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Correlation between Vaccination and Child Mortality Rate Using Multivariate Linear Regression Model

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Abstract. Population has increased drastically over the years and new diseases compete with the population. Immunisation is a preventive measure, which makes the person resistant or immune to the disease. Vaccination stimulates our own immune system against infection or diseases. Vaccines are available for more than twenty life-threatening diseases and it saves millions of lives throughout the world. In the 70th World Assembly conducted in the year 2017, around 194 countries participated and took the oath to strengthen vaccination thereby achieving goals of Global Vaccine Action Plan (GVAP). In spite of remarkable immunisation progress, approximately 20 million infants are not exposed to vaccination every year. The immunisation progress has stalled or even reversed in some countries, and there is a real risk that complacency will undermine past achievements. This paper considered the database of vaccine consumption rate from many countries issued by WHO to analyse the reason for poor access to vaccine with respect to the morality and poverty levels. For this analysis, the relation between vaccine consumption by children below five years, the children's death rate record issued by the United Nations Children's Education Fund (UNICEF), poverty index issued by the United Nations are considered. Multivariate linear regression algorithm is used to identify the correlation between datasets. The result shows that an increase in vaccination coverage results in reduction on mortality rate in most of the countries. A correlation coefficient of 0.7 was found between IMR and the vaccine dosages. Sub-Sahara countries' poverty index has direct impact on the declined view of vaccination coverage.

Keywords: Immunisation; morbidity; mortality; multivariate linear regression; vaccine.

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1. Introduction

The effective way to protect children from infectious and preventable diseases is with the help of properly scheduled immunisation. Prophylactic vaccination is one of the best ways to prevent diseases. Vaccines prevent more than 25 debilitating or life-threatening diseases, which include polio, measles, typhoid, tetanus, diphtheria, influenza, cervical cancer (Bhattacharya *et al.*, 2021). In 1980 WHO declared that, smallpox is eliminated across the globe. The carter centre international task force for disease eradication has reported that diseases such as lymphatic filariasis (Elephantiasis), polio, measles, mumps, rubella and pork tapeworm can possibly be eradicated (Stampi *et al.*, 2005).

World Health Organization, UNICEF and every country are taking necessary measures to ensure the Children are vaccinated on time/Periodically. Statistical report shows that still over 20 million population throughout the world are not getting vaccine and this leads to serious diseases, disabilities such as brain damages, hearing loss, blindness and death. Poor vaccination is the major cause of increased child mortality rate. It was reported that more than 20% of children under the age of five years die due to the lack of vaccine worldwide (Larson *et al.*, 2011; Tan *et al.*, 2021). The administration of complete time bound vaccination protects children from vaccine preventable diseases. Delayed vaccination results in increased mortality and morbidity among the children (Greenwood, 2014).

The United Nations analyses multidimensional poverty index of countries based on health, education and standard of living. World Bank measures poverty index with reference to national-level margin income and international-level margin income (Paulussen *et al.*, 2006; Moran *et al.*, 2008; Yu *et al.*, 2021). UNICEF concentrates on children's immunisation, disease prevention, education, disaster relief and so on. In order to identify the correlation between children vaccination and mortality rate vaccination consumption dataset of various countries issued by WHO, children mortality rate observed by UNICEF, poverty index measurement from UN and world bank are considered.

In a gathering during the COVID pandemic, WHO Director General, Tedros Dhanom Ghebreyesus stated that the problem of vaccine equity is failing. It is also claimed that 1 in 4 persons in high income countries had received a vaccination, where just 1 in 500 did so in less developed nations. Senior representatives from the UN, governments, businesses, the scientific community and civil society discussed strategies to ensure that everyone has access to vaccinations as a global public good and to improve national readiness for their distribution, which would otherwise result in an increase in new cases and deaths (Courville *et al.*, 2023; World Health Organisation, 2023).

The application of machine learning to COVID-19 has increased significantly. To forecast various ailments, the researchers used RNN, GNN, GRU and LSTM deep learning models and Vector autoregression model (Kamalov *et al.*, 2022; Rajab *et al.*, 2022). In the proposed work, multivariate linear regression analysis is taken to evaluate the relation between multiple vaccines and death rate.

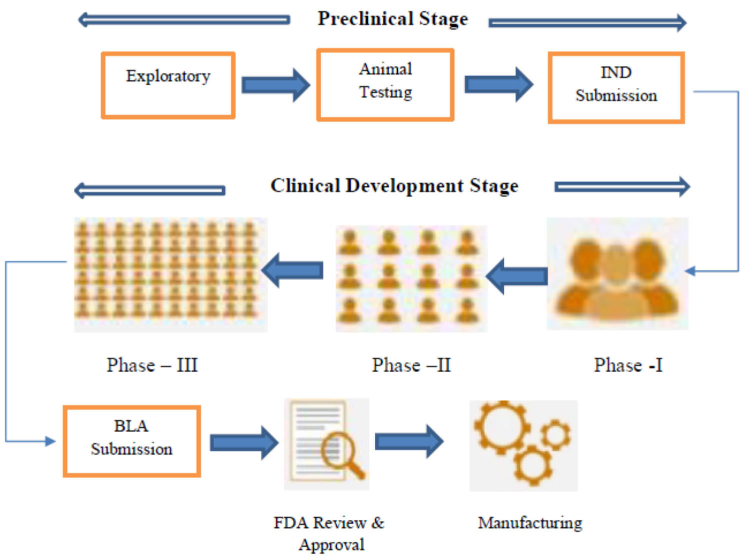

Fig. 1. Vaccination development stages.

1.1. *Vaccination development stages*

Prior to the recommendation, vaccines have been through a rigorous series of clinical trials. The well-regulated approval process ensures safety, purity, potency and efficacy of new vaccines. Pharmaceutical companies spend almost a decade in the development process, in addition to massive amounts. Characteristics of each disease is different hence the development path differs across vaccines. However, all vaccines follow the guidelines prescribed by the regulatory bodies. Centers for Disease Control and Prevention (CDC) (Centers for Disease Control and Prevention) and WHO suggested the general development stages of the vaccine which is shown in Fig. 1.

The preclinical stage is divided into three phases, namely exploration phase, animal testing phase and submission of Investigational New Drug to FDA. The promising results from 2–4 years of laboratory research move the vaccine development process from exploratory phase into animal testing phase. The 1–2 years of animal testing assesses the safety and immunogenicity of the vaccine. The safe dose and method of vaccine delivery are determined by purposely infecting the animals with target pathogens. The detailed description of lab reports along with proposed clinical studies are submitted to FDA for review. In the stipulated 30 days' time, FDA decides on the approval of new vaccine to the next phase.

The first phase of clinical development process performs a trial on 20–80 healthy adults with symptoms that the vaccine can treat. It assesses the safety and immunogenicity of the vaccine approximately in two months' time. The second phase tests the impact of the vaccine on several hundred people in different age groups. In addition to immunogenicity, proposed dosage, schedule of immunisation and vaccine delivery methods are arbitrated in this phase. In the final phase of the clinical trial, the vaccine is tested among tens of thousands of people to find any random side effects of the vaccine. Various regulatory bodies review the findings to approve and label the vaccine. Stringent quality control measures are imposed by the manufacturing company to ensure potency and purity of the vaccine. Vaccines are closely monitored even after their introduction into the market to assess its safety and effectiveness over large populations. The comprehensive review and testing of vaccines by scientists, doctors and regulatory bodies ensures the safety of vaccines. In addition to protecting the recipient, it also helps to prevent the spreading of disease to others.

1.2. *Recommended vaccination schedule by WHO*

Childhood immunisation rates are imperative in reducing infant mortality. Initiatives like Global Alliance for Vaccine and Immunisation (GAVI) and Expanded Program on Immunisation (EPI) reinforce the uptake of vaccination. Despite various actions, it is assessed that approximately 1.5 million children under the age of five years die every year from vaccine-preventable diseases.

Vaccines prompt the child's immune system to develop antibodies by emulating infection in a child's body. Vaccinations are given at different time intervals and in multiple doses to attain maximum effectiveness. The recommended vaccination schedule by WHO is given in Table 1.

The above-summarised recommendations assist the planners in scheduling appropriate vaccination. Few vaccinations can be co-administered in the same visit. Contradiction to a particular vaccine may happen very rarely which needs the attention of physicians.

In order to assess the impact of children receiving vaccines in a timely manner on their mortality rate, data on vaccination and death rates were acquired from WHO and UNICEF for this study. The evaluation of several vaccines recommended by the WHO takes into account their coverage rates in various regions of the world. Multivariate analysis is the analysis technique used to handle many vaccinations (Chilot *et al.*, 2020; Goldman and Miller, 2023).

The effect of vaccines in various parts of the world are analysed in Sec. 2. Section 3, discusses various stages of vaccination and includes vaccination chart recommended by WHO. Section 4, elaborates the proposed methodology with necessary datasets with algorithms along with results. Finally, Sec. 5 concludes our work and directions for future work.

2. Literature Survey

Child mortality rate is the key indicator to express socio-economic well-being of a country. Global efforts have been made to improve children's health by increasing

Table 1. Vaccination schedule recommended by WHO.

Name of vaccine	No. of doses	Age of First Dose	Interval between doses	Booster dose	Disease it prevents
BCG - Bacille Calmette-Guérin	1	Within 24 h of birth time			Bladder Cancer & TB
HEPB - Hepatitis B	3	Within 24 h of birth time	Interval of 4 weeks with DTPCV for every dose		Hepatitis B
POLIO	3	Within 24 h of birth time	Minimum 4 weeks interval between the bOPV doses	Applicable if primary series begins earlier	Polio attack
DTP - Diphtheria, Tetanus, Pertussis	3	Minimum 6 Weeks	Minimum interval of 4 weeks between the doses	2 boosters in 6 months interval between doses.	Diphtheria Tetanus & Pertussis
HIB Haemophilus influenzae type b	3	Minimum 6 Weeks	Minimum interval of 4 weeks between the doses	Atleast 6 months after last dose.	Infections caused by Bacteria.
PCV - Pneumococcal conjugate vaccine	3	Minimum 6 Weeks	Minimum interval of 4 weeks between the doses	9 – 18 months	Pneumonia
RCV - Rubella-containing vaccine	3	Minimum 6 Weeks with DTP1	Minimum interval of 4 weeks with DTPCV		Severe Diarrheal Disease
MMR - Measles, Mumps, Rubella	2	9 or 12 months	6 months interval after first dose.		Measles, Mumps, Rubella
HPV - Human Papillomavirus	2	From 9 years of age (females only)	6 months		

immunisation rates (Agrawal *et al.*, 2021). This comprehensive review records the key findings on the association between vaccination coverage and Infant Mortality Rate (IMR). Rino *et al.* said that vaccines will be the efficient life insurance for the 21st century people (Rappuoli *et al.*, 2011). The understanding of immunisation will pave the path for therapeutic vaccines to fight against diseases due to chronic infections and cancer. Afrin *et al.* express concern in his article that the people living in remote areas are under-immunised and unvaccinated. Resurgence of measles virus threatens those people with a lifelong disability such as brain damage, hearing loss, etc. The author said that the respective government, Vaccine Alliance and UNICEF have to plan precisely to wipe out measles globally (Afri *et al.*, 2020).

Neil and Gary examined the immunisation schedule of 34 nations and the doses of vaccine given to the infants. The authors have formed five different clusters among the nations, based on vaccine dosage. Linear regression algorithm is applied to find the correlation between the number of vaccine doses and infant mortality rate (Miller and Goldman, 2011). The results show that there exists a significant correlation between Vaccination coverage and Child mortality rate with correlation coefficient of 0.992 (Liu *et al.*, 2021). McGovern and Canning estimated the relationship between vaccination and childhood mortality using 149 – cross-sectional health surveys and demographic data. The authors formed 490 clusters from 62 countries, which covered approximately 1 million children and they have considered the vaccines namely BCG, DTP, Polio and Tetanus. The modified Poisson regression algorithm is employed to estimate the child mortality rate in each cluster. The results emphasize the need to increase the vaccination coverage rate (McGovern and Canning, 2015).

Goldhaber-Fiebert analysed measles mortality and MCV coverage using linear and logistic regression algorithms. The lagged covariates such as birth rate, death rate due to other causes, population in urban areas, resulted in a nonlinear relationship between coverage and mortality. The authors concluded that the high level of MCV vaccination coverage reduces measles death (Goldhaber-Fiebert *et al.*, 2010).

Berg *et al.* examined the magnitude of rotavirus infection among children in the age group of less than five years. The authors modeled Diarrhea associated cause of death ensemble model shortly known as CODEm. The Bayesian ensemble model CODEm includes numerous sub-models which consider varied covariates and model types. The predictive regression model of CODEm estimates the cause-specific mortality based on surveillance system data. This model revealed that rotavirus infection is liable for 29.3% of deaths among children less than five years. The authors clinched that the proper administration of Rotavirus vaccination is essential to avoid morbidity and mortality due to rotavirus infection (Berg *et al.*, 2020). Berg *et al.* conducted research to find the protective effect of BCG vaccination on COVID-19 infections. The research included various attributes like HDI score, DP/capita, population density/km^2, etc. of 52 countries in their analysis. They applied a linear mixed model to find the relationship between BCG vaccination level and confirmed deaths. The research results show a significant slower growth rate of COVID-19 cases for the countries which mandated BCG vaccination (Staszkiewicz *et al.*, 2020).

The recent research findings on COVID-19 point that BCG vaccination provides extensive protection on respiratory infections. Miller *et al.* (2020) investigated BCG vaccination policies of various countries with mortality rates of COVID-19. The vaccination policies were collected from "http://www.bcgatlas.org" and details of COVID-19 cases and deaths were acquired from "https://google.org/crisis response/covid19-map". The upshots of analysis using Mat lab scripts show that the countries with BCG in their vaccination schedule recorded a smaller number of COVID-19 spread (Miller *et al.*, 2020).

The comprehensive study illustrates the association between vaccination coverage and mortality rate. The correlation between vaccination and morbidity and mortality unveils the significance of properly scheduled vaccination in reducing child mortality rate (Larson *et al.*, 2014). In addition, factors which affect vaccination coverage such as difficulty in accessing health care services, long distance to health centre, unavailability of physician in health centre, etc. need to be addressed to improve immunisation (Cobos Muñoz *et al.*, 2015).

Adult schooling attainment in India was studied by Arindam Nandia *et al.* in conjunction with the Universal Immunisation Programme (UIP) (Nandia *et al.*, 2020). Fixed effect linear regression models were used to encompass a wide range of socioeconomic characteristics, demographic indicators, amenities, state, village/city ward and health-care access. More schooling grades were documented for household fixed effects with a 95% confidence range. Schooling grades were found to have a positive link with UIP in both urban and rural houses.

India's Sustainable Development Goals (SDGs) contain vaccination targets to reduce child mortality. The SDG addresses inequalities in immunisation. Srivastava *et al.* looked on the differences in vaccination coverage among children aged 12–59 months based on their socioeconomic status (Srivastava *et al.*, 2020). The study analysed data from the National Family Health Survey from 2015 to 2016. At the micro level, the fundamental characteristics linked to disparity among completely, partially, or never immunised new born babies are explored.

In order to determine the association between IMR and vaccine doses, Miller *et al.* applied linear regression algorithm on immunisation data collected from 34 nations. Canning and McGovern used the modified Poisson regression technique to demonstrate the relative risk of mortality rate. Goldhaber *et al.* compared the pre-vaccination risk levels using logistic regression and linear regression. For 90% MCV coverage, they claimed that the death rate had significantly decreased. According to the summary of the research, it should be taken into account how different vaccines affect mortality and how they are related in order to improve the model's precision. The multivariate algorithm determines how several independent variables interact with dependent variables.

3. Proposed Method

Effective vaccination and precise diagnostic tests can eradicate potential infectious diseases completely. High level of immunized population for prolonged periods across the world pave the path for disease eradication. The carefully organized "National Smallpox Eradication Program" marked the success of smallpox eradication from the planet. The Centre for Disease Control and Prevention mentioned that we have completely forgotten nearly 14 diseases with the help of vaccination. The development of less reactogenic vaccines offers excellent safety which shows that "Vaccine scares" tend to be false alarms.

3.1. *Vaccinations vs child mortality rate*

The impact of vaccination on child mortality rate is analysed along with poverty level of the countries (Larson *et al.*, 2014). Child mortality rate is the key indicator of socio-economic well-being of the country. Forty years of immunisation experience with Meningococcal Conjugate Vaccine recommends that tremendous improvement in the levels of vaccination coverage is compulsory to crop sharp reductions in measles deaths (Rajput *et al.*, 2021). Sustainable benefits achievement needs a combination of extended vaccine programs and supplementary vaccine efforts. Misguided safety concerns in some countries have led to a fall in vaccination coverage, causing the re-emergence of pertussis and measles (Stefanoff *et al.*, 2010; Okafor *et al.*, 2023).

The proposed work focuses on the association of BCG, DTP, HEP3 and other vaccines with all-cause mortality for the cluster level of age group under five years. Countries with less than 100% immunisation coverage are included for case analysis. Data set on mortality rate of children under five years is collected from the UNICEF data base and immunisation coverage data is obtained from the World Health Organization portal. The snippet of the vaccination dataset (WHO and UNICEF, 2023) and child mortality dataset (UNICEF, 2023) is depicted in Tables 2 and 3, respectively.

Figure 2 shows the process flow of the proposed model. Preparing data in suitable form is essential while building a machine learning model. Processing and understanding data are necessary for building an effective machine learning model. The recommended vaccines depend on the mortality rate. We made use of power BI, the data visualization tool to interpret the data. The analysis does not include the countries whose vaccination coverage data is missing. The regression method

Table 2. Snippet of the vaccination data set.

Country	BCG	DTP1	DTP3	HEP3	HIB3	MCV1	MCV2	POL3	RCV1
Chad	63	73	44	44	44	64	0	73	0
Central African Republic	74	99	47	47	47	95	0	99	0
Nigeria	64	96	53	53	53	80	2	91	0
Mali	82	99	76	76	76	99	1	99	0
Equatorial Guinea	83	67	50	50	50	51	0	51	0
Cote d'Ivoire	91	99	84	84	84	93	0	95	30
Angola	63	91	59	55	55	94	32	84	20
Burkina Faso	98	96	91	91	91	95	63	94	84
Cameroon	84	98	72	72	72	95	0	95	37
Liberia	89	90	81	81	81	94	3	85	0
Pakistan	87	96	74	74	74	98	65	96	0
Comoros	94	91	91	91	91	85	0	86	0
Burundi	92	99	92	92	92	99	74	99	54
Gambia	94	99	93	93	93	97	72	98	53
Zambia	96	92	91	91	91	92	60	91	57
Ethiopia	71	98	67	67	67	98	8	98	0
Malawi	90	99	89	89	89	96	57	98	52
Kiribati	85	99	88	88	89	96	82	98	85
Yemen	64	84	69	69	69	71	46	75	67
Congo	80	99	75	75	75	97	2	97	12

Table 3. Snippet of the mortality data set.

Country	2019	2018	2017	2016	2015	2014	2013	2012	2011	2010
Afghanistan	62.28	64.73	67.45	70.38	73.55	76.95	80.47	84.13	87.95	91.87
Albania	8.82	9.02	9.27	9.60	10.05	10.65	11.41	12.30	13.30	14.38
Algeria	23.48	24.02	24.51	24.95	25.34	25.72	26.14	26.68	27.41	28.34
Andorra	2.89	3.01	3.14	3.27	3.43	3.61	3.79	3.98	4.18	4.39
Angola	77.16	80.44	84.01	88.13	92.94	98.40	104.95	112.50	120.49	129.02
Antigua and Barbuda	6.44	6.69	6.97	7.29	7.64	8.04	8.52	9.04	9.59	10.17
Argentina	9.94	10.42	10.94	11.48	12.05	12.65	13.27	13.88	14.44	14.92
Armenia	12.38	13.01	13.66	14.37	15.11	15.87	16.70	17.58	18.52	19.48
Australia	3.69	3.74	3.79	3.87	3.98	4.13	4.32	4.54	4.77	4.99
Austria	3.52	3.58	3.65	3.71	3.80	3.91	4.05	4.20	4.33	4.44
Azerbaijan	21.52	22.88	24.49	26.32	28.32	30.45	32.68	35.08	37.64	40.31
Bahamas	10.23	10.54	10.86	11.16	11.47	11.78	12.12	12.48	12.87	13.29
Bahrain	7.09	7.27	7.43	7.57	7.70	7.83	8.00	8.23	8.53	8.92
Bangladesh	30.16	31.94	33.94	36.10	38.40	40.84	43.43	46.18	49.10	52.18
Barbados	12.17	12.55	12.93	13.27	13.59	13.88	14.15	14.39	14.62	14.85
Belarus	3.42	3.62	3.82	4.03	4.25	4.50	4.78	5.11	5.52	6.00
Belgium	3.65	3.76	3.88	3.99	4.09	4.19	4.29	4.37	4.46	4.55
Belize	13.01	13.75	14.53	15.32	16.12	16.91	17.65	18.32	18.91	19.42
Benin	92.99	95.46	97.65	99.86	102.07	104.36	106.62	108.86	111.12	113.30

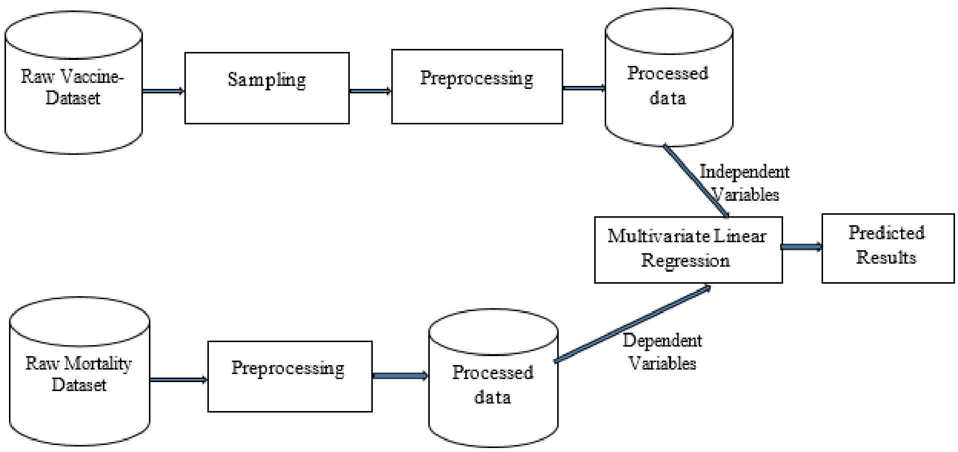

Fig. 2. Process Flow diagram of the proposed model.

is used to smooth the data. Details on 195 distinct countries are included in the collected and processed data.

Due to the magnitude of the vaccine data set's population, sampling techniques had to be used to examine its features. The study's sample was chosen using a modified poison regression cluster sampling method. To improve the data set's analytical value, data preparation was done. We eliminated the nations for whom there were insufficient vaccination data from the study. The number of missing values in the mortality data set was smaller in number. The direction of the data analysis is clear when the initial hypothesis is in place. The Linear regression algorithm is applied on the infant mortality rate and routine vaccinations given to infants. It was found that the correlation coefficient of 0.7 between IMR and the vaccine dosages. Hence the missing values in the mortality data set were replaced using logistic regression algorithm. The multivariate linear regression method was applied to the cleaned-up data set to forecast the relationship between vaccination coverage and infant mortality. The environmental set up and the tools used are discussed in Sec. 4.

4. Results and Discussion

The vaccines such as BCG, DTP1, DTP3, HEPB3, HIB3, MCV1, MCV2, POL3 and RCV1 are considered for study. Multivariate linear regression algorithm is employed to identify the correlation between vaccines and mortality rate. Multivariate analysis is a technique which identifies the impact of more independent factors on the dependent variable. When numerous variables have an impact on the result, the conclusion we get via multivariate analysis is more correct. Multivariate analysis can help estimate the impact of several vaccines on mortality (Mosena *et al.*, 2022). The proposed model considers the set of vaccines as independent variables and the mortality rate as dependent variable.

The multivariate linear regression model is built using Python programming software version 3.9.7(http://www.python.org/), anaconda version 1.9.0 libraries and TensorFlow version 2.6.0 libraries. The records in the UNICEF mortality data go from 1990 to 2019. Three alternative uncertainty bounds—lower, middle and upper were available in the dataset for each region. We used data from 2005 to 2019 for our proposed study because there was more missing information in the earlier years. The correlation graph between dependent and independent variables is shown in Fig. 3.

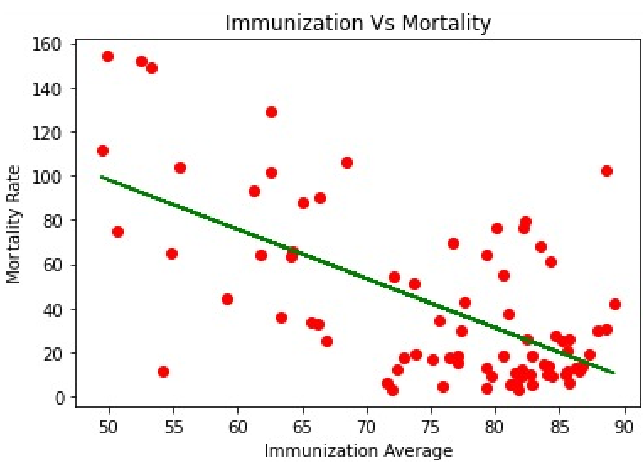

Fig. 3. Immunisation versus mortality.

The line (Fig. 3) indicates that most of the countries with a decline in vaccination coverage have high mortality rate. Countries with vaccination average of more than 75% have comparatively lower mortality rate. The United Nation's multidimensional poverty index is shown in Fig. 4 for each region where nutrition and child mortality play a vital role. Children aged less than 18 years bear the greatest burden of multidimensional poverty. Sub-Sahara Africa has 63.5% multidimensional poverty children. It includes more than 100 countries with 5.7 billion people which are continuously monitored over time.

With references to the UN's observation on Sub-Sahara African countries' poverty index, a graph is drawn for Sub-Sahara African countries with their vaccination coverage ratio to child mortality rate which is shown in Fig. 5 (Bangura *et al.*, 2020). The graph is on par with our previous results i.e. low vaccination coverage countries have high mortality ratio. Few countries like Nigeria, Mali, and Liberia have less impact on mortality rate though they have low vaccination coverage, which is due to massive variation in multidimensional poverty within countries.

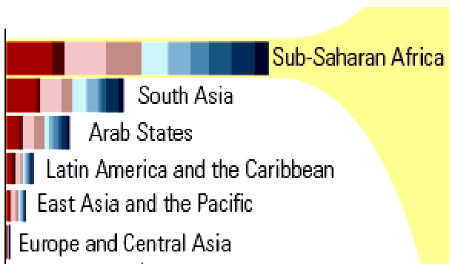

Fig. 4. United Nation's multidimensional poverty index.

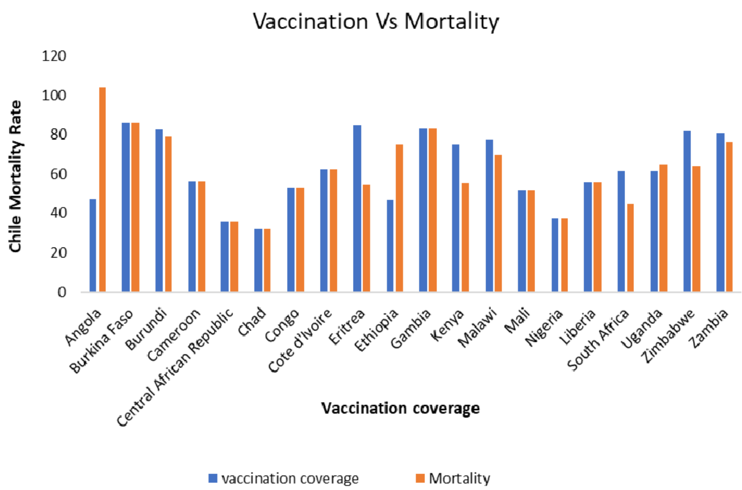

Fig. 5. Vaccination versus mortality in Sub Sahara Africa countries.

Figure 5 depicts the association between various vaccinations and the rates of mortality. The graph shows that, despite improvements in vaccine coverage, some African countries still have higher child mortality rates. Family size, parental care, mother education and other socioeconomic characteristics are among the acceptable considerations.

Figure 6 depicts the vaccination coverage and the mortality rates by region. Some of the localities still need to take effective measures to boost the vaccination coverage and to lower the mortality rates.

Figure 7 depicts the vaccination coverage and the mortality rates by region. Western Europe covers almost 100% of all vaccinations except HEB3 (80%) which implies very less child mortality. Eastern and Southern Africa has high mortality rate due to poor vaccination status (RCV1 < 40%, MCV2 <50%). West and Central Africa has child mortality rate of around 60% and its vaccination rates are less than 80%. South Asia's poor vaccination on RCV1, MCV2 shows 50% mortality rate.

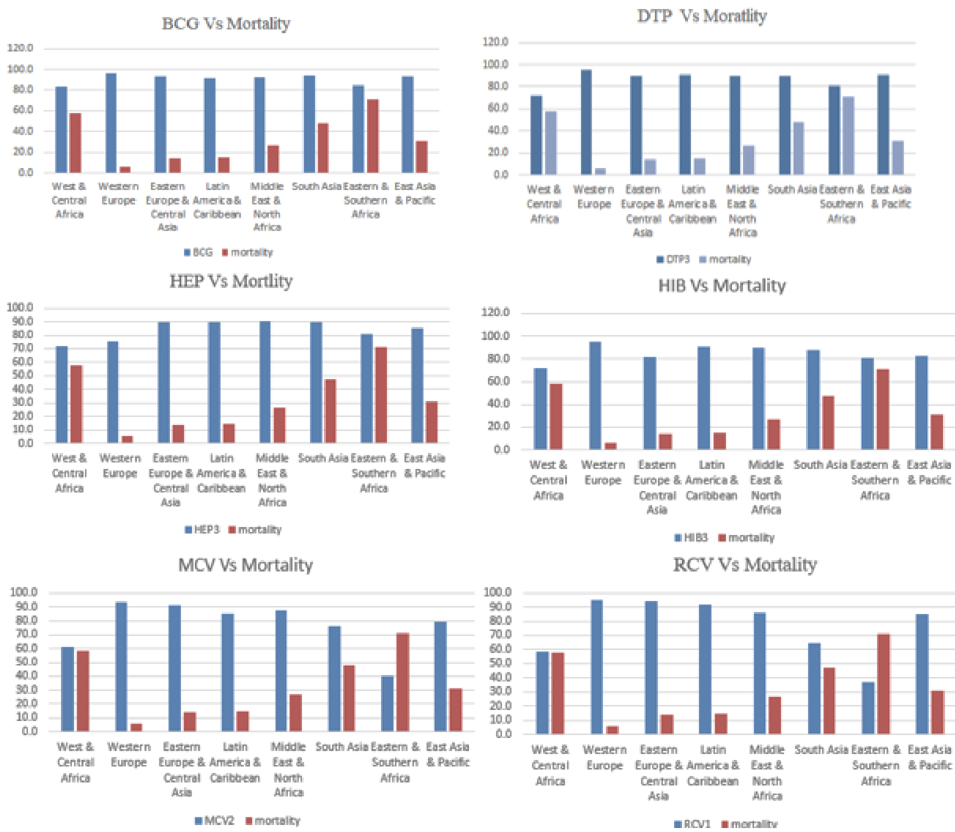

Fig. 6. Region-wise specific vaccination versus mortality.

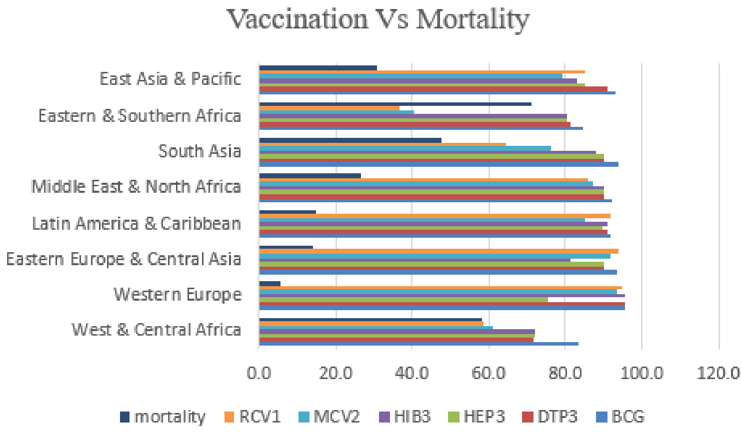

Fig. 7. Vaccination versus mortality in regions.

5. Conclusion

Wealth of the nation is directly proportionate to their people's health. The pandemic diseases such as SARS, MERS, COVID-19, have exposed the importance of vaccines. World Health Organization ensures and validates the quality of vaccines. Due to poverty, lack of awareness, poor accessibility and affordability still certain regions are not able to reach the specified vaccination level to all the people. Childhood mortality is still greater in some low- and middle-income nations due to differences in immunisation coverage. The suggested research looks into the characteristics including mother's literacy, institutional delivery, place of living, geographic region and socioeconomic status. To undertake a micro-level study of all related factors with vaccination coverage, a multi-variate linear regression technique is used. This will help the researchers to figure out the root cause of the problem and identify a solution for it. The vaccination coverage by region is also examined in order to discover the region-specific issues that will aid in increasing the immunisation and consequently to reduce childhood mortality. The same experiment is done on Sub-Saharan African countries based on UN multidimensional poverty index data. This result is also on par with our existing conclusion. Still, there are a few variations in results due to nutrition, education, awareness about vaccines, income level, physical location of country, country's vaccination plan, immune system of the children. All countries along with WHO, UNICEF and CDC are taking appropriate steps to create awareness of vaccination and ensure the availability and affordability of the same in order to reduce child mortality rate.

Immunisation coverage and child mortality were directly related. The proposed work did not take into account death due to other complications. The socioeconomic component, parents' literacy levels and geographic location are a few more factors that affect vaccination coverage. These variables may be used in subsequent research to increase prediction accuracy.

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