%	
Measles virus IgG	Vaccinated	Male	48	70.6	20	29.4	68	58.12	CalX2= 4.856 p value 0.028*
		Female	43	87.8	6	12.2	49	41.88	
		Total	91	77.8	26	22.2	117	100	
	Unvaccinated	Male	18	50	18	50	36	61.02	CalX2= 3.326 p value 0.068 ^{NS}
		Female	6	26.1	17	73.9	23	38.98	
		Total	24	40.7	35	59.3	59	100	

* = Significant Difference

NS = non-significant difference

Table 3. Estimation levels of Measles Virus IgG According to Child Status, Sex, and Doses.

Parameters	Mean $\pm$ S.D		t-test (p value)
	Vaccinated No. 117	Unvaccinated No. 59	
Measles virus IgG	2.38 $\pm$ 0.90 U/L	1.95 $\pm$ 0.69 U/L	0.002*
	Male No. 68	Female No. 49	
	2.38 $\pm$ 0.90	1.95 $\pm$ 0.69	0.016*
	One dose of vaccine (n = 16 children)	Two dose of vaccine (n = 101 children)	
	2.04 $\pm$ 0.68	2.44 $\pm$ 0.92	0.055 ^{NS}

* = Significant Difference

NS = non-significant difference

Table 4. Measles Virus IgG in the case group according to age group.

Age in Months	Cases No.	Mean $\pm$ S. D
< 25	14	2.35 $\pm$ 0.77
25 – 48	39	2.32 $\pm$ 0.90
49 – 72	30	2.22 $\pm$ 0.92
73 – 96	9	2.53 $\pm$ 0.65
> 96	25	2.65 $\pm$ 1.02
(ANOVA) p value		0.457 ^{NS}

NS = non-significant

Table 5. The Pearson correlation between the studied immune parameters.

parameters		IL-6	INF- γ
Measles Virus IgG	r	-0.191	-0.095
	P- value	0.039*	0.311

*Correlation is significant at the 0.05 level (2-tailed).

Discussion

The success of a vaccination strategy in a population depends on wide population coverage and the immune system's response to vaccines [20]. But waning immunity after vaccination is believed to be a pivotal factor in the resurgence of diseases [21]. A high vaccination rate and the lasting immunity brought about by vaccines are necessary to effectively control and eradicate measles [22]. The limitations that were included in this study were removing any doubted case regarding vaccinated status.

Out of the 117 children who have been vaccinated and were involved in this study, only 91 (77.8%) were seropositive for the measles virus, while 26 (22.2%) were seronegative. This is consistent with two studies where a portion of vaccinated children were seronegative [22, 23]. Bolotin *et al.*, using linear regression, observed that measles antibodies decreased with time in participants who received two doses of the measles vaccine [24].

This study disagreed with a Norwegian study conducted that showed IgG antibody concentrations were 'protective levels' for measles.

97.1% [25], and an Indian study, the rate of seroprotection against the measles virus was 88.7% [26]. In an Argentina study, IgG titers were 92.2% [27]. A study was carried out in Kuwait its results showed that measles had the highest percentage of seropositive (94.6%), which was substantially greater in females compared to males [28]; It contrasts with our regarding vaccine efficacy. These differences may be due to the sample size, range of age, vaccine coverage rate, and systems of immunization in these countries.

According to the results in this study, 26 (22.2%) of the 117 children in the case group were seronegative. This agreed with a study performed by Quach, H.Q., *et al.*, According to their findings, 37.6% of research participants tested negative for measles IgG [22], and with Bolotin, S., *et al.*, [24]. In addition, this study agreed with a study performed in Iraq by Al-Hamdani, A.H., The study revealed that 45 (23.8%) participants were seronegative for measles antibodies [9]. Studies in high-income European countries showed that some vaccinated people were seronegative years later, increasing the measles risk. Anichini, G., *et al.*, [29]. This may be due to the fact that antibody concentrations in people

who have had measles virus (a natural infection) last longer than in people who have been vaccinated [30]. Many researches indicate that anti-measles antibody levels decrease with age. This tends to happen faster after immunization than after illness [29, 31-33]. vaccine-induced measles antibodies declined by 0.009 per year [34].

This study found a significant difference between the case and control groups ($\text{CalX}^2 = 23.838$, $p\text{-value} < 0.001$). This agreed with a Korean study ($P\text{-value} < 0.001$) [35], and a Saudi Arabian study found a similar result ($p\text{-value} = 0.0001$) [36]. In this study, the control group found that 24 of the 59 children of origin were seropositive for the measles virus IgG. The source of IgG in unvaccinated children is infection by the measles virus or from the mother (across the placenta or breastfeeding) [10]. Only several months after birth can infants be protected by maternal antibodies transmitted transplacentally following that, everyone is susceptible to the infection [30, 37]. As noted in measles elimination locations, maternal antibody levels are lower because measles does not spread endemically and most immunity comes from immunization. So, baby immunity declines earlier, and the susceptibility gap between maternal antibody degradation and baby immunization is larger than in the non-eliminated region [37]. Our study agreed with Turkey's study, Protective measles antibody levels were 80% in mothers and 85% in neonates by Cetin Coban, S., *et al.*, [38]. In addition, this study agreed with three studies performed in Babylon Province, Iraq, by Mohammed *et al.*, Aljothery, A.H., *et al.*, and Hasan, S., [5, 14, 39].

Males and females have different innate and adaptive immune responses. This could be related to hormones. Klein, S.L., *et al.*, found that sex is often, but not always, a strong predictor of vaccine reactions; females have larger humoral immune responses to immunizations in most viral vaccines, but in the case of the MMR vaccine (human/antibody response and cell-mediated immunity; $F=M$) [40]. This disagreed with this study, which found the measles virus IgG for females was higher than males ($p\text{-value} = 0.016$). This difference may be due to methodology. Also, our study was in contrast to a study by Kennedy, R.B., *et al.*, US, that found no statistically significant differences in antibody titer change between males and females ($p\text{-value} = 0.15$) [31]. These differences may be due to the fact that their findings were

obtained from vaccinated people who had immunological responses to measles and were evaluated at two points, 7 and 17 years after vaccination, or perhaps because of the smaller cohort size. But our study compatible with Bolotin, S., *et al.*, ($p\text{-value} = 0.013$) [24].

There was no statistically significant difference in the concentration of IgG levels between children who have received one dosage and those who have received two doses of the MMR vaccine ($p\text{-value} < 0.055$). This may be due to the small sample size or may be due to the vaccine efficacy (one dose 95% and two doses 99%). It is consistent with the findings of Wanlapakorn, N., *et al.*, [41]. But differs with Gupta, M., *et al.*, in comparing children who have received one dose of the MMR vaccine to those who have received two or more doses. The children's seroprotection against the measles was considerably greater ($P\text{-value} < 0.001$) [23]. This difference may be due to the study design or range of the age (5-10 years). In addition to contradicting Verma, S.K., *et al.*'s study ($P\text{-value} < 0.001$) after the second dose [26]. Perhaps attributable to the chosen research methodology, or due to the restricted age range of newborns (between 9 and 12 months).

The results of the study revealed that the levels of measles virus IgG not differ statistically significantly according to age group ($p\text{-value} 0.457$). This agreed with Pedranti, M., *et al.*, ($p\text{-value} = 0.105$) [27]. But was incompatible with Lin, M., *et al.*, Their research found a substantial difference ($p\text{-value} < 0.001$). This disparity could be attributed to the age range (18-70 years), a sample size of (2905 participants), or the research period from 2008 to 2018 [42].

The cytokines regulate and effect the immunological response [43]. This study seeks to find a connection between interleukin 6 (IL-6) and interferon gamma ($\text{INF-}\gamma$) and the measles virus IgG. Our results showed that interleukin 6 (IL-6) has a negative correlation with MeV's IgG ($r = -0.191$; $p\text{-value} = 0.039$). This disagreed with Ovsyannikova, I.G., *et al.*, there was no evidence of a link between measles and IL-6 secretion ($r = 0.010$; $p\text{-value} = 0.80$) [44]. This may be due to sample size, study design (cohort), people's race, period of study (from 2001–2007), or age of participants. As well as this conflicting with the findings of Melot, L., *et al.*, they found that vaccine-infected cells had higher IL-6 levels [4].

Additionally, disagreed with Suwanmanee, S., *et al.*, [3].

Interferon- γ (IFN- γ), this study revealed that there was no correlation between measles virus IgG and IFN- γ secretion ($r = -0.095$; p -value = 0.311). This did not correspond with Ovsyannikova, I.G., *et al.*, whose results showed evidence of a correlation between MeV's IgG and IFN- γ ($r = 0.079$; p -value = 0.04). This could be because 84.9% of individuals identified as Caucasian-American, whereas 8.2% identified as African-American, or other causes may be present, like study design (cohort), sample size, period of study, or age of participants [44].

Conclusion

Iraq, is still suffering from the appearance of measles from time to time. According to the findings of this study, which revealed that a portion of children did not develop immunity to the measles virus, their percentage was 22.2%. This may be a negative indicator for measles re-emerging in Iraq. So, there must be increased efforts to achieve maximum immunization coverage, educate the population about the importance of vaccination, and perform more studies in many Iraqi cities to ensure measles vaccine efficacy.

Author contributions

(1) Gumar A. and Ali T. both contribute to the conception and design of the study and the analysis and interpretation of data (except the acquisition of data, which was done by Gumar A.). (2) Both authors shared in draughting the article and revising it critically for scientific content. (3) All authors had seen and approved the submission of the manuscript with full responsibility

Conflict of Interest:

The authors declare that they have no conflict of interest.

Financial disclosure

The authors deny receiving any financial support or grant from any organization.

Data availability

The data that support the findings of this study are available from the corresponding author upon request.

References

- 1- Holzmann H, Hengel H, Tenbusch M, Doerr HW. Eradication of measles: remaining

challenges. *Medical Microbiology and Immunology*. 2016;205(3):201-8.

- 2- Moss WJ. Measles. *The Lancet*. 2017;390(10111):2490-502.
- 3- Suwanmanee S, Ghimire S, Edwards J, Griffin DE. Infection of Pro- and Anti-Inflammatory Macrophages by Wild Type and Vaccine Strains of Measles Virus: NLRP3 Inflammasome Activation Independent of Virus Production. *Viruses*. 2023;15(2).
- 4- Melot L, Bankamp B, Rota PA, Coughlin MM. Characterizing infection of B cells with wild-type and vaccine strains of measles virus. *Iscience*. 2023;26(10).
- 5- Mohammed AK, Nasir AR, Alsweedy MMJ. Clinical and epidemiological study of measles cases in central teaching hospital of pediatrics in Babylon Province. *Medical Journal of Babylon*. 2022;19(4):518.
- 6- Dixon MG, Ferrari M, Antoni S, Li X, Portnoy A, Lambert B, et al. Progress toward regional measles elimination—worldwide, 2000–2020. *Morbidity and Mortality Weekly Report*. 2021;70(45):1563.
- 7- Venkatesan P. Worrying global decline in measles immunisation. *The Lancet Microbe*. 2022;3(1):e9.
- 8- WHO. Measles. (online) available from <https://www.who.int/en/news-room/fact-sheets/detail/measles>. 2023(accessed Feb 18, 2024).
- 9- Al-Hamdani AH. Seroepidemiological study of measles virus among young adults: response to revaccination. *Baghdad Science Journal*. 2014;11(4):1493-502.
- 10- Gastañaduy PA, Banerjee E, DeBolt C, Bravo-Alcántara P, Samad SA, Pastor D, et al. Public health responses during measles outbreaks in elimination settings: Strategies

- and challenges. *Human Vaccines & Immunotherapeutics*. 2018;14(9):2222-38.
- 11- Misin A, Antonello RM, Di Bella S, Campisciano G, Zanotta N, Giacobbe DR, et al. Measles: An Overview of a Re-Emerging Disease in Children and Immunocompromised Patients. *Microorganisms*. 2020;8(2).
 - 12- Pandey A, Galvani AP. Exacerbation of measles mortality by vaccine hesitancy worldwide. *Lancet Glob Health*. 2023;11(4):e478-e9.
 - 13- Wilder-Smith AB, Qureshi K. Resurgence of Measles in Europe: A Systematic Review on Parental Attitudes and Beliefs of Measles Vaccine. *J Epidemiol Glob Health*. 2020;10(1):46-58.
 - 14- Aljothery AH, Baiee HA, Hussein KF, Baiee AH, Abdulameer TS, Hadi AA, et al. Epidemiologic and Clinical Characteristics of Children with Measles during the Year 2019. *Indian Journal of Forensic Medicine & Toxicology*. 2020;14(3):1399-404.
 - 15- Comfort H, Lafta RK, Flaxman AD, Hagopian A, Duber HC. Association Between Subnational Vaccine Coverage, Migration, and Incident Cases of Measles, Mumps, and Rubella in Iraq, 2001–2016. *Frontiers in Public Health*. 2022;9:689458.
 - 16- Jawad AW, Al Hares S, Al Suraifi M, Aldujaili A, Muttaasher H. Epidemiological characteristics of Under Five Measles cases, Al Najaf Al Ashraf Province, Iraq, 2006-2018. *Kufa Journal for Nursing Sciences*. 2021;11(1):75-82.
 - 17- Harbi MR, Al-Mosawi RA, editors. Statistical analysis of the immunization service for children under 6 years old by geographic information system technique in Dhi Qar Province_Iraq. AIP Conference Proceedings; 2023: AIP Publishing.
 - 18- AL-Sarray AAM. Evaluation of Application of Quality Improvement Program Among a Samples of Primary Health Care Centers In Thi-qar Governorate. *University of Thi-Qar Journal Of Medicine*. 2018;15(1):12-28.
 - 19- Alhaddad AR, Ahmadnezhad E, Fotouhi A. The vaccination coverage rate in under-5 children in Nasiriyah, Iraq before and during the COVID-19 pandemic. *Epidemiol Health*. 2022;44:e2022035.
 - 20- Jamieson AM. Influence of the microbiome on response to vaccination. *Human vaccines & immunotherapeutics*. 2015;11(9):2329-31.
 - 21- Gupta R, Saxena N, Gupta P. Determination of ELISA reactive mumps IgG antibodies in MMR vaccine recipients in comparison with MMR vaccine naive children: A cross sectional study. *Scripta Medica*. 2021;52(3):174-80.
 - 22- Quach HQ, Ovsyannikova IG, Grill DE, Warner ND, Poland GA, Kennedy RB. Seroprevalence of Measles Antibodies in a Highly MMR-Vaccinated Population. *Vaccines*. 2022;10(11):1859.
 - 23- Gupta M, Tripathy JP, Verma M, Singh MP, Kaur R, Ratho RK, et al. Seroprevalence of measles, mumps & rubella antibodies among 5-10 years old children in north India. *Indian J Med Res*. 2019;149(3):396-403.
 - 24- Bolotin S, Osman S, Hughes SL, Ariyaratnam A, Tricco AC, Khan S, et al. In Elimination Settings, Measles Antibodies Wane After Vaccination but Not After Infection: A Systematic Review and Meta-Analysis The Journal of Infectious Diseases. 2022;226(7):1127-39.
 - 25- Kukule L. IgG protection status for humoral immune response to MMR vaccine among

- the Norwegian population of children and method assessment of MMR-Multi-Plex Immunoassay: Norwegian University of Life Sciences, Ås; 2022.
- 26- Verma SK, Shah D, Singh A, Singh PK, Das S, Gupta P. Immunogenicity of measles-rubella vaccine administered under India's Universal Immunization Programme in the context of measles-rubella elimination goal: A longitudinal study. *Indian Journal of Medical Research*. 2023;157(4).
 - 27- Pedranti M, Isa MB, Riberi MI, Hernandez G, Alfaro J, Tenaglia M, et al. Measles and Rubella Seroprevalence Among Children and Adolescents of Córdoba, Argentina: A Cross-Section Study in the Context of the Elimination Program. *Viral Immunol*. 2023;36(6):429-34.
 - 28- Madi N, Altawalrah H, Alfouzan W, Al-Nakib W, Al-Roumi E, Jeragh A. Assessment of immune status against measles, mumps, and rubella in young Kuwaitis: MMR vaccine efficacy. *J Med Virol*. 2020;92(8):963-70.
 - 29- Anichini G, Gandolfo C, Fabrizi S, Miceli GB, Terrosi C, Gori Savellini G, et al. Seroprevalence to measles virus after vaccination or natural infection in an adult population, in Italy. *Vaccines*. 2020;8(1):66.
 - 30- Smetana J, Chlibek R, Hanovcova I, Sosovickova R, Smetanova L, Gal P, et al. Decreasing seroprevalence of measles antibodies after vaccination-possible gap in measles protection in adults in the Czech Republic. *PLoS One*. 2017;12(1):e0170257.
 - 31- Kennedy RB, Ovsyannikova IG, Thomas A, Larrabee BR, Rubin S, Poland GA. Differential durability of immune responses to measles and mumps following MMR vaccination. *Vaccine*. 2019;37(13):1775-84.
 - 32- Carryn S, Feyssaguet M, Povey M, Di Paolo E. Long-term immunogenicity of measles, mumps and rubella-containing vaccines in healthy young children: A 10-year follow-up. *Vaccine*. 2019;37(36):5323-31.
 - 33- Kim YC, Nam H, Choi JY, Shin E-C, Choi YH. The third dose of measles-containing vaccine induces robust immune responses against measles in young seronegative healthcare workers who had previous two-dose measles vaccination. *Journal of Infection and Public Health*. 2023;16(10):1643-9.
 - 34- Schenk J, Abrams S, Theeten H, Van Damme P, Beutels P, Hens N. Immunogenicity and persistence of trivalent measles, mumps, and rubella vaccines: a systematic review and meta-analysis. *The Lancet Infectious Diseases*. 2021;21(2):286-95.
 - 35- Choi WS, Go UY, Han YR, Jeong YW, Kim KH, Kong KA, et al. Timeliness of MMR vaccination and barriers to vaccination in preschool children. *Epidemiology and Infection*. 2011;139(2):247-56.
 - 36- Khalil MK, Nadrah HM, Al-Yahia OA, Al-Saigul AM. Sero-response to measles vaccination at 12 months of age in Saudi infants in Qassim Province. *Saudi Med J*. 2008;29(7):1009-13.
 - 37- Guerra FM, Crowcroft NS, Friedman L, Deeks SL, Halperin SA, Severini A, et al. Waning of measles maternal antibody in infants in measles elimination settings - A systematic literature review. *Vaccine*. 2018;36(10):1248-55.
 - 38- Cetin Coban S, Temel F, Duman P, Cosgun Y, Ozarslan F, Kayman T, et al. Prevalence of Protective Measles Virus Antibody Levels in Umbilical Cord Blood Samples and Sera of Mothers and Transplacental Transport

- Ratio in Turkey. *Jpn J Infect Dis.* 2019;72(3):185-92.
- 39- Hasan S. Measles Epidemic in Babylon Teaching Hospital for Pediatrics and Gynecology from 2017 to 2021. *International Journal of Computational Intelligence in Control.* 2021;Vol. 13(2021).
- 40- Klein SL, Jedlicka A, Pekosz A. The Xs and Y of immune responses to viral vaccines. *Lancet Infect Dis.* 2010;10(5):338-49.
- 41- Wanlapakorn N, Puenpa J, Thongmee T, Srimuan D, Thatsanathorn T, Vongpunsawad S, et al. Antibodies to measles, mumps, and rubella virus in Thai children after two-dose vaccination at 9 months and 2.5 years: A longitudinal study. *Vaccine.* 2020;38(24):4016-23.
- 42- Lin MY, Shao HH, Tsou MT. Measles immunity in medical center staff after changes in national and local hospital vaccination policies. *BMC Infect Dis.* 2022;22(1):427.
- 43- Salih AM. STUDY ON SOME CYTOKINE ELEVATION DURING MEASLES VIRUS INFECTION IN CHILDREN. *Biochemical & Cellular Archives.* 2021;21(1).
- 44- Ovsyannikova IG, Salk HM, Larrabee BR, Pankratz VS, Poland GA. Single-nucleotide polymorphism associations in common with immune responses to measles and rubella vaccines. *Immunogenetics.* 2014;66(11):663-9.