



Analysis of the Impact of Immunization Programme on Some Prevalent Childhood Diseases (A case study of Aboh Mbaise General Hospital, Imo State from 1998-2012)

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Abstract

This study attempts with how statistical measures are applied to the study of infants immunized under National Programme on immunization and total number of infants with the six childhood diseases in Aboh Mbaise General Hospital, Imo State from 1998 – 2012. The statistical software packages were used for the analysis. The use of Bartlett's test of homogeneity of variance shows variation in the data, and the test for normality assumption failed. The Non-parametric Kruskal Wallis test and the Spearman's rank correlation coefficient were adopted in the analysis, and their formulas were explicitly derived. The number of infants responding to the immunization programme is increasing over the years, while the number of infants that are contracting the six childhood diseases are decreasing over the years under study. These findings indicate the effectiveness of the immunization programme. The number of infants with the six childhood diseases depends on the number of infants immunized, except for Measles vaccine which didn't have a significant impact on Measles, other vaccines had a significant impact on the diseases they are meant to prevent. This development would explain for the high number of infants with measles. The Kruskal-Wallis test revealed that the various vaccines for infant immunization are significant, and further analysis using the pair-wise comparisons revealed that all the various vaccines are significant, except for; BCG and DPT, BCG and Measles and DPT and OPV that are not significant. Also, the various diseases contracted by infants differ, and further analysis showed that all the various diseases are significant, except for; measles and tetanus, pertussis and Tuberculosis, pertussis and poliomyelitis, pertussis and diphtheria, poliomyelitis and tetanus, poliomyelitis and diphtheria and tetanus and diphtheria that are the same (insignificant).

Keywords: Immunization programme, prevalent childhood diseases, kruskal-wallis test, multiple comparisons, Spearman's rank correlation coefficient.

Introduction

It is obvious that in Africa, marriage is never considered happy and successful without the blessing of children. After wedding, the expectation of the couples as well as people around them is the blessing of God in respect of children. Should this be delayed, fear and anxiety set in. It is therefore not unusual to see parents doing everything within their capabilities to ensure the survival of the child. In the event that a matrimonial home is without a surviving child, the negative consequence to the marriage is usually great. In such circumstance, series of advice get to one or both of the couples to take alternative partner. Consequently, such relationships end in divorce. Over the years, many families lost their children to any one of the childhood killer disease, thus dashing the hopes of parents on such children. The effects of such losses often involve social, economic and political implications on the home. To prevent loss of children and its consequences, many parents consult the herbalists and oracles, make incisions and scarifications on the bodies of their children, administer concoctions and perform a number of rituals to appease aggrieved gods, demons and devils believed to be the cause of the unfortunate occurrences¹.

As a way of preventing the loss of children through these killer diseases, the World Health Organization (WHO) in 1977 launched a health scheme tagged the 'Expanded Programme on Immunization (EPI). The EPI is a UNICEF/WHO scheme designed to expand the accessibility of immunization services to an increased number of children within the age range of 0 - 2 years. The programme aimed at combating the six common disease of childhood namely -measles, poliomyelitis, tuberculosis, tetanus, whooping cough (pertussis) and diphtheria². It also aimed at educating individuals and mobilizing governments to adopt health policies that will protect children and mothers. Through the EPI, children who are within the first two years of life are immunized against the six childhood diseases. Similarly, pregnant women are vaccinated against tetanus in an effort to, at least, ameliorate, if not eradicate, infant mortality resulting from the childhood diseases.

Following the initiation of the EPI (Now NPI, National Programme on Immunization) by WHO in 1977, Nigeria launched her own chapter of the NPI in 1979. The programme was revised in 1984. The objective of the programme in Nigeria was to achieve 60% of the target population by 1987, and 80% by 1990. The different states of the federation also launched their own chapters of the programme. Following this, the local government chapters were launched and selected health centres were designated "NPI implementation centers".

The objectives of this research study are: i. To know the relationship between the number of children immunized by a particular vaccine and the children that contracted the diseases. ii. To know if significant difference exists among the number of infants immunized for the various diseases, and iii. To determine if the number of infants with various diseases are significant.

Statement of the Problem

Generally, children's health is an important aspect of any government planning because they are leaders of tomorrow. And as such, it is of utmost importance to reduce death rate among children. Hence, the NPI is meant for the protection of children and pregnant mothers against the six deadly diseases. But, unfortunately, mothers and children appear not to have effectively availed themselves of the services provided by this programme hence the prevalent relatively high number of children that contracted the diseases in Imo State.

Also important to consider, the impact of immunization on the mortality and morbidity caused by these six childhood diseases, since recipients are assured protection on the completion of the immunization schedules. The question now is how effective is the protection offered by these immunization?

Another significant problem facing the NPI is the inconsistent funding of the programme by the Federal Government. This has contributed to inadequate procurement of equipments and non-recruitment of qualified staff for the realization of the aims of NPI.

It is these constraints that this study seeks to statistically identify as well as provide good statistics, using statistical methods for proper evaluation of the NPI in Aboh Mbaise General Hospital, Imo State.

Scope of the Study

The scope of this study is mainly children aged 0 – 2 years and pregnant women who have been immunized and infants that contracted the diseases in Aboh Mbaise General Hospital. Groups considered during the course of study include infants that are fully and partially immunized. Data used spanned a period of fifteen years from 1998 to 2012, hence is wide enough to give a fairly good assessment of the impact of the NPI programme.

Definition of Terms

Measles: measles is a disease characterized by a high fever, rashes on the body, cough, running nose and red eyes³. It is a viral disease and highly infectious. Serious cases of measles cause blindness and death. i. Symptoms: high fever, running nose, rashes, redness of the eyes, white spots inside the cheek and mouth. ii. Transmission: it is spread by droplet or through direct contact with the secretion from the nose and throat of an infected person. iii. Prevention: it is prevented by immunization with the vaccine immune serum globulin (ISG) at 9 months of age. Measles vaccine is a live attenuated virus in powdered form. This should be diluted with cold dilutes.

Whooping cough (pertussis): Pertussis is a serious disease, which affects young children and last for about 6 weeks. It is caused by bacteria *pertussis bacilli*. i. Cough followed by characteristic spasmodic whoop or sometimes in younger children vomiting, running nose, loss of appetite, puffiness of the face around the eyelids, and hernia in severe cases. Some of these complications may lead to death. ii. Transmission: it is a droplet infection and also by direct contact with the discharge from the mucous membrane of an infected person. iii. Prevention: it is prevented by the vaccine DPT. Pertussis vaccine is the "P" component in DPT. It is given to infants from 6 weeks of age and repeated at intervals of at least 4 weeks for 3 doses.

Diphtheria: This is caused by bacterial infections of the skin or respiratory tract (usually the throat). If it is very serious, it kills through suffocation and heart failure. i. Symptoms: inflammation of area of respiratory tract, paleness of face, skin infection resembles common skin lesion with pus. Abnormalities of heart and nervous system. ii. Transmission: it is an air born disease. iii. Prevention: it is prevented by immunization with DPT vaccine. Diphtheria vaccine is the "D" component in DPT. It is given from 6 weeks of age and repeated of at least 4 weeks for 3 doses.

Neonatal Tetanus: This is caused by a bacterial organism, which enters the body through open wounds and punctures, affects the new born baby through the umbilicus at circumcision. It has a high mortality rate. i. Symptoms: muscle spasms, lock jaw, the baby stops sucking the breast, high temperature and stiff neck. ii. Prevention: it is prevented by immunization of pregnant women and infants by tetanus toxoid (TT). TT is given to pregnant women at 10 weeks of and second dose at a minimum of interval of 4 weeks. This protects the mother for 3 years and the baby for 6 weeks after birth, before DPT is given to the baby. DPT contains the antigen vaccine against tetanus. The “T” component in DPT stands for tetanus vaccine.

Poliomyelitis: polio is a disease characterized by muscle weakness or paralysis, especially of legs. It can affect the muscle of respiration thereby causing death. i. Symptoms: fever, the limb maybe weak or paralysed, flaccid paralysis of one leg or both legs. ii. Transmission: facial oral spread is the major route of transmission when sanitation is poor. iii. Prevention: it is prevented with either oral or injectable polio vaccine. The oral vaccine is given to infants from 6 weeks of age, along with DTP for 3 doses at 4 weeks interval. It is given in form of mouth drips.

Tuberculosis: Tuberculosis is an infectious disease caused by Tubercle bacillus and is contacted mainly through droplets from cough of an infected person and also by drinking raw and unpasteurised milk. i. Symptoms: Low grade fever, marked loss of weight, profuse sweating at night, dry-unproductive cough. It is infectious contagious milk. ii. Transmission: it is spread by droplet and direct contact with saliva coughed out from the throat of the infected person (sputum). iii. Prevention: BCG (Bacilli Calmette Guerine) vaccine should be given as soon as possible after birth. Proper disposal of the sputum of an infected person and isolation from the new born baby. Only one dose of BCG gives life immunity.

Vaccine failure: when a vaccine lose its potency, expires and the mother’s antibodies acquired by the child may neutralize the vaccine. When any of these three conditions takes place we say that the vaccine has failed to protect the child.

Booster Dose: additional dose of a vaccine given to an individual when he has already been given the recommended dose by EPI for the continued protection of the individual against any of the immunizable disease is called a booster dose.

Cold Chain: this is a procedure that ensures that the potency of vaccine are secured by seeing that they are kept at the correct low temperature from the time they leave the producer until they reach the people to be vaccinated.

Literature Review

In a study carried out in UCTH Calabar, showed that there was an increase in the incidence, morbidity and mortality ratios from measles infection in the year 1997 to 1999 compared to year 1992 of 1996. 1997 to 1999 recorded a total of 72 cases of measles while 1992 to 1996 recorded a total of 36 cases of measles. They attributed the upsurge to changes in the methods vaccine procurement and distribution in the country⁴. A research from epidemiological findings about communicable diseases concluded that polio was known to be responsible for at least 100,000 cripples in Nigeria⁵.

In a seminar on the “incidence of Tetanus in Nigeria” recorded that the percentage of children immunized and that of pregnant women immunized against tetanus in Nigeria in 1993 was 31.06 and that of 1995 was 44.26 showing a 13.2% increase in the programme in 1995⁶. In a seminar on the “control of tuberculosis” on World Tuberculosis Day, showed that world wide, that there are about 10 million new cases of tuberculosis with 3 to 4 million deaths. He revealed that without treatment after 5 years that 5% of pulmonary tuberculosis patients will be “some-where” while 25% will remain ill with chronic infectious diseases⁷.

In a research of studying immunization against tuberculosis, diphtheria, pertussis, tetanus and polio in Nsukka local government area, found that the immunization status of children in this area was slow. Using five towns in Nsukka Local government area, namely Opi, Isieniu, Edem, Nsukka and Ehandiagu, he discovered that only 512 or 4.7% of the 10,851 one year old children surveyed has received the BCG vaccine, 609 or 5.6% received the triple antigen vaccine, and 120 or 1.1% were immunized with polio vaccines. He concluded that low immunization status was due to lack of vaccines in Health centres within the local government, lack of refrigeration for preservation and poor responses by illiterate parents⁸. In a study carried out on 94 cases of post-neonatal tetanus patients in University College Hospital, Ibadan between 1988 to 1999 shows that 82 (87%) case of the 94 cases were aged 5 years and above. 43, 8 and 15 patients received doses of DPT immunization of 0, 1 – 2 and 3 doses respectively. No patient had tetanus toxoid (TT) administered after infancy. The findings indicates that the current EPI recommended doses of DPT vaccine given during infancy without provision for booster doses is inadequate for tetanus prevention during childhood. It suggested two extra doses of TT between ages four-six and 11 to 12 years be given to all children⁹.

WHO, in its annual report estimated that more than 75% of infants born in 1993 were fully immunized and 45% of pregnant women were immunized to protect their babies against neonatal tetanus. With the current levels of immunization, EPI prevent an estimated 2,900,000 deaths from measles, neonatal tetanus and pertussis and 560,000 cases of poliomyelitis each year. It also, estimated that each year 110,000 children are still being crippled by polio, 500,000 babies die of neonatal tetanus, and 1,200,000 children die from measles¹⁰.

Morley, in his literature on the virulence of infectious disease in developing countries, observed that disease which are largely preventable, constitute major health problems in developing countries¹¹.

Having reviewed other people’s work, we shall use the Spearman’s rank correlation coefficient and Kruskal-Wallis test techniques to investigate the records of infants immunized by specific vaccines for the years 1998-2012 and the number of infants that contracted the six childhood diseases for the years 1998-2012, using Aboh Mbaise General Hospital, Imo State.

Data Collection

The data collected for this study, are secondary data. These data collected are on the number of infants immunized by specific vaccines for the years 1998 – 2012 and the number of infants that contracted the six childhood diseases for the years 1998 – 2012, from the department of medical records Aboh Mbaise General Hospital, Imo State.

At this point, it would be interesting to explain how these figures were obtained. For the data on the number of infants immunized in the hospital, nurses that carry out the immunization, records the number of infants immunized every week of the month in a register, Which is transferred to the medical records department at the end of every month-while for the data on the number of infants that contracted the six childhood diseases, the nurses at the pediatrics department records the number of infants that were brought to the hospital with the diseases in a register on a daily basis. In the pediatrics section, there are two kinds of registers used for the recording of these cases of infants with these diseases; namely i. In-patients registers and ii. Out-patients register

Problems Encountered

It would be absurd to assume that for a study of this nature, no obstacles were met along the line.

We encountered problems like: i. The available data were not well recorded; as a result they were clumsy and difficult to retrieve. ii. In spite of the assistance rendered by the record officer, it took the researchers several weeks to retrieve/compile the data for the number of infants that contracted the six childhood diseases from their muddled up registers. iii. We spent huge amount of money transporting to and fro Aboh Mbaise General Hospital, for the data collection.

Data Presentation: The collected data are hereby presented below:

Table-1
Total number of infants immunized from 1998 – 2012 by type of vaccine

Year	BCG	DPT	OPV	Measles	Tetanus toxoid	Total
1998	432	458	782	453	862	2987
1999	521	683	798	512	1081	3595
2000	538	658	834	608	1121	3759
2001	486	698	842	698	1132	3856
2002	502	708	728	728	1213	3879
2003	618	806	921	864	1312	4521
2004	572	728	963	912	1082	4257
2005	682	689	1082	982	1213	4648
2006	728	782	1074	1008	1821	5413
2007	694	861	969	638	1632	4794
2008	862	892	1082	692	2108	5636
2009	892	946	1217	812	1386	5253
2010	986	869	1418	896	1216	5385
2011	1082	928	1508	728	1314	5560
2012	972	1082	1669	718	1816	6257
Total	10567	11788	15887	11249	20309	69800

Table-2
Total Number of Infants That Contracted the Six Childhood Diseases From 1998 – 2012

Year	Measles	Pertussis	Tuberculosis	Poliomyelitis	Tetanus	Diphtheria	Total
1998	48	23	14	31	38	47	201
1999	39	24	16	23	48	38	188
2000	47	18	12	27	34	36	174
2001	51	17	8	26	38	41	181
2002	48	21	6	24	46	31	176
2003	29	32	4	19	34	28	146
2004	52	18	3	15	36	12	136
2005	27	17	4	21	25	11	105
2006	38	14	3	24	28	9	116
2007	42	10	2	16	21	8	99
2008	29	3	1	8	17	9	67
2009	38	4	2	10	13	7	74
2010	32	2	3	11	19	4	71
2011	21	2	2	6	14	3	48
2012	28	3	2	5	9	2	49
Total	569	208	82	266	420	286	1831

Table-3
Percentages of the Total Number of Infants Immunized and Total Number of Infants with Disease Each Year

Year	Total No. of infants immunized each year	Percentage	Total No. of infants with disease each year	Percentage
1998	2987	4.28	201	10.98
1999	3595	5.15	188	10.27
2000	3759	5.39	174	9.50
2001	3856	5.52	181	9.88
2002	3879	5.56	176	9.61
2003	4521	6.48	146	7.97
2004	4257	6.10	136	7.43
2005	4648	6.66	105	5.74
2006	5413	7.76	116	6.34
2007	4794	6.87	99	5.41
2008	5636	8.07	67	3.66
2009	5253	7.53	74	4.04
2010	5385	7.71	71	3.88
2011	5560	7.97	48	2.62
2012	6257	8.96	49	2.68
Total	69800	100	1831	100

Method of Analysis

The method of analysis we shall use in this research work is as follows; i. Spearman’s Rank Correlation Coefficient. ii. Kruskal-Wallis Test

Kruskal-Wallis Test: The Kruskal-Wallis Test may be describe thus: Suppose that we have k samples of sizes N_1, N_2, \dots, N_k , with the total size of all samples taken together being given by $N = N_1 + N_2 + \dots + N_k$ ¹².

Supposing again that the data from all the samples taken together are ranked and that the sums of the ranks for the k samples are R_1, R_2, \dots, R_k . If we define the statistic as in equation (14) then it can be shown that the sampling distribution of H is very nearly a chi-square distribution with k – 1 degrees of freedom, provided N_1, N_2, \dots, N_k are all at least 5.

Consider the sampling scheme where n integers are selected at random, without replacement, from the first N integers, 1 to N . Let X_i be the i th integer selected, and let

$$T_n = X_1 + X_2 + \dots + X_n \tag{1}$$

be the sum of the integers selected. The expected value of T_n is given by

$$E[T_n] = E[X_1 + X_2 + \dots + X_n] = \frac{n}{N} [X_1 + X_2 + \dots + X_N] \tag{2}$$

$$= \frac{n}{N} \left[\sum_{i=1}^N X_i \right] = \frac{n}{N} \frac{N(N+1)}{2}$$

$$\therefore E(T_n) = \frac{n(N+1)}{2} \tag{3}$$

and the variance of T_n is given by

$$Var(T_n) = E(T_n^2) - [E(T_n)]^2 \tag{4}$$

$$\text{where } E(T_n^2) = E\{[X_1 + X_2 + \dots + X_n]^2\} \tag{5}$$

$$= E[X_1^2 + X_2^2 + \dots + X_n^2 + 2X_1X_2 + \dots + 2X_{n-1}X_n]$$

By symmetry

$$= E[X_1^2 + X_2^2 + \dots + X_n^2] = \frac{n}{N} [X_1^2 + X_2^2 + \dots + X_N^2] \tag{6}$$

also,

$$E[2X_1X_2 + \dots + 2X_{n-1}X_n] = \frac{n(n-1)}{N(N-1)} [2X_1X_2 + \dots + 2X_{N-1}X_N]$$

$$= \frac{n(n-1)}{N(N-1)} [(X_1 + X_2 + \dots + X_N)^2 - (X_1^2 + X_2^2 + \dots + X_N^2)] \tag{7}$$

Adding Equations (6) and (7), we have

$$E(T_n^2) = \frac{n}{N} [X_1^2 + X_2^2 + \dots + X_N^2] + \frac{n(n-1)}{N(N-1)} [(X_1 + X_2 + \dots + X_N)^2 - (X_1^2 + X_2^2 + \dots + X_N^2)]$$

$$= \frac{n}{N} \left[\frac{N(N+1)(2N+1)}{6} \right] + \frac{n(n-1)}{N(N-1)} \left[\left\{ \frac{N(N+1)}{2} \right\}^2 - \frac{N(N+1)(2N+1)}{6} \right]$$

$$= \frac{n(N+1)(2N+1)}{6} + \frac{n(n-1)}{N(N-1)} \left[\frac{N^2(N+1)^2}{4} - \frac{N(N+1)(2N+1)}{6} \right]$$

$$= \frac{n(N+1)(2N+1)}{6} + \frac{n(n-1)}{N(N-1)} \left[\frac{3N^2(N+1)^2 - 2N(N+1)(2N+1)}{12} \right]$$

$$= \frac{n(N+1)(2N+1)}{6} + \frac{n(n-1)}{12(N-1)} [3N^2(N+1)^2 - 2N(N+1)(2N+1)] \tag{8}$$

Substitute Equations (3) and (8) into Equation (4) to obtain

$$Var(T_n) = \frac{n(N+1)(2N+1)}{6} + \frac{n(n-1)}{12(N-1)} [3N^2(N+1)^2 - 2N(N+1)(2N+1)] - \frac{n^2(N+1)^2}{4}$$

$$\begin{aligned}
 &= \frac{1}{12(N-1)} \left[2n(N^2-1)(2N+1) + n(n-1)(N+1) \{ 3N^2 - N - 2 \} - 3n^2(N^2-1)(N+1) \right] \\
 &= \frac{1}{12(N-1)} \left[2n(N^2-1)(2N+1) + n(n-1)(N+1) \{ (3N+2)(N-1) \} - 3n^2(N^2-1)(N+1) \right] \\
 &= \frac{1}{12} \left[2n(N+1)(2N+1) + n(n-1)(N+1)(3N+2) - 3n^2(N+1)^2 \right] \\
 &= \frac{n(N+1)}{12} [4N+2+3Nn+2n-3N-2-3nN-3n] \\
 \text{Var}(T_n) &= \frac{n(N+1)(N-n)}{12} \tag{9}
 \end{aligned}$$

A version of the central limit theorem implies that

$$Z = \frac{T_n - E(T_n)}{\sqrt{\text{Var}(T_n)}} \tag{10}$$

has an approximate standard normal distribution when n is of at least moderate size, say n > 5. In this paper, we shall replace T_n with R_i, the sum of the ranks for group i. Then

$$Z = \frac{R_i - E(R_i)}{\sqrt{\text{Var}(R_i)}} = \frac{R_i - n_i(N+1)/2}{\sqrt{n_i(N+1)(N-n_i)}/12} \sim N(0, 1) \tag{11}$$

And so
$$Z^2 = \frac{\left[R_i - n_i(N+1)/2 \right]^2}{\sqrt{n_i(N+1)(N-n_i)}/12} \sim \chi^2_{(1)} \tag{12}$$

But, since the R_i's are not independent, an adjustment is needed when summing, and one degree of freedom is lost. The weighted sum of the Z²'s for all k groups is

$$\begin{aligned}
 T &= \sum_{i=1}^k \frac{N-n_i}{N} \frac{\left[R_i - n_i(N+1)/2 \right]^2}{\sqrt{n_i(N+1)(N-n_i)}/12} \sim \chi^2_{(k-1)} \tag{13} \\
 &= \frac{1}{N} \sum_{i=1}^k \frac{R_i^2 - \frac{2R_i n_i(N+1)}{2} + \frac{n_i^2(N+1)^2}{4}}{\frac{n_i(N+1)}{12}} \\
 &= \frac{1}{N} \sum_{i=1}^k \frac{4R_i^2 - 4R_i n_i(N+1) + n_i^2(N+1)^2}{4} \cdot \frac{12}{n_i(N+1)} \\
 &= \frac{1}{N} \sum_{i=1}^k \left[\frac{12R_i^2}{n_i(N+1)} - 12R_i + 3n_i(N+1) \right] \\
 &= \frac{1}{N} \sum_{i=1}^k \frac{12R_i^2}{n_i(N+1)} - \frac{12}{N} \sum_{i=1}^k R_i + \frac{3(N+1)}{N} \sum_{i=1}^k n_i
 \end{aligned}$$

$$= \frac{12}{N(N+1)} \sum_{i=1}^k \frac{R_i^2}{n_i} - \frac{12}{N} \frac{N(N+1)}{2} + \frac{3(N+1)}{N} N$$

$$= \frac{12}{N(N+1)} \sum_{i=1}^k \frac{R_i^2}{n_i} - 6(N+1) + 3(N+1)$$

$$\therefore T = H = \frac{12}{N(N+1)} \sum_{i=1}^k \frac{R_i^2}{n_i} - 3(N+1) \tag{14}$$

If there are many ties, and $n_i > 5$, use the test statistic

$$T(\text{ties}) = \frac{1}{S^2} \left[\sum \frac{R_i^2}{n_i} - \frac{N(N+1)^2}{4} \right] \tag{15}$$

$$\text{where } S^2 = \frac{1}{N-1} \left[\sum_{\text{all ranks}} R(X_{ij})^2 - \frac{N(N+1)^2}{4} \right] \tag{16}$$

under H_0 , $T(\text{ties}) \sim \chi^2_{(k-1)}$

Multiple Comparisons: If H_0 is rejected at level α , we can say that populations i and j seem to be different if the following inequality is satisfied.

$$\left| \frac{R_i}{n_j} - \frac{R_j}{n_i} \right| > t_{1-\alpha/2} \left(s^2 \frac{N-1-T}{N-k} \right)^{\frac{1}{2}} \left(\frac{1}{n_i} + \frac{1}{n_j} \right)^{\frac{1}{2}} \tag{17}$$

Spearman's Rank Correlation Coefficient: Spearman's rank correlation coefficient, r_s , provides a measure of correlation between ranks¹³. The formula for this measure of correlation is given in equation (28).

If X_i and Y_i values are expressed in ranks, then

$$\sum_{i=1}^n X_i = \frac{n(n+1)}{2} = \sum_{i=1}^n Y_i \tag{18}$$

$$\sum X_i^2 = \frac{n(n+1)(2n+1)}{6} = \sum Y_i^2 \tag{19}$$

$$d = x_i - y_i$$

$$\sum d^2 = \sum (x_i - y_i)^2$$

$$\sum d^2 = \sum x_i^2 - 2\sum x_i y_i + \sum y_i^2 \tag{20}$$

Recall that the correlation coefficient between two variables say X and Y is given by

$$r_s = \frac{\sum x_i y_i}{\sqrt{\sum x_i^2 \sum y_i^2}} \tag{21}$$

From equation (20), we have

$$2\sum x_i y_i = \sum x_i^2 + \sum y_i^2 - \sum d^2 \tag{22}$$

From equation (21),

$$\sum x_i y_i = r_s \sqrt{\sum x_i^2 \sum y_i^2} \tag{23}$$

Put equation (23) into equations (22) to get

$$2r_s \sqrt{\sum x_i^2 \sum y_i^2} = \sum x_i^2 + \sum y_i^2 - \sum d^2 \tag{24}$$

But in deviation form,

$$\sum x_i^2 = \sum X_i^2 - \frac{(\sum X_i)^2}{n} \tag{25}$$

$$\sum y_i^2 = \sum Y_i^2 - \frac{(\sum Y_i)^2}{n} \tag{26}$$

Put equations (18) and (19) into equation (25) to obtain

$$\begin{aligned} \sum x_i^2 &= \frac{n(n+1)(2n+1)}{6} - \left[\frac{n(n+1)}{2} \right]^2 \left(\frac{1}{n} \right) \\ &= \frac{n(n+1)(2n+1)}{6} - \frac{n^2(n+1)^2}{4n} \\ \frac{2n(n+1)(2n+1) - 3n(n+1)^2}{12} &= \frac{n(n+1)[4n+2-3n-3]}{12} \\ &= \frac{n(n+1)(n-1)}{12} = \frac{n(n^2-1)}{12} \\ \therefore \sum x_i^2 = \sum y_i^2 &= \frac{n(n^2-1)}{12} \end{aligned} \tag{27}$$

Substitute equation (27) into equation (24) to get

$$\begin{aligned} 2r_s \sqrt{\frac{n(n^2-1)}{12} \frac{n(n^2-1)}{12}} &= \frac{2n(n^2-1)}{12} - \sum d^2 \\ 2r_s \left[\frac{n(n^2-1)}{12} \right] &= \frac{n(n^2-1)}{6} - \sum d^2 \\ r_s \left[\frac{n(n^2-1)}{6} \right] &= \frac{n(n^2-1) - 6\sum d^2}{6} \end{aligned}$$

Cross multiplication gives

$$\begin{aligned} r_s [n(n^2-1)] &= n(n^2-1) - 6\sum d^2 \\ r_s &= 1 - \frac{6\sum d^2}{n(n^2-1)} \end{aligned} \tag{28}$$

Equation (28) is the formula for Spearman's rank correlation coefficient where;

d = difference between corresponding ranks and n is the number of pairs of observation. If we encounter ties in the data, then equation (28) can be written as

$$r_s = 1 - \frac{6(\sum d^2 + T_x + T_y)}{12} \tag{29}$$

where $T_x = T_y = \frac{t^3 - t}{12}$ (30)

Hypothesis Test for ρ : It is of interest to know if a set of sample data provides sufficient evidence to indicate that the population correlation coefficient ρ is nonzero¹⁴. If the null hypothesis that $\rho = 0$ can be rejected, it can be concluded that there is a linear relationship between X and Y.

The test statistic we shall use is given by

$$t = r \sqrt{\frac{n-2}{1-r^2}} \tag{31}$$

which follows the t distribution with $n - 2$ degrees of freedom when $\rho = 0$.

Data Analysis

Using all the statistical techniques discussed in this paper, we now proceed with the analysis of the observed data.

Finding the Strength of Relationship between the Number of Children Immunized by a Particular Vaccine and the Number of Children that Contracted the Diseases

For clarity, the vaccines and the diseases they prevent are shown below:

Table-4
Vaccines and the diseases they prevent

S/N	Vaccines	Disease it prevents
1	B.C.G	Tuberculosis
2	D.P.T	Diphtheria, pertussis and Tetanus
3	O.P.V	Poliomyelitis
4	Tetanus Toxoid	Tetanus
5	Measles vaccine	measles

Correlation Co-Efficient Between BCG Vaccine and Tuberculosis

Let BCG vaccine be X_i
 Tuberculosis be Y_i

Testing the hypothesis that the population correlation co-efficient is significantly different from zero, that is to test;

$H_0 : \rho = 0$
 $H_1 : \rho \neq 0$

Using a statistical package known as SPSS Version 17.0, we have that
 $r = -0.829$; $p\text{-value} = 0.000$, $\alpha = 0.05$

Conclusion

Since $p\text{-value}$ is less than α , we reject H_0 and conclude that $r = -0.829$ is significantly different from zero. In order words, the number of children who received BCG immunization is negatively correlated with the number of children who contracted tuberculosis. Thus, we can say with 95% confidence that as the number of BCG vaccines administered increases, the number of infants contracting tuberculosis decreases.

Using the same procedure and the same statistical software package the value of r , together with the corresponding $p\text{-values}$, and decisions for the other vaccine and diseases are shown in table 5.

Table 5
Value of r and corresponding p-values, and decisions for the other vaccine and diseases

s/n	Vaccine and Disease	r	p-value	Decisions
1	DPT and Diphtheria	-0.897	0.000	Reject H_0 and conclude that 'r' is significantly different from zero
2	DPT and Pertussis	-0.754	0.001	Reject H_0 and conclude that 'r' is significantly different from zero
3	DPT and Tetanus	-0.850	0.000	Reject H_0 and conclude that 'r' is significantly different from zero
4	OPV and Polio	-0.844	0.000	Reject H_0 and conclude that 'r' is significantly different from zero
5	Measles vaccine and measles	-0.295	0.286	Accept H_0
6	Tetanus toxoid and Tetanus	-0.763	0.001	Reject H_0 and conclude that 'r' is significantly different from zero

Testing for the Significance Difference of the Number of Infants Immunized for the Various Vaccines: Kruskal-Wallis Test shall be used to determine which of the vaccine(s) is (are) in higher demand. Using the MINITAB software package to run the data in Table 1, we have the result below;

H = 38.69

From the chi-square table, $\chi^2_{4,0.05} = 9.488$ at 5% level of significant.

The null and alternative hypotheses are

H₀ : All vaccines are equal

H₁ : At least one vaccine differs

Since the H value is greater than the chi-square tabulated, we reject H₀ and conclude that at least one of the children immunized for different vaccine differs.

Comparing BCG and DPT, we have

$$\left| \frac{336}{15} - \frac{435}{15} \right| > 1.960 \left(475 \left(\frac{75 - 1 - 38.69}{70} \right) \right)^{\frac{1}{2}} \left(\frac{1}{15} + \frac{1}{15} \right)^{\frac{1}{2}}$$

Since 6.6 < 11.078, we conclude that BCG and DPT have the same number of infants immunized.

Using the same test statistic, the values of the test statistic, together with the corresponding decisions for the remaining 9 comparisons are shown in table 6

Table 6
Values of the test statistic and corresponding decisions for the remaining

	Comparisons	Result	Decisions
1	BCG and OPV	26.4 > 11.078	Differs significantly
2	BCG and Measles	4 < 11.078	They do not differ
3	BCG and Tetanus toxoid	41 > 11.078	Differs significantly
4	DPT and OPV	19.8 > 11.078	Differs significantly
5	DPT and Measles	2.6 < 11.078	They do not differ
6	DPT and Tetanus toxoid	34.4 > 11.078	Differs significantly
7	OPV and Measles	22.4 > 11.078	Differs significantly
8	OPV and Tetanus toxoid	14.6 > 11.078	Differs significantly
9	Measles and Tetanus toxoid	37 > 11.078	Differs significantly

Testing for the Significance Difference between the number of Infants with Various Diseases: Using the same Kruskal-Wallis Test and the statistical software applied in section 13, we have H = 45.64

The null and alternative hypotheses are: H₀ : All the six childhood diseases are the same, H₁ : At least one childhood disease differs

From the chi-square table, $\chi^2_{5,0.05} = 11.070$ at 5% level of significant.

Comparing Measles and Pertussis, we have

$$\left| \frac{1128}{15} - \frac{522}{15} \right| > 1.960 \left[682.5 \left(\frac{90 - 1 - 45.64}{84} \right) \right]^{\frac{1}{2}} \left(\frac{1}{15} + \frac{1}{15} \right)^{\frac{1}{2}}$$

Since 40.4 > 23.017, measles differs significantly from pertussis, statistically speaking.

Using the same test statistic, the values of the test statistic, together with the corresponding decisions for the remaining 14 comparisons are shown in table 7

Table 7
Values of the test statistic and corresponding decisions for the remaining 14 comparisons

	Comparisons	Result	Decisions
1	Measles and Tuberculosis	$58.9 > 23.017$	Differs significantly
2	Measles and Poliomyelitis	$31.6 > 23.017$	Differs significantly
3	Measles and Tetanus	$15.1 < 23.017$	They are the same
4	Measles and Diphtheria	$32.2 > 23.017$	Differs significantly
5	Pertussis and Tuberculosis	$18.5 < 23.017$	They are the same
6	Pertussis and Poliomyelitis	$8.8 < 23.017$	They are the same
7	Pertussis and Tetanus	$25.3 > 23.017$	Differs significantly
8	Pertussis and Diphtheria	$8.2 < 23.017$	They are the same
9	Tuberculosis and Poliomyelitis	$27.3 > 23.017$	Differs significantly
10	Tuberculosis and Tetanus	$43.8 > 23.017$	Differs significantly
11	Tuberculosis and Diphtheria	$26.7 > 23.017$	Differs significantly
12	Poliomyelitis and Tetanus	$16.5 < 23.017$	They are the same
13	Poliomyelitis and Diphtheria	$0.6 < 23.017$	They are the same
14	Tetanus and Diphtheria	$17.1 < 23.017$	They are the same

Conclusion

The number of infants responding to the immunization programme in Aboh Mbaise General Hospital is increasing over the years, while the number of infants that are contracting the six childhood diseases are decreasing over the years under study. These findings indicate the effectiveness of the immunization programme. The number of infants with the six childhood diseases depends on the number of infants immunized, except for Measles vaccine which didn't have a significant impact on Measles, other vaccines had a significant impact on the diseases they are meant to prevent. This development would explain for the high number of infants with measles. The kruskal-wallis test revealed that the various vaccines for infant immunization are significant, and further analysis using the pair-wise comparisons revealed that all the various vaccines are significant, except for; BCG and DPT, BCG and Measles and DPT and OPV that are not significant. Also, the various diseases contracted by infants differ, and further analysis showed that all the various diseases are significant, except for; measles and tetanus, pertussis and Tuberculosis, pertussis and poliomyelitis, pertussis and diphtheria, poliomyelitis and tetanus, poliomyelitis and diphtheria and tetanus and diphtheria that are the same (insignificant).

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