Health, 2015, 7, 1578-1590
Published Online November 2015 in SciRes. http://www.scirp.org/journal/health
http://dx.doi.org/10.4236/health.2015.711171

Comparison of Survey Sampling Methods for Estimation of Vaccination Coverage in an Urban Setup of Assam, India

Dilip C. Nath*, Bhushita Patowari

Department of Statistics, Gauhati University, Guwahati, India
Email: *dilipc.nath@gmail.com, pbhushita@yahoo.com

Received 29 September 2015; accepted 20 November 2015; published 23 November 2015

Abstract

Background: Immunization averts a large number of children in each year. The burden of vaccine preventable diseases remains high in developing countries compared to developed countries. To overcome from this burden different types of immunization programs have been implemented. For better immunization coverage in developing countries, considerable progress is to be made to improve the knowledge and awareness regarding importance of vaccines. In this study a comparative study of immunization coverage under two sampling methods has been performed. Methods: In this study variance and design effect of proportion of children vaccinated against different types of vaccines (BCG, OPV, DPT, Hepatitis B, Hib, Measles and MMR) are estimated under two stage (30 × 30) cluster and systematic sampling for comparison of these two survey sampling methods. Also the homogeneity of clusters has been tested by using chi-square test. Results: It is observed that BCG, OPV and DPT vaccination coverage is more than 90% whereas Hepatitis B, Measles, Hib and MMR vaccination coverage is between 50% - 64% only. Here systematic random sampling is more complicated than two stage (30 × 30) cluster sampling. Also the result shows that the clusters are homogeneous with respect to proportion of children vaccinated. Conclusion: There is no significant difference between the two survey methodologies regarding the point estimation of vaccination coverage but estimation of variances of vaccination coverage is less in two stage (30 × 30) cluster sampling than that of the systematic sampling. Also the clusters are homogeneous. Very less improvement has been observed in case of fully vaccination coverage than the previous study. From the study it can be said that two stage (30 × 30) cluster sampling will be preferred to systematic sampling and simple random sampling method.

Keywords

Vaccine Coverage, Cluster Sampling, Systematic Sampling, Design Effect, Marascuilo Procedure

*Corresponding author.

How to cite this paper: Nath, D.C. and Patowari, B. (2015) Comparison of Survey Sampling Methods for Estimation of Vaccination Coverage in an Urban Setup of Assam, India. *Health*, **7**, 1578-1590. http://dx.doi.org/10.4236/health.2015.711171

1. Introduction

World Health Organization (WHO) recommends that all children should receive one dose of Bacillis Calmette-Guerin Vaccine (BCG), three doses of diphtheria-tetanus-pertusis vaccine (DPT), three doses of either oral polio vaccine (OPV) or inactivated polio vaccine (IPV), three doses of hepatitis B vaccine, and one dose of a measles virus-containing vaccine (MVCV), either anti-measles alone or in combination with other antigens. It also recommends three doses of vaccine against infection with Haemophilus influenza type b (Hib). To boost immunity at older ages, additional immunizations are recommended for healthcare workers, travelers, high-risk groups and people in areas where the risk of specific vaccine-preventable diseases is high [1]. The important role played by the WHO's EPI (Expanded Programme on Immunization) Cluster Survey in the success of national immunization programme efforts in many countries is widely recognized. The programme monitoring capability provided through the conduct of periodic cluster surveys has been especially important in developing country settings, where administrative records are often incomplete [2]. Together with EPI sampling other survey sampling has been compared in different studies [3]-[5]. According to WHO coverage of BCG vaccine is 87%, DPT3 vaccine is 72% and OPV3 vaccine is 70% in 2011 [6]. In a study Phukan *et al*. reported that the children of Assam in the North-East Region of India have consistently evidenced low rates for routine childhood immunizations. About 62.2% of the children were fully immunized [7]. Children are considered fully immunized if they receive one dose of BCG, three doses of OPV and DPT each and one dose of measles vaccine before reaching one year of age.

In this study estimates of vaccination coverage have been compared using design effect and variance of estimated proportion of children vaccinated against BCG, OPV, DPT, Hepatitis B, Hib, Measles and MMR (measles mumps rubella) vaccines under two stage (30 × 30) cluster sampling and systematic random sampling.

2. Methods

The data that has been used in this study is taken from a survey "Comparison of Two Survey Methodologies to Estimate Total Vaccination Coverage" sponsored by Indian Council of Medical Research (ICMR), New Delhi. It has been collected during the period from January to October, 2011 using following sampling techniques.

Two stage (30 × 30) cluster sampling: In this method the population needs to be divided into a complete set of non-overlapping subpopulations, usually defined by geographic or political boundaries. These subpopulations are called clusters. In the first stage, 30 of these clusters are sampled with probability proportionate to the size (PPS) of the population in the cluster. Sampling with probability proportionate to size allows the larger clusters to have a greater chance of being selected. The clusters are sampled without replacement. In the second stage of sampling, thirty subjects are selected within each cluster. Although the sampling unit is the individual subject, the sampling is conducted on the household level. Cluster sampling is often a practical approach to surveys because it samples by groups (clusters) of elements rather than by individual elements. It simplifies the task of constructing sampling frames, and it reduces the survey costs [8]. The advantages of two stage (30 × 30) cluster sampling over other designs are same as cluster sampling. A sampling frame listing all elements in the population may be impossible or costly to obtain, whereas to obtain a list of all clusters may be easy. Also the cost of obtaining data may be inflated by travel cost if the sampled elements are spread over a large geographic area.

Systematic random sampling: Systematic sampling is a random method of sampling in which only the first unit is selected with the help of random numbers and the rest get selected automatically according to some pre-designed pattern. If the population size $N = nk$, where n is the sample size and k is an integer, and a random number less than or equal to k be selected and every k^{th} unit thereafter. This procedure is linear systematic sampling. When $N \neq nk$ then every k^{th} unit be included in a circular manner till the whole list is exhausted, it is called circular systematic sampling. Systematic sampling is commonly used as an alternative to simple random sampling (SRS) because of its simplicity. It selects every k^{th} element after a random start (between 1 and k). Its procedural tasks are simple, and the process can easily be checked, whereas it is difficult to verify SRS by examining the results. It is often used in the final stage of multistage sampling when the fieldworker is instructed to select a predetermined proportion of units from the listing of dwellings in a street block. The systematic sampling procedure assigns each element in a population the same probability of being selected [8].

With the two stage (30 × 30) cluster sampling method in the first stage 30 wards are selected and in the second stage 30 units from each ward are selected. For the selection of second stage units in a selected ward only the first household is randomly selected. After the first household is visited, the surveyor moves to the "next"

household, which is defined as the one whose front door is closest to the one just visited. Where there are bylane in a particular lane survey procedure is carried out in that place according to the serial household number in that bylane. This process continues until all 30 eligible subjects are found. The subjects are chosen by selecting a household and for more than one eligible subject (children from 6 months to 5 years of age) in a household all are selected.

After completing the 1st sampling method (that is two stage (30 × 30) cluster sampling) in a ward, 2nd sampling method (systematic random sampling) is carried out in same ward. In this sampling technique a random number is selected from random number table on the basis of the number of household in a lane where the survey was carried out in case of two stage (30 × 30) cluster sampling and this became the first sampling unit (household) of the systematic random sampling. After that each household is selected at an interval of 10 household and continuing the process until the 30 sampling units are not completed. Here the interval of household is taken as 10 so that the interval is neither too small nor too large. If we take the interval too small then we should get so many repetitions of the samples from two stage (30 × 30) cluster sampling which results same sampling unit in the 2nd sampling method (systematic sampling) and if we take the interval too large then there should not be any similarity between the two sampling methodologies as the larger interval will cover larger area and both the sampling techniques would take different places.

3. Statistical Analysis

Analysis has been carried out in the following two sections.

3.1. Section A

Here, variance of proportion of vaccination coverage and design effect of the same has been estimated.

Let, P = proportion of children who are vaccinated

Since same number of children has sampled per cluster, estimate of P $\left(\hat{P}\right)$ is given by

$$\hat{P} = \sum_{i=1}^{n=30} \frac{p_i}{n} \tag{1}$$

where p_i = the proportion of surveyed children in i^{th} cluster

n = the number of clusters

Then approximate estimated variance of $\hat{P}_c$ under cluster sampling [4] is given by

$$\hat{v}\left(\hat{P}_c\right) = \sum_{i=1}^{n}\left(p_i - \hat{P}\right)^2 \Big/ \left[n(n-1)\right] \tag{2}$$

Again the estimated variance of $\hat{P}_{sy}$ under systematic sampling [9] is

$$\hat{v}\left(\hat{P}_{sy}\right) = \left(\frac{N-n}{N}\right)\frac{\hat{p}(1-\hat{p})}{n-1} \tag{3}$$

An approximate 95% confidence interval on P can be obtained by using

$$\hat{P} \pm 1.96\sqrt{v\left(\hat{P}\right)} \tag{4}$$

The design effect may be estimated as

$$deff = \frac{\hat{v}(\text{esimated proportion under specified sampling})}{\hat{v}\left(\hat{P}_s\right)} \tag{5}$$

where

$$\hat{v}\left(\hat{P}_s\right) = \hat{P}\left(1-\hat{P}\right)\Big/\left[\left(\sum_{i=1}^{n=30} n_i\right) - 1\right] \tag{6}$$

is the estimated variance under simple random sampling [4].

Also the design effect for cluster sampling vs systematic sampling is obtained as

$$deff = \frac{\hat{v}\left(\hat{P}_c\right)}{\hat{v}\left(\hat{P}_{sy}\right)} \tag{7}$$

3.2. Section B

In this section homogeneity of clusters have been tested by using chi-square test. That is to test equality of proportion of children vaccinated in each clusters. The test procedure is carried out taking Hepatitis B (at birth) vaccine (two stage (30 × 30) cluster sampling).

The null hypothesis is that there are no significant differences among the proportions of children vaccinated against Hepatitis B (at birth) in each clusters.

H_0: $P_1 = P_2 = \cdots = P_{30}$

Against the alternative that all the proportions are not equal.

H_1: Not all P_j's are equal (where $j = 1, 2, \cdots, 30$)

The test statistic is

$$\chi^2 = \sum \frac{\left(f_o - f_e\right)^2}{f_e} \tag{8}$$

where

f_o = observed frequency in a particular cell of a 2 × 30 contingency table

f_e = expected frequency in a particular cell if the null hypothesis is true

If the null hypothesis is true the proportions are all equal across the population. And rejecting the null hypothesis only allows to reach the conclusion that all proportions are not equal. But the test statistics does not give any information about proportions that differ. To identify the differences between proportions we will rely on a multiple comparison procedure. The Marascuilo procedure [10] enables us to make comparisons between all pairs of groups. In this procedure the absolute value of the pairwise difference between sample proportions has to be computed. The absolute values of these differences are the test statistics. For each pairwise comparison a critical value is computed as follows:

$$CV_{ij} = \sqrt{\chi^2_{\alpha,k-1}} \sqrt{\frac{\bar{p}_i\left(1-\bar{p}_i\right)}{n_i} + \frac{\bar{p}_j\left(1-\bar{p}_j\right)}{n_j}} \tag{9}$$

where α = level of significance, k = number of clusters

To compare each of test statistics with the corresponding critical value a specific pair is significantly different if the absolute difference in the sample proportion $\left|p_i - p_j\right|$ is greater than its critical range.

4. Results

Table 1 gives estimated coverage of BCG (at birth), OPV (OPV1 at birth, OPV2 at 6 weeks, OPV3 at 10 weeks, OPV4 at 14 weeks, OPV5 at 15 - 18 months and OPV6 at 5 years), DPT (DPT1 at 6 weeks, DPT2 at 10 weeks, DPT3 at 14 weeks, DPT4 at 15 - 18 months and DPT5 at 5 years), Hepatitis B (HepB1 at birth and HepB2 at 6 weeks), Hib (Hib1 at 6 weeks, Hib2 at 10 weeks and Hib3 at 14 weeks), Measles (at 9 months) and MMR (at 15 - 18 months) vaccine with 95% confidence intervals under two stage cluster and systematic sampling. Coverage of BCG vaccine is 99%, OPV and DPT vaccine coverage is more than 90% except for OPV6 and DPT5. But coverage of Hepatitis B, Hib, Measles and MMR vaccines are only between 50% - 64%. Though the individual vaccination coverage is high for BCG, OPV and DPT vaccine but fully vaccination coverage is only 63.52%. Both the survey methods have given point estimates of vaccination coverage with less difference.

Estimated variance of proportion of vaccination coverage is given in **Table 2**. It is seen that variances are less in case of two stage cluster sampling than the systematic sampling for all the vaccines namely BCG, OPV, DPT, Hepatitis B, Hib, Measles and MMR that are considered in the study. So the interval estimation of vaccination coverage has given better estimate in case of two stage (30 × 30) cluster sampling than the systematic sampling with less standard error (SE).

Table 1. Estimated coverage of vaccines under two stage cluster (30 × 30) and systematic sampling.

Vaccine		Two stage cluster (30 × 30)		Systematic sampling	
		Coverage estimate	95% CI	Coverage estimate	95% CI
BCG		0.99	(0.98, 0.99)	0.99	(0.98, 0.99)
OPV	OPV1	0.99	(0.98, 0.99)	0.99	(0.98,0.99)
	OPV2	0.98	(0.97, 0.98)	0.99	(0.98,0.99)
	OPV3	0.98	(0.97, 0.98)	0.99	(0.98,0.99)
	OPV4	0.97	(0.96, 0.97)	0.99	(0.98,0.99)
	OPV5	0.90	(0.89, 0.90)	0.89	(0.86,0.91)
	OPV6	0.54	(0.53, 0.54)	0.54	(0.50,0.57)
DPT	DPT1	0.98	(0.97, 0.98)	0.99	(0.98,0.99)
	DPT2	0.98	(0.97, 0.98)	0.99	(0.98,0.99)
	DPT3	0.97	(0.96, 0.97)	0.98	(0.98,0.99)
	DPT4	0.90	(0.89, 0.90)	0.90	(0.88,0.91)
	DPT5	0.52	(0.51, 0.52)	0.51	(0.47,0.54)
Hepatitis B	HepB1	0.58	(0.57, 0.58)	0.56	(0.52,0.59)
	HepB2	0.59	(0.58, 0.59)	0.56	(0.52,0.59)
Hib	Hib1	0.57	(0.56, 0.57)	0.55	(0.51,0.58)
	Hib2	0.57	(0.56, 0.57)	0.55	(0.51,0.58)
	Hib3	0.57	(0.50, 0.64)	0.55	(0.51,0.58)
Measles		0.64	(0.63, 0.64)	0.64	(0.60, 0.67)
MMR		0.52	(0.51, 0.52)	0.50	(0.46, 0.53)

Table 2. Estimated variance of proportion of vaccination coverage $\left(\hat{P}\right)$.

Vaccines		Methodology	
		Two stage cluster (30 × 30)	Systematic sampling
BCG		9.2009×10^{-09}	2.44173×10^{-06}
OPV	OPV1	1.1947×10^{-08}	4.87257×10^{-06}
	OPV2	3.2958×10^{-08}	9.70164×10^{-06}
	OPV3	3.2134×10^{-08}	1.32949×10^{-05}
	OPV4	1.2785×10^{-07}	1.56768×10^{-05}
	OPV5	5.4684×10^{-06}	2.29435×10^{-04}
	OPV6	6.0007×10^{-07}	1.06516×10^{-04}
	OPV7	9.5874×10^{-07}	2.73425×10^{-04}
DPT	DPT1	3.2958×10^{-08}	9.70164×10^{-06}
	DPT2	6.4818×10^{-08}	1.20999×10^{-05}
	DPT3	9.4344×10^{-08}	1.32949×10^{-05}
	DPT4	6.4134×10^{-07}	1.03118×10^{-04}
	DPT5	9.8328×10^{-07}	2.75069×10^{-04}
Hepatitis B	HepB1	1.1741×10^{-06}	2.7177×10^{-04}
	HepB2	1.1741×10^{-06}	2.71907×10^{-04}
Hib	Hib1	1.2841×10^{-06}	2.72553×10^{-04}
	Hib2	1.2814×10^{-06}	2.72303×10^{-04}
	Hib3	1.305×10^{-06}	2.72429×10^{-04}
Measles		1.6381×10^{-06}	2.53068×10^{-04}
MMR		1.702×10^{-06}	2.75305×10^{-04}

Table 3 represents estimates of design effect of proportion of children vaccinated against different types of vaccines. Design effect estimates are calculated for two stage cluster sampling vs simple random sampling, systematic sampling vs simple random sampling and cluster sampling vs systematic sampling. It is seen that design effect estimates are high in systematic sampling vs simple random sampling rather than the two stage cluster sampling vs simple random sampling and cluster sampling vs systematic sampling for all the vaccines considered here.

To study the homogeneity of clusters chi-square test has been performed. Here calculated value of χ^2 is 116.68 with 29 d.f. and p value is 0.00 that is the test statistic is significant and we reject the null hypothesis and concluded that the proportions of children vaccinated against Hepatitis B (at birth) are not equal. Let us start with computing all the proportions of children vaccinated against Hepatitis B (at birth) (given in **Table 4**).

Table 3. Estimates of design effect of proportion of children vaccinated.

Vaccine		Design effect		
		Cluster vs SRS	Systematic vs SRS	Cluster vs systematic
BCG		0.000835516	0.221728395	0.003768
OPV	OPV1	0.001084923	0.442469136	0.002452
	OPV2	0.001511716	0.880987654	0.003397
	OPV3	0.0014739	1.207284	0.002417
	OPV4	0.003949769	1.423580247	0.008155
	OPV5	0.022256	0.933037	0.023834
	OPV6	0.005094	0.831239	0.005634
	OPV7	0.001308	0.411678	0.003506
DPT	DPT1	0.001511716	0.880987654	0.003397
	DPT2	0.002973041	1.098765432	0.005357
	DPT3	0.002914598	1.207283951	0.007096
	DPT4	0.0054443	0.87535464	0.00622
	DPT5	0.00133547	0.41166791	0.003575
Hepatitis B	HepB1	0.004333	0.991563	0.00432
	HepB2	0.004364	0.992063	0.004318
Hib	Hib1	0.004710096	0.99	0.004712
	Hib2	0.0047	0.989091	0.004706
	Hib3	0.0047867	0.9895506	0.00479
Measles		0.0059581	0.9380207	0.006473
MMR		0.0052098	0.8413334	0.006182

Table 4. Estimated proportions of children vaccinated against Hepatitis B (at birth).

Sl. No.	Ward No.	Estimated proportions	
1	2	p_1	0.17
2	4	p_2	0.70
3	5	p_3	0.23
4	11	p_4	0.93
5	12	p_5	0.53
6	15	p_6	0.60
7	17	p_7	0.47
8	18	p_8	0.70
9	24	p_9	0.17

Continued

10	25	p_{10}	0.67
11	26	p_{11}	0.63
12	33	p_{12}	0.73
13	35	p_{13}	0.40
14	36	p_{14}	0.63
15	37	p_{15}	0.63
16	38	p_{16}	0.43
17	40	p_{17}	0.53
18	42	p_{18}	0.73
19	43	p_{19}	0.67
20	46	p_{20}	0.53
21	47	p_{21}	0.57
22	48	p_{22}	0.60
23	50	p_{23}	0.80
24	51	p_{24}	0.63
25	53	p_{25}	0.67
26	54	p_{26}	0.63
27	55	p_{27}	0.37
28	57	p_{28}	0.70
29	59	p_{29}	0.57
30	60	p_{30}	0.83

It is seen that Hepatitis B (at birth) vaccine coverage is higher for ward number 11 (p_4 = 0.93) than all other wards. After that $\left|p_i - p_j\right|$ and CV_{ij} are computed and compared each of test statistics with the corresponding critical value CV_{ij} (given in **Table 5**).

Results are significant only for proportion of Hepatitis B (at birth) vaccine coverage for ward number 1 vs ward number 4 (p_1 vs p_4), ward number 1 vs ward number 30 (p_1 vs p_{30}), ward number 3 vs ward number 4 (p_3 vs p_4), ward number 4 vs ward number 9 (p_4 vs p_9) and ward number 9 vs ward number 30 (p_9 vs p_{30}). That is these proportions are not equal. Out of 435 pairs of proportions of vaccination coverage only 5 pairs of proportions are unequal.

5. Discussion

Estimates of variances and design effect have been used by Milligan *et al*. [4] to compare two cluster sampling methods for health surveys in developing countries. Both the methods gave very similar point estimates of vaccination coverage. The estimates of the proportion fully vaccinated were 0.56 (EPI) and 0.54 (segmented method) and suggest that EPI method can give accurate and precise results. On the basis of this previous study the current study tries to estimate the design effect of vaccination coverage of the considered study population. In a study of comparison of survey methodologies relative feasibility of the sampling methodologies was assessed by Luman *et al*. [3]. Coverage with routine vaccinations among children aged 12 - 23 months was much lower than coverage achieved through the measles SIA (supplemental immunization activities). Also Katz *et al*. studied bias estimate and design effects associated with the EPI sampling design [11]. Brogan *et al*. suggested techniques for improving the accuracy of the EPI cluster survey method [12]. In Bangladesh overall only 64.1% of children received the measles vaccine, polio1 has the highest coverage rate in both urban and rural areas. The study also reported that percentage of receiving DPT and polio vaccine decreases when higher doses are given [13]. Chhabra *et al*. studied the factors affecting the vaccination coverage in two urbanized villages of East Delhi. The coverage levels were highest for BCG (82.7%) and DPT/OPV1 (81.5%) and lowest for HBV3 (24.3%). About 65.3% had received primary immunization while only 41.6% of children had received MMR vaccine [14].

Table 5. Pairwise Comparison of test statistics ($|p_i - p_j|$) and critical values (CV_{ij}).

Sl No.	$\|p_i - p_j\|$		CV_{ij}	Sl No.	$\|p_i - p_j\|$		CV_{ij}	Sl No.	$\|p_i - p_j\|$		CV_{ij}
1	$p_1 - p_2$	0.53	0.71	146	$p_6 - p_{17}$	0.07	0.83	291	$p_{13} - p_{22}$	0.20	0.83
2	$p_1 - p_3$	0.06	0.67	147	$p_6 - p_{18}$	0.13	0.79	292	$p_{13} - p_{23}$	0.40	0.75
3	$\mathbf{p_1 - p_4}^*$	**0.76**	**0.54**	148	$p_6 - p_{19}$	0.07	0.81	293	$p_{13} - p_{24}$	0.23	0.82
4	$p_1 - p_5$	0.36	0.74	149	$p_6 - p_{20}$	0.07	0.83	294	$p_{13} - p_{25}$	0.27	0.81
5	$p_1 - p_6$	0.43	0.74	150	$p_6 - p_{21}$	0.03	0.83	295	$p_{13} - p_{26}$	0.23	0.82
6	$p_1 - p_7$	0.30	0.74	151	$p_6 - p_{22}$	0.00	0.83	296	$p_{13} - p_{27}$	0.03	0.82
7	$p_1 - p_8$	0.53	0.71	152	$p_6 - p_{23}$	0.20	0.75	297	$p_{13} - p_{28}$	0.30	0.80
8	$p_1 - p_9$	0.00	0.63	153	$p_6 - p_{24}$	0.03	0.82	298	$p_{13} - p_{29}$	0.17	0.83
9	$p_1 - p_{10}$	0.50	0.72	154	$p_6 - p_{25}$	0.07	0.81	299	$p_{13} - p_{30}$	0.43	0.74
10	$p_1 - p_{11}$	0.46	0.73	155	$p_6 - p_{26}$	0.03	0.82	300	$p_{14} - p_{15}$	0.00	0.81
11	$p_1 - p_{12}$	0.56	0.69	156	$p_6 - p_{27}$	0.23	0.82	301	$p_{14} - p_{16}$	0.20	0.82
12	$p_1 - p_{13}$	0.23	0.74	157	$p_6 - p_{28}$	0.10	0.80	302	$p_{14} - p_{17}$	0.10	0.83
13	$p_1 - p_{14}$	0.46	0.73	158	$p_6 - p_{29}$	0.03	0.83	303	$p_{14} - p_{18}$	0.10	0.78
14	$p_1 - p_{15}$	0.46	0.73	159	$p_6 - p_{30}$	0.23	0.74	304	$p_{14} - p_{19}$	0.04	0.80
15	$p_1 - p_{16}$	0.26	0.74	160	$p_7 - p_8$	0.23	0.81	305	$p_{14} - p_{20}$	0.10	0.83
16	$p_1 - p_{17}$	0.36	0.74	161	$p_7 - p_9$	0.30	0.74	306	$p_{14} - p_{21}$	0.06	0.82
17	$p_1 - p_{18}$	0.56	0.69	162	$p_7 - p_{10}$	0.20	0.82	307	$p_{14} - p_{22}$	0.03	0.82
18	$p_1 - p_{19}$	0.50	0.72	163	$p_7 - p_{11}$	0.16	0.83	308	$p_{14} - p_{23}$	0.17	0.75
19	$p_1 - p_{20}$	0.36	0.74	164	$p_7 - p_{12}$	0.26	0.80	309	$p_{14} - p_{24}$	0.00	0.81
20	$p_1 - p_{21}$	0.40	0.74	165	$p_7 - p_{13}$	0.07	0.83	310	$p_{14} - p_{25}$	0.04	0.80
21	$p_1 - p_{22}$	0.43	0.74	166	$p_7 - p_{14}$	0.16	0.83	311	$p_{14} - p_{26}$	0.00	0.81
22	$p_1 - p_{23}$	0.63	0.65	167	$p_7 - p_{15}$	0.16	0.83	312	$p_{14} - p_{27}$	0.26	0.81
23	$p_1 - p_{24}$	0.46	0.73	168	$p_7 - p_{16}$	0.04	0.84	313	$p_{14} - p_{28}$	0.07	0.79
24	$p_1 - p_{25}$	0.50	0.72	169	$p_7 - p_{17}$	0.06	0.84	314	$p_{14} - p_{29}$	0.06	0.82
25	$p_1 - p_{26}$	0.46	0.73	170	$p_7 - p_{18}$	0.26	0.80	315	$p_{14} - p_{30}$	0.20	0.73
26	$p_1 - p_{27}$	0.20	0.73	171	$p_7 - p_{19}$	0.20	0.82	316	$p_{15} - p_{16}$	0.20	0.82
27	$p_1 - p_{28}$	0.53	0.71	172	$p_7 - p_{20}$	0.06	0.84	317	$p_{15} - p_{17}$	0.10	0.83
28	$p_1 - p_{29}$	0.40	0.74	173	$p_7 - p_{21}$	0.10	0.84	318	$p_{15} - p_{18}$	0.10	0.78
29	$\mathbf{p_1 - p_{30}}^*$	**0.66**	**0.63**	174	$p_7 - p_{22}$	0.13	0.83	319	$p_{15} - p_{19}$	0.04	0.80
30	$p_2 - p_3$	0.47	0.74	175	$p_7 - p_{23}$	0.33	0.76	320	$p_{15} - p_{20}$	0.10	0.83
31	$p_2 - p_4$	0.23	0.62	176	$p_7 - p_{24}$	0.16	0.83	321	$p_{15} - p_{21}$	0.06	0.82
32	$p_2 - p_5$	0.17	0.81	177	$p_7 - p_{25}$	0.20	0.82	322	$p_{15} - p_{22}$	0.03	0.82
33	$p_2 - p_6$	0.10	0.80	178	$p_7 - p_{26}$	0.16	0.83	323	$p_{15} - p_{23}$	0.17	0.75
34	$p_2 - p_7$	0.23	0.81	179	$p_7 - p_{27}$	0.10	0.83	324	$p_{15} - p_{24}$	0.00	0.81
35	$p_2 - p_8$	0.00	0.77	180	$p_7 - p_{28}$	0.23	0.81	325	$p_{15} - p_{25}$	0.04	0.80
36	$p_2 - p_9$	0.53	0.71	181	$p_7 - p_{29}$	0.10	0.84	326	$p_{15} - p_{26}$	0.00	0.81
37	$p_2 - p_{10}$	0.03	0.78	182	$p_7 - p_{30}$	0.36	0.74	327	$p_{15} - p_{27}$	0.26	0.81
38	$p_2 - p_{11}$	0.07	0.79	183	$p_8 - p_9$	0.53	0.71	328	$p_{15} - p_{28}$	0.07	0.79
39	$p_2 - p_{12}$	0.03	0.76	184	$p_8 - p_{10}$	0.03	0.78	329	$p_{15} - p_{29}$	0.06	0.82
40	$p_2 - p_{13}$	0.30	0.80	185	$p_8 - p_{11}$	0.07	0.79	330	$p_{15} - p_{30}$	0.20	0.73
41	$p_2 - p_{14}$	0.07	0.79	186	$p_8 - p_{12}$	0.03	0.76	331	$p_{16} - p_{17}$	0.10	0.84
42	$p_2 - p_{15}$	0.07	0.79	187	$p_8 - p_{13}$	0.30	0.80	332	$p_{16} - p_{18}$	0.30	0.79
43	$p_2 - p_{16}$	0.27	0.80	188	$p_8 - p_{14}$	0.07	0.79	333	$p_{16} - p_{19}$	0.24	0.81

Continued

44	p_2 - p_{17}	0.17	0.81	189	p_8 - p_{15}	0.07	0.79	334	p_{16} - p_{20}	0.10	0.84
45	p_2 - p_{18}	0.03	0.76	190	p_8 - p_{16}	0.27	0.80	335	p_{16} - p_{21}	0.14	0.83
46	p_2 - p_{19}	0.03	0.78	191	p_8 - p_{17}	0.17	0.81	336	p_{16} - p_{22}	0.17	0.83
47	p_2 - p_{20}	0.17	0.81	192	p_8 - p_{18}	0.03	0.76	337	p_{16} - p_{23}	0.37	0.76
48	p_2 - p_{21}	0.13	0.80	193	p_8 - p_{19}	0.03	0.78	338	p_{16} - p_{24}	0.20	0.82
49	p_2 - p_{22}	0.10	0.80	194	p_8 - p_{20}	0.17	0.81	339	p_{16} - p_{25}	0.24	0.81
50	p_2 - p_{23}	0.10	0.72	195	p_8 - p_{21}	0.13	0.80	340	p_{16} - p_{26}	0.20	0.82
51	p_2 - p_{24}	0.07	0.79	196	p_8 - p_{22}	0.10	0.80	341	p_{16} - p_{27}	0.06	0.82
52	p_2 - p_{25}	0.03	0.78	197	p_8 - p_{23}	0.10	0.72	342	p_{16} - p_{28}	0.27	0.80
53	p_2 - p_{26}	0.07	0.79	198	p_8 - p_{24}	0.07	0.79	343	p_{16} - p_{29}	0.14	0.83
54	p_2 - p_{27}	0.33	0.79	199	p_8 - p_{25}	0.03	0.78	344	p_{16} - p_{30}	0.40	0.74
55	p_2 - p_{28}	0.00	0.77	200	p_8 - p_{26}	0.07	0.79	345	p_{17} - p_{18}	0.20	0.80
56	p_2 - p_{29}	0.13	0.80	201	p_8 - p_{27}	0.33	0.79	346	p_{17} - p_{19}	0.14	0.82
57	p_2 - p_{30}	0.13	0.71	202	p_8 - p_{28}	0.00	0.77	347	p_{17} - p_{20}	0.00	0.84
58	**p_3 - p_4^***	**0.70**	**0.59**	203	p_8 - p_{29}	0.13	0.80	348	p_{17} - p_{21}	0.04	0.84
59	p_3 - p_5	0.30	0.78	204	p_8 - p_{30}	0.13	0.71	349	p_{17} - p_{22}	0.07	0.83
60	p_3 - p_6	0.37	0.77	205	p_9 - p_{10}	0.50	0.72	350	p_{17} - p_{23}	0.27	0.76
61	p_3 - p_7	0.24	0.78	206	p_9 - p_{11}	0.46	0.73	351	p_{17} - p_{24}	0.10	0.83
62	p_3 - p_8	0.47	0.74	207	p_9 - p_{12}	0.56	0.69	352	p_{17} - p_{25}	0.14	0.82
63	p_3 - p_9	0.06	0.67	208	p_9 - p_{13}	0.23	0.74	353	p_{17} - p_{26}	0.10	0.83
64	p_3 - p_{10}	0.44	0.75	209	p_9 - p_{14}	0.46	0.73	354	p_{17} - p_{27}	0.16	0.83
65	p_3 - p_{11}	0.40	0.76	210	p_9 - p_{15}	0.46	0.73	355	p_{17} - p_{28}	0.17	0.81
66	p_3 - p_{12}	0.50	0.73	211	p_9 - p_{16}	0.26	0.74	356	p_{17} - p_{29}	0.04	0.84
67	p_3 - p_{13}	0.17	0.77	212	p_9 - p_{17}	0.36	0.74	357	p_{17} - p_{30}	0.30	0.74
68	p_3 - p_{14}	0.40	0.76	213	p_9 - p_{18}	0.56	0.69	358	p_{18} - p_{19}	0.06	0.77
69	p_3 - p_{15}	0.40	0.76	214	p_9 - p_{19}	0.50	0.72	359	p_{18} - p_{20}	0.20	0.80
70	p_3 - p_{16}	0.20	0.77	215	p_9 - p_{20}	0.36	0.74	360	p_{18} - p_{21}	0.16	0.79
71	p_3 - p_{17}	0.30	0.78	216	p_9 - p_{21}	0.40	0.74	361	p_{18} - p_{22}	0.13	0.79
72	p_3 - p_{18}	0.50	0.73	217	p_9 - p_{22}	0.43	0.74	362	p_{18} - p_{23}	0.07	0.71
73	p_3 - p_{19}	0.44	0.75	218	p_9 - p_{23}	0.63	0.65	363	p_{18} - p_{24}	0.10	0.78
74	p_3 - p_{20}	0.30	0.78	219	p_9 - p_{24}	0.46	0.73	364	p_{18} - p_{25}	0.06	0.77
75	p_3 - p_{21}	0.34	0.77	220	p_9 - p_{25}	0.50	0.72	365	p_{18} - p_{26}	0.10	0.78
76	p_3 - p_{22}	0.37	0.77	221	p_9 - p_{26}	0.46	0.73	366	p_{18} - p_{27}	0.36	0.78
77	p_3 - p_{23}	0.57	0.69	222	p_9 - p_{27}	0.20	0.73	367	p_{18} - p_{28}	0.03	0.76
78	p_3 - p_{24}	0.40	0.76	223	p_9 - p_{28}	0.53	0.71	368	p_{18} - p_{29}	0.16	0.79
79	p_3 - p_{25}	0.44	0.75	224	p_9 - p_{29}	0.40	0.74	369	p_{18} - p_{30}	0.10	0.69
80	p_3 - p_{26}	0.40	0.76	225	**p_9 - p_{30}^***	**0.66**	**0.63**	370	p_{19} - p_{20}	0.14	0.82
81	p_3 - p_{27}	0.14	0.76	226	p_{10} - p_{11}	0.04	0.80	371	p_{19} - p_{21}	0.10	0.81
82	p_3 - p_{28}	0.47	0.74	227	p_{10} - p_{12}	0.06	0.77	372	p_{19} - p_{22}	0.07	0.81
83	p_3 - p_{29}	0.34	0.77	228	p_{10} - p_{13}	0.27	0.81	373	p_{19} - p_{23}	0.13	0.74
84	p_3 - p_{30}	0.60	0.67	229	p_{10} - p_{14}	0.04	0.80	374	p_{19} - p_{24}	0.04	0.80
85	p_4 - P_p	0.40	0.67	230	p_{10} - p_{15}	0.04	0.80	375	p_{19} - p_{25}	0.00	0.79
86	p_4 - p_6	0.33	0.66	231	p_{10} - p_{16}	0.24	0.81	376	p_{19} - p_{26}	0.04	0.80
87	p_4 - p_7	0.46	0.67	232	p_{10} - p_{17}	0.14	0.82	377	p_{19} - p_{27}	0.30	0.80

Continued

88	p_4 - p_8	0.23	0.62	233	p_{10} - p_{18}	0.06	0.77	378	p_{19} - p_{28}	0.03	0.78
89	**p_4 - p_9***	**0.76**	**0.54**	234	p_{10} - p_{19}	0.00	0.79	379	p_{19} - p_{29}	0.10	0.81
90	p_4 - p_{10}	0.26	0.64	235	p_{10} - p_{20}	0.14	0.82	380	p_{19} - p_{30}	0.16	0.72
91	p_4 - p_{11}	0.30	0.65	236	p_{10} - p_{21}	0.10	0.81	381	p_{20} - p_{21}	0.04	0.84
92	p_4 - p_{12}	0.20	0.61	237	p_{10} - p_{22}	0.07	0.81	382	p_{20} - p_{22}	0.07	0.83
93	p_4 - p_{13}	0.53	0.66	238	p_{10} - p_{23}	0.13	0.74	383	p_{20} - p_{23}	0.27	0.76
94	p_4 - p_{14}	0.30	0.65	239	p_{10} - p_{24}	0.04	0.80	384	p_{20} - p_{24}	0.10	0.83
95	p_4 - p_{15}	0.30	0.65	240	p_{10} - p_{25}	0.00	0.79	385	p_{20} - p_{25}	0.14	0.82
96	p_4 - p_{16}	0.50	0.66	241	p_{10} - p_{26}	0.04	0.80	386	p_{20} - p_{26}	0.10	0.83
97	p_4 - p_{17}	0.40	0.67	242	p_{10} - p_{27}	0.30	0.80	387	p_{20} - p_{27}	0.16	0.83
98	p_4 - p_{18}	0.20	0.61	243	p_{10} - p_{28}	0.03	0.78	388	p_{20} - p_{28}	0.17	0.81
99	p_4 - p_{19}	0.26	0.64	244	p_{10} - p_{29}	0.10	0.81	389	p_{20} - p_{29}	0.04	0.84
100	p_4 - p_{20}	0.40	0.67	245	p_{10} - p_{30}	0.16	0.72	390	p_{20} - p_{30}	0.30	0.74
101	p_4 - p_{21}	0.36	0.66	246	p_{11} - p_{12}	0.10	0.78	391	p_{21} - p_{22}	0.03	0.83
102	p_4 - p_{22}	0.33	0.66	247	p_{11} - p_{13}	0.23	0.82	392	p_{21} - p_{23}	0.23	0.76
103	p_4 - p_{23}	0.13	0.57	248	p_{11} - p_{14}	0.00	0.81	393	p_{21} - p_{24}	0.06	0.82
104	p_4 - p_{24}	0.30	0.65	249	p_{11} - p_{15}	0.00	0.81	394	p_{21} - p_{25}	0.10	0.81
105	p_4 - p_{25}	0.26	0.64	250	p_{11} - p_{16}	0.20	0.82	395	p_{21} - p_{26}	0.06	0.82
106	p_4 - p_{26}	0.30	0.65	251	p_{11} - p_{17}	0.10	0.83	396	p_{21} - p_{27}	0.20	0.82
107	p_4 - p_{27}	0.56	0.65	252	p_{11} - p_{18}	0.10	0.78	397	p_{21} - p_{28}	0.13	0.80
108	p_4 - p_{28}	0.23	0.62	253	p_{11} - p_{19}	0.04	0.80	398	p_{21} - p_{29}	0.00	0.83
109	p_4 - p_{29}	0.36	0.66	254	p_{11} - p_{20}	0.10	0.83	399	p_{21} - p_{30}	0.26	0.74
110	p_4 - p_{30}	0.10	0.54	255	p_{11} - p_{21}	0.06	0.82	400	p_{22} - p_{23}	0.20	0.75
111	p_5 - p_6	0.07	0.83	256	p_{11} - p_{22}	0.03	0.82	401	p_{22} - p_{24}	0.03	0.82
112	p_5 - p_7	0.06	0.84	257	p_{11} - p_{23}	0.17	0.75	402	p_{22} - p_{25}	0.07	0.81
113	p_5 - p_8	0.17	0.81	258	p_{11} - p_{24}	0.00	0.81	403	p_{22} - p_{26}	0.03	0.82
114	p_5 - p_9	0.36	0.74	259	p_{11} - p_{25}	0.04	0.80	404	p_{22} - p_{27}	0.23	0.82
115	p_5 - p_{10}	0.14	0.82	260	p_{11} - p_{26}	0.00	0.81	405	p_{22} - p_{28}	0.10	0.80
116	p_5 - p_{11}	0.10	0.83	261	p_{11} - p_{27}	0.26	0.81	406	p_{22} - p_{29}	0.03	0.83
117	p_5 - p_{12}	0.20	0.80	262	p_{11} - p_{28}	0.07	0.79	407	p_{22} - p_{30}	0.23	0.74
118	p_5 - p_{13}	0.13	0.83	263	p_{11} - p_{29}	0.06	0.82	408	p_{23} - p_{24}	0.17	0.75
119	p_5 - p_{14}	0.10	0.83	264	p_{11} - p_{30}	0.20	0.73	409	p_{23} - p_{25}	0.13	0.74
120	p_5 - p_{15}	0.10	0.83	265	p_{12} - p_{13}	0.33	0.79	410	p_{23} - p_{26}	0.17	0.75
121	p_5 - p_{16}	0.10	0.84	266	p_{12} - p_{14}	0.10	0.78	411	p_{23} - p_{27}	0.43	0.75
122	p_5 - p_{17}	0.00	0.84	267	p_{12} - p_{15}	0.10	0.78	412	p_{23} - p_{28}	0.10	0.72
123	p_5 - p_{18}	0.20	0.80	268	p_{12} - p_{16}	0.30	0.79	413	p_{23} - p_{29}	0.23	0.76
124	p_5 - p_{19}	0.14	0.82	269	p_{12} - p_{17}	0.20	0.80	414	p_{23} - p_{30}	0.03	0.65
125	p_5 - p_{20}	0.00	0.84	270	p_{12} - p_{18}	0.00	0.75	415	p_{24} - p_{25}	0.04	0.80
126	p_5 - p_{21}	0.04	0.84	271	p_{12} - p_{19}	0.06	0.77	416	p_{24} - p_{26}	0.00	0.81
127	p_5 - p_{22}	0.07	0.83	272	p_{12} - p_{20}	0.20	0.80	417	p_{24} - p_{27}	0.26	0.81
128	p_5 - p_{23}	0.27	0.76	273	p_{12} - p_{21}	0.16	0.79	418	p_{24} - p_{28}	0.07	0.79
129	p_5 - p_{24}	0.10	0.83	274	p_{12} - p_{22}	0.13	0.79	419	p_{24} - p_{29}	0.06	0.82
130	p_5 - p_{25}	0.14	0.82	275	p_{12} - p_{23}	0.07	0.71	420	p_{24} - p_{30}	0.20	0.73
131	p_5 - p_{26}	0.10	0.83	276	p_{12} - p_{24}	0.10	0.78	421	p_{25} - p_{26}	0.04	0.80

Continued

132	$p_5 - p_{27}$	0.16	0.83	277	$p_{12} - p_{25}$	0.06	0.77	422	$p_{25} - p_{27}$	0.30	0.80
133	$p_5 - p_{28}$	0.17	0.81	278	$p_{12} - p_{26}$	0.10	0.78	423	$p_{25} - p_{28}$	0.03	0.78
134	$p_5 - p_{29}$	0.04	0.84	279	$p_{12} - p_{27}$	0.36	0.78	424	$p_{25} - p_{29}$	0.10	0.81
135	$p_5 - p_{30}$	0.30	0.74	280	$p_{12} - p_{28}$	0.03	0.76	425	$p_{25} - p_{30}$	0.16	0.72
136	$p_6 - p_7$	0.13	0.83	281	$p_{12} - p_{29}$	0.16	0.79	426	$p_{26} - p_{27}$	0.26	0.81
137	$p_6 - p_8$	0.10	0.80	282	$p_{12} - p_{30}$	0.10	0.69	427	$p_{26} - p_{28}$	0.07	0.79
138	$p_6 - p_9$	0.43	0.74	283	$p_{13} - p_{14}$	0.23	0.82	428	$p_{26} - p_{29}$	0.06	0.82
139	$p_6 - p_{10}$	0.07	0.81	284	$p_{13} - p_{15}$	0.23	0.82	429	$p_{26} - p_{30}$	0.20	0.73
140	$p_6 - p_{11}$	0.03	0.82	285	$p_{13} - p_{16}$	0.03	0.83	430	$p_{27} - p_{28}$	0.33	0.79
141	$p_6 - p_{12}$	0.13	0.79	286	$p_{13} - p_{17}$	0.13	0.83	431	$p_{27} - p_{29}$	0.20	0.82
142	$p_6 - p_{13}$	0.20	0.83	287	$p_{13} - p_{18}$	0.33	0.79	432	$p_{27} - p_{30}$	0.46	0.73
143	$p_6 - p_{14}$	0.03	0.82	288	$p_{13} - p_{19}$	0.27	0.81	433	$p_{28} - p_{29}$	0.13	0.80
144	$p_6 - p_{15}$	0.03	0.82	289	$p_{13} - p_{20}$	0.13	0.83	434	$p_{28} - p_{30}$	0.13	0.71
145	$p_6 - p_{16}$	0.17	0.83	290	$p_{13} - p_{21}$	0.17	0.83	435	$p_{29} - p_{30}$	0.26	0.74

*Significant pair.

In an Urban Area of Meerut 93.25% of children in community were found to be completely immunized, 5.25% partially immunized an only 1.5% non-immunized [15]. In a study Jain *et al*. mentioned that 28.9% of children aged 12 - 23 months were fully immunized with BCG, 3 DPT, 3 OPV and Measles vaccines; around 26.5% had not received even a single vaccine and 44.5% were found partially immunized. Around 55.95% of the eligible children were vaccinated for BCG and measles 43.6%. Though nearly 66.8% were covered with first dose of DPT and OPV but about 33.2% children dropped out of the third dose of DPT and OPV for various reasons [16]. In an another study in Gujarat coverage for BCG, OPV3, DPT3 & Measles were 92.04%, 85.23%, 83.71% & 82.20% respectively. Although the vaccination coverage shows higher coverage than previous studies, it is still below the minimum targets set as national goal [17]. Immunization status of children and mothers in the nor-theastern states (except Assam) was evaluated in comparison with data at the national level using a WHO 30-cluster survey methodology. The proportion of children receiving all the vaccinations like BCG, DPT, OPV, measles in north-eastern states were about 51.9% as against 63.3% achieved at the all India level [18]. In this current study it has been observed that the fully vaccination coverage in the study population is not so high; it is almost same with the previous study reported by Phukan *et al*. [7] with a difference of 1.32% only. The differences between the two survey methods in case of point estimate are not significant and interval estimates has given better estimates in two stage (30 × 30) cluster sampling. Two stage (30 × 30) cluster sampling has given better estimate of variance and design effect of vaccination coverage and design effects are less in two stage cluster sampling vs simple random sampling and cluster sampling vs systematic sampling rather than systematic sampling vs simple random sampling. It has been observed that the clusters are homogeneous (since only 5 pairs of proportions are significant).

6. Conclusion

The finding of the present study revealed that there are no significant differences between the point estimates obtained under two sampling schemes. But there are differences between estimated variance of proportion of children vaccinated in two sampling methods. Also in case of interval estimation two stage (30 × 30) cluster sampling has given better intervals than that of under systematic sampling. Vaccination coverage is high for BCG, OPV and DPT vaccine but it is low for Measles, Hepatitis B, Hib and MMR vaccine and the later doses of OPV and DPT vaccine. Finally the two stage cluster (30 × 30) sampling is more consistent than the systematic sampling as well as simple random sampling for this study population.

Acknowledgements

The research was supported by the grant (number 69/40/2008-ECD-II) from Indian Council of Medical Research (ICMR), New Delhi and UGC-BSR one time grant (No. F.19-145/2015(BSR)) and provided to the first author.

Conflict of Interest

None.

References

[1] Burton, A., Monasch, R., Lautenbach, B., Gacic-Dobo, M., Neill, M., Karimov, R., Wolfson, L., Jones, G. and Birmingham, M. (2009) WHO and UNICEF Estimates of National Infant Immunization Coverage: Methods and Process. *Bulletin of the World Health Organization*, **87**, 535-541. http://dx.doi.org/10.2471/BLT.08.053819

[2] Turner, A.G., Magnani, R.J. and Shuaib, M. (1996) A Not Quite as Quick Bit Much Cleaner Alternative to the Expanded Programme on Immunization (EPI) Cluster Survey Design. *International Journal of Epidemiology*, **25**, 198-203. http://dx.doi.org/10.1093/ije/25.1.198

[3] Luman, E.T., Worku, A., Berhane, Y., Martin, R. and Cairns, L. (2007) Comparison of Two Survey Methodologies to Assess Vaccination Coverage. *International Journal of Epidemiology*, **36**, 633-641. http://dx.doi.org/10.1093/ije/dym025

[4] Milligan, P., Njie, A. and Benneu, S. (2004) Comparison of Two Cluster Sampling Methods for Health Surveys in Developing Countries. *International Journal of Epidemiology*, **33**, 469-476. http://dx.doi.org/10.1093/ije/dyh096

[5] Nath, D.C. and Patowari, B. (2014) Estimation and Comparison of Immunization Coverage under Different Sampling Methods for Health Surveys. *International Journal of Population Research*, **2014**, Article ID: 850479. http://dx.doi.org/10.1155/2014/850479

[6] WHO-SEARO EPI Fact Sheet India, 2011. http://www.searo.who.int/entity/immunization/data/india_epi_factsheet_2011.pdf?ua=1

[7] Phukan, R.K., Barman, M.P. and Mahanta, J. (2009) Factor Associated with Immunization Coverage of Children in Assam, India: Over the First Year of Life. *Journal of Tropical Pediatrics*, **55**, 249-252. http://dx.doi.org/10.1093/tropej/fmn025

[8] Lee, E.S. and Forthofer, R.N. (2006) Analyzing Complex Survey Data. 2nd Edition, Sage Publications, Thousand Oaks.

[9] Levy, P.S. and Lemeshow, S. (2008) Sampling of Populations: Methods and Applications. 4th Edition, John Wiley & Sons, Hoboken. http://dx.doi.org/10.1002/9780470374597

[10] The Marascuillo Procedure. www.itl.nist.gov/div898/handbook/prc/section4/prc474.htm

[11] Katz, J., Yoon, S.S., Brendel, K. and West Jr., K.P. (1997) Sampling Designs for Xerophthalmia Prevalence Surveys. *International Journal of Epidemiology*, **26**, 1041-1048. http://dx.doi.org/10.1093/ije/26.5.1041

[12] Brogan, D., Flagg, E.W., Deming, M. and Waldman, R. (1994) Increasing the Accuracy of the Expanded Programme on Immunization's Cluster Survey Design. *Annals of Epidemiology*, **4**, 302-311. http://dx.doi.org/10.1016/1047-2797(94)90086-8

[13] Rahman, M. and Obaida-Nasrin, S. (2010) Factors Affecting Acceptance of Complete Immunization Coverage of Children under Five Years in Rural Bangladesh. *Salud Pública de México*, **52**, 134-140. http://dx.doi.org/10.1590/S0036-36342010000200005

[14] Chhabra, P., Nair, P., Gupta, A., Sandhir, M. and Kannan, A.T. (2007) Immunization in Urbanized Villages of Delhi. *Indian Journal of Pediatrics*, **74**, 131-134. http://dx.doi.org/10.1007/s12098-007-0004-3

[15] Chopra, H., Singh, A.K., Singh, J.V., Bhatnagar, M., Garg, S.K. and Bajpai, S.K. (2006-2007) Status of Routine Immunization in an Urban Area of Meerut. *Indian Journal of Community Health*, **18**(2)-**19**(1), 19-22.

[16] Jain, S.K., Chawla, U., Gupta, N., Gupta, R.S., Venkatesh, S. and Lal, S. (2006) Child Survival and Safe Motherhood Program in Rajasthan. *Indian Journal of Pediatrics*, **73**, 43-47. http://dx.doi.org/10.1007/BF02758259

[17] Sheth, J.K., Trivedi, K.N., Mehta, J.B. and Oza, U.N. (2012) Assessment of Vaccine Coverage by 30 Cluster Sampling Technique in Rural Gandhinagar. *Gujarat National Journal of Community Medicine*, **3**, 496-501.

[18] Yadav, R.J. and Singh, P. (2004) Immunisation of Children and Mothers in Northeastern States. *Health and Population-Perspectives and Issues*, **27**, 185-193.

Abbreviations

BCG: Bacillis Calmette-Guerin;
OPV: Oral Polio Vaccine;
DPT: Diphtheria-Tetanus-Pertusis;
MMR: Measles Mumps Rubella;
Hib: Haemophilus influenza type b;
WHO: World Health Organization;
EPI: Expanded Programme on Immunization.