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Research Article

Evaluation of the Efficacy of MMR Vaccination by Continent between 2011-2024

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Abstract— Aim: A comparison in the number of measles(Rubella) infection across the six regions of the world namely Americas, Africa, Eastern Mediterranean Region, Southeast Asia, West Pacific Region, and Europe, and the impact of the use of MMR vaccination in combating the Measles virus, so as to identify which continent has the lowest measles occurrence to-date, and what factors contributed to its achievement.
Research Design: A secondary research method was adopted using statistics obtained from the United Nations Children Fund (UNICEF) database, from the 6 regions, across 223 countries. Data was also obtained from the World Health Organization provisional measles and rubella data
Methodology: The quantitative research methodology was adopted for the study of measles cases and immunization from children between 12 to 23 months old, across 223 countries, through the exploration of numerical patterns over a period of 14 years. The aggregated data from UNICEF allowed for sophisticated data analysis, with visibility into trends of MMR vaccination. Data was analyzed for 1st and 2nd dose of administration on MMR across the targeted countries, to confirm the impact of vaccination, against cases per year.

Keywords— MMR, UNICEF, AFR, SEAR EUR, EMR, WPR, Measles (Rubella), Quantitative Research Methodology, Quantitative Analysis.

1. Introduction

Measles is an infectious airborne diseases caused by the morbillivirus, and can be spread when an infected person coughs, sneezes, breathes and talks. It was first reported in the 10th century by a Persian Doctor Rhazes, who gave its first clear clinical description and demarcated it from similar diseases like small pox. As a result of its high infectious rate, especially among children between the ages of 5 to 6 months, with its highest mortality rate between 1 to 3 years old, the need to create a preventive cure became very paramount across the globe. In the year 2022, an approximate 9 million cases were recorded globally, with continuous cases been continuously reported from all countries. [3][8]. In the year 2000, measles was successfully eradicated in the United States of America; however, 1300 new cases were recorded in 2019, showing how contagious and persistence the disease was.

Measles infection occurs in 3 phases. The first phase, which is the incubation phase, can last between 9 to 12 days. During this phase, access to the human body occurs through the upper respiratory tract. This could be the mouth, nasal cavity, throat (pharynx), nostrils, and voice box (larynx). The virus then spreads to the lymph nodes, causing destruction and leading to leucopenia. A primary viraemia follows, leading to the rapid spread of the virus to the rest of the respiratory system and the reticuloendothelial system. This is the second phase (prodromal phase), characterized by conjunctivitis, fever, malaise, upper respiratory track symptoms like, cough, sneezing and nasal discharge. This can last between 3 to 4 days. The third phase (exantherm) starts when a secondary viraemia occurs, causing the virus to spread to the kidney, bladder, viscera and skin. This is the point where a rash appears on the scalp and behind the ears. By day 2 of rash appearance, the presence of the virus is yet to be detected in the pharyngeal secretion. The rash then progresses to the neck, trunk and by day 3, the whole body is covered. Measles infection is also characterized by the appearance of Koplik spots in the mouth, which are pathognomonic and usually occurs 24 to 48 hours before the rash onset, and lasting between 2 to 3 days. It has been recorded that the fever subsides and the the rash clears after 6 to 7 days of the third phase.

Top countries that were recorded to experience measles outbreak between February - July 2024 include Iraq (24,191) Ethiopia (20,291), Kazakhstan (18,250), Pakistan (18,129), Yemen (14,097), India (13,172), Russian Federation (11,889), Kyrgyzstan (9,876), Romania (9,223), and Azerbaijan (8,570) [3]. Measles outbreak is occurring everywhere in the world and is most prevalent in countries where there is no vaccination, or the people are not vaccinated, having missed one of the two doses of administration. Measles infection can be prevented through vaccination, through the development of life-long immunity from the vaccine. However, with the implementation of vaccination, the age of infection shifted from children under 5 years old to older ones, and even pregnant women.
The outcome of this study shows the trends in measles infection across 223 countries, over a period of 14 years (2011 - 2014) with focus on children between 12 to 23 months, using values from percentage of surviving infants that received both the 1st and 2nd doses, from UNICEF Data, and also a focus on WHO data, to show the trend in the number of cases per country per year, against impact of vaccination for each year.

The hypothesis was formed using time as an independent variable against the impact of 1st and 2nd doses of MMR vaccination per country, and measles cases re-occurrence. Did the re-occurrence of measles cases reduce after the 2nd does over the years? Which countries have the least reoccurring measles case as impacted by MMR Vaccination.
This paper is organized as follows, (Section 1 contains the introduction of the research, Section 2 contain the related work of in the use of MMR vaccination, Section 3 contain the theory applied for the research, Section 4 contain the method and study design, section 5 describes results and discussion, Section 6 concludes the research work with future directions).

1.1 Measles Virus

The measles microbe is a member of the genus Morbillivirus, and family Paramyxoviridae. These pathogens are found in both humans and animals and cause mostly acute fatal disease. Morbillivirus virions are pleomorphic in nature, with size that ranges between 100 to 300 nm. They are easily affected by sunlight, lip-destroying chemicals, heat and pH. They usually possess linear, single-stranded negative-sense RNA that are non-segmented and linear, between 15,040 (morbillivirus from rodents: longquan berylmys bowersi morbillivirus 1, LBbMV) to 16,050 (Feline Morbillivirus, FeMV), with nucleotides which encrypt eight proteins: P (phosphoprotein), V, C, M (matrix), N (nucleocapsid), F (fusion), L (large polymerase) and H (hemagglutinin). Of these necleotides, six are structural proteins and are within the virus. The Morbilliviruses mainly infects its host through the respiratory track. There are 5 stages of infection namely: incubation, prodromal, mucosal, diarrheic, and convalescent. Once a host is infected, morbillivirus propagates in the pharyngeal regions, after which viremia occurs and then progresses to lymphatic and epithelial tissues across the whole body. These infection leads to lymphopenia and immunosuppression, and allows other for secondary infection by opportunistic bacterias and viruses [15].

1.2 MMR (Measles, Mumps, Rubella) Vaccine

The MMR vaccine is a combined safe vaccine to combat 3 highly infection diseases namely, measles, mumps and rubella. MMR is administered in 2 doses.

MMR vaccine was first created as a result of a measles outbreak in 1954, at a boarding school in the outskirts of Boston, Massachusetts. This provided an opportunity for Medical practitioners at Boston Children's Hospital to isolate the measles virus from blood samples and throat swabs of infected students.

From the culture obtained by the Medical Director, Thomas Peebles, from an 11-year-old patient, David Edmonston, the virus was successfully cultivated, which led to the creation of the first measles vaccine [13].

In further research to combat other strains of the virus, John Franklin Enders, Peebles's boss, also known as 'the father of modern vaccines', developed the measles vaccine from the 'Edmonston-B' strain, and named it after David. Their creation has been adopted as the basis for most live-attenuated vaccines to this day. The created vaccine was tested on a small group for a period of 2 years between 1958 to 1960, after which trials commenced on thousands of children in Nigeria and New York.
The trial was successful and in 1961, the vaccine was marked as 100% effective and licensed for global use in 1963 [13].

Further work was done by Dr Maurice Hilleman, who created an improved version through testing on chick embryo 40 times, to identify its weakness. This resulted in a vaccine with less severe side-effects [13].

In the year 1971, a scientist named Hilleman, tried a combination dose of vaccines against measles, mumps and rubella (MMR), which is administered in 2 doses, and in 2005, the varicella vaccine was also combined, to make the combined MMRV vaccine [13].

2. Related Work

To support this research the following related work were reviewed.
An assessment was carried out for life monitoring of infectious diseases outbreak, adopting Google trend as a tool in a Measles case study [6].

A global surveillance was carried out on Measles to show the trends and implication in health interventions for the public [7].

With the intent to raise awareness in the epidemiological patterns of measles, an assessment was carried out on Measles and MMR venerability in Hungary and Croatia through sero-surveillance [5].

World Health Organization (WHO) engaged in efforts to track progress made in measles and rubella elimination [3].

A trend analysis was carried out on the compulsory vaccination that took place in Italy from 2000 to 2021 [9].

A trend analysis was carried out between 2018 and 2022 to determine the impact of MMR vaccination in Ghana, a Country in the Savannah region [10].

A trend analysis with a scope of 5 years of measles and its related factors was carried out on Pahang populace in Malaysia [11].

A paper was written on the incident of measles and its eradication, focusing on the immunological aspect of the infectious disease [1].

A by case assessment of measles during a large outbreak from epidemiological record was compared to laboratory results [4].

A controlled study was carried out to investigate outbreak of measles in Southwestern Ethiopia, focusing on the district of Tocha [15].

3. Theory/Calculation

Trend analysis was adopted, by observing the frequency of measles cases per year across 223 countries, MMR vaccination coverage, and how it impacted the number of outbreaks and cases, using data obtained from UNICEF and WHO.

4. Experimental Method/Procedure/Design

4.1 Study Design

The study was conducted through analyzing secondary data on measles cases and vaccination from 2011 - 2024.

4.2 Study Location:

223 countries from the six regions of the world, who have been engaged in global vaccination programs by WHO and UNICEF were the focal point for trend analysis. Children from between the ages of 12 - 24 months, who received both the 1st and 2nd doses of MMR vaccination (UNICEF), and the cases of measles per month per country was reviewed to determine the trend of occurrence.

UNICEF recorded observations of MMR vaccination for 1st and 2nd doses in Afghanistan, Albania, Algeria, Americas, Bangladesh, Andorra, Barbados, Angola, Bahrain, Antigua and Barbuda, Argentina, Bahamas, Armenia, Belgium, Australia, Botswana, Austria, Brunei Darussalam, Azerbaijan, Belarus, Canada, Democratic People's Republic of Korea, Bulgaria, Cape Verde, Belize, Cambodia, Benin, Central African Republic, Bhutan, Chad, Bolivia, Bosnia and Herzegovina, Chile, Brazil, Cameroon, Burkina Faso, Colombia, Burundi, China, Denmark, Comoros, Djibouti, Congo, Ecuador,Cook Islands, Dominican Republic, Costa Rica, Dominica, Croatia, D EAPR, Cuba, ESAR, Cyprus, Eastern and Southern Africa, Czechia, El Salvador, Côte d'Ivoire, Democratic Republic of the Congo, ECAR, Eastern Mediterranean, Egypt, Fiji, Equatorial Guinea, Finland, Eritrea, France, Estonia, Europe and Central Asia, Eswatini, Ethiopia, Gabon, Haiti, Gambia, Honduras, Georgia, Hungary, Germany, Iceland, Ghana, India, Greece, Indonesia, Grenada, Guatemala, Iran, Guinea, Iraq, Guinea-Bissau, Kenya, Guyana, Ireland, Kiribati, Israel, Italy, Kazakhstan, Jamaica, Kuwait, Japan, LACR, Jordan, Kyrgyzstan, Lao People's Democratic Republic, Madagascar, Latin America and the Caribbean, Malawi, Latvia, Malaysia, Lebanon, Maldives, Lesotho, Liberia, Libya, Lithuania, Luxembourg, MENA, Namibia, Mali, Nauru, Malta, New Zealand, Marshall Islands, Nicaragua, Mauritania, North Macedonia, Niue, Mauritius, Nigeria, Mexico, Netherlands, Micronesia, Nepal, Monaco, Norway, Mongolia, Palau, Montenegro, Oman, Morocco, Panama, Mozambique, Poland, Myanmar, Niger, Philippines, North America, Qatar, Pakistan, ROSA, Papua New Guinea, Russian Federation, Paraguay, Republic of Moldova, Peru, San Marino, Portugal, Republic of Korea, Saudi Arabia,, Romania, Senegal, Rwanda, Singapore, Saint Kitts and Nevis, South Asia, Saint Lucia, South Sudan, Saint Vincent and the Grenadines, Tajikistan, Togo, Samoa, Trinidad and Tobago, Sao Tome and Principe, Tonga, Serbia, Tunisia, Seychelles, Timor-Leste, Sierra Leone, Türkiye, Slovakia, Tuvalu, Slovenia, Turkmenistan, Solomon Islands, United Republic of Tanzania, Somalia, Syrian Arab Republic, South Africa, Sudan, Southeast Asia, Thailand, Spain, Sri Lanka, Sweden, State of Palestine, Suriname, Switzerland, Uganda, Vanuatu, Ukraine, United States, United Arab Emirates, Venezuela, United Kingdom, Viet Nam, Uruguay, WCAR, Uzbekistan, West and Central Africa, Zimbabwe, Western Pacific, Yemen, Western Europe and Zambia and (223 countries).

WHO recorded measles cases in Angola, Burundi, Benin, Central African Republic, Burkina Faso, Democratic Republic of the Congo, Botswana, Algeria, Côte d'Ivoire, Ethiopia, Cameroon, Gabon, Congo, Ghana, Comoros, Guinea, Cabo Verde, Madagascar, Eritrea, Gambia, Mali, Guinea-Bissau, Mauritius, Equatorial Guinea, Malawi, Senegal, Kenya, Liberia, South Sudan, Eswatini, Lesotho, Seychelles, Mozambique, Chad, Mauritania, Uganda, Namibia, South Africa, Niger, Antigua and Barbuda, Nigeria, Rwanda, Zambia, Barbados, Sierra Leone, Canada, Sao Tome and Principe, Costa Rica, Colombia, Togo, Brazil, United Republic of Tanzania, Cuba, Zimbabwe, Dominican Republic, Argentina, Bahamas, Haiti, Belize, Saint Lucia, Bolivia, Paraguay, Chile, United States of America, Dominica, Ecuador, Saint Vincent and the Grenadines, Grenada, El Salvador, Guatemala, Peru, Guyana, Suriname, Honduras, United Arab Emirates, Jamaica, Saint Kitts and Nevis, Venezuela, Mexico, Lebanon, Nicaragua, Oman, Panama, Morocco, Trinidad and Tobago, Jordan, Iran, Uruguay, Pakistan, Afghanistan, Azerbaijan, Bahrain, Bosnia and Herzegovina, Djibouti, Egypt, Tunisia, Iraq, Bulgaria, Kuwait, Denmark, Libya, Spain, Qatar, Cyprus, Saudi Arabia, Czechia, Sudan, Croatia, Estonia, Somalia, France, Syrian Arab Republic, Yemen, United Kingdom of Great Britain and, Northern Ireland, Albania, Italy, Andorra,

Armenia, Israel, Austria, Monaco, Belgium, Latvia, Belarus, Switzerland, Republic of Moldova, Germany, Finland, Georgia, Netherlands, Greece, Slovakia, Montenegro, Croatia, Hungary, Russian Federation, Ireland, Turkmenistan, Iceland, Kazakhstan, Sweden, Kyrgyzstan, Lithuania, Bangladesh, Luxembourg, Bhutan, Macedonia, Uzbekistan, Myanmar, Malta, Norway, Poland, Maldives, Romania, San Marino, Serbia, Slovenia, Tajikistan, Thailand, Türkiye, Ukraine, Indonesia, Cook Islands, India, Sri Lanka, Nepal, Democratic People's Republic of Korea, Lao People's Democratic Republic, Timor-Leste, New Zealand, Australia, Palau, Brunei Darussalam, Philippines, China, Fiji, Nauru, Micronesia, Japan, Tuvalu, Cambodia, Solomon Islands, Niue, Kiribati, Republic of Korea, Marshall Islands, Mongolia, Malaysia, Papua New Guinea, Singapore, Tonga, Samoa Viet Nam, Portugal, Vanuatu, (194 countries).

4.3 Data Collection:

The population of immunized children from 12 - 24 months was obtained from UNICEF database, available for public access and downloaded in csv format. Bio Information of participants was not available for public use, and only contains the list of countries, OBS percentage and year of administration. The data obtained from WHO was equally downloaded from its database in CSV format, and contained the values of the region, country, year and the number of cases per month per country.

4.4 Data Analysis

For the WHO data, data was analyzed by plotting a bar chart of the number of cases by country per month against each year to determine if there was either an increase or decrease in measles cases.

For the UNICEF data, analysis was carried out through comparing the OBS values percentages per country per year, so as to determine either an increase or decrease in the percentage of immunization per year.

The results from both was used to determine if there has been an improvement, plus decline in measles cases globally as a result of MMR immunization over the period of 2011 - 2024.

5. Results and Discussion

Hypothesis 1 - Did the re-occurrence of measles cases reduce after the 2nd does over the years?

Hypothesis 2 - Which countries have the least reoccurring measles case as impacted by MMR Vaccination?

5.1 Analysis of Measles Cases and Vaccination in Eastern Mediterranean Region

Figure 1 below shows the percentage of surviving infants (12 to 24 months) in Afghanistan (EMR), who received the 1st dose of measles containing MMR vaccine from 2014 - 2024.

There was a gradual increase in the amount of vaccination administered from 2014, with the highest percentage recorded in 2018 (66%). The lowest amount of MMR vaccine administered was recorded in 2021 (51%).

The 2nd dose administered (Figure 2) also showed 2018 (46%) to be the highest, with the lowest administration in 2019 and 2,021 (37%).

Table 4 shows that in Afghanistan, in 2012, there were 2,791 measles cases, which dropped to 552 cases in 2014. However, it spiked by 300% in 2018, resulting in 2012 measles cases, which is also the period of highest vaccination for both the 1st and 2nd doses of MMR vaccine. Measles cases dropped to its lowest level (212 cases) in 2019, but is currently at 7,023 cases in 2024.

Based on events recorded in Afghanistan in the years with the highest number of measles cases, namely 2018 and 2024, these were the periods during which humanitarian activities and immunization were paused momentarily due to forced change in government, high inflation and conflicts.

In the Eastern Mediterranean Region (EMR), Figure 27 shows a spike in measles case in 2018 (67,720 cases), and another spike in 2023 (90,855 cases). The lowest number of cases was recorded in the year 2020 (9,829 cases).

It can be deduced that after the continuous decline in measles cases in the EMR, from 2011 to 2016 as a result of successful vaccination activities, there has been speedy and prevalent increase in the number of cases from 2017 till date, with rapid spikes experienced twice.

5.2 Analysis of Measles Cases and Vaccination in African Region

Figure 5 below shows the percentage of surviving infants (12 to 24 months) in Angola (AFR), who received the 1st dose of measles containing MMR vaccine from 2014 - 2024.

There was a gradual decrease in the percentage of children that received the 1st dose of MMR vaccine from 2011 - 2017, which were 56%, 51%, 45%, and 42% respectively. However, there was a sharp increase to 50% in 2018 and 51% in 2019. This later continued to decrease to its lowest percentage in 2021 (36%). There was a notable increase in 2023 to 50%.

Table 6 shows the 2nd dose of MMR vaccinate administered in Angola. A lower proportion of children where administered the 2nd dose from 2015 - 2024, with the lowest percentage being 16% in 2015 and 2016, and the highest being 35% in 2023.

Figure 8 shows that the highest number of measles cases recorded in Angola in 2014 was 12,009 units, and has greatly declined to 549 cases in 2024.

Globally across the African region, Figure 25 shows that the highest number of measles cases recorded by WHO between 2011 - 2024, was 289,766 cases in 2019, which has continued to decline and is currently lower by 25% in 2024.

It can be deduced that MMR vaccination has been very active from 2011, and also successful in reducing the number of measles cases. However, the sharp increase recorded in 2019 could be due to the COVID-19 pandemic which put a stop to

human and social interaction, hence the temporal pause in vaccination programs across Africa. The positive decline in the amount of measles cases from 2020 till present date could mean that, vaccination activities resumed and has been thus far impactful.

5.3 Analysis of Measles Cases and Vaccination in the Americas

Figure 9 below shows the percentage of surviving infants (12 to 24 months) in Argentina (AMR), who were administered the 1st dose of MMR vaccine from 2014 - 2024.

The percentage of children who were administered the 1st dose of MMR vaccination ranged from 77% to 95% between 2014 to 2023 as shown in UNICEF data.

Figure 10, however showed that a lower parentage of 54% received the 2nd dose in 2023, which is less 35% of those that received the 1st dose in the same year.

From WHO data, Argentina has zero cases of measles recorded between 2011- 2016. The highest number of cases was recorded in 2019 (134 cases), which fell back to zero cases from 2021 (Figure 12).

In the America Region, Figure 26 shows zero cases recorded from 2011 - 2013, with the highest cases recorded by WHO in 2019 (23,279 cases), which declined to 72 cases in 2023, but rose again to 333 cases in 2024.

It can be deduced that the occurrence of the COVID-19 pandemic in 2019 had a direct effect on the high number of measles cases in the Americas and the prevailing decline could be as a result of the resumption of MMR vaccination activities. However, the jump in 2024 could be as a result of the recent measles epidemiology ongoing in the region, were over 14,000 cases have been reported (PAHO, 2024).

5.4 Analysis of Measles Cases and Vaccination in Europe Region

Figure 13 below shows the percentage of surviving infants (12 to 24 months) in Albania (EUR), who were administered the 1st dose of MMR vaccine in from 2014 - 2024.

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There was a gradual and progressive decline in the percentage of children that received the 1st dose of the MMR Vaccine, with 98% recorded in 2014 and 83% recorded in 2024. A similar progressive decline was noticed for the 2nd dose (Figure 14), with 98% recorded for 2014 and 93% in 2023.

Figure 16 shows the highest number of measles cases in Albania was recorded in 2018 (1,466 cases), which fell sharply to 3 cases in 2023. However, there has been a notable increase to 44 cases in 2024.

Figure 28, shows that in the European Region, there was a decline in recorded measles cases from 2011 - 2016. This however climbed rapidly from 2017 with the highest recorded in 2019 (104,442 cases). This declined to 150 cases in 2021, but has greatly increased by 650% in 2024.

It can be inferred that the onset of the COVID-19 pandemic in 2019 directly resulted in a high amount of measles occurrence recorded in the European region, due to pause in ratiocination activities. However, the recent jump in 2024, even though the resumption of vaccination since 2020, could be as a result of recent measles epidemiology.

5.5 Analysis of Measles Cases and Vaccination in the Southeast Asian Region

Figure 17 below shows the percentage of surviving infants (12 to 24 months) in Bangladesh (SEAR), who received the 1st dose of MMR vaccine in from 2014 - 2024.

There was a stable proportion of children receiving the 1st dose of MMR vaccine from 2014 - 2023, with the highest being 97% from 2015 - 2023 and the lowest being 94% in 2014.

Figure 18 shows a similar trend of vaccination for the 2nd dose, with the highest being 93% from 2017 - 2023, and lowest being 89% in 2014.

The highest cases of measles recorded in Bangladesh as shown in Figure 20 was in 2019 with 5,479 cases, and a progressive slow declining number of cases to 282 in 2024.

Figure 29 shows an undulating rise and fall in the number of measles cases in the Southeast Asian Region, with peaks in 2014 (92,880 cases) and 2023 (90,972 cases).

This infers that measles cases has been prevalent with repetitive epidemics in the Southeast Asian Region from 2011 - 2024. There was an unexpected decline to 29,137 measles cases in 2019, during the onset of the COVID-19 epidemic and further decline to 6,740 cases in 2021. This could mean that the less contact people had, the less the virus could spread from child-to-child, and a possibility of good hygiene and environmental sanitation practice within the different states in the region, though a temporary pause of vaccination within the region.

5.6 Analysis of Measles Cases and Vaccination in the West Pacific Region

Figure 21 below shows the percentage of surviving infants (12 to 24 months) in Australia (WPR), who were administered the 1st dose of measles containing MMR vaccine in from 2014 - 2024.

There was a stable proportion of children receiving the 1st dose of MMR vaccine from 2014 - 2023, with the highest being 96% in 2022 and the lowest being 94% in 2014. 2017, 2018 and 2019.

Figure 22 shows a similar trend of vaccination for the 2nd dose, with the highest being 94% in 2016, 2019, 2020 and 2021, and lowest being 91% in 2022.

Figure 24 shows that the highest number of measles cases in Australia were 2014 (340 cases) and 2019 (385 cases). There

was a sharp decline from 2020, with an increasing commencing in 2024.

Figure 30 shows a progressive decline in measles cases in the West Pacific Region of up-to 5,742 cases in 2023. However, there was a rise in 2024 to 7,137 cases.
This could infer that MMR vaccination has been impactful in the West Pacific region from 2011, up-til 2023. However the rise in 2024 could be as a result of the current measles epidemic affecting the region.

From the above analysis of MMR vaccination and measles cases in the 6 regions across the world, it can be seen that Eastern Mediterranean Region, Europe, America and West Pacific Region has recently experienced spikes in measles cases, differing from previous years, though continued vaccination in 2024. African Region has experienced a progressive decline after the COVID-19 pandemic and Southeast Region has experienced a gradual decline from the spike in 2023.

Figures and Tables

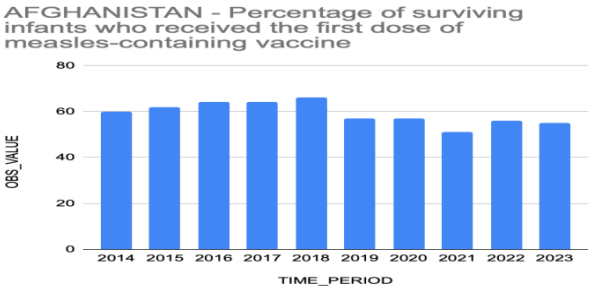

Figure 1: Percentage of surviving infants who received the 1st dose of measles containing vaccine in Afghanistan (EMR)

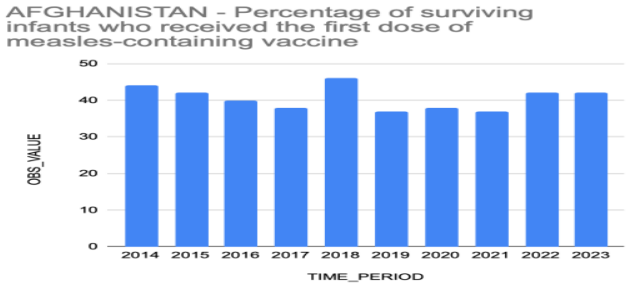

Figure 2: Percentage of surviving infants who received the 2nd dose of measles containing vaccine in Afghanistan (EMR)

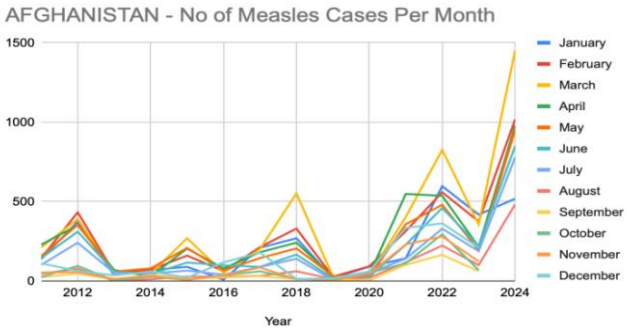

Figure 3: Number of Measles Cases in Afghanistan per month between 2011-2024 (EMR)

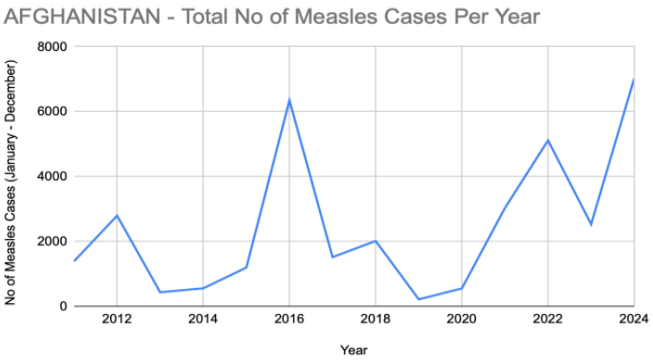

Figure 4: Summation of Measles cases per year in Afghanistan in 2011 - 2024 (EMR)

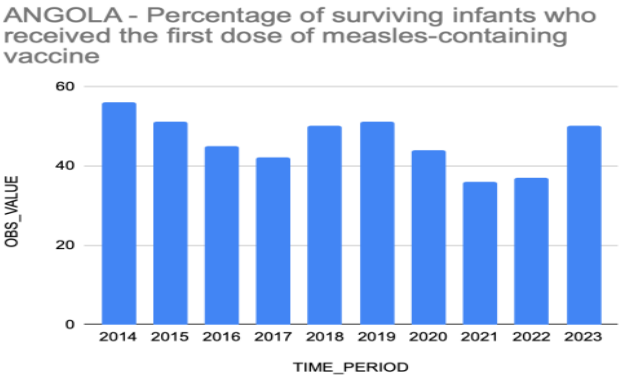

Figure 5: Percentage of surviving infants who received the 1st dose of measles containing vaccine in Angola (AFR)

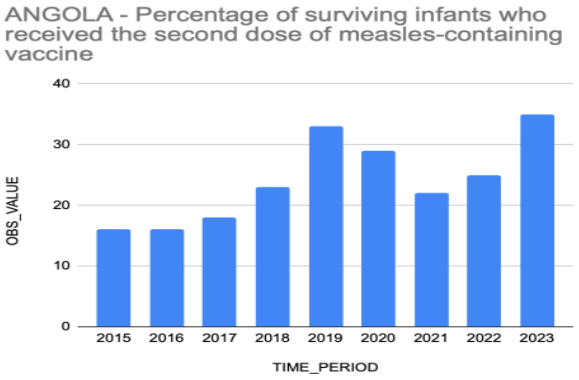

Figure 6: Percentage of surviving infants who received the 2nd dose of measles containing vaccine in Angola (AFR)

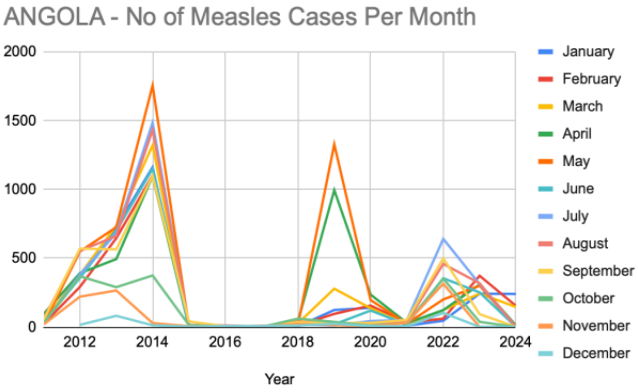

Figure 7: Number of Measles Cases in Angola per month between 2011-2024 (AFR)

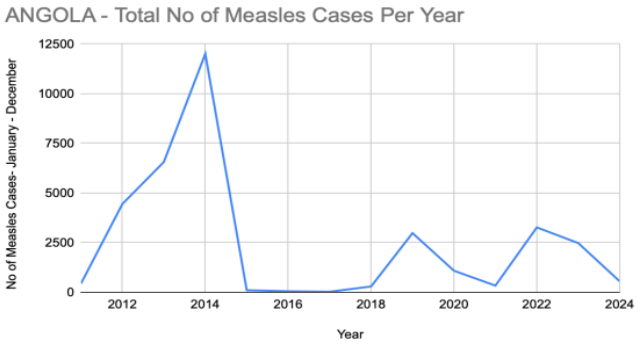

Figure 8: Summation of Measles cases per year in Angola in 2011 - 2024 (AFR)

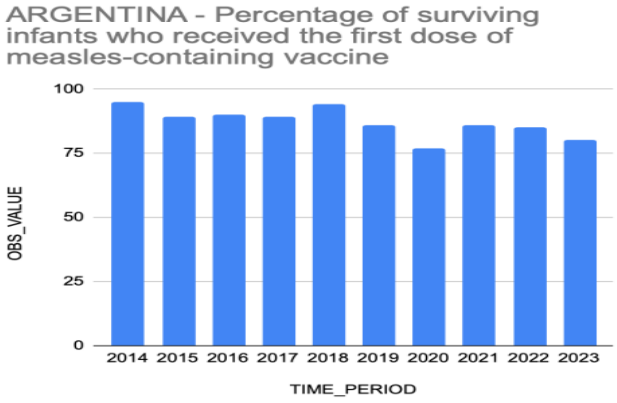

Figure 9: Percentage of surviving infants who received the 1st dose of measles containing vaccine in Argentina (AMR)

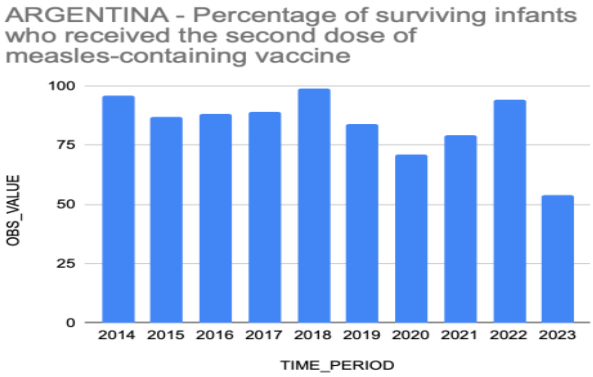

Figure 10: Percentage of surviving infants who received the 2nd dose of measles containing vaccine in Argentina (AMR)

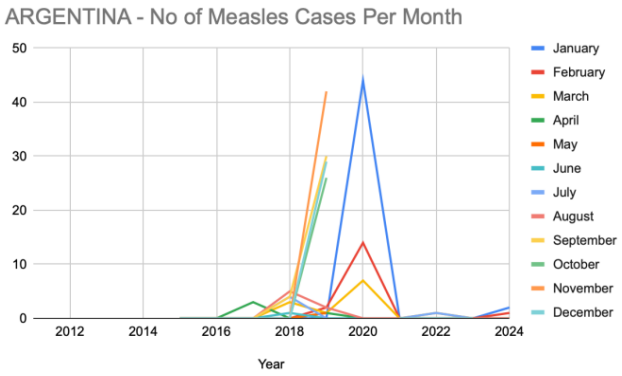

Figure 11: Number of Measles Cases in Argentina per month between 2011-2024 (AMR)

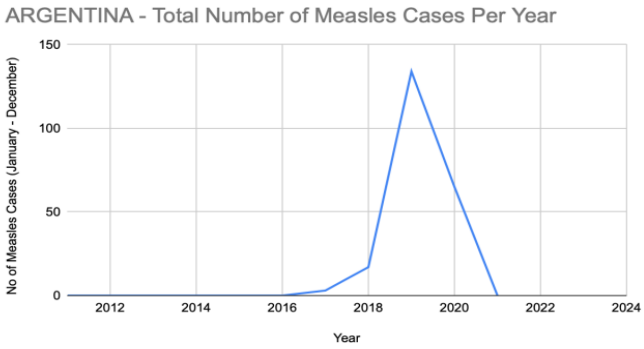

Figure 12: Figure 8: Summation of Measles cases per year in Argentina in 2011 - 2024 (AMR)

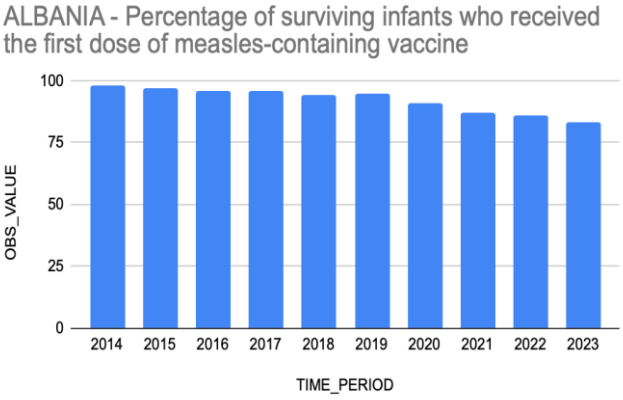

Figure 13: Percentage of surviving infants who received the 1st dose of measles containing vaccine in Albania (EUR)

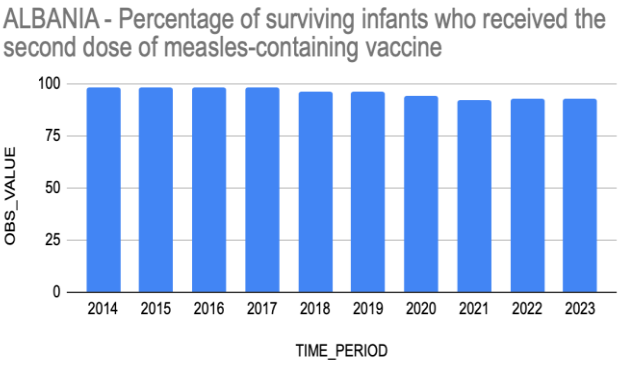

Figure 14: Percentage of surviving infants who received the 2nd dose of measles containing vaccine in Albania (EUR)

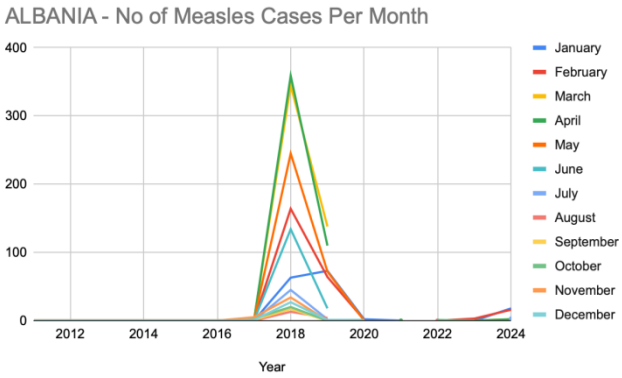

Figure 15: Number of Measles Cases in Albania per month between 2011-2024 (EUR)

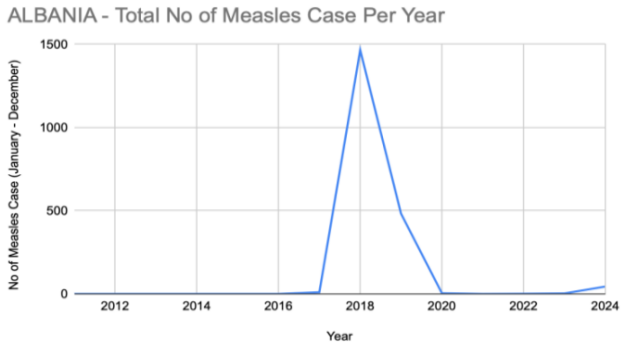

Figure 16: Summation of Measles cases per year in Albania in 2011 - 2024 (EUR)

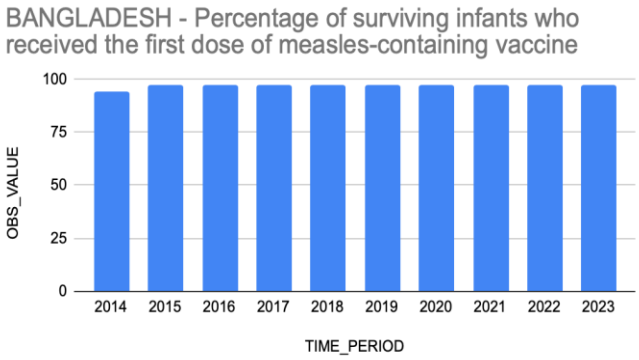

Figure 17: Percentage of surviving infants who received the 1st dose of measles containing vaccine in Bangladesh (SEAR)

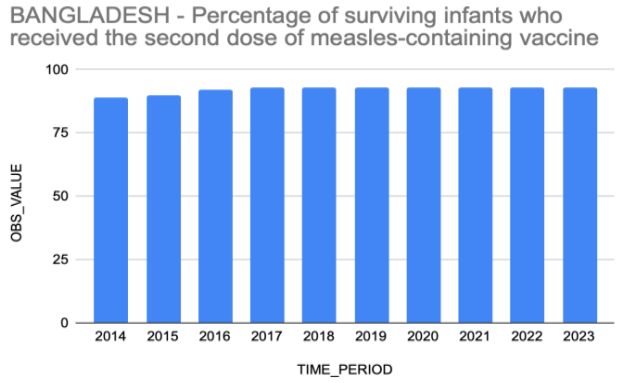

Figure 18: Percentage of surviving infants who received the 2nd dose of measles containing vaccine in Bangladesh (SEAR)

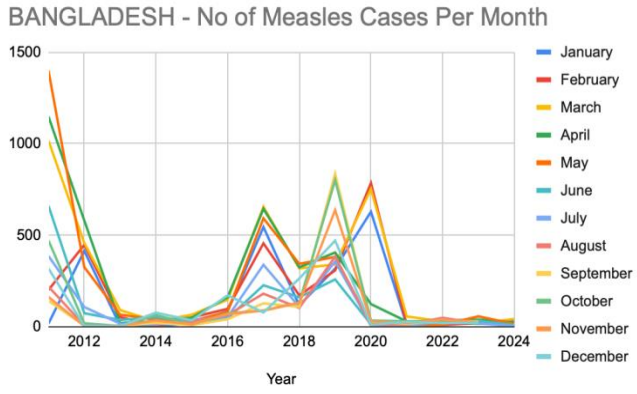

Figure 19: Number of Measles Cases in Bangladesh per month between 2011-2024 (SEAR)

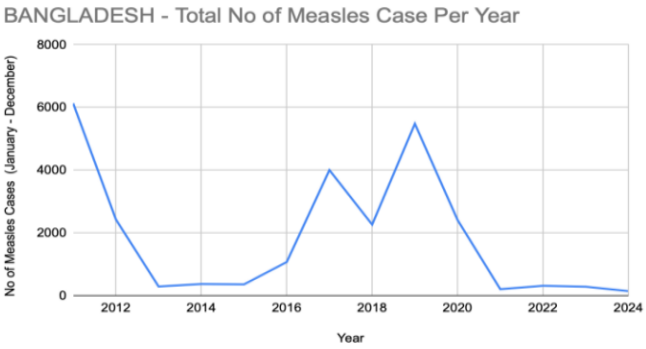

Figure 20: Summation of Measles cases per year in Bangladesh in 2011 - 2024 (SEAR)

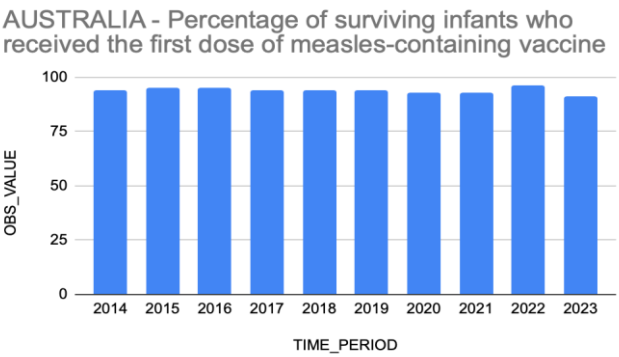

Figure 21: Percentage of surviving infants who received the 1st dose of measles containing vaccine in Australia (WPR)

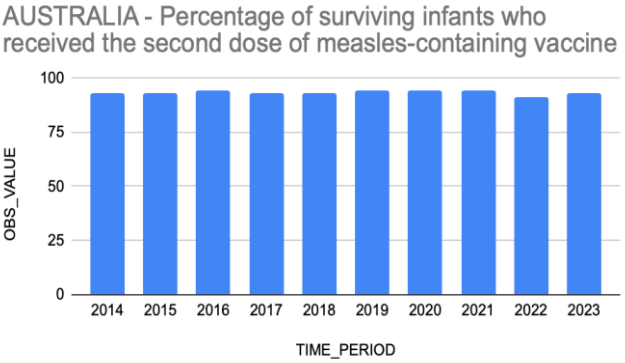

Figure 22: Figure 18: Percentage of surviving infants who received the 2nd dose of measles containing vaccine in Australia (WPR)

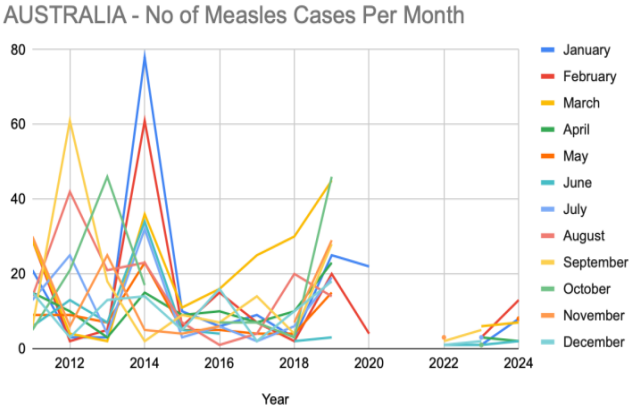

Figure 23: Number of Measles Cases in Australia per month between 2011-2024 (WPR)

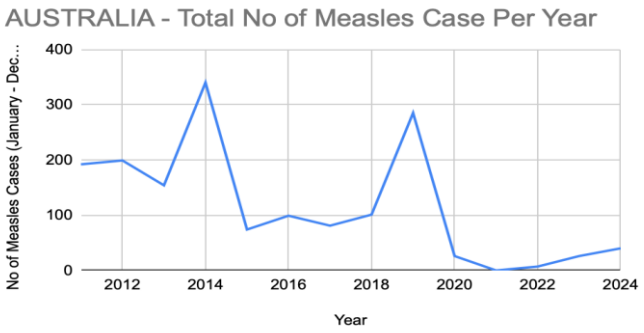

Figure 24: Summation of Measles cases per year in Australia in 2011 - 2024 (WPR)

Comparison per Region

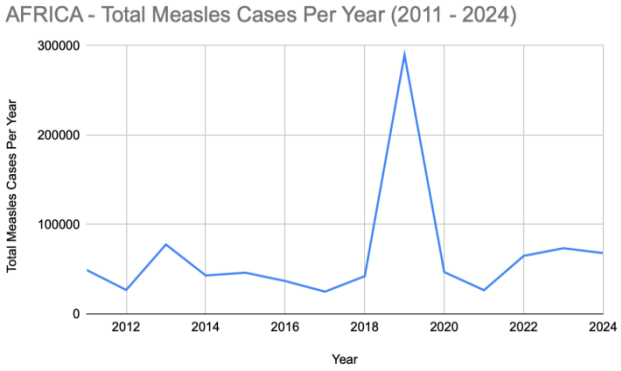

Figure 25: Total Number of Measles Cases - AFRICA

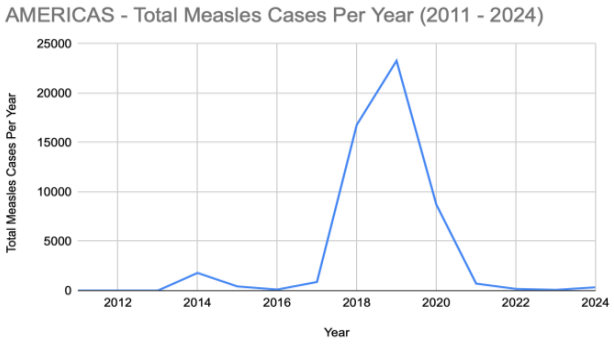

Figure 26: Total Number of Measles Cases - AMERICAS

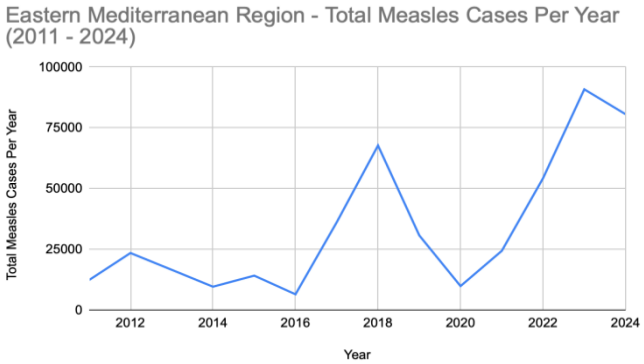

Figure 27: Total Number of Measles Cases - EASTERN MEDITERRANEAN REGION

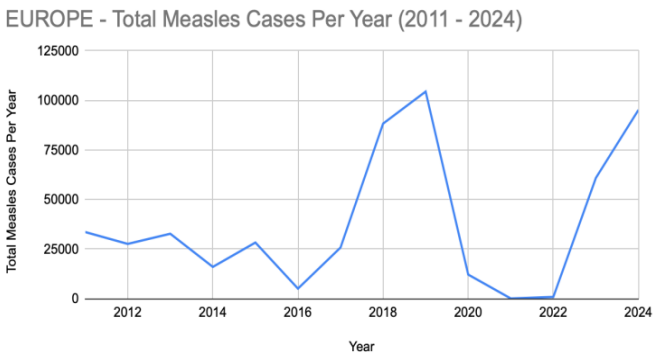

Figure 28: Total Number of Measles Cases - EUROPE

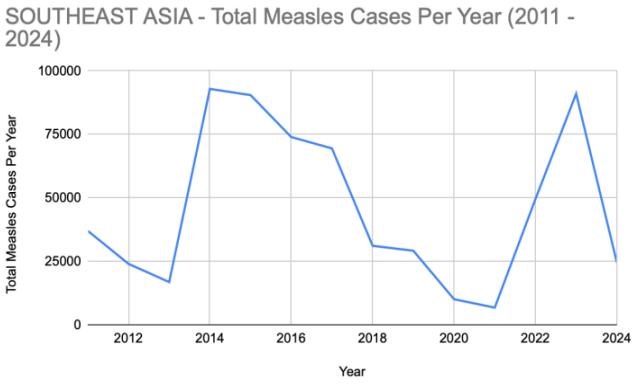

Figure 29: Total Number of Measles Cases - SOUTHEAST ASIA

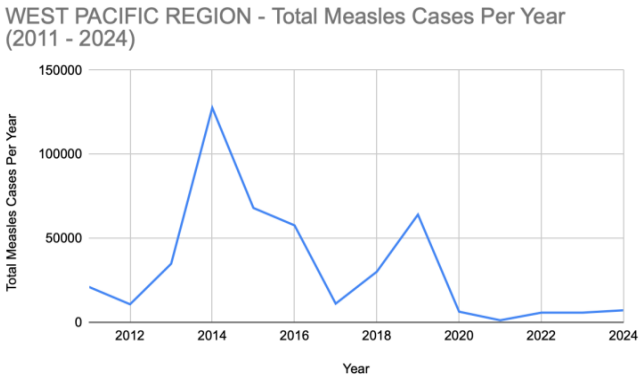

Figure 30: Total Number of Measles Cases - WEST PACIFIC REGION

Table 1: Showing percentage of children that 1st does of MMR vaccination - Afghanistan

1st Dose Vaccination		
Geographic area	**TIME_PERIOD**	**OBS_VALUE**
Afghanistan	2014	60
Afghanistan	2015	62
Afghanistan	2016	64
Afghanistan	2017	64
Afghanistan	2018	66
Afghanistan	2019	57
Afghanistan	2020	57
Afghanistan	2021	51
Afghanistan	2022	56
Afghanistan	2023	55

Table 2: Showing percentage of children that received 2nd does of MMR vaccination - Afghanistan

2nd Dose Vaccination		
Geographic area	**TIME_PERIOD**	**OBS_VALUE**
Afghanistan	2014	44
Afghanistan	2015	42
Afghanistan	2016	40
Afghanistan	2017	38
Afghanistan	2018	46
Afghanistan	2019	37
Afghanistan	2020	38
Afghanistan	2021	37
Afghanistan	2022	42
Afghanistan	2023	42

Table 3: Showing proportion of measles cases per month in Afghanistan (2011 - 2024)

Country	Year	Jan	Mar	May	Jul	Sep	Nov	Dec
Afghanistan	2011	138	211	157	102	24	53	111
Afghanistan	2012	374	390	354	241	46	56	63
Afghanistan	2013	36	47	59	51	8	13	35
Afghanistan	2014	69	46	79	47	39	32	60
Afghanistan	2015	89	269	208	65	16	8	21
Afghanistan	2016	8	52	66	40	22	35	117
Afghanistan	2017	209	201	144	88	30	85	179
Afghanistan	2018	269	551	205	140	12	11	12
Afghanistan	2019	18	28	32	7	10	11	17
Afghanistan	2020	90	39	27	51	5	45	60
Afghanistan	2021	143	403	357	140	102	230	334
Afghanistan	2022	597	826	480	329	164	280	363
Afghanistan	2023	418	356	193	188	62	123	210
Afghanistan	2024	518	1450	950	779			

Table 4: Showing Proportion of Measles Cases Per Year - **Afghanistan**

Afghanistan									
Year	2012	2014	2016	2018	2020	2021	2022	2023	2024
No of Measles Cases (January - December)	2791	552	6348	2012	548	3028	5111	2529	7023

Table 5: Showing percentage of children that received 1st does of MMR vaccination - Angola

1st Dose Vaccination		
Geographic area	**TIME_PERIOD**	**OBS_VALUE**
Angola	2014	56
Angola	2015	51
Angola	2016	45
Angola	2017	42
Angola	2018	50
Angola	2019	51
Angola	2020	44
Angola	2021	36
Angola	2022	37
Angola	2023	50

Table 6: Showing percentage of children that received 2nd does of MMR vaccination - Angola

2nd Dose Vaccination		
Geographic area	**TIME_PERIOD**	**OBS_VALUE**
Angola	2015	16
Angola	2016	16
Angola	2017	18
Angola	2018	23
Angola	2019	33
Angola	2020	29
Angola	2021	22
Angola	2022	25
Angola	2023	35

Table 7: Showing Proportion of measles cases per month in Angola (2011 - 2024)

Country	**Year**	**Jan**	**Mar**	**May**	**Jul**	**Sep**	**Nov**	**Dec**
Angola	2011	40	43	20	24	52	18	
Angola	2012	373	381	548	382	569	220	15
Angola	2013	724	735	725	682	564	265	81
Angola	2014	1161	1320	1755	1484	1098	28	12
Angola	2015	4	0	3	4	40	5	2
Angola	2016	3	0	6	5	5	5	7
Angola	2017	1	2	3	1	2	2	6
Angola	2018	4	26	15	18	35	21	10
Angola	2019	123	278	1327	10	28	13	23
Angola	2020	139	136	195	43	29	2	6
Angola	2021	9	19	24	51	51	31	5
Angola	2022	45	123	200	640	498	314	102
Angola	2023	242	243	300	311	93	0	0
Angola	2024	240	145	0	0	0	0	0

Table 8: Showing Proportion Measles Cases Per Year - Angola

Angola								
Year	**2011**	**2013**	**2015**	**2017**	**2019**	**2021**	**2023**	**2024**
No of Measles Cases- January - December	**436**	**6562**	**103**	**27**	**2980**	**335**	**2475**	**549**

Table 9: Showing percentage of children that 1st does of MMR vaccination - Argentina

1st Dose Vaccination		
Geographic area	**TIME_PERIOD**	**OBS_VALUE**
Argentina	2014	95
Argentina	2015	89
Argentina	2016	90
Argentina	2017	89
Argentina	2018	94
Argentina	2019	86
Argentina	2020	77
Argentina	2021	86
Argentina	2022	85
Argentina	2023	80

Table 10: Showing percentage of children that 2nd does of MMR vaccination - Argentina

2nd Dose Vaccination		
Geographic area	**TIME_PERIOD**	**OBS_VALUE**
Argentina	2014	96
Argentina	2015	87
Argentina	2016	88
Argentina	2017	89
Argentina	2018	99
Argentina	2019	84
Argentina	2020	71
Argentina	2021	79
Argentina	2022	94
Argentina	2023	54

Table 11: Showing Proportion of measles cases per month in Argentina (2011 - 2024)

Country	**Yr**	**Jan**	**Mar**	**May**	**Jul**	**Sep**	**Nov**	**Dec**
Argentina	2011							
Argentina	2012							
Argentina	2013							
Argentina	2014							
Argentina	2015	0	0	0	0	0	0	0
Argentina	2016	0	0	0	0	0	0	0
Argentina	2017	0	0	0	0	0	0	0
Argentina	2018	0	3	0	4	4	0	0
Argentina	2019	0	1	1	0	30	42	29
Argentina	2020	44	7					
Argentina	2021	0	0	0	0	0	0	0
Argentina	2022	0	1	0	1	0	0	0
Argentina	2023	0	0	0	0	0	0	0
Argentina	2024	2	0	0	0			

Table 12: Showing of Measles Cases Per Year - Argentina

Argentina								
Year	2011	2013	2015	2017	2019	2021	2022	2023
No of Measles Cases- January - December	0	0	0	3	134	0	0	0

Table 13: Showing percentage of children that 1st does of MMR vaccination - Albania

1st Dose Vaccination		
Geographic area	**TIME_PERIOD**	**OBS_VALUE**
Albania	2014	98
Albania	2015	97
Albania	2016	96
Albania	2017	96
Albania	2018	94
Albania	2019	95
Albania	2020	91
Albania	2021	87
Albania	2022	86
Albania	2023	83

Table 14: Showing percentage of children that 2nd does of MMR vaccination - Albania

2nd Dose Vaccination		
Geographic area	**TIME_PERIOD**	**OBS_VALUE**
Albania	2014	98
Albania	2015	98
Albania	2016	98
Albania	2017	98
Albania	2018	96
Albania	2019	96
Albania	2020	94
Albania	2021	92
Albania	2022	93
Albania	2023	93

Table 15: Showing Proportion of measles cases per month in Albania (2011 - 2024)

Country	**Year**	**Jan**	**Mar**	**May**	**Jul**	**Sep**	**Nov**	**Dec**
Albania	2011	0	0	0	0	0	0	0
Albania	2012	0	0	0	0	0	0	0
Albania	2013	0	0	0	0	0	0	0
Albania	2014	0	0	0	0	0	0	0

Albania	2015	0	0	0	0	0	0	0
Albania	2016	0	0	0	0	0	0	0
Albania	2017	0	0	0	0	1	5	1
Albania	2018	63	345	245	45	17	34	27
Albania	2019	73	138	72	2	0	0	1
Albania	2020	2		0		0		1
Albania	2021	0						
Albania	2022							
Albania	2023	0	0					
Albania	2024	18	2	2	3			

Table 16: Showing Proportion of Measles Cases Per Year - Albania

Albania								
Year	2011	2013	2015	2017	2019	2021	2023	2024
No of Measles Case(January - December)	0	0	0	10	482	0	3	44

Table 17: Showing percentage of children that 1st does of MMR vaccination - Australia

1st Dose Vaccination		
Geographic area	**TIME_PERIOD**	**OBS_VALUE**
Australia	2014	94
Australia	2015	95
Australia	2016	95
Australia	2017	94
Australia	2018	94
Australia	2019	94
Australia	2020	93
Australia	2021	93
Australia	2022	96
Australia	2023	91

Table 18: Showing percentage of children that 2nd does of MMR vaccination - Australia

2nd Dose Vaccination		
Geographic area	**TIME_PERIOD**	**OBS_VALUE**
Australia	2014	93
Australia	2015	93
Australia	2016	94
Australia	2017	93
Australia	2018	93
Australia	2019	94
Australia	2020	94
Australia	2021	94
Australia	2022	91
Australia	2023	93

Table 19: Showing Proportion of measles cases per month in Australia (2011 - 2024)

Country	**Year**	**Jan**	**Mar**	**May**	**Jul**	**Sep**	**Nov**	**Dec**
Australia	2011	21	29	9	13	6	30	15
Australia	2012	3	4	9	25	61	6	3
Australia	2013	3	2	7	4	18	25	13
Australia	2014	78	36	23	32	2	5	14
Australia	2015	10	11	5	3	9	4	5
Australia	2016	6	16	5	6	7	6	16
Australia	2017	9	25	4	2	14		2
Australia	2018	3	30	4	6	4	7	10
Australia	2019	25	45	15	19	28	29	18
Australia	2020	22						
Australia	2021							
Australia	2022					2	3	1
Australia	2023	1	6		3	5		2
Australia	2024	8	7	8				

Table 20: Showing Proportion of Measles Cases Per Year - Australia

Australia								
Year	2011	2013	2015	2017	2019	2021	2023	2024
No of Measles Cases (January - December)	192	154	74	81	285	0	26	40

Table 21: Showing percentage of children that 1st does of MMR vaccination - Bangladesh

1st Dose Vaccination		
Geographic area	**TIME_PERIOD**	**OBS_VALUE**
Bangladesh	2014	94
Bangladesh	2015	97
Bangladesh	2016	97
Bangladesh	2017	97
Bangladesh	2018	97
Bangladesh	2019	97
Bangladesh	2020	97
Bangladesh	2021	97
Bangladesh	2022	97
Bangladesh	2023	97

Table 22: Showing percentage of children that 2nd dose of MMR vaccination - Bangladesh

2nd Dose Vaccination		
Geographic area	**TIME_PERIOD**	**OBS_VALUE**
Bangladesh	2014	89
Bangladesh	2015	90
Bangladesh	2016	92
Bangladesh	2017	93
Bangladesh	2018	93
Bangladesh	2019	93
Bangladesh	2020	93
Bangladesh	2021	93
Bangladesh	2022	93
Bangladesh	2023	93

Table 23: Showing Proportion of measles cases per month in Bangladesh (2011 - 2024)

Country	**Year**	**Jan**	**Mar**	**May**	**Jul**	**Sep**	**Nov**	**Dec**
Bangladesh	2011	15	1016	1400	385	140	161	317
Bangladesh	2012	413	456	324	106	5	2	2
Bangladesh	2013	3	89	64	15	3	4	1
Bangladesh	2014	0	28	38	11	19	32	75
Bangladesh	2015	17	64	29	35	7	12	33
Bangladesh	2016	83	146	80	51	39	68	170
Bangladesh	2017	543	654	591	337	126	86	76
Bangladesh	2018	115	317	342	107	107	130	262
Bangladesh	2019	316	339	380	355	835	636	469
Bangladesh	2020	627	751	3	8	27	27	9
Bangladesh	2021	7	54	5	3	14	18	25
Bangladesh	2022	20	28	9	27	30	37	18
Bangladesh	2023	14	16	55	16	26	20	19
Bangladesh	2024	18	41	13	2			

Table 24: Showing Proportion of Measles Cases Per Year - Bangladesh

Bangladesh								
Year	2011	2013	2015	2017	2019	2021	2022	2023
No of Measles Cases (January - December)	6129	288	356	4001	5479	203	311	282

Table 25: Showing Proportion of Measles Cases Per Year - AFRICA

AFRICA REGION		
Region	**Year**	**Total Measles Cases Per Year**
AFR	**2011**	**49251**
AFR	**2012**	**26760**
AFR	**2013**	**77593**
AFR	**2014**	**42957**
AFR	**2015**	**46103**
AFR	**2016**	**36753**
AFR	**2017**	**24845**
AFR	**2018**	**42167**
AFR	**2019**	**289766**
AFR	**2020**	**46747**
AFR	**2021**	**26492**
AFR	**2022**	**64922**
AFR	**2023**	**73443**
AFR	**2024**	**67976**

Table 26: Showing Proportion of Measles Cases Per Year - AMERICAS

AMERICAS		
Region	Year	Total Measles Cases Per Year
AMR	2011	0
AMR	2012	0
AMR	2013	0
AMR	2014	1796
AMR	2015	425
AMR	2016	103
AMR	2017	876
AMR	2018	16791
AMR	2019	23279
AMR	2020	8708
AMR	2021	712
AMR	2022	169
AMR	2023	72
AMR	2024	333

Table 27: Showing Proportion of Measles Cases Per Year - Eastern Mediterranean Region

EASTERN MEDITERRANEAN REGION		
Region	Year	Total Measles Cases Per Year
EMR	2011	12346
EMR	2012	23445
EMR	2013	16535
EMR	2014	9573
EMR	2015	14137
EMR	2016	6446
EMR	2017	36132
EMR	2018	67720
EMR	2019	30703
EMR	2020	9829
EMR	2021	24329
EMR	2022	54245
EMR	2023	90855
EMR	2024	80607

Table 28: Showing Proportion of Measles Cases Per Year - EUROPE

EUROPE REGION		
Region	Year	Total Measles Cases Per Year
EUR	2011	33646
EUR	2012	27657
EUR	2013	32779
EUR	2014	16070
EUR	2015	28344
EUR	2016	5131
EUR	2017	25812
EUR	2018	88296
EUR	2019	104442

EUR	2020	12193
EUR	2021	150
EUR	2022	936
EUR	2023	60941
EUR	2024	95204

Table 29: Showing Proportion of Measles Cases Per Year - SOUTHEAST ASIA

SOUTHEAST ASIA REGION		
Region	Year	Total Measles Cases Per Year
SEAR	2011	36991
SEAR	2012	23985
SEAR	2013	16804
SEAR	2014	92880
SEAR	2015	90441
SEAR	2016	73921
SEAR	2017	69444
SEAR	2018	31086
SEAR	2019	29139
SEAR	2020	10050
SEAR	2021	6740
SEAR	2022	49492
SEAR	2023	90972
SEAR	2024	24541

Table 30: Showing Proportion of Measles Cases Per Year - WEST PACIFIC REGION

WEST PACIFIC REGION		
Region	Year	Total Measles Cases Per Year
WPR	2011	21054
WPR	2012	10701
WPR	2013	34815
WPR	2014	127612
WPR	2015	68024
WPR	2016	57661
WPR	2017	11081
WPR	2018	30097
WPR	2019	64072
WPR	2020	6313
WPR	2021	1196
WPR	2022	5742
WPR	2023	5742
WPR	2024	7137

Equation/Formula

Trend analysis using excel was applied using bar charts and line graphs.

6. Conclusion and Future Scope

In concluding this research from the analysis of UNICEF data, which captured the record of the percentage of children between the ages of 12 - 24 months who received the 1st and 2nd doses of MMR vaccination across the six regions of the world from 2014 - 2023, and WHO data, which captured the number of cases from 2011- 2024, one can infer that an adoption of the measles vaccination from 2014 lead to a decline in the number of measles cases in four regions namely, Africa, Americas, Eastern Mediterranean Regions, and Europe. However, a sharp increase was noticed in same regions from 2019 due to the onset of the COVID-19 pandemic, which later declined after vaccination activities resumed. Though recently, spiking cases of measles resurfaced in the same regions in 2024. Though the continuous vaccination activities, these spikes could be as result of increased immigration, inability to continue vaccination due to civil unrest, war, high inflation rates affecting transportation of vaccines, increased natural disasters, the prevalent post COVID-19 impact and other factors.

In both the Southeast Asian and West Pacific Regions, measles cases were prevalent in the year 2014 and experienced sharp decline pre, and at the onset of the COVID-19 era. This is a contract to the experience in the four regions mentioned earlier.There has however been gradual rise in the number if cases in 2024. The decline experienced in 2017, 2018 and 2019 could be as a result of increased environmental health practices and awareness, and the restriction of social contacts, contributing to inability to spread the virus among children.
Based on the above, it can be inferred that success of MMR vaccination is highly dependent on combined social, environmental and health actors, the availability of vaccination and its wide coverage, inclusive of border checks.

Limitations to this research includes working with only data received from UNICEF and WHO online databases. The UNICEF data had the records of 1st and 2nd doses of vaccination in percentage, without availability of the actual number of children that were vaccinated. This made it impossible to carry out correlations using actual number of cases against actual number of vaccinations, since percentages across different countries in the regions is based on the actual number of those vaccinated, which could vary in amount.

Future scope of work for this research could include a survey on factors either inhibiting or promoting the spread of measles across the six regions and recurrence of measles in already vaccinated children.

Data Availability
Data associated with this research includes statistics obtained from the United Nations Children Fund (UNICEF) database, from the 6 regions, across 223 countries. Data was also obtained from the World Health Organization provisional measles and rubella data. Data is available on request from the researcher.

Conflict of Interest
No conflict of interest exists either financial, personal or other relationships with other people or organizations that could inappropriately influence, or be perceived to influence, this research.

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Authors' Contributions
Yemisi Otasanya researched literature and conceived the study, was involved in protocol development, and data analysis.

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