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Comparison of two survey methodologies to assess vaccination coverage

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Background Measuring vaccination coverage permits evaluation and appropriate targeting of vaccination services. The cluster survey methodology developed by the World Health Organization, known as the 'Expanded Program on Immunization (EPI) methodology', has been used worldwide to assess vaccination coverage; however, the manner in which households are selected has been criticized by survey statisticians as lacking methodological rigor and introducing bias.

Methods Thirty clusters were selected from an urban (Ambo) and a rural (Yaya-Gulelena D/Libanos) district of Ethiopia; vaccination coverage surveys were conducted using both EPI sampling and systematic random sampling (SystRS) of households. Chi-square tests were used to compare results from the two methodologies; relative feasibility of the sampling methodologies was assessed.

Results Vaccination coverage from a recent measles campaign among children aged 6 months through 14 years was high: 95% in Ambo (both methodologies), 91 and 94% (SystRS and EPI sampling, respectively, P-value = 0.05) in Yaya-Gulelena D/Libanos. Coverage with routine vaccinations among children aged 12–23 months was <20% in both districts; in Ambo, EPI sampling produced consistently higher estimates of routine coverage than SystRS. Differences between the two methods were found in demographic characteristics and recent health histories. Average time required to complete a cluster was 16h for EPI sampling and 17 h for SystRS; total cost was equivalent. Interviewers reported slightly more difficulty conducting SystRS.

Conclusions Because of the methodological advantages and demonstrated feasibility, SystRS would be preferred to EPI sampling in most situations. Validating results in additional settings is recommended.

Keywords EPI cluster survey, systematic random sampling, sampling methodology, vaccination coverage survey, Ethiopia, measles, routine vaccinations

Introduction

Vaccine-preventable diseases are a major source of mortality among children throughout the developing world, causing an estimated 2.5 million deaths per year.[1] To prevent these diseases, vaccines are delivered through routine health services and through supplemental immunization activities (SIAs). Measuring vaccination coverage permits evaluation of vaccination services, appropriate targeting of additional services and, when linked to surveillance data, assessment of the success of vaccination strategies in preventing disease. Although most countries routinely calculate vaccination coverage using

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administrative data (i.e. by dividing the number of doses administered by the estimated target population), results can be unreliable, particularly when the target population size is poorly known.[2–4]

Population-based cross-sectional surveys are conducted to more accurately determine the percentage of children within a certain geographic area and age group that have been vaccinated. In the late 1980s, the World Health Organization (WHO) developed the Expanded Program on Immunization (EPI) survey methodology,[5,6] which has since been widely used to assess vaccination coverage achieved through routine health services ('routine vaccination') to within roughly ±10 percentage points at 50% coverage.[7–10] In this methodology, 30 geographical clusters are selected from a list of primary sampling units. A direction is randomly selected from the centre of each cluster; interviewers count the number of households that lie in that direction to the edge of the community, select one household at random for enumeration, and proceed by sequentially selecting the next-nearest household until seven age-eligible children are found. However, this approach to selecting households has been criticized by survey statisticians as lacking methodological rigour, introducing bias towards the centre of the cluster, and producing unstable results in heterogeneous clusters.[11–14] Obtaining precise and unbiased coverage estimates has become increasingly important as countries strive to attain the high coverage levels required for population immunity and move towards elimination goals.

Alternative second-stage sampling methods with statistical properties that are superior to the EPI method have been proposed,[8,11–21] including systematic random sampling (SystRS). In this study, we compared coverage estimates obtained from EPI sampling and SystRS, as well as the relative difficulty of implementing the approaches, by simultaneously conducting surveys in rural and urban Ethiopian districts using both methodologies at the same sites.

Methods

Setting/background

In November 2003, we conducted this study in the West and North Shoa zones of the Oromia region in south-central Ethiopia, one of the world's poorest countries.[22] Since geographic and demographic characteristics of the communities studied could affect the results, we selected both a relatively urban and a rural district. Ambo District in West Shoa was chosen because it has the largest urban population in the region; of the estimated 177 465 residents in 1994, 39 535 (22%) lived in urban areas.[23] Yaya-Gulelena D/Libanos, a district with an estimated population of 80 365 of which 73 738 (92%) residents were considered to live in rural settings,[23] was selected from rural districts within North Shoa using random sampling with probability proportional to estimated size (PPS).

The Ethiopian Ministry of Health recommends that all children receive nine vaccination doses by age 12 months [1 dose of Bacille Calmette Guerin vaccine (BCG), 3 doses of Diphtheria, Tetanus, and Pertussis vaccine (DTP), 4 doses of oral poliovirus vaccine, and 1 dose of measles vaccine]. In addition, to increase population immunity to measles, an SIA to vaccinate all children aged 6 months through 14 years against measles was conducted in the selected districts in October–November 2003, immediately prior to the study.

Survey procedures

Thirty clusters were selected from each of the two districts using two-stage systematic random sampling with PPS, consistent with standard WHO EPI protocol. Sub-districts were listed and selected in the first stage, and villages or groups of villages within selected sub-districts were selected as clusters in the second stage. The same clusters were used for both sampling methodologies. Sample sizes were based on coverage estimates for children aged 6 months through 14 years (i.e. those eligible for the measles SIA). A desired sample size of 900 children per site per sampling methodology was calculated to provide 95% confidence intervals of SIA coverage estimates within 5 percentage points of actual coverage in each district, assuming a design effect of 2 and expected vaccination coverage of 85%.

For the EPI method, the first household was selected by randomly choosing a direction from a central location in the cluster, and then counting the households along that directional line to the edge of the cluster area and randomly selecting one. Proximity sampling was then conducted, with interviewers moving from one household to the next nearest household until the pre-determined quota of 30 households with at least one age-eligible child was reached.

For SystRS, we assumed, based on input from local authorities, that approximately two-thirds of households would have an eligible child. Thus, a sampling interval (i) was determined for each cluster by dividing the estimated number of households in the cluster by 45 to yield an average of 30 households with eligible children per cluster. Sampling intervals ranged from 3 to 9, with a median of 7. The first household was selected at the edge of the cluster among the first i households by randomly drawing a number between 1 and i. Interviewers selected subsequent households by proceeding in a serpentine manner, visiting every i'th household, until the entire cluster was canvassed. Clusters were visited on different days by teams from the two methodologies, with order of visits randomly assigned. In some cases, households were selected and interviewed for both methodologies.

Locally recruited interviewers were high school graduates who spoke both Amharic (the national language) and Oromifia (the local oral dialect) fluently. Interviewers worked in teams of two to increase reliability and ensure safety. Teams were randomly assigned to a sampling methodology and training included instruction on household selection; length of training was the same for the two methodologies. Surveys were conducted in both districts simultaneously from November 4 to 20, 2003. In households with children aged 6 months through 14 years resident for the past 6 months, we obtained verbal consent from a parent or caregiver and collected information on receipt of measles vaccination during the SIA for all age-eligible children. For children aged 12–23 months, interviewers transcribed vaccination histories from hand-held vaccination cards when possible and from parental report when cards were not available. Surveys were written in Amharic, and interviews were conducted in Oromifia.

Outcome measures

Measles SIA coverage was defined as the percentage of children aged 6 months through 14 years who received a measles vaccine during the SIA as reported by the parent or guardian. We also evaluated SIA coverage among children who had not previously been vaccinated against measles through the routine vaccination programme ('zero-dose children'), as reported by the parent or guardian.

Routine vaccination coverage for each required vaccine dose was defined as the percentage of children aged 12–23 months living in selected households for the past 6 months who received the respective dose; complete vaccination coverage was defined as the percentage of these children who received all doses. We present two measures of routine vaccination coverage: coverage determined only from doses documented on a hand-held vaccination card ('card only') and that determined by combining vaccination card with verbal report from parent or guardian ('card + history').

In addition to vaccination coverage, we evaluated the percentage of children aged 6 months through 14 years that had had measles during the 6 months preceding the survey and the percentage that had experienced diarrhoea or respiratory tract infection during the two weeks preceding the survey, as reported by the parent or caregiver using local Oromifia terms. We compared the populations reached by the two sampling methodologies by examining demographic characteristics of the households (respondent's perception of their household wealth compared with their neighbours', occupation of the head of household, and usual source of water) and of mothers (age group, education level, religion and marital status), as reported by the parent or caregiver.

To compare feasibility of implementing the two sampling methodologies, detailed daily time logs were kept by all interview teams. Average time per cluster was calculated for travel to the cluster, searching for eligible households, and conducting interviews. For the EPI method, time required to select the first household was not recorded; we assumed an average of 30 min based on supervisor observation and interviewer feedback. Because the number of households interviewed in each cluster varied for SystRS, we also calculated the average time required to complete each component for the first 30 households in each cluster, as well as the average time required per household interviewed, per child aged 6 months through 14 years, and per child aged 12–23 months. Interviewer perception of the difficulty of household selection and conducting interviews was obtained by interviewer questionnaire at the end of the survey.

Statistical analysis

Data entry and cleaning were conducted in Epi Info 2000 (Centers for Disease Control and Prevention, GA) and SAS version 8.0 (SAS Institute, NC). Analyses were conducted in SUDAAN version 9.0.0 (Research Triangle Institute, NC) using the Design=WR option; variance estimates are based on the between-cluster component of variance, properly accounting for the positive within-cluster correlation resulting from households selected for both methodologies. Univariate analysis was used to calculate estimates and 95% confidence intervals for vaccination coverage, demographic characteristics and other health outcomes for each sampling method in each district and in both districts combined. Chi-square tests were used to compare results obtained for the two sampling methodologies. All analyses accounted for sampling design and were weighted to account for difference in probability of selection. Median responses to questions regarding interviewer perceptions of feasibility of various components of the survey were evaluated.

Results

Vaccination coverage

Estimated vaccination coverage from the measles SIA was 95% in Ambo and >90% in Yaya-Gulelena D/Libanos (Table 1). In Ambo, EPI sampling and SystRS yielded nearly identical coverage estimates. However, the two methods yielded greater differences in Yaya-Gulelena D/Libanos, with 94% coverage estimated via EPI sampling and 91% via SystRS ($P = 0.05$).

Coverage with routine vaccinations among children aged 12–23 months was much lower than coverage achieved through the measles SIA (Table 1). Card-documented coverage for all vaccines combined was <20% in Ambo and <5% in Yaya-Gulelena D/ Libanos; card-documented coverage for individual doses was somewhat higher. When we supplemented documented coverage with verbal report (card + history), coverage rates increased substantially; still, <50% of children were completely vaccinated in both districts. Due to small sample sizes for this age-group confidence intervals were wide, limiting our ability to statistically compare results from the two methodologies. However, some statistically significant differences were found in Ambo and in the two districts combined; vaccination coverage estimates obtained through EPI sampling were consistently higher than with SystRS, with substantially more children found to be completely vaccinated (16 vs 9%, $P = 0.04$ in Ambo; 10 vs 5%, $P = 0.02$ in both districts combined).

Feasibility

There was no difference between the two methodologies in terms of cost to complete the survey; training time and number of interview days was identical. The average time required for a team to complete a cluster was ~16 h for EPI sampling and 17 h for SystRS (Table 2). This included 7 h of travel to reach the cluster and return, 4 (EPI sampling) to 5 (SystRS) h to search for selected households and 5 h to conduct interviews. Overall, 24% more households were interviewed through SystRS than through EPI sampling; survey time per household and per child surveyed was higher for EPI sampling than for SystRS. Time to complete the first 30 households was equivalent for the two methodologies.

Interviewers generally reported moderate difficulty in implementing both sampling methods, with slightly more difficulty for SystRS than for EPI sampling (Fig. 1). Interviewers conducting SystRS also perceived each aspect of the actual interview to be more difficult than their EPI counterparts, although both groups conducted identical interviews.

Table 1 Vaccination coverage

	Ambo			Yaya-Gulelena D/Libanos			Total		
	EPI[j] %	SystRS[k] %	*P*-Value	EPI %	SystRS %	*P*-Value	EPI %	SystRS %	*P*-Value
Measles campaign[a] (Children aged 6 months to 14 years)									
All children	95.3	95.1	0.69	93.9	90.5	0.05	94.6	92.6	0.11
Age-group									
6–11 months	87.5	90.2	0.89	82.6	81.2	0.91	85.5	84.8	0.82
12–23 months	95.4	93.9	0.84	92.9	85.7	0.03	94.2	89.7	0.07
24 months to 5 years	96.3	95.1	0.32	96.6	92.6	0.03	96.5	93.7	0.03
6–14 years	95.4	95.8	0.83	93.4	90.4	0.15	94.3	92.8	0.32
Among 0-dose children[b]	92.8	93.1	0.80	94.1	85.3	0.03	93.5	91.1	0.13
Routine vaccinations (Children aged 12 to 23 months)									
BCG[c]									
Card only[d]	28.9	21.1	0.18	10.4	6.5	0.30	19.2	13.4	0.09
Card + history[e]	55.0	57.0	0.80	47.2	51.6	0.59	51.0	54.2	0.57
DTP3[f]									
Card only	24.2	16.0	0.09	9.2	5.8	0.33	16.4	10.7	0.05
Card + history	49.0	32.4	0.02	46.0	49.7	0.66	47.4	41.5	0.27
Polio4[g]									
Card only	24.8	17.2	0.13	9.8	5.8	0.29	17.0	11.2	0.07
Card+history	49.7	33.6	0.02	46.0	49.7	0.66	47.8	42.0	0.28
Measles[h]									
Card only	18.8	13.7	0.19	8.6	5.1	0.38	13.5	9.2	0.12
Card + history	44.3	30.2	0.02	44.8	47.9	0.72	44.6	39.5	0.33
Completely vaccinated[i]									
Card only	16.1	9.4	0.04	3.7	1.1	0.24	9.6	5.0	0.02
Card + history	40.9	25.4	0.02	39.9	43.8	0.65	40.4	35.0	0.32

[a] Received measles vaccine during the October/November 2003 campaign, as reported by the parent or guardian.
[b] Children previously unvaccinated against measles.
[c] Received 1 or more doses of Bacille Calmette Guerin vaccine (BCG).
[d] Vaccination documented on a hand-held vaccination record.
[e] Vaccination documented on a hand-held vaccination record or verbally reported by the parent or guardian.
[f] Received 3 or more doses of Diphtheria, Tetanus and Pertussis vaccine (DTP).
[g] Received 4 or more doses of poliovirus vaccine.
[h] Received 1 or more doses of measles vaccine (excluding doses given during the measles campaign).
[i] Received 1 dose of BCG, 3 DTP, 4 poliovirus, and 1 measles vaccine.
[j] Sampling households based on the Expanded Program on Immunization cluster survey methodology.
[k] Sampling households based on systematic random sampling.

Other outcomes

Some differences between the two methodologies were found in the demographic characteristics of the respondents (Table 3). The EPI survey identified more children who lived in households with similar wealth to their neighbours (38 vs 28%, $P < 0.01$), while SystRS found more children who had higher or lower wealth than their neighbours. Families identified through EPI sampling were more likely to obtain their water from a tap or well (28 vs 17%, $P < 0.01$) as opposed to a spring, pond or river. The EPI survey also found more mothers who were <30 years old (35 vs 30%, $P < 0.01$) and were not Orthodox in religion (20 vs 15%, $P = 0.02$).

Approximately 10% of children identified by both survey methodologies were reported by the parent or caregiver to have had measles in the month prior to the survey. Among them, children identified through SystRS were more likely to have been treated by a traditional or spiritual healer (9 vs 2%, $P = 0.08$). In general, EPI sampling identified children with poorer health outcomes.

Discussion

In selecting a sampling methodology for a coverage survey, consideration should be given to the goals and intended uses of the study, statistical properties of existing methods, and the relative feasibility of the options. A successful survey must balance these factors to ensure that feasibility is maximized while methods are rigorous enough to produce results that may be used as a basis for programme and policy decisions.

Table 2 Sample sizes and time required to conduct survey

	Ambo			Yaya-Gulelena D/Libanos			Total		
	EPI[b]	SystRS[c]	SystRS 1st 30 HHs[d]	EPI	SystRS	SystRS 1st 30 HHs[e]	EPI	SystRS	SystRS 1st 30 HHs
Number of households and children									
Interviewed households									
Total	869	1124	874	893	1067	877	1762	2191	1751
Average per cluster	29.0	37.5	29.1	29.8	35.6	29.2	29.4	36.5	29.2
Children aged 6 months to 14 years									
Total	2385	3395	3284	2541	2976	2375	4926	6371	5659
Average per cluster	79.5	113.2	109.5	84.7	99.2	79.2	82.1	106.2	94.3
Children aged 12 to 23 months									
Total	148	227	221	163	180	163	311	407	384
Average per cluster	4.9	7.6	7.4	5.4	6.0	5.4	5.2	6.8	6.4
Average time per cluster (h)									
Travel	6.8	6.8	6.8	6.5	6.5	6.5	6.7	6.7	6.7
Search[a]	5.3	5.3	4.9	3.1	4.5	3.6	4.2	4.9	4.2
Interview	5.0	6.3	4.3	4.5	4.3	3.9	4.8	5.3	4.1
Total	17.0	18.5	16.0	14.1	15.3	14.0	15.7	16.9	15.0
Average time per household interviewed (min)									
Travel	14.1	10.9	14.0	13.1	11.0	13.4	13.6	10.9	13.7
Search	10.9	8.5	10.1	6.1	7.6	7.4	8.5	8.1	8.6
Interview	10.4	10.1	8.9	9.1	7.3	8.0	9.7	8.7	8.4
Total	35.3	29.6	33.0	28.4	25.8	28.8	32.1	27.7	30.7
Average total time per child (min)									
Aged 6 months to 14 years	12.9	9.8	8.8	10.0	9.3	10.6	11.5	9.5	9.5
Aged 12 to 23 months	207.3	146.3	130.3	155.5	153.1	154.6	181.7	149.3	140.2

[a] Includes time visiting households with no eligible children. Assumes 30 min for selecting first household for EPI.
[b] Sampling households based on the Expanded Program on Immunization cluster survey methodology.
[c] Sampling households based on systematic random sampling.
[d] Clusters had fewer than 30 households.
[e] Clusters had fewer than 30 households.

Survey goals

In this study, there was little difference in estimated SIA coverage between the two methodologies. This may reflect the apparently universally high coverage achieved in the study areas—coverage high enough that the practical implications of any biases in sample selection were minimized. Nonetheless, there are settings in which even a small difference in estimated coverage may be important; for example, a disease control setting in which SIA coverage below a pre-determined threshold triggers a 'mop-up' activity, or a study setting in which the impact of an intervention on vaccine coverage is assessed. In these circumstances, it is important to use a statistically rigorous sampling methodology.

On the other hand, when surveys are used to evaluate the general level of programme functioning, less rigorous methodology may be adequate. In our study, the substantial differences we found in the percentage of completely vaccinated children between EPI sampling and SystRS were of little programmatic importance because both methods produced extremely low estimates. It is possible that programmatically meaningful differences in estimated coverage between methodologies might be found in a setting with moderate coverage.

Methodological rigor

The statistical properties of both sampling methodologies used in this study have been thoroughly discussed elsewhere.[5–14,24,25] Methodologically, SystRS has clear advantages over EPI sampling. Because EPI is a quota sample, every eligible member of the target population does not have a known nonzero chance of being selected; thus EPI is not a true probability sample. Furthermore, because EPI sampling selects households from a single geographical area within each cluster rather than from all areas of the cluster, it is likely to have a greater design effect and be prone to variability of results if there is 'pocketing' of unvaccinated children. Lastly, the EPI sampling methodology has been criticized for potentially biasing the survey sample towards the centre of the village relative to other methodologies. This is due to the manner of selection of the first household (houses near the center of town are more likely to lie within a given distance from multiple potential directional lines than

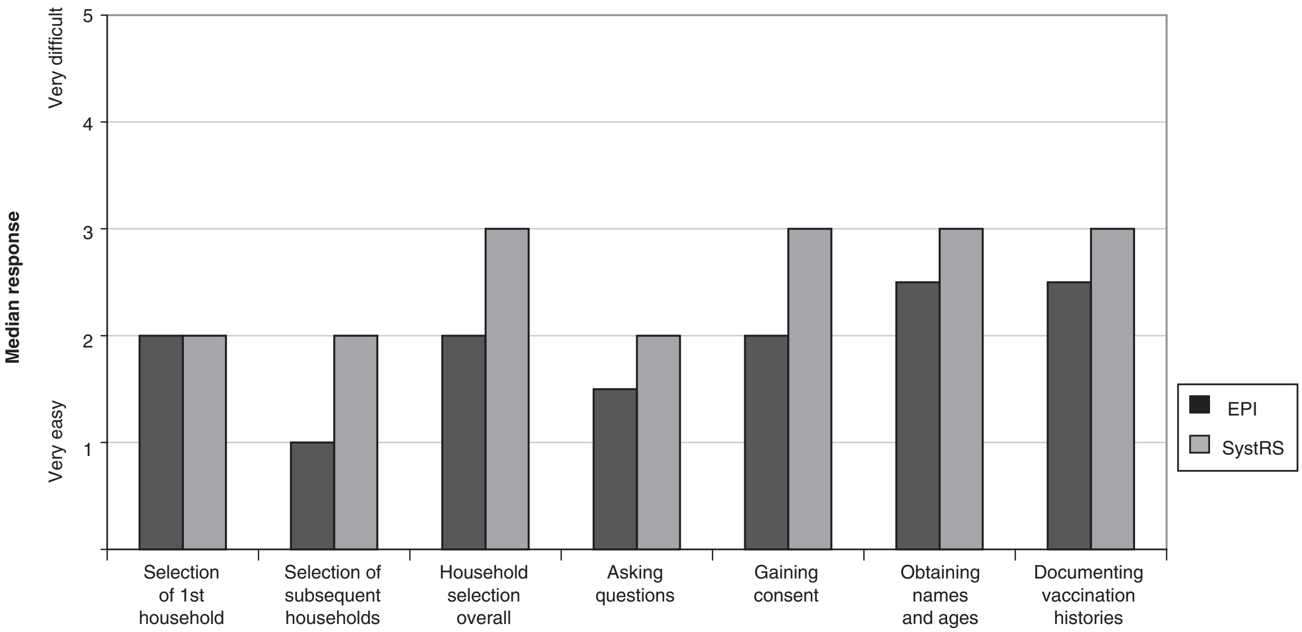

Figure 1 Interviewer responses to feasibility questions

are those at the periphery), as well as selection of subsequent households (generally, households are closer together as you move towards the centre of town, thus the 'next nearest' household is more likely to be towards the centre than away from it). SystRS, on the other hand, ensures that households are selected with equal probability and from all areas of each cluster.

The magnitude of bias and increase in variance resulting from an EPI survey will depend on the geographical distribution of vaccination status. If there is a tendency for individuals living within an area to share vaccination characteristics, proximity sampling used in EPI methodology may decrease precision of the sample result. If centrally located children are more or less likely to be vaccinated than their peripheral counterparts, EPI sampling will tend to result in biased estimates since it is more likely to include these children. Several of our findings validate these concerns: the relative economic homogeneity of households selected through EPI sampling as opposed to those selected through SystRS suggests increased clustering of houses selected through EPI sampling, while the greater percentage of households using taps or wells as a water source rather than surface water suggests that EPI sampling may have resulted in the selection of more centrally located houses. Finally, differences in the recent medical history of children selected through EPI sampling vs SystRS suggest that the two methodologies identified subtly different populations.

Feasibility

In general practice, both EPI sampling and SystRS have the advantage that rough population estimates are sufficient for selection of clusters. More precise population estimates in selected clusters are needed to determine sampling intervals for SystRS, but these can usually be obtained in the field from community members. Identification of cluster boundaries is needed for both methods.

Two factors determine the relative efficiency of SystRS and EPI sampling for conducting a survey: time required to identify the first household, and time required to travel to subsequent households. With SystRS, interviewers can select from among the first few households reached at the edge of the cluster. However, when proceeding to subsequent households, they must canvas the entire cluster area. For EPI sampling, substantial time is required to identify the first household; interviewers must walk to the cluster's centre, walk to its edge along the selected direction to count households, and then return to the selected household to interview. However, once the first household is selected, interviewers proceed directly to the next nearest household, minimizing distance travelled from house to house. The overall time difference between the methodologies will be determined by the density of the clusters, the sampling interval for SystRS, and the difficulty of travel within clusters.

In this study, we found that time spent searching for eligible households was, on average, slightly longer for SystRS than for EPI sampling. However, 24% more households were interviewed in the SystRS survey than in the EPI sampling survey. This could be due to an underestimate of the number of households in selected clusters, an underestimate of the proportion of households with an age-eligible child, or poorly identified cluster boundaries. When we calculated the time that it would have taken to conduct the survey with 30 households per cluster, search times were equivalent for the two sampling methodologies.

Lack of predictability of final sample size is a drawback of probability sampling compared with quota sampling methods. Surveying a greater number of children than necessary will be disadvantageous if it leads to greater survey costs, whereas surveying fewer children will reduce precision. The ability to accurately estimate the number of households in

Table 3 Household, child and maternal characteristics and other health outcomes[a] among children aged 6 months to 14 years

	EPI[b] %	SystRS[c] %	*P*-Value
Demographics			
Household wealth compared with neighbours			0.008
Lower	46.7	48.9	
Same	37.8	27.8	
Higher	15.5	23.3	
Occupation			0.15
Farmer	82.5	84.4	
Pastoralist	1.3	2.8	
Employed/business	12.8	10.5	
Other	3.5	2.3	
Water source			0.003
Private tap	3.8	3.7	
Public tap	16.5	9.9	
Well	7.9	3.6	
Spring	31.9	52.3	
Pond/river/other	39.9	30.3	
Child's age-group			0.55
6–11 months	3.3	3.0	
12–23 months	5.8	6.1	
24 months to 5 years	31.4	30.3	
6–15 years	59.1	60.0	
Mother's age group			0.009
<20 years	2.7	2.0	
20–29 years	32.0	27.8	
30–39 years	33.6	39.4	
>40 years	31.8	30.8	
Mother's education level			0.26
Illiterate	80.2	82.7	
Grade 1–6	12.9	10.4	
Grade 7+	6.9	6.9	
Mother's religion			0.02
Orthodox	79.5	84.7	
Protestant, catholic, or other christian	10.9	11.5	
Other or none	9.6	3.8	
Mother married	87.9	87.5	0.81
Other outcomes			
Child sick with measles in previous 6 months	10.7	9.0	0.54
Measles treatment among children with measles			0.08
Hospital/clinic	12.3	9.7	
Traditional/spiritual	2.0	8.6	
Home or none	85.7	81.7	
Child sick with diarrhoea in previous 2 weeks	9.2	6.7	0.04
Child sick with respiratory tract infection in previous 2 weeks	19.4	10.2	0.001

[a] Reported by the parent or guardian.

[b] Sampling households based on the Expanded Program on Immunization cluster survey methodology.

[c] Sampling households based on systematic random sampling.

selected clusters and the percentage of those households with age-eligible children, or to accurately define geographical boundaries, will vary according to setting.

Because the argument has been made that the EPI sampling method is easier for field workers to carry out than more rigorous methods, we evaluated whether or not our field workers found SystRS to be harder to implement than EPI sampling. In our study, none of the interviewers had experience with either methodology, and the two groups of interviewers were comparable in education and experience. When asked about ease of implementation, interviewers reported slightly more difficulty with SystRS. However, those conducting SystRS also reported slightly more difficulty conducting interviews than did those conducting EPI sampling, thus leading one to wonder whether the difficulty in household selection perceived by interviewers reflected actual differences in difficulty of implementation, differences in attitude between the two groups of interviewers, or the qualitative nature of the questions.

Limitations

This study had at least three limitations. First, few children had vaccination cards to verify routine vaccination history. However, even among children with cards, estimated coverage with all vaccines remained low: 38% with EPI sampling and 22% with SystRS ($P = 0.02$) for both districts combined (data not shown). Second, the time required to select the first household for EPI sampling was not recorded in the field; we used a conservative assumption of 30 min, based on supervisor observations and interviewer feedback. Third, sample sizes were based on children who were eligible for the measles SIA (i.e. aged 6 months through 14 years), and may have been too small to detect some differences between methodologies for routine vaccination coverage (i.e. among children aged 12–23 months).

Conclusions

As immunization programmes become well established, the objective of vaccination coverage surveys shifts from producing rough estimates of coverage to producing the more precise estimates needed to measure the degree of population immunity, demonstrate trends over time and make comparisons between areas. Countries approaching national, regional and international immunization goals must document success and measure relatively small increases in coverage; thus, greater precision and accuracy are crucial, and limitations of the EPI sampling design are increasingly apparent. Because of the documented methodological advantages, SystRS or another rigorous sampling option would be preferred to EPI sampling unless there are legitimate feasibility concerns that prohibit their use.

We found that SystRS was not cost-prohibitive nor overly complex to implement in this geographically challenging setting. Time required to implement the two sampling methods was nearly equal, especially after adjusting for the larger sample sizes of SystRS. Cost was also identical; interviewers received the same amount of training and completed the survey in the same number of days.

Although our study suggested that the populations identified through SystRS and through EPI sampling were subtly different from each other, vaccination coverage estimates were fairly similar for the two methodologies. It is important to bear in mind, however, that these results are highly dependent on the geographic and demographic characteristics of the communities surveyed. Additional comparison studies should be conducted in highly urban settings as well as in settings with moderate vaccination coverage.

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KEY MESSAGES

- The EPI sampling methodology has been widely used to assess general functioning of vaccination programmes throughout the developing world; however, more statistically sound methods, such as systematic random sampling, may also be logistically feasible.
- Statistically rigorous sampling methodology can be used to obtain the precise and unbiased estimates of vaccination coverage needed as countries move towards elimination goals.
- We found that, compared with the EPI sampling method, systematic random sampling was not cost-prohibitive or overly complex to implement for a vaccination coverage survey in rural Ethiopia.
- Those conducting survey research should consider using a rigorous sampling methodology rather than EPI sampling, unless there are legitimate feasibility concerns that prohibit their use.

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