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Full Length Research Paper

Sero-surveillance of measles amongst vaccinated and non-vaccinated children: An age stratified population based survey in Pakistan

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Measles is one of the most contagious human diseases; it remains a leading cause of death among young children and its elimination is one of the major global public health priorities. It is estimated that in year 2008 approximately 100,000 deaths in children aged less than 5 years was attributable to measles. The increase in measles vaccination coverage in the developing world has produced significant changes in the epidemiology of the infection. The present age stratified cross sectional survey was conducted in Islamabad, Pakistan and its adjoining areas during January to June, 2009 to determine the measles protective titre in children of 1 to 15 years. 927 blood samples of children were collected to ascertain the measles antibodies by ELISA assay. 588 were males and 339 were female (p = 0.001). Measles IgG antibodies sero-positive ratio in children among examined population was 741 (79.9%), sero-negative 174 (18.77%) (p = 0.001). Out of 174 seronegative children, 135 (14.5%) were vaccinated while 39 (4.20%) children were non-vaccinated. The children were divided into three groups, that is, 1 to 5 years (pre school age), 6 to 10 years (primary school group) and 11 to 15 years (secondary school going children). Sero-positive antibodies percentage increased age. Measles IgG antibodies ratio is higher in male children as compared to female. Sero-surveillances should be conducted at regional and provincial levels to assess the actual level of protective titre throughout the country and to evaluate the country's vaccination program. The routine coverage of immunization should also increase from 80 to 100%.

Key words: Sero-surveillance, measles, vaccinated children, Pakistan.

INTRODUCTION

Measles is one of the most contagious human diseases and remains a leading cause of death among young children, despite the availability of a safe and effective vaccine for the past 40 years. It is estimated that in 2008 approximately 100,000 deaths in children aged less than 5 years was attributable to measles (WHO, 2000; Black et al., 2010). Pneumonia is one of the most common fatal complications of measles (Duke and Mgone, 2003). Its elimination is one of the major global public health priorities (Dodd and Cassels, 2006). The increase in measles vaccination coverage in the developing world has produced significant changes in the epidemiology of the infection (Cliff et al., 2003), such as a shift to a higher incidence of measles in older children and young adults (Coetzee et al., 1994). Morbidity and mortality related to measles frequently occurs before nine months of age.

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However, vaccination against measles is recommended at the age of 9 months in developing countries (Tapia et al., 2005). Maternal antibody confers protection to infants against measles during the first few months of life (Assaad, 1983). In Pakistan, 25% of measles cases occur under one year of age and in Bangladesh 17% of cases are below five years of age in infants (de-Francisco, 1998). Women have shown varied levels of antibody titers to pass it on to their infants, and Asian women have low tendency of placental antibody transfer, which can aggravate the overall protection of infants against measles in the region (Black, 1989).

In developed countries, children aged 12 to 15 months are given first dose, and a second dose of measles vaccine was added to the vaccination schedule of 7 years old (Janaszek et al., 2000). In 2008, all World Health Organization (WHO) member states reaffirmed their commitment to reduce the global measles mortality to less than 75,000 deaths by 2010, that is, 90% reduction in measles mortality compared to the year 2000.

Serosurveillance is an important component of any comprehensive surveillance system for vaccine preventable diseases. Serosurveillance is therefore the gold standard for measuring immunity in a population, and complements disease surveillance. Serological surveys of specific antibody status in vaccinated populations provide valuable information to health authorities on the impact of the intervention on continued transmission (Babad et al., 1995; Gay et al., 1995), the distribution (by age and geographical location) of proportions sero-negative (Cutts et al., 1995; Gay et al., 1997; Cox et al.,1998; de Melker et al., 2001), the risks of an outbreak (Babad et al., 1995; Gay et al., 1997) and the progress towards elimination (Janaszek et al., 2000). Surveys that report on the level of detectable antibody, rather than presence or absence, may further inform on the likely distribution of sub-clinical, mild and typical measles re-infection and on the potential for community persistence of measles (Cutts et al., 1995; Cox et al., 1998; Mossong et al., 1999; Lee, 1999, Lee et al., 2000). The data from serosurveillance is also an essential contribution to mathematical modeling, which can predict the potential for cases in the future, and thus when, and in which age groups-intervention is required to prevent an epidemic. The serological studies has also shown that post vaccination measles antibody titre declines in the absence of natural reinfection and age at vaccination has an influence on the immune response (Christenson and Bottiger, 1994; Boulianne et al., 1995). The sero-surveillance program is also an important source of information for public health action. There is little recent data on measles sero-epidemiology and the impact of vaccination on measles transmission in Pakistan.

The present study is age stratified serological survey to ascertain the levels of antibody against measles in vaccinated/non-vaccinated children ranging from 1 to 15 years from various parts of Islamabad and its adjoining areas. It also looked into the possible associations between age, sex, socioeconomic and immunological response to measles vaccine. It can provide an important data to support the evaluation of country vaccination program and efficacy of Expanded Program on Immunization (EPI) on (measles) vaccine in Pakistan.

MATERIALS AND METHODS

Study design

The present study is age stratified serological survey, which was carried out for six months from January, 2009 to June, 2009. There are two methods that can be used to obtain sera for the serosurvey. Ideally, a nationally representative sample would be randomly selected from the study population and participation would be 100%. The alternative is to use a convenience sample of sera that have been collected for other purposes. Both approaches have been used internationally. Population based has been used in USA as part of their National Health and Nutritional Examination Surveys Programs. In Netherlands, a cluster sampling technique is used to select the sample (Gidding, 2003).

In this study, a total of 927 blood samples of children were collected from Islamabad and its adjoining areas from selected groups of children/adults ranging from 1 to 15 years. The study was approved by the board of studies of Quaid-i-Azam, University, Islamabad, Pakistan. Vaccination history and blood samples were also collected. The sera were separated and kept at -20°C till the samples were analyzed for the presence of measles-specific IgG antibodies using commercial ELISA kits. The phlebotomist and investigators also explained the purpose of study to the parents/guardians and sought their written consent for taking the blood from children. The results were calculated by applying SPSS 14.

Including criteria: Vaccinated/ non-vaccinated; age 1 to 15 years old; and both genders, male/female children. Excluding criteria: Immuno-compromised; Infected with human immunodeficiency virus; recently infected with measles and other infection such as tuberculosis, hepatitis etc.

RESULTS

A total of 927 samples for all age groups were collected of which 588 were males and 339 were female ($p = 0.001$). The male sero-positive ratio is greater than female in all age groups except one, five, eleven and fifteen year children. Measles IgG antibodies sero-positive ratio in children among examined population was 741 (79.9%), sero-negative 174 (18.77%), equivocal ratio was 12 (1.29%). Out of 174 seronegative children, 135 (14.5%) were vaccinated while 39 (4.20%) children were non-vaccinated as mentioned in Table 1. The details of the children according to sex and age are given in Table 2. The age wise sero-positive prevalence amongst male and female and equivocal sera is given in Table 3. Prevalence of measles IgG antibodies in different age groups is shown in Table 4. The children were divided into three groups, that is, 1 to 5 years (pre school age), 6 to 10 years (primary school group) and 11 to 15 years (secondary school going children). In first and second

Table 1. Measles sero-prevalence in the examined population.

Age (years)	No. of sera tested	No. of positive sera (%)	No. of negative sera (vaccinated) (%)	No. of non-vaccinated children (seronegative) (%)	No. of equivocal sera (%)	p value
1-15	927	741 (79.9)	135 (14.56)	39 (4.20)	12 (1.30)	P = 0.001

Table 2. Prevalence of measles antibodies, in vaccinated and non-vaccinated children, according to age and sex in 1 to 15 years old children.

Age (Years)	Vaccinated children (male)			Vaccinated children (female)			Non-vaccinated		Equivocal
	Sero +ve	Sero -ve	Sero +ve (%)	Sero +ve	Sero -ve	Sero +ve (%)	Male	Female	
1	12	9	57.14	18	9	66.66	3	3	
2	30	12	71.42	6	12	33.3	-	-	
3	45	9	83.33	21	6	77.8	3	-	M-3, F-3
4	42	6	87.5	24	6	80		6	
5	30	3	90.90	18	-	100	3	3	
6	21	-	100	15	9	62.5	9	-	
7	33	-	100	33	3	91.66	3	3	F-3
8	30	-	100	18	-	100	-	-	
9	39	3	92.85	12	-	100	-	3	F-3
10	48	12	80	15	15	50	-	-	
11	39	6	86.7	27	-	100	-	-	
12	66	3	95.7	21	3	87.5	-	-	
13	18	-	100	12	3	80	-	-	
14	15	-	100	3	-	100	-	-	
15	27	6	81.8	3	-	100	-	-	
Total	495	69	87.76	246	66	78.84	21 (2.26%)	18 (1.94%)	12 (1.3%)

Table 3. Distribution and prevalence of measles IgG antibodies according to sex in different age groups.

Age groups (Years)	Vaccinated children (male)			Vaccinated children (female)			Non-vaccinated		Equivocal
	Sero+ (%)	Sero- (%)	No.	Sero+ (%)	Sero- (%)	No.	Male	Female	
1 - 5	159 (80)	39 (19.69)	198	87 (72.5)	33 (27.5)	120	9	12	M-3, F-3
6 - 10	171 (92)	15 (8.0)	186	93 (77.5)	27 (22.5)	120	12	6	F-6
11 - 15	165 (88.7)	15 (8.33)	180	66 (91.66)	6 (8.3)	72	-	-	
Total	495	69	564	246	66	12	21 (2.26)	18 (1.94)	12 (1.3)

group of female children, measles IgG antibodies titer was less than male children, except third group in which female contain 91.66% and male children contain 88.7%, respectively. As age increases the sero-positive antibodies percentage also increased. Sero-negative percentage decreased as age increased in Table 3 and Figure 1, distribution and prevalence of measles IgG antibodies according to sex are given which shows that sero-prevalence measles antibodies ratio is higher in male children as compared to female and sero-negative was also higher in female than male children.

DISCUSSION

This serological study examined the prevalence of measles antibodies in vaccinated/non-vaccinated children and teenagers following the national measles vaccination program in Pakistan which used a one-dose regimen. Measles is a highly infectious and contagious disease but can be prevented by vaccination. Despite achieving more than 80% immunization since 1998, every year immunization schedules are organized by Expanded Program on Immunization (EPI), Ministry of Health

Table 4. Prevalence of measles IgG antibodies in different age groups.

Characteristic age group (years)	Test results		Total no. (n = 927)	Non-vaccinated children (%) (N = 39)	Equivocal
	Sero +ve No. (%)	Sero –ve No. (%)			
1 - 5	246 (72.6	72 (22.64)	318 (100)	21	
6 - 10	264 (81.5)	42 (13.72)	306 (100)	18	12 (1.30)
11 - 15	231 (91.7)	21 (8.3)	252 (100)		
Total	741	135	876	39	12

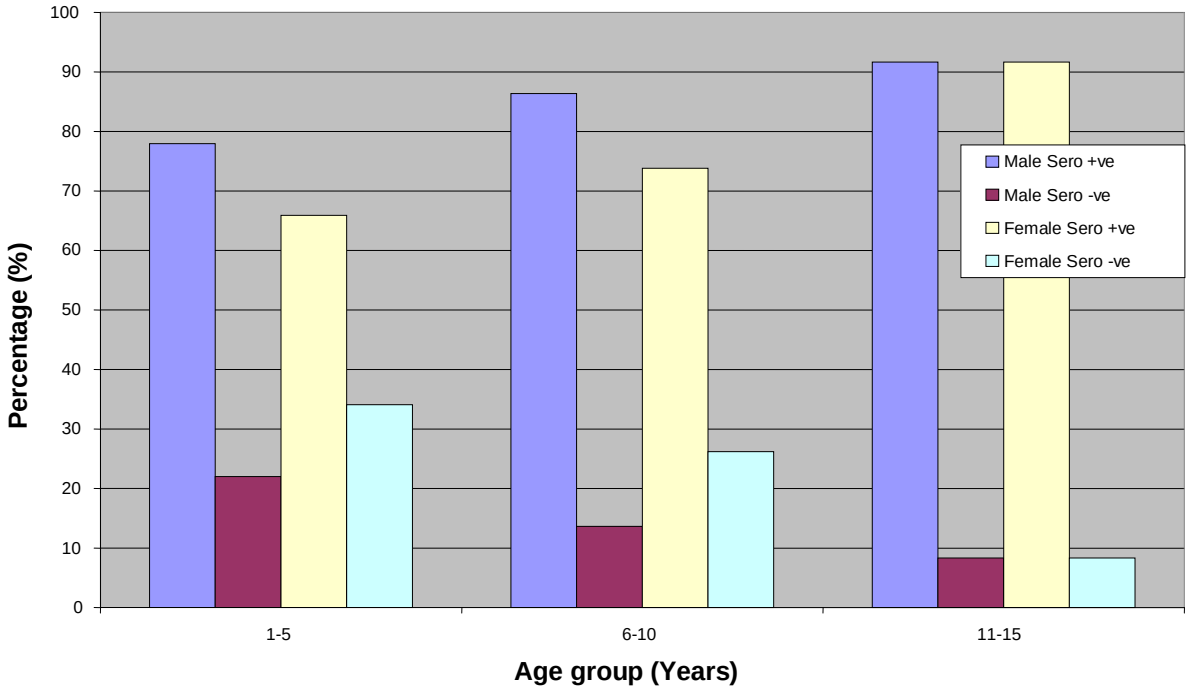

Figure 1. Distribution and prevalence of measles IgG antibodies according to sex in different age groups.

(MOH), Pakistan but incidence of measles has been reported every year. Vaccination against measles, poliomyelitis, diphtheria, pertusis and tetanus, are being provided free of cost to all infants through the EPI/MOH, Government of Pakistan. It has been reported that cellular and humoral responses are involved in immunity to measles virus (Bellini et al., 1981; UytdeHaag et al., 1994; van Binnendijk et al., 1992, 1993). This survey was conducted for the first time since vaccination of measles started by EPI in wide range of age groups. A few studies were carried out in Pakistan but their approach was in children up to 1 to 3 years of age and in one from 3 to 5 years (reference). The present study was conducted in the age group of 1 to 15 years considering the possible association between age, sex, and immunological responses to measles vaccine.

In this study, we analyzed 927 samples, out of these 588 male, and 339 were female children ($p = 0.001$); out of 927 subjects, 741 (79.9%) were sero-positive, 174 (18.77%) sero-negative (135 (14.5%) were vaccinated, 39 (4.2%) were non-vaccinated and 12 (1.3%) equivocal (Tables 1 and 2). The results revealed that vaccinated sero-negative and non-vaccinated children percentage was alarming in the capital city and its rural areas because of vaccine failure or non-immunization of the children due to negligence of parents.

The results of Tables 2 to 4 indicated that as age increased, the percentage of sero-positive samples also increased in both male and female sex, except the ages two and ten years in which female, 33 and 50% respectively. Sero-positive prevalence also decreased at the age of two and ten years in male children which contain 71.42 and 80%, respectively. The main objective of our study was to detect antibody level in different age groups as mentioned in Tables 3 and 4. As age increases, both in male and female, the percentage of antibody level

also increases. In the first group, there is 72.6%, in the second group antibodies level increased up to 81.48% and in third group, it is 91.7%; in contrary, as age increases the sero-negative antibody level decreases. The increasing antibody level by age factor was supported by many researchers as in Korean children (Kim et al., 2004); age group formed (1 to 3 years) antibody level was 78.6%, 4 to 6 years group was 87.4% which is increasing gradually 7 to 9, 10 to 12, and 13 to 15 years, increasing percentage of antibody level as 87.6, 92.7 and 93.9%, respectively.

The increasing antibody titer with age is also reported by Salmaso et al. (2000) and WHO Report (2000) in Italian children, the antibody percentage in group 2 to 4 years was 68.1%, 70.7% in 5 to 9 years, old children and 68.5% in 15 to 19 years (adolescent group). These type of studies were also carried out by Gilbert et al. (2001) in Australian children in pre-school children (2 to 5 years), sero-positive level was recorded as 82%, in primary school level children, 84% and at secondary level children 89%, which are lower as compared to our findings in 11 to 15 years, antibody level was 91.7% which is not statistically significant. The increasing prevalence of measles antibodies in the older children may be due to either vaccination or exposure to natural measles infection/ mature immune system.

Another study that also supported our findings was carried out in Ireland by Johnson et al. (1995) in 11 to 14 years age group, in which antibody level detected was 95% which is in line with our findings in which third group contain 91.7%. He also observed that the level of immunity to measles increased with age reaching up to 95% by 14 years of age, 7% of 13 to 16 years old children were found not to have measles antibody, this also correlates with our results as negative percentage of 11 to 15 years age groups. In Iran, Karimi et al. (2004) found that sero-prevalence in 15 years old children was 96.8%.

Another main indicator in our objective of study was comparison of male and female prevalence of antibody level. There was much more difference in first two groups, as mentioned in Table 3 (1 to 5 and 6 to 10 years). In the first group, male children measles antibody level was 80% while in female children it was 72.5%, while sero-negative male children 19% and female 27.5%. As in primary school level children, sero-positive level of male children were higher 92% than female children 77.5%, and sero-negative was also less in male than female children, which was above double figures, that is, in male 8.0% and in female 22.5%. Interestingly, there was slightly difference in adolescent group (11 to 15 years) having sero-positive percentage of 88.7% in male and 91.6% in female, and sero-negative antibody prevalence was the same in both gender which was 8.33%, respectively. Our findings were correlated to the findings of Kim et al. (2004), who observed that in Korea male, sero-prevalence is higher as compared to female children in age group 7 to 9 years (male 92.1% and female 81.2%). However, Tayil et al. (1998) reported higher percentage of antibodies in female (87.6%) than that of male children (85.0%). Other researchers explained that there was no significant difference between male and female sero-prevalence antibodies. Gilbert et al. (2001) explained that in Australian children, the age specific sero-positive prevalence against measles reached 50% in male at the age of one year and in female 60% positivity. The same results were achieved by WHO (2000), that there is no difference in antibody titer between males and females. Elimination of measles can only be achieved if is below levels that can sustain transmission of measles. The WHO has set targets for the elimination of measles. For the age group of 0 to 4 years, the susceptibility target set to 15% or less, for 5 to 9 years to 10% or less, and for the older age groups to 5% or less. The WHO states that these goals only can be achieved through a two dose measles vaccination schedule with minimally 95% coverage for both doses. In Pakistan, we are far below the target vaccine coverage 80% for one dose vaccination. In this study, the prevalence of susceptibility found in Islamabad area exceeded the target level for 1 to 5 years old children (27.4%), 6 to 10 years old (18.5%), and 11 to 15 years old (8.3%).

Conclusions

Average sero-positive prevalence for measles vaccine in male children is higher than female children, and antibody titre increased with increase in age, and sero-negative decreased up to 15 years age (as our study designed). Sero-positive ratio increased with increasing age groups such as 72.6, 81.5 and 91.6% were observed in group one (1 to 5 years), group two (6 to 10) and group three (10 to 15 years), respectively. It is recommended that sero-surveillances should be conducted at regional and provincial levels to assess the actual level of protective titre throughout the country and to evaluate country vaccination program. The susceptibility profile for a particular country can be estimated from vaccination coverage and disease incidence data, but the most direct evidence comes from seroprevalence studies (Gay, 2000).

The increase in routine coverage of immunization from 80 to 100% will help reduce the sero-negative ratio in children. It has been reported that different countries applied different strategies for interruption of measles transmission. Most industrialized countries use a two-dose schedule, second dose during earlier or later childhood to compensate for primary vaccine failure after first dose. Although, the conclusions outlined here were based on a restricted number of samples, they have provided us some baseline data of prevalence of antibody levels in vaccinated/unvaccinated children with

a single-dose vaccination schedule. The information obtained from this study will be useful in future years to evaluate and compare immune status.

REFERENCES

Assaad F (1983). Measles: Summary of Worldwide impact. Rev. Infect. Dis., 5: 452-459.

Babad HR, Nokes DJ, Gay NJ, Miller E, Morgan-Capner P, Anderson RM (1995). Predicting the impact of measles vaccination in England and Wales: model validation and analysis of policy options. Epidemiol. Infect., 114: 319–344.

Bellini WJ, McFalin DE, Silver GD, Mingiol ESi and McFarland HF. (1981). Immune reactivity of purified hemagglutinin of measles virus. Infect. Immun., 32: 1051–1057.

Black FL (1989). Measles active and passive immunity in the world wide perspective. Prog. Med. Virol., 36: 1-33.

Black RE, Cousens S, Johnson HL, Lawn JE, Rudan I, Bassani DG, Jha P, Campbell H, Walker CF, Cibulskis R, Eisele T, Liu L, Mathers C; Child Health Epidemiology Reference Group of and UNICEF (2010). Global, Regional and National Causes of Child Mortality, 2008. Lancet, 375(9730): 1969 – 1987.

Boulianne N, De Serres G, Ratnam S, Ward BJ, Joly JR, Duval B (1995). Measles, mumps, and rubella antibodies in children 5-6 years after immunization: effect of vaccine type and age at vaccination. Vaccine, 13: 1611-1616.

Christenson B, Bottiger M (1994). Measles antibody Comparison of long-term vaccination titres, early vaccination titres and naturally acquired immunity to and booster effects on the measles virus. Vaccine, 2: 129-133.

Cliff J, Simango A, Augusto O, Van Der Paal L, Biellik R (2003). Failure of targeted urban supplemental measles vaccination campaigns (1997–1999) to prevent measles epidemics in Mozambique (1998–2001). J. Infect. Dis., 187(1): S 51-57.

Coetzee N, Hussey GD, Visser G, Barron P, Keen A: (1994). The 1992 measles epidemic in Cape Town–a changing epidemiological pattern. S. Afr. Med. J., 84(3): 145-149.

Cutts FT, Bartoloni A, Guglielmetti P *et al.* (1995). Prevalence of measles antibody among children under 15 years of age in Santa Cruz, Bolivia: implications for vaccination strategies Trans. Royal Soc. Trop. Med. Hyg., 89: 119–122.

Cox MJ, Azevedo RS, Massad E, Fooks AR, Nokes DJ (1998). Measles antibody levels in a vaccinated population in Brazil. Trans. Royal Soc. Trop. Med. Hyg., 92: 227–230.

Dodd R, Cassels A (2006). Health development and the Millennium Development Goals. Annals of tropical medicine and parasitology, 100 (5–6): 379-387.

de Melker H, Pebody RG, Edmunds WJ, Lévy-Bruhl D, Valle M, Rota MC, Salmaso S, van den Hof S, Berbers G, Saliou P, Spaendonck MCV, Crovari P, Davidkin I, Gabutti G, Hesketh L, Morgan-Capner P, Plesner AM, Raux M, Tische A, Miller E (2001). The seroepidemiology of measles in Western Europe. Epidemiol. Infect., 126: 249–259.

Duke T, Mgone CS (2003). Measles: not just another viral exanthema. Lancet., 361 (9359): 763-773.

Gay NJ, Hesketh LM, Morgan-Capner P, Miller E. (1995). Interpretation of serological surveillance data for measles using mathematical models: implications for vaccine strategy. Epidemiol, Infect., 115: 139–156.

Gay N, Ramsay M, Cohen B, Hesketh L, Morgan-Capner P, Brown D, Miller E (1997). The epidemiology of measles in England and Wales since the 1994 vaccination campaign. CDR, 7: R17–R21.

Gay NJ. (2000). Eliminating measles: no quick fix. Bull. W. H. O, 78: 949.

Gidding H (2003). Australias National Sersurveillance Program. New South Wales Public Health Bulletin, 14: 90-93.

Gilbert GL, Escott RG, Gidding HF, Turnbull FM, Heath TC, McIntyre PB, Burgess MA (2001). Impact of the Australian Measles Control Campaign on immunity to measles and rubella. Epidemiol. Infect., 127: 297-303.

Janaszek W, Gut W, Gay NJ. (2000). The epidemiology of measles in Poland: Prevalence of measles virus antibodies in the population. Epidemiol. Infect., 125: 385–392.

Karimi A, Arjomandi A, Alborzi A, Rasouli M, Kadivar MR, Obood B, Pourabbas B (2004). Prevalence of measles antibody in children of different ages in Shiraz, Islamic Republic of Iran. Eastern Mediterranean Health J., 10 (4/5): 468-473.

Kim SS, Han HW, Go U, Chung HW (2004). Sero-epidemiology of measles and mumps in Korea: impact of the catch-up campaign on measles immunity. Vaccine, 23: 290-297.

Lee MS, Nokes DJ, Hsu HM, Lu CF (2000). Protective titres of measles neutralising antibody. J. Med. Virol., 62: 511–517.

Lee MS (1999). An investigation of measles elimination in Taiwan. Seroepidemiology and modeling. Oxford: Oxford University, p. 106.

Mossong J, Nokes DJ, Edmunds WJ, Cox MJ, Ratnam S, Muller CP. (1999). Modeling the impact of subclinical measles transmission in vaccinated populations with waning immunity. Am. J. Epidemiol., 150: 1238–1249

Salmaso S, Gabutti G, Rota MC, Giordano C, Penna C, Mandolini D, Crovari P (2000). Pattern of susceptibility to measles in Italy. Bulletin of the ., 78: 950-955.

Tapia MD, Sow SO, Medina-Moreno S, Lim Y, Pasetti MF, Kotloff K, Levine MM (2005). A serosurvey to intensify the window of vulnerability to wild-type measles among infants in Rural Mali. Am. J. Trop. Med. Hyg., 73: 26-31.

Tayil SE, El-Shazly M K, El-Amrawy SM, Ghouneim FM, Abou Khatwa SA, Masoud GM (1998). Sero-epidemiological study of Measle after 15 years of compulsory vaccination in Alexandria, Egypt. Eastern Mediterranean Health J., (4): 437-447.

UytdeHaag FG, van Binnendijk RS, Kenter MJ and Osterhaus MA (1994). Cytotoxic T lymphocytes responses against measles virus. Curr. Top. Microbiol. Immunol., 189: 151–167.

van Binnendijk RS, van Baalen CA, Poelen MC *et al.* (1992). Measles virus transmembrane fusion protein synthesized de novo or presented in immunostimulating complexes is endogenously processed for HLA class I- and class II-restricted cytotoxic T cell recognition. J. Exp. Med., 176: 119–128.

van Binnendijk, RS, Versteeg-van Oosten J.P.M, Poelen MCM., Brugghe HF, Hoogerhout P, Osterhaus, ADME, Uytdehaag FGCM (1993). Human HLA class I- and class II-restricted cloned cytotoxic T lymphocytes identify a cluster of epitopes on the measles virus fusion protein. J. Virol., 67: 2276–2284.

World Health Organisation (2000). Vaccine, Immunization, and Biological Study: Measles. World Health Organization publication. November.

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