The Professional Medical Journal
www.theprofesional.com

ORIGINAL PROF-2722

INFANT POLIO IMMUNIZATION;
TIME SERIES MODELING TOWARDS COVERAGE IN PAKISTAN

Muhammad Imran[1], Jamal Abdul Nasir[2], Syed Arif Ahmed Zaidi[3]

1. MS Scholar, Department of Statistics, TheIslamia University of Bahawalpur, Bahawalpur, Pakistan
2. Director Sub Campus Rahim Yar Khan (RYK) & Assistant Professor of Statistics, The Islamia University of Bahawalpur, Pakistan:
3. Department of Community Medicine, Quaid-e-Azam Medical College, Bahawalpur

Correspondence Address:
Muhammad Imran
MS Scholar,
Department of Statistics,
The Islamia University of Bahawalpur,
Bahawalpur, Pakistan
imranshakoor84@yahoo.com
njamal76@hotmail.com

Article received on:
28/11/2014
Accepted for publication:
06/01/2015
Received after proof reading:
17/04/2015

ABSTRACT... Poliomyelitis is a highly infectious disease but preventable by effective vaccines. Children under five year of age affected by this disease as a result a permanent paralysis. **Objectives:** To uncover the trend of infant polio immunization coverage through modeling is a significant concern to formulate an adequate vaccination strategies and program after the outbreak of new cases of polio in a recent year in Pakistan. **Design:** The reported data of monthly infant polio immunization coverage to National Institute of Health, Islamabad, Pakistan from January 2008 to July 2013 for the present study has been taken from Pakistan bureau of statistics with total time series entities 67. National Institute of Health, Islamabad took the record of per month number of doses administered (0-11 months)children by the registered health centre in pakistan. **Period:** January 2008 - July 2013. **Setting:** Pakistan bureau of statistics (Statistics House) **Methods:** A set of various short term time series forecasting models namely Box-Jenkins, single moving average, double moving average, single parameter exponential smoothing, brown, Holts and winter models were carried out to expose the infant polio immunization coverage trend. **Results**: Among the several forecasting models ARIMA models are chosen due to lower measure of forecast errors namely root mean square error (RMSE), mean absolute error (MAE) and mean absolute percentage error (MAPE). ARIMA (2,1,1), ARIMA (1,0,2), ARIMA (0,1,2) and ARIMA (2,1,1) models are established as an adequate models for the prediction of OPV-0, OPV-1, OPV-2 and OPV-3 respectively. **Conclusions:** With the exception of OPV-1 the infant polio immunization coverage is expected to rise in Pakistan.

Key words: Time Series Models; Infant polio Immunization coverage; Pakistan

Article Citation: Imran M, Nasir JA, Zaidi SAA. Infant polio immunization; time series modeling towards coverage in Pakistan. Professional Med J 2015;22(4):507-513.

INTRODUCTION

Poliomyelitis is a highly infectious disease but preventable by effective vaccines. Children under five year of age affected by this disease as a result a permanent paralysis. A global struggle to eradicate polio began in 1988, since then large vaccination companion have declined the globally number of polio cases by more than 99%[1]. Polio is now endemic in three countries of world including Pakistan, Afghanistan and Nigeria. According to global polio emergency action plan 2012-13, the number of polio cases ascended from 2010 to 2011 in Afghanistan by 220%, in Nigeria by 185% and in Pakistan by 37%.[2]There are many obstacle in the failure of oral polio vaccine (OPV) in the three endemic counties like weak public infrastructure and health system, insecurity, large scale population movements, corruption, political change and insufficient accountability[2]. However a mass polio vaccination campaigns and programs started in Pakistan 1994 and are still under way[3]. But the goals set by WHO for the polio eradication is still unachieved and Pakistan placed first in term of high number of occurrence of polio cases in 2014[4]. Coverage of some antigens such as polio in routine immunizations actually declined while funding increase[5]. Vaccination coverage in Pakistan is lagging behind regional countries like Bangladesh and Sri Lanka[5]. Our neighbouring and the second most populous country India is become a polio free country[2]. Immunization in Pakistan needs improvement[6]. Religious opposition by Muslim fundamentalists is one of the major factor in the failure of immunization programmes against polio in Pakistan[7]. On the other hand violence threats towards polio worker particularly in tribal areas, Khyber Pakhtunkhwa and in Karachi interrupted the polio campaign as results the increment in number of confirmed WPV cases from 58 in 2012 to 91 in 2013[4].

Factor Affecting Immunization Coverage in Pakistan

Pakistan is a developing as well as 6th most populous county in the globe. More than 70% of the world's unimmunized children live in only 10 developing countries, mainly in Africa and Asia[8]. Socio-economic determinants have the potential to affect immunization programs. Many children remain unvaccinated due to many socio-economic constraints, poor marginalized people have a low awareness with respect to the importance of polio vaccine along with social hierarchies, and educational attainment of parents is a strong indicator of defining awareness level regarding immunization[9]. Immunization is varying geographical area. Large populations and fragile immunization structures make these children difficult to reach. Naeem et al (2011)[10] made a cross sectional study in Peshawar and found that immunization in rural areas is lower than urban areas due to many factors like of accessibility to health centres, lack of awareness and misconceptions, while parents in rural areas have a much lower education status and knowledge regarding immunization. The main reason of non- immunization are lack of awareness, poor economic conditions, misconception about immunization low literacy rate and low salary and security threat to the polio teams[11]. Unawareness and the misinterpretation about polio by religious leaders is a major hurdle in the real success of polio campaign[12].

METHODS AND MATERIAL

The monthly data for present study has been taken from Pakistan Bureau of Statistics (statistics House), from January 2008 to July 2013 with total time series entities 67. A set of various short term time series forecasting models namely Box-Jenkins, single moving average, double moving average, single parameter exponential smoothing, brown, Holts and winter models[13-15] are carried out to uncover the immunization trend. Minitab 15.0 has been used for the execution various models.

Measures of Forecast Accuracy

To compare forecasted values with actual values and to see how well one model works or to compare models.[16]Some popular and very useful accuracy measures are (i) Mean Square Error (MSE). Square root of mean square error is termed as root mean square error (RMSE) (ii) mean absolute error (iii) mean absolute percentage error.

Forecast error = Actual value – Forecast value

$$\text{Mean square error} = \frac{\sum (A_t - F_t)^2}{n} \quad (1)$$

Where A_t and F_t is actual and forecast value respectively.

$$\text{MAPE} = \frac{\sum \left| \frac{\text{Error}}{\text{Actual}} \right|}{n} \times 100 \quad (2)$$

$$\text{MAD} = \frac{\sum |e|}{n} \quad (3)$$

RESULTS AND DISCUSSION

Average monthly number of doses administered to (0-11 months) children during January 2008 to July 2013 along with absolute and relative measures of desperation and minimum, maximum immunization coverage are given in table I. OPV-3 coverage is a more consistent as compared to OPV-0, OPV-1 and OPV-2 due to lower value of

Variable	OPV-0	OPV-1	OPV-2	OPV-3
Mean	318467	473965	442574	430596
St Dev	32347	34675	31790	29137
Minimum	238133	405034	366309	352106
Maximum	389623	602661	533852	481946
C.V	10.16%	7.32%	7.18%	6.77%

Table-I. Descriptive statistics

coefficient of variation 6.7%.

To uncover the trend of infant immunization coverage during January 2008 t0 July 2013 in Pakistan, a set of various time series forecasting models namely Box-Jenkins, three year single moving average, double moving average, single parameter exponential smoothing, brown, Holts and winter models are carried out. An optimum smoothing constant which minimize the accuracy measures are taken for single parameter smoothing exponential, brown, Holts and winter models. An adequate model is selected by taking under consideration the forecast accuracy measures with focusing root mean square error. Box-Jenkins methodology has lower accuracy measures than other models ARIMA (2,1,1), ARIMA (1,0,2),ARIMA (0,1,2) and ARIMA (2,1,1) have a good agreement between real and forecasted data for OPV-0, OPV-1, OPV-2 and OPV-3 respectively the detail statistics of model selection along with accuracy measures are given in table 3. OPV-0, OPV-2 and OPV-3 is expected to rise say 100 doses administered (0-11 months) children during February to July (6 month) in 2013 approximately 106, 103 and 101 are expected in next 6 month (august to January), On the other hand OPV-1 expected to slightly decline by -0.45%. OPV-1 and OPV-3 are expected to remain fairly stable. The detail of expected % change under various ARIMA models is shown in table iv. According to the vaccination schedule 2010[5] and onward the OPV-0, OPV-1, OPV-2 and OPV-3 are given at birth, after six weeks, 10 weeks and 14 weeks of birth respectively.

Box-Jenkins methodology is often used in the prediction of infectious disease[17-22]. Box-Jenkins methodology is a systematic iterative process until an adequate model is achieved. A procedure is enhanced step by step identification, estimation of parameters, diagnostic checks and finally forecast. A model consist the three parameters one autoregressive (p), second differencing order (d) and third moving average order(q)[14-15].

The initial step of the Box-Jenkins process is identification, in this step the given time series is checked weather it is mean reverting series or not. Kwiatkowski-phillips-schmidt-shin (KPSS) test with the hypothesis H0: The series is stationary and H1: The series is not stationary is carried out to check the given series are stationary or not. The detail of KPSS test is shown in table II. With the exception of Opv-1 series all other series are stationary at first difference (d=1).

	Difference level	Test statistic
OPV-0	d=0	1.2939
	d=1	0.0254*
OPV-1	d=0	0.2584*
OPV-2	d=0	0.5234
	d=1	0.0483*
OPV-3	d=0	0.6875
	d=1	0.0455*

Table-II. Kwiatkowski-phillips-schmidt-shin test
***test statistic value<Critical value at 5%**

By establishing the particular ARIMA models with estimated parameters under the sophisticated computational algorithms, we next see whether the chosen models are adequate or not. A model is considered as an adequate the residual of that model are distributed as white noise, i.e., they are independent and normality distributed with zero mean and constant variance and uncorrelated for all lags. Ljung-Box.Q statistic is used as a diagnostic purpose, the acceptance of null hypothesis leads toward that the fit is good. The null hypothesis is accepted because the p-value at lags 12, 24, 36 and 48 is greater than the level of significance (5%) for all the models (OPV-0, OPV-1, OPV-2 and OPV-3) that indicating the best fit.

By substituting the final estimates of parameters, the model equation is given below in equation (4) to (7). While the time plot of final selected ARIMA models with half year forecast along with 95% confidence limits are illustrated in figure 1 to figure 4.

ARIAM (2, 1, 1) model for OPV-0

$$\hat{Y}_t = 683.0 + Y_{t-1} + 0.3110 (Y_{t-1} - Y_{t-2}) + 0.1509 (Y_{t-2} - Y_{t-3}) - 0.9713e_{t-1} \quad (4)$$

ARIMA (2, 1, 1) model for OPV-3

$$\hat{Y}_t = 389.1 + Y_{t-1} + 0.3416 (Y_{t-1} - Y_{t-2}) + 0.09 (Y_{t-2} - Y_{t-3}) - 0.96e_{t-1} \quad (5)$$

ARIMA (0, 1, 2) model for OPV-2

$$\hat{Y}_t = 822.1 + Y_{t-1} - 0.6863e_{t-1} - 0.3726 e_{t-2} \quad (6)$$

ARIMA (1, 0, 2) model for OPV-1

$$\hat{Y}_t = 1.0Y_{t-1} - 0.7475e_{t-1} - 0.2203e_{t-2} \quad (7)$$

	Actual	Predicted	% change
OPV-0	2088363.00	2183487.04	4.55
OPV-1	2862944.00	2850128.46	-0.45
OPV-2	2734024.00	2813106.50	2.89
OPV-3	2679057.00	2701954.71	0.85

Table-IV. Expected % change under selected ARIMA models

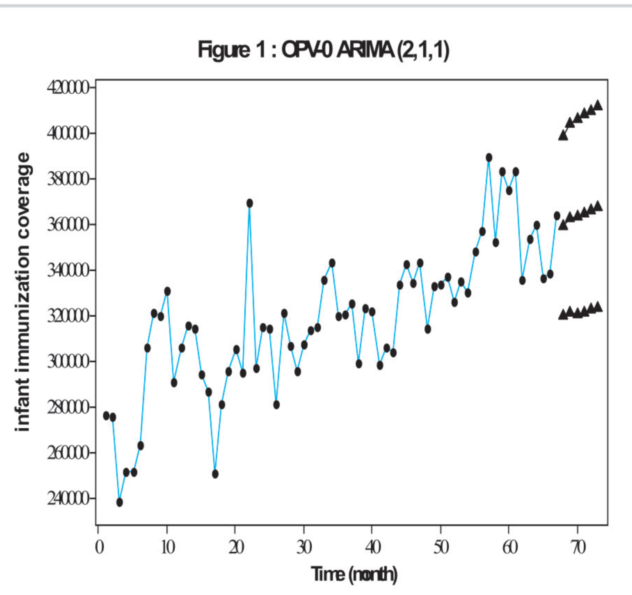
CONCLUSIONS

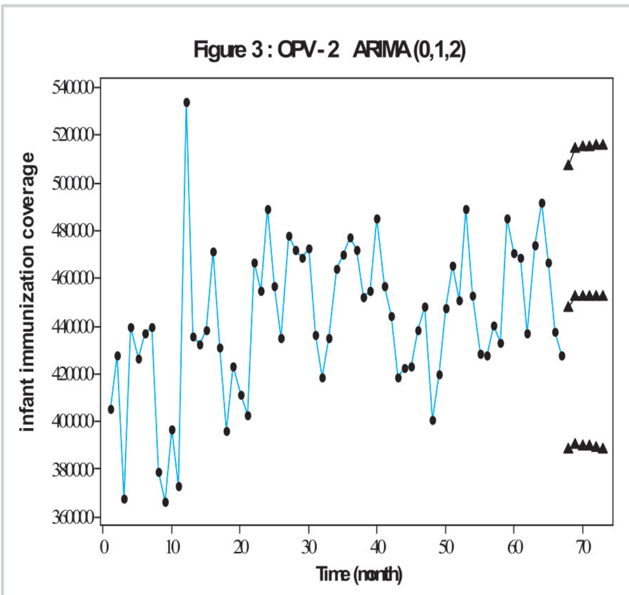
Pakistan needs smart effective and proactive anti polio policies to eradicate polio. Although a rising trend in infant polio vaccination coverage is expected except OPV-1, but achieving a high level of coverage is not enough, the outbreaks of polio have occurred in under vaccinated population.[23] Availability of this statistical outcome will serve as a guide to better understand the pattern, improvement in polio vaccination and to re-

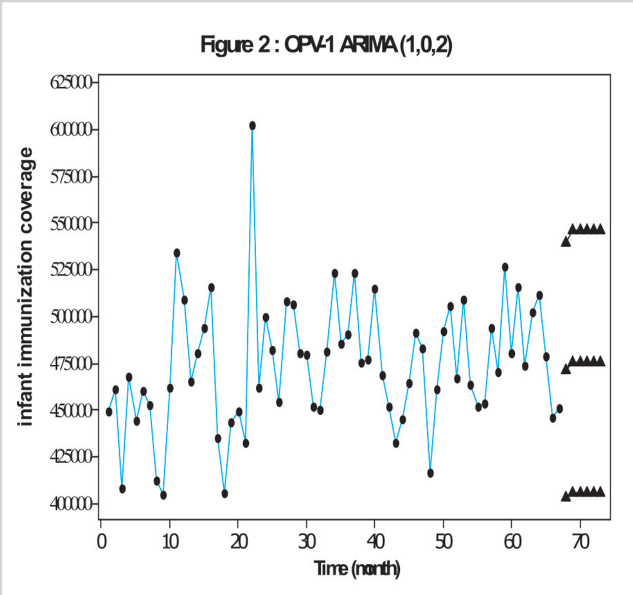
Model	RMSE	MAD	MAPE
OPV-0			
ARIMA (1,1,1)	19756.57	15076.74	4.77
ARIMA (0,1,1)	21246.09	16063.55	5.07
ARIMA (1,1,0)	21393.22	16846.08	5.33
ARIMA (2,1,0)	21235.69	16360.62	5.18
***ARIMA (2,1,1)**	**19492.51**	**14880.63**	**4.71**
ARIMA (0,1,2)	20129.39	15222.42	4.82
ARIMA (1,1,2)	21134.16	16133.69	5.09
Singe Moving Average	21698.90	16469.39	5.17
Double moving average	25305.89	20290.24	6.39
Single Exponential Method	21152.89	15781.79	5.00
Brown method	22094.47	16314.84	5.20
Holt method	21993.76	16036.27	5.11
Winter method	21947.19	16407.026	5.23
OPV-1			
ARIMA (1,0,1)	34633.94	26430.80	5.53
ARIMA (0,0,1)	259619.88	249007.80	52.54
ARIMA (1,0,0)	43291.39	32650.12	6.81
ARIMA (2,0,0)	40809.55	30993.15	6.48
ARIMA (2,0,1)	40134.52	30820.33	6.49
***ARIMA (1,0,2)**	**34061.43**	**26019.75**	**5.43**
ARIMA (0,0,2)	162380.34	145230.30	30.55
Singe Moving Average	39446.19	30136.85	6.28
Double moving average	51055.38	41223.73	8.63
Single Exponential Method	34950.72	26207.52	5.45
Brown method	36251.86	27300.01	5.72
Holt method	35772.02	27018.32	5.67
Winter method	38713.07	29442.21	6.25
OPV-2			
ARIMA (1,1,1)	28983.32	22157.11	5.01
ARIMA (0,1,1)	30038.02	24304.79	5.53
ARIMA (1,1,0)	33146.08	25106.46	5.66

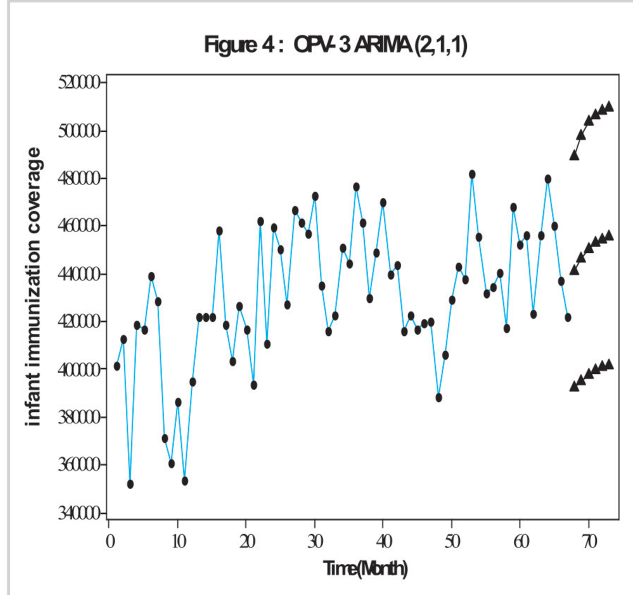
ARIMA (2,1,0)	32680.13	24313.36	5.47
ARIMA (2,1,1)	32961.70	25146.43	5.68
***ARIMA (0,1,2)**	**28474.84**	**21888.20**	**4.97**
ARIMA (1,1,2)	28515.29	22199.46	5.05
Singe Moving Average	33513.71	24741.47	5.53
Double moving average	42678.57	34245.80	7.69
Single Exponential Method	30418.72	23438.93	5.29
Brown method	31075.13	23893.43	5.42
Holt method	31359.82	24639.53	5.60
Winter method	34740.22	25867.69	5.91
OPV-3			
ARIMA (1,1,1)	24617.84	20204.01	4.74
ARIMA (0,1,1)	25238.78	21726.76	5.11
ARIMA (1,1,0)	26326.92	21783.45	5.13
ARIMA (2,1,0)	25712.39	21274.33	5.01
***ARIMA (2,1,1)**	**23966.18**	**19757.49**	**4.67**
ARIMA (0,1,2)	24491.32	20253.30	4.78
ARIMA (1,1,2)	24539.90	20259.19	4.75
Singe Moving Average	25856.99	21254.85	4.96
Double moving average	30868.26	25760.37	6.03
Single Exponential Method	25076.92	21008.22	4.94
Brown method	25982.03	21901.26	5.17
Holt method	26071.82	21502.38	5.08
Winter method	26957.29	21171.03	5.03

Table-III. A detail summery of models and accuracy measures
*Lowest values of RMSE, MAD and MAPE









examine the existing policies.

REFERENCES

1. **Forty-first World Health Assembly. Resolutions and decisions.** WHA41.28. Global eradication of poliomyelitis by the year 2000. Geneva: World Health Organization; 1988.
2. **World Health Organization (2012),** Global Polio Emergency Action Plan 2012-13: Action to Stop Polio now in Nigeria, Pakistan and Afghanistan
3. Nishtar S. **Pakistan Politics and Polio.** Bull World Health Organ 2010; 88:159–60.
4. **National emergency action plan 2014 for polio eradication:** Government of Islamic republic of Pakistan.
5. **Childhood Immunization in Pakistan,** Research and Development Solutions Policy Briefs Series No. 3, February 2012.
6. Ahmad, K., **Pakistan struggles to eradicate polio.** The Lancet Infectious Diseases.2007; 7(4): 247.
7. Loevinsohn B, Hong R, Gauri V. **Will more inputs improve the delivery of health services? Analysis of district vaccination coverage in Pakistan.** Int J Health Plann Manage 2006; 21:45-54
8. UNICEF Polio Immunization, Available at: http://www.unicef.org/immunization/index_polio.html
9. SheebaArooj, S.A., Nimra Baber, AtifAbbasi, Midhat. **Ali Socioeconomic factors effecting polio vaccination in Pakistan Health.** 2013;5(5):892-897.
10. Naeem, M. et al, **Causes of non-immunization in children for measles in urban and rural areas of Peshawar.** J. Med. Sci. 2011; 19(4):181-184.
11. Naeem, M. et al, **Coverage and causes of missed oral polio vaccine in urban and rural areas of Peshawar.** J Ayub Med CollAbbottabad 2011; 23(4):98-102.
12. Mehmood K, HashmiInamQadir J, Rashid AZ, Bashir RA, Khosa ZA, Khalid S, Hashmi KTK. **Polio vaccination; knowledge, attitude, and practice about in District Abbottabad, Khyber Pakhtunkhwa Pakistan.** Professional Med J.2014; 21(5):1026-1032.
13. Spyros G. Makridakis, Steven C. Wheelwright, Rob J. Hyndman. **Forecasting: Methods and applications.** 1997;New York, Wiley.
14. Box, G. P. & Jenkins, G. M. 1976. **Time series analysis: forecasting and control,** San Francisco, Calif., Holden-Day.
15. Box, G. P. & Jenkins, G. M. & Reinsel, G. C. 1994. **Time series analysis: forecasting and control, Englewood Cliffs,** N.J., Prentice Hall.
16. Armstrong, J. S., &Collopy, F. **Error measures for generalizing about forecasting methods: Empirical comparison.** International Journal of Forecasting. 1992;8, 69-80.
17. Imran M, Nasir JA, Zaidi SAA: **Forecasting of new cases of Tb, using Box-Jenkins approach.** JUMDC. 2014; 5(2):37-42.

18. R. P. **SoebiyantoRKK: modeling influenza transmission using environmental parameters international archives of the photogrammetry, remote sensing and spatial information science.** 2010; xxxviii: 330-334.

19. Permanasari et al : **Prediction of Zoonosis Incidence in Human using Seasonal Auto Regressive Integrated Moving Average (SARIMA) International Journal of Computer Science and Information Security.** 2009;5(1):103-110.

20. Kwame AsareGyasi-Agyei, A. G.-A. a. W. O.-D. **Mathematical Modeling of the Epidemiology of Tuberculosis in the Ashanti Region of Ghana.** British Journal of Mathematics&ComputerScience.2014;4(3): 375-393.

21. Moosazadeh etal: **Forecasting Tuberculosis Incidencein Iran Using Box-Jenkins Models Iran** Red Crescent Med J.2014; 16(5): 1-6.

22. MahmoodMoosazadeh NK, Abbas Bahrampour. **Seasonality and Temporal Variations of Tuberculosis in the NorthofIran.** Tanaffos. 2013; 12(4):35-41.

23. William, M.W., Peter, J.W. and Gilbert, B. **Factors associated with missed vaccination during mass immunization campaigns.** Journal of health population & nutrition. 2009; 27: 358-367.

“The price of greatness is responsibility.”

Winston Churchill

AUTHORSHIP AND CONTRIBUTION DECLARATION

Sr. #	Author-s Full Name	Contribution to the paper	Author=s Signature
1	Muhammad Imran	Main author	
2	Jamal Abdul Nasir	Co-author	
3	Syed Arif Ahmed Zaidi	Co-author	