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Statistics in Child Health and Nutrition

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Abstract

Statistical methods are commonly used in survey based estimation and other analytical problems in child health and nutrition. Some of the applications relating to monitoring and evaluation, sample size, use of basic statistical tools, misclassification of nutritional status, food and nutrition security, and 30-cluster design for immunization coverage are discussed and it is shown that these applications suffer from problems leading to far reaching implications. Some other useful applications like logistic regression, randomized response technique, small area estimation and geo hot spots are also discussed.

Keywords: monitoring and evaluation; sample size; basic statistical tools; misclassification of nutritional status, food and nutrition security; 30-cluster design; logistic regression; randomized response technique; small area estimation; geo hot spots.

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1. Introduction

The use of statistical methods is quite common in the fields of child health and nutrition. Some of these applications have flaws which have far reaching policy implications. The present paper describes these flaws in the methods employed thus far and the ways to overcome these. The areas discussed are monitoring and evaluation, sample size, use of basic statistical tools, misclassification of nutritional status, food and nutrition security, 30-cluster design for immunization coverage and logistic regression. It also gives some statistical methods which are very promising but have hardly been used in our country. These are randomized response technique for sensitive characteristics, small area estimation for bridging data gaps and geo hot spot technique for diseases in community clusters. Each of the methods, logistic regression, randomized response technique, small area estimation and geo hot spot technique has been explained through live data examples. It is suggested that geo hot spot technique can also be applied for Japanese encephalitis which takes epidemic form in Eastern Uttar Pradesh.

2. Monitoring and Evaluation

An important component of development is assessing the current status of any ongoing activity. This is also called the situational analysis. Monitoring and evaluation are very important tools of development research. Monitoring mid term assessment are part of concurrent evaluation for identifying the weaknesses and taking remedial measures for improving the program. Evaluation is the outcome or impact assessment after project is completed.

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For effective evaluation, it is necessary to compare key indicators in the pre and post stage of the project. The pre stage determination of key indicators has to be done through a base line survey carried out in the project area. It can also be done in a control area having similar features as the project area. For making valid comparisons between findings of end line and baseline surveys one has to ensure that these are comparable.

However, many research studies differ in the two stages in respect of sampling designs, coverage, sample size, questionnaire and analytical tools. Some projects have been implemented even without any base line survey and have substituted it with the past data from other surveys. There are also instances of giving more emphasis to process indicators like purchases, infrastructure, staff etc. rather than outcome of the project.

Evidence based decision making has emerged as a critical tool for effective programs and policies. Vistaar project of IntraHealth International (USAID) conducted evidence reviews (2007) with the objective of knowledge sharing, facilitating consensus and collaboration around evidence-based models and approaches. It also attempted to generate lessons learned and recommendations, and identify knowledge gaps for demonstration and learning. The reviews covered wide ranging topics like complementary feeding, anemia prevention and treatment, newborn care and skilled birth among others.

These reviews involved wide group of experts and stakeholders. Its focus was on effectiveness, efficiency and expandability, using high standards of evidence, and look for models that can be adopted at scale within Government programs. One core consideration from statistical point of view was to assess quality of evaluation/ methodology. Many of the projects under evidence reviews failed on this count because of inadequacy of sample size, inappropriate or non inclusion of base line or doing the impact assessments by project staff instead of an external agency.

3. Sample Size

Adequate sample size is very crucial to valid estimation and inference. Sample size has to be adequate to provide valid estimates and allow tests of statistical significance to be applied to the data collected. However, sometimes there could be constraints of cost, time and the efforts prohibiting a larger sample size.

In district nutrition profile surveys by National Nutrition Monitoring Bureau (NNMB) though sample size is adequate to assess state level dietary and nutritional status of communities and clinical deficiencies like Bitot's spots, iodine deficiency disorders, etc., it is inadequate for district level nutrition profile. Consider the case of determining sample size for say Bitot's spots in children with an expected prevalence of say $p = 0.04$. The sample size for 10 percent relative margin of error is 9600, which when multiplied with design of effect, say, 1.5 comes to 14400. NNMB surveys take only 250-300 children in each district. Because of grossly inadequate sample size district nutrition profiles report the prevalence close to zero in most districts. Many previous studies by different workers/agencies also had very low sample sizes and their results lacked consistency and differed widely.

Sample size is sometimes arbitrarily decided, without taking into consideration the extent and nature of the variability in the character being studied. Even when adequate sample size is taken, there is an attempt to present analysis in terms of related socio-economic, demographic, housing or household characteristics. This leads to decomposition of sample size according to these sub groups. Examples of this are found in reporting of NNMB, National Family Health Survey (NFHS), Reproductive Child Health (RCH), and District Level Household Surveys (DLHS) and others. It may be a better practice to give interval estimates instead of point estimates. Several examples of these types of disaggregated reporting are described in Nigam (2008) and Nigam and Singh (2011).

While sample size is decided mainly on the basis of prevalence of the indicator, sometimes some special feature or pattern in the prevalence may lead to crucial clues for improving the representativeness of the sample. Based upon the bar diagram of IASDS data (1995) in the age groups of unequal widths: 3-5, 6-11, 12-23, 36-74 and 48-59 months, a UNICEF study reported maximum underweight percentage around 24 months of age. It led policy makers scaling down focus from children up to 3 years to 2 years. This analysis was somewhat erroneous because of unequal width of class intervals of age. A correct approach is to examine the underweight pattern by single months as was done by Vir and Nigam (2001). This analysis changed the inference as it showed that the maximum underweight is attained at 11 months with the plateau beginning at 12 months itself instead of 24 months, as shown above.

The month wise analysis also indicates that malnutrition increases gradually early in life and picks up during 8-11 months. Maximum malnutrition prevalence is attained around one year followed by a plateau at 12-35 months. Causative factors like breastfeeding and complementary feeding practices, hygiene, and diseases like diarrhea and ARI operate crucially during 8-11 months of child’s growth. This pattern may be useful in making sample allocation more precise. Current practice is to uniformly distribute the derived sample size, say 400, over age, say up to 5 years even though maximum malnutrition is during 8-11 months and there is a plateau during 12-35 months, with hardly any variation in the extent of malnutrition. While very few samples are required for 12-35 group, much larger size is needed for 8-11 months. An increased sample size for the 8-11 months age group would also ensure carrying out critical in-depth analysis of associated risk factors.

4. Use of basic Statistical Tools

Arithmetic mean is one of the most common measures of central tendency. It was being used by NNMB for average weights/heights by single ages. As the distribution of weights/heights for a given age is skewed with extreme values, median is more appropriate. Some other examples of skewed data sets are: income, consumption and expenditure, and dietary intakes. An insight into dietary intake data of NNMB and other agencies reveals that the data are asymmetrical and have extreme values. Some of the mean intakes, both at household and individual level, also have large standard errors. This suggests using median as the average intake instead of mean.

Another measure which is normally used for computation of index numbers is the geometric mean. Specifically, the geometric mean is useful in analyzing exponential trends and population growth. It also dampens the effects of extreme data points.

5. Misclassification of Nutritional Status

For assessing nutritional status, the observed growth performance is evaluated against a standard which is considered to best represent normal growth. Most common among cut-offs of malnutrition have been Indian Association of Pediatricians (IAP) and standard deviation (sd) classifications. Under IAP classifications children below 60 percent of reference median are referred to as severely malnourished. These classifications were used by Integrated Child Development Services (ICDS) for growth monitoring. Under sd classifications, the recommended cut-off point for severe malnutrition is -3sd.

A recent study by Nigam (2003) showed that -3sd cut-off is same as 67 percent of median (standard) weight-for-age. This is in contrast to IAP cut-offs which is 60 percent of median. A comparison between the two cut-offs made in another study by Nigam (2005) using district level results from the study of NIN and IASDS (Nutrition Profile of Community, Uttar Pradesh, 2002) showed considerable gaps in reporting severe malnutrition under field conditions.

Though in terms of percentage cut-offs, there is only a difference of 7 percent between two classifications, the percentages of children left out by IAP classification were very high across all the districts. The reason for this is the underlying asymmetry in the distribution of severe malnutrition.

In intervention projects, severely malnourished children are targeted and monitored. As ICDS used IAP classifications for growth monitoring and identifying severely malnourished children, it was perhaps an important reason why malnutrition was not declining in the country. However, fortunately the situation is likely to change due to the introduction of new growth standards of WHO, which use only sd classification for assessing malnutrition.

6. Food and Nutrition Security

Besides ICDS, mid day meal program for school children also aims at food and nutrition security. The mid day meal program intends to improve enrolment and retention. Reports suggest that while both the programs have problems like pilferage, there have been complaints of inadequate quantity and poor quality of meals for mid day meal program. There have also been reports of lack of hygiene in preparation of food.

Studies by IASDS on impact assessments of nutrition interventions through food for education in Madhya Pradesh, Uttarakhand and Chhattisgarh (2004, 2005) and status of mid day meal in Madhya Pradesh (2005) reveal that there is still huge nutritive gap as both iron and vitamin A intakes are far below recommended levels. This makes a case for food fortification to bridge the gap. Fortunately, agricultural scientists are now developing protein and vitamin rich varieties. It is expected that fortified cereals, pulses, oils, vegetables and fruits enriched with nutrients will be available in near future in our country.

7. Sampling Design for Immunization Coverage

Immunization prevents many childhood diseases. Vaccination coverage data focuses on the age group 12-23 months, the age by which children should have received all vaccinations. According to NFHS-3, all India coverage percentages are: full- 43.5, BCG – 78, Polio – 78, DPT – 55 and measles – 59. The coverage levels differ widely among different states.

A commonly used two-stage cluster sampling scheme, the 30 x 7 sample was developed by the WHO. This 30 cluster design has been adopted for other purposes such as rapid needs assessments with no or little modification. This sampling scheme is thought to be sufficient for most sampling of community health factors. In the 30 x 7 design, one can randomly select 30 first stage units, blocks or villages, and then randomly select 7 target group members from each of these blocks/villages. The target group members could be or children of 12-23 months age. This gives a total sample size of 210 selection sites or children.

The sample size 210 may be adequate for BCG and Polio each with 78 percent coverage. But it may not be adequate for other coverage components. It may be so for full immunization which is only 43.5 percent.

8. Logistic Regression

Logistic regression is a useful tool for identifying risk factors associated with under nutrition. The analysis provides relative importance (factor loads or odds ratios) of different factors. Besides identifying risk factors associated with under nutrition, logistic regression can be usefully exploited in many other areas as well. One of these could be risk factors associated with diseases like tuberculosis, cancer and Japanese encephalitis.

In multivariate logistic regression, expected value of the dependent variable y is given by

$$\check{Y} = [1/(1+e^{-(\Sigma}\beta_i x_i)] \text{ , } i=0,1,\ldots,k$$

where, β_0 is a constant, $\beta_1,\ldots, \beta_k$ are regression coefficients for the independent variables $x_1,\ldots, x_k$. All the variables are coded as 0 or 1.

One of the first studies in our country for identifying risk factors associated with under nutrition in children was reported in the publication of DWCD, UP, 1999 part of which also appeared later in Vir and Nigam (2001). The analyses were done for each of the indicators – underweight, stunting and wasting. The analyses were done for under nutrition (less than -2sd times reference median) and severe under nutrition (less than -3sd times reference median).

These variables along with their codes were (i) Child’s age: Children of age 12-35 months (1), Others (0), (ii) hygiene: Children from kutcha households with no toilet facility and with inadequate drainage (1), Others (0), (iii) disease: Children suffering from any of the diseases- diarrhea, measles and ARI (1), Others (0), (iv) care: Children whose mothers took better diet, more rest and did less heavy work during the last three months of pregnancy (1), Others (0), (v) literacy: Children of illiterate mothers (1), Others (0), (vi) BMI: Children of mothers with BMI<18.5 (1), Others (0).

Odd ratios for under nutrition were: BMI-1.63, disease-1.58, child’s age-1.41, literacy-1.28 for underweight; BMI-1.30, literacy-1.27, child’s age-1.26, hygiene-1.19 for stunting and disease-1.64, BMI-1.29, child’s age-1.19, literacy-1.17 for wasting. For severely undernourished children, the odd ratios were: literacy-204, child’s age-1.79, disease-1.75, BMI-1.74, care-1.50 for underweight; literacy-1.84, child’s age-1.61, hygiene-1.28, BMI-1.26 for stunting and care-1.93, disease-1.57, BMI-1.55, literacy-1.39, child’s age-1.31 for wasting.

9. Sensitive Characteristics

Often it is intended to ascertain information on sensitive characteristics through a survey. Some examples are extent of child labor employed in such industries as glass and carpet, female feticide and child sexual abuse. Information on such characteristics is still being ascertained through traditional qualitative methods based upon direct questioning, but because of sensitive nature there is either complete refusal to respond or give an incorrect or misleading response.

Randomized response technique allows estimation of the proportion of the population possessing a sensitive characteristic. The technique which utilizes a randomized device ensures confidentiality of the respondent. The status of the respondent whether he belongs to a sensitive group is not revealed to the interviewer. This makes this technique more useful than the one based upon direct questioning.

In 1997, IASDS used randomized response technique to determine high risk sexual behavior by highway truck operators in a study on HIV/AIDS. The technique was recently used in another state level study for Plan India on assessment of child sexual abuse in Uttar Pradesh in 2001 by Vatsalya with IASDS as a partner**.** Focus of the study was to assess the status of sexual abuse in children in the age groups 5-10 years and 11-17 years. For children in the age group 5-10 years, information was gathered by direct questioning method. The children belonging to 11-17 years age group were classified into four categories viz.: (i) children in family environment, (ii) school going children, (iii) working children and (iv) children in institutional care.

For details reference can be made of Srivastava, Nigam and Singh (2015).

10. Small Area Estimation

In India, with such large variations, there is an increasing concern about issues of distribution, equity and disparity. For instance, some sub-groups may be far below the average in certain respects and may need upgrading. This has led to put more focus on sub groups called domains. There has been a growing demand for reliable small area estimates for smaller domains both from the public and private sectors

Small area estimation is a statistical technique which makes it possible to enhance the precision of subgroup estimates. The technique uses the idea of borrow strength from similar other areas to develop more accurate estimates for a given area. The technique is explained by applying it for a crucial indicator, namely, chronic energy deficiency (CED). The necessity arose because of a peculiar reason. District-wise CED estimates were already available in the NIN, IASDS Nutritional Profile study (2002). However, the study whose data were collected in 1999-2000 was for 54 districts which were in existence at the time of survey. In n 2008 there were 70 districts in the state due to reorganization. Some districts were carved out of older districts. The problem was to obtain reliable estimates of CED for 70 reorganized districts by using already available CED estimates of 54 districts which were in existence in 1991. As the reorganization occurred in 33 (of 54) districts, there were 49 new affected districts and 21 unaffected districts. Each of the affected districts had much smaller sample size. This necessitated the use of small area estimation technique to estimate CED.

An Area level random effect model was used for application of small area estimation technique as information on the covariates was available only at the area/district level. Specifically, Empirical Best Linear Unbiased Predictor (EBLUP) methodology (Prasad and Rao, 1990) was utilized to arrive at the small area estimates (SAE) for CED. EBLUP methodology basically uses appropriate covariates related to direct estimate to arrive at SAE of CED. To start with, direct estimates of proportion of population having BMI less than 18.5 were calculated. The next step is to choose certain covariates having significant correlation with CED. The covariate could be generally related to nutrition and dietary intakes. The criterion used to compare direct estimates with SAE was coefficient of variation. Following Table gives small area estimates of percentage of total population with CED for the 33 districts.

Percentage of population with CED (Total)				
S.No	District	Direct Estimate	Estimate (SAE)	% improvement over direct estimate
1	Aligarh	31.3 (6.07)	31.3(5.96)	1.81
2	Allahabad	33.6 (5.89)	33.5 (5.83)	1.02
3	Ambedkar Nagar	32.6 (6.44)	32.7 (6.32)	1.86
4	Auraiya	13.6 (13.16)	14.0 (12.64)	3.95
5	Baghpat	53.3 (5.23)	51.8 (5.36)	-2.49
6	Bahriach	47.0 (4.26)	46.4 (4.27)	nil
7	Balrampur	34.3 (7.38)	34.5 (7.17)	2.85
8	Banda	33.8 (7.01)	33.6 (6.91)	1.43
9	Basti	42.4 (4.79)	41.8 (4.80)	nil
10	Bulandshahr	30.0 (5.87)	30.4 (5.74)	2.21
11	Chandauli	25.3 (9.60)	25.6 (9.27)	3.44
12	Chitrakut	30.9 (8.12)	31.4 (7.80)	3.94
13	Deoria	29.6 (7.64)	29.7 (7.42)	2.88
14	Etawah	19.3 (10.52)	20.0 (10.08)	4.18
15	Faizabad	35.3 (7.00)	35.0 (6.91)	1.29
16	Farrukkhabad	29.6 (7.26)	29.3 (7.24)	nil
17	Gautam Budh Nagar	20.4 (10.98)	21.2 (10.44)	4.92
18	Gaziabad	29.8 (6.00)	30.0 (5.89)	1.83
19	Gonda	38.0 (5.05)	38.0 (4.97)	1.58
20	Hamirpur	22.7 (8.02)	23.0 (7.83)	2.37
21	Hathras	32.8 (8.02)	32.8 (7.86)	2.37
22	Jyotiba Phule Nagar	41.8 (7.49)	41.4 (7.26)	3.07
23	Kannuaj	30.2 (7.85)	30.4 (7.58)	3.60
24	Kaushambi	38.3 (13.08)	37.6 (12.26)	6.27
25	Kushinagar	35.8 (6.06)	35.6 (5.98)	1.32
26	Mahoba	17.8 (11.52)	18.1 (11.19)	2.86
27	Mathura	33.2 (5.12)	32.9 (5.11)	nil
28	Meerut	41.2 (5.27)	41.0 (5.21)	1.14
29	Moradabad	38.5 (5.27)	38.1 (5.26)	nil
30	Sant Kabir Nagar	49.0 (6.39)	47.9 (6.33)	nil
31	Sant Ravidas Nagar	23.2 (12.20)	24.0 (11.47)	5.98
32	Shravasti	49.3 (7.08)	48.3 (6.91)	2.40
33	Varanasi	27.4 (9.09)	27.7 (8.76)	3.63

Figures in parentheses indicate cv

11. Other potential applications of small area estimation

Some other applications of small area estimation are now discussed (For details see; Nigam, 2015). The technique can be applied to develop these estimates for (i) sub group estimates: analysis by caste, religion, age groups, gender, residence etc., (ii) estimates with low prevalence: severe malnutrition (8-10%)/severe anemia (5-8%)/ bitot's spots (4-5%) / vitamin A deficiency (10-12%). Sample size required with 10 percent relative margin of error and with design effect 1.5 is approximately: 4000 for severe malnutrition, 5500 for severe anemia, 14400 for bitot's spots, and 3500 for vitamin A deficiency.

We, however, restrict ourselves to the case of estimation of infant mortality rate (IMR) and maternal mortality ratio (MMR). For determining sample sizes for infant mortality around 40 gives p as 0.04, and expected maternal mortality around 200 gives p as 0.002. These are to be multiplied by the design effect which is usually taken as 1.5. The sample sizes at 10 percent relative margin of error required are 14400 live births for IMR and approximately 3 lakhs live births for MMR. For tracking such huge number of births, if we assume the birth rate of 28.5 per thousand population, a population of over one crore needs to be tracked. Similarly, for IMR at 40, the population that needs to be tracked is over 5 lakhs.

For the estimation of MMR/IMR information on all the characters which have close association with maternal/infant survival like pre-intra-post natal practices, and availability, access and utilization of maternal health services is to be ascertained. Also needed are the information on maternal and delivery complications, accurate classification of mother's death as the maternal death and data on factors associated with maternal mortality. All this information is required for the several past years to be able to get to such huge number of births. In our country we have virtually a failed health service system with unreliable and inconsistent record keeping. It is difficult, time consuming and costly task to get quality data on so many births and health practices and services. Almost a similar scenario exists for IMR though of smaller magnitude. The sample size requirement is lower in comparison to MMR, and so is the requirement of information on covariates - variables closely associated with IMR.

All this calls for resorting to small area estimation as this would enable seeking information on these characteristics at a much smaller scale.

12. Diseases in Community Clusters

Some of the diseases are found in community clusters. Examples of these are tuberculosis, cancer, ehrlichiosis and sclerosis. Among children, there are diseases/disorders like Japanese encephalitis, Bitot's Spots and polio which are located in clusters. The basic problems in geographical surveillance for a spatially distributed disease are the identification of areas of exceptionally high prevalence, called geo hot spots, to test their statistical significance and to identify the reasons behind the elevated prevalence of the disease for such diseases. Temporal, spatial and space-time scan statistics are now commonly used for disease cluster detection and evaluation.

The spatial scan statistic developed by Martin Kulldorff (1997) can both detect and provide inference for spatial and space-time disease clusters. The spatial scan statistic implemented in SaTScan software by Kulldorff (2006) offers several advantages over the existing techniques for detection of disease clusters. The use of geographic information system (GIS) with spatial statistics, including spatial filtering and cluster analysis has been applied to many diseases to analyze and more clearly display the spatial patterns of disease (Curtis, 1999). The detection of these clusters may be highly useful in surveillance of the disease, finding the factors behind the spread of the disease, and making suitable policies to control these factors. The effect of various socio-economical and environmental factors on the occurrence of disease can also be studied. The geographical correlation analysis can be used to study the association between the disease and its causative factors.

In India the work on detection of tuberculosis geo hot spots has been done by Tiwari et al (2006, 2010, 2012). A very potential area of the applications of geo hot spots in children in India can be for Japanese encephalitis (JE) which is a leading viral cause of Acute Encephalitis Syndrome (AES). Seventy percent of those who develop illness either die or survive with a long-term neurological disability. Seasonal outbreaks of acute encephalitis syndrome (AES) occur with striking regularity in India and lead to substantial mortality. Uttar Pradesh has the maximum disease load which has 20 districts listed for the epidemic.

Human vaccination is the only effective long term control measure against JE. It is felt that one can also identify statistically significant clusters of JE/AES which has seasonal outbreaks with striking regularity leading to substantial mortality. Clearly the methods as described above are all applicable to JE hot spots detection, its surveillance and control.

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