ORIGINAL RESEARCH

Enhancing Local Health Department Disaster Response Capacity with Rapid Community Needs Assessments: Validation of a Computerized Program for Binary Attribute Cluster Sampling

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Abbreviations:
CDC = Centers for Disease Control and Prevention
EPI = World Health Organization Expanded Programme on Immunization
GIS = geographic information systems
LOJIC = Louisville/Jefferson County Information Consortium
RATP = Rapid Assessment Tools Package
REMF = Real Estate Master File

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Abstract

Introduction: Local health departments are among the first agencies to respond to disasters or other mass emergencies. However, they often lack the ability to handle large-scale events. Plans including locally developed and deployed tools may enhance local response. Simplified cluster sampling methods can be useful in assessing community needs after a sudden-onset, short duration event.

Methods: Using an adaptation of the methodology used by the World Health Organization Expanded Programme on Immunization (EPI), a Microsoft Access-based application for two-stage cluster sampling of residential addresses in Louisville/Jefferson County Metro, Kentucky was developed. The sampling frame was derived from geographically referenced data on residential addresses and political districts available through the Louisville/Jefferson County Information Consortium (LOJIC). The program randomly selected 30 clusters, defined as election precincts, from within the area of interest, and then, randomly selected 10 residential addresses from each cluster.

The program, called the Rapid Assessment Tools Package (RATP), was tested in terms of accuracy and precision using data on a dichotomous characteristic of residential addresses available from the local tax assessor database. A series of 30 samples were produced and analyzed with respect to their precision and accuracy in estimating the prevalence of the study attribute. Point estimates with 95% confidence intervals were calculated by determining the proportion of the study attribute values in each of the samples and compared with the population proportion. To estimate the design effect, corresponding simple random samples of 300 addresses were taken after each of the 30 cluster samples.

Results: The sample proportion fell within ±10 absolute percentage points of the true proportion in 80% of the samples. In 93.3% of the samples, the point estimate fell within ±12.5%, and 96.7% fell within ±15%. All of the point estimates fell within ±20% of the true proportion. Estimates of the design effect ranged from 0.926 to 1.436 (mean = 1.157, median = 1.170) for the 30 samples.

Conclusions: Although prospective evaluation of its performance in field trials or a real emergency is required to confirm its utility, this study suggests that the RATP, a locally designed and deployed tool, may provide population-based estimates of community needs or the extent of event-related consequences that are precise enough to serve as the basis for the initial post-event decisions regarding relief efforts.

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Introduction

In the wake of a sudden-onset event, the responsibilities of public health departments include determining the nature and extent of the effects on the health of the population and assessing the immediate and long-term health

needs of the community. Effective execution of these responsibilities depends on the ability of officials to rapidly obtain reliable, objective, population-based data upon which to base decisions regarding medical care and other relief services. To this end, rapid, community needs assessments have been utilized in the United States in response to large-scale emergencies such as Hurricane Andrew in 1992; and a number of subsequent natural events,[3,4] including, most recently, Hurricanes Isabel in 2003 and Charley in 2004.[5,6] Such assessments have provided useful information on affected demographics, morbidity, sanitation, electricity, transportation, food and water supply, and access to medical care during the first few days following such events.[7] Community needs assessments also have been used to set priorities and direct public health interventions in the weeks following an event. In New York City, for example, community surveys were conducted to assess physical and mental health needs following the terrorist attacks on the World Trade Center in September 2001.[8]

After Hurricane Andrew, Florida state and federal officials conducted population-based surveys using an adaptation of a two-stage cluster sampling method originally developed by the World Health Organization's Expanded Programme on Immunization (EPI) for assessing immunization coverage.[1] Previously, rapid survey methods had been used to assess aspects of population health status and the delivery of health services in mass emergencies[9] (particularly in the developing world)[10–12], but this was the first time it had been used to assess community needs in an sudden-onset disaster in the United States.

Population-based surveys that make use of this type of simplified cluster sampling method are well-suited for emergencies or other situations in which financial and other resources are limited because they are rapid, inexpensive, and do not demand a lot of labor or technical expertise. Additionally, they do not require detailed knowledge of the demographics of the affected area. Although this information is not as detailed as that provided by more rigorous methods, it is sufficiently accurate to guide initial decisions relative to relief efforts.[13–17]

Since the events of 11 September 2001 and the subsequent anthrax attacks, public health agencies at all levels in the United States, increasingly have been expected to develop their capacities to respond to incidents of terrorism and other hazards.[18–22] Local health departments are among the first agencies to respond to such events. However, especially in small- to mid-size jurisdictions, they often lack the ability to handle large-scale events, and must rely on state, federal, or other assistance to mount an effective response.[7,19,23] Without previous disaster-response experience or sufficiently detailed planning, local health departments might manage large-scale events in an *ad hoc* manner until assistance arrives. However, locally developed and deployed response plans can take advantage of available local resources, more effectively address local needs, reduce reliance on non-local agencies, and quickly initiate effective response activities.[7,18–23]

As a part of its ongoing, disaster preparedness planning, the Louisville Metro Health Department identified the need to improve its response capabilities. After the Centers for Disease Control and Prevention (CDC) suggested that state and local health jurisdictions conduct emergency preparedness program development and research, including cluster sampling for rapid needs assessments,[24] the Department developed the Rapid Assessment Tools Package (RATP). The RATP is a Microsoft Access-based (Microsoft, Inc., Redmond, Washington) application for rapid, two-stage cluster sampling, data collection, storage, and processing. The application of the RATP is within the capacity of most local health departments, and can enhance disaster response capacity with rapid cluster sampling of residential addresses for community needs assessments and other public health surveys.

Methods

RATP Design

The RATP cluster-sampling function is designed to produce automatically a sample of 300 Louisville Metro households using an adaptation of the EPI methodology. The program randomly selects 10 residential addresses from among each of 30 randomly selected clusters, defined as election precincts, from within a geographical area specified by the user. The user defines the area of interest within Louisville/Jefferson County Metro (Louisville Metro) by selecting all or any combination of the 26 Metro Council districts for inclusion in the sampling frame.

The RATP data collection features include two premade survey instruments, one for community needs and one for psychological impact assessments, with electronic forms to facilitate data input. Data items included in the community needs survey instruments relate to household demographics, morbidity, sanitation, food supply, transportation, and utilities and are based on suggestions made by the CDC in a proposal for state or local emergency preparedness research studies.[24] The psychological impact assessment instrument is adapted from a CDC mental health survey tool.[25] Both instruments can be easily expanded to capture event-specific or other data required by local officials. The tables that underlie the data input forms can be populated automatically with the addresses included in the cluster sample.

The underlying geographic data for addresses and political districts were obtained from the Louisville/Jefferson County Information Consortium (LOJIC), a public, interagency organization that provides comprehensive geographic information systems (GIS) data, products, and services to member agencies and the public.[26] Through LOJIC, the Health Department has access to geographically-referenced data from numerous public agencies including police and fire departments, emergency medical services, public works, sewer district, planning and zoning, code enforcement, tax assessor, and the Board of Elections. Using LOJIC data, a table of residential addresses, which forms the basis of the program's sampling frame, was created by using ArcView 3.2 GIS software (ESRI, Redlands, California) to identify all addresses located within residentially zoned areas of the county.

Randomization of both primary (clusters) and secondary (residential addresses) sampling units is accomplished by assigning a random number to each record and

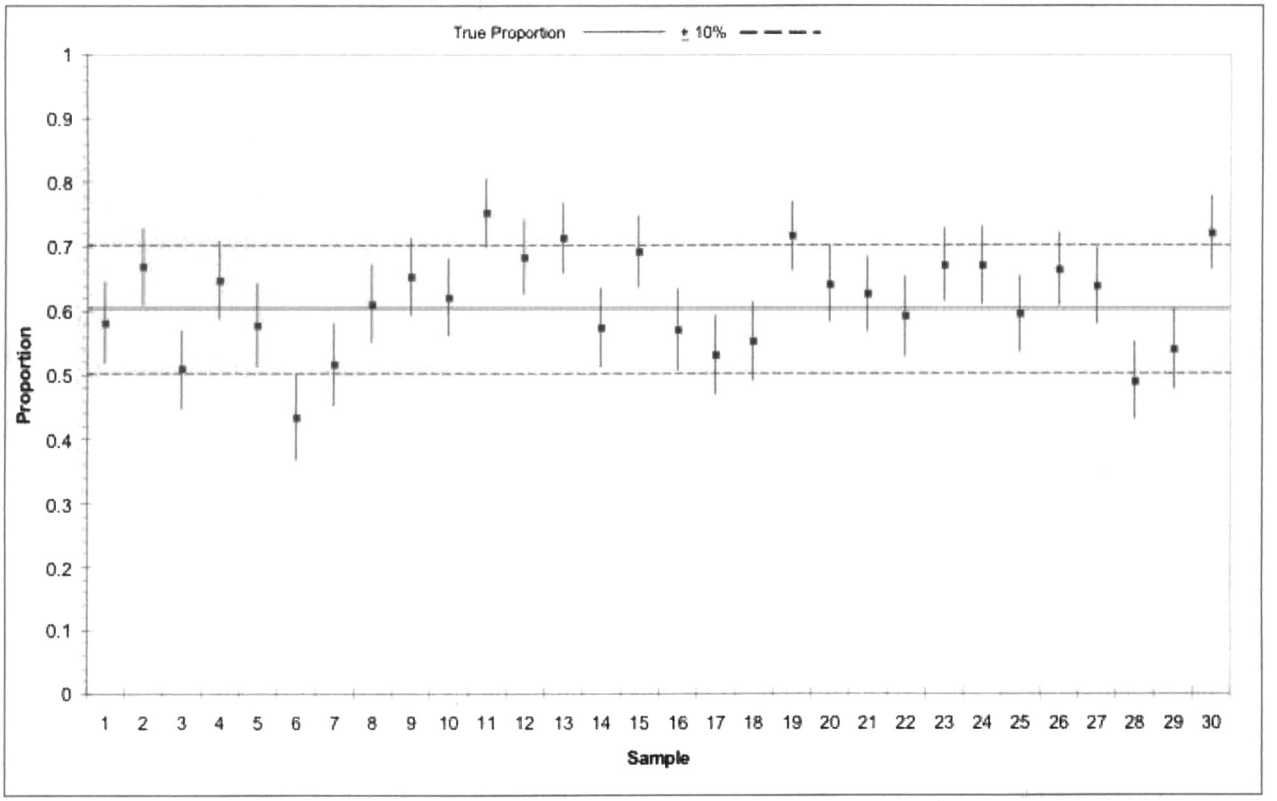

Figure 1—Point estimates and 95% confidence interval of the proportion of Louisville metro residential addresses with attribute (basement) in 30 cluster samples

sorting the records in numerical order. Then, a series of queries is used to select the top 30 of all randomized clusters within the Metro Council Districts selected by the user, and these are used to select the top 10 randomized addresses from within each cluster. The resulting 300 addresses comprise the cluster sample and are printed in report form organized by district and cluster (precinct). These data also can be exported to a GIS program for mapping, routing, and other geographic processing and management functions. Each step in the sampling process is automated by a series of macros so that once the user has selected the districts to be sampled, the sample can be produced in a matter of seconds with a single mouse click.

Analysis of Test Samples

To assess the RATP's performance, a series of 30 samples were produced and analyzed with respect to their precision and accuracy in estimating the prevalence of a particular attribute associated with residential addresses. Precision was assessed in terms of the proportion of estimates with confidence intervals within ±10 %, as has been done in previous studies.[27]

The opportunity to assess the accuracy of sample estimates is rare because the true value of a population parameter only rarely is known for attributes of interest to public health. If it was, there would be no need to take a sample. However, attribute data for all Louisville Metro residential addresses are available through the LOJIC, and can be used to simulate data of public health interest that might be associated with households. The presence or absence of a basement is a convenient binary variable associated with residential addresses, and should be known for every structure in the county. These data are contained in the Jefferson County Property Valuation Administrator's (PVA) Real Estate Master File (REMF) database and are available electronically through the LOJIC.

The data acquired from the REMF on building characteristics were matched to the sample addresses using the Parcel Identifier, an identification code associated with land parcels. Point estimates with 95% confidence intervals of the "true" proportion of all addresses in the county where the structure has a basement were calculated by determining the proportion of addresses with basements in each of the 30 samples.

Accuracy was assessed in terms of the proportion of sample estimates within ±10 absolute percentage points of the true prevalence of the study attribute. To estimate the design effect, defined as the ratio of the variance of the cluster sample result to the variance of the result from a simple random sample of the same size,[28] corresponding simple random samples of 300 addresses were taken after each of the 30 cluster samples.

Results

The RATP sampling frame comprises 271,826 residential addresses. Of these, based on the Parcel Identifier, 225,297 (83%) have matching records in the REMF. The discrepancy is explained largely by the fact that, in some cases,

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Sample	Addresses in Sample	REMF Data Available		Addresses with Attribute (Basement)		
	Number	Number	Percent	Number	Proportion	SE
1	300	238	79.33	138	0.5798	0.0320
2	300	241	80.33	161	0.6680	0.0303
3	300	268	89.33	136	0.5075	0.0305
4	300	238	79.33	154	0.6471	0.0310
5	296	229	77.36	132	0.5764	0.0327
6	283	217	76.68	94	0.4332	0.0336
7	300	241	80.33	124	0.5145	0.0322
8	300	253	84.33	154	0.6087	0.0307
9	300	247	82.33	161	0.6518	0.0303
10	292	260	89.04	161	0.6192	0.0301
11	300	254	84.67	191	0.7520	0.0271
12	300	255	85.00	174	0.6824	0.0292
13	300	264	88.00	188	0.7121	0.0279
14	300	253	84.33	145	0.5731	0.0311
15	300	262	87.33	181	0.6908	0.0286
16	300	239	79.67	136	0.5690	0.0320
17	300	253	84.33	134	0.5296	0.0314
18	300	252	84.00	139	0.5516	0.0313
19	300	278	92.67	199	0.7158	0.0271
20	300	261	87.00	167	0.6398	0.0297
21	300	269	89.67	168	0.6245	0.0295
22	300	244	81.33	144	0.5902	0.0315
23	300	264	88.00	177	0.6705	0.0289
24	300	227	75.67	152	0.6696	0.0312
25	300	278	92.67	165	0.5935	0.0295
26	300	267	89.00	177	0.6629	0.0289
27	300	251	83.67	160	0.6375	0.0303
28	300	270	90.00	132	0.4889	0.0304
29	300	247	82.33	133	0.5385	0.0317
30	300	247	82.33	178	0.7206	0.0285

Table 1—Cluster samples of Louisville metro addresses (REMF = Real Estate Master File; SE = standard error)

street addresses are assigned to land parcels that have no structure on them. In other cases, a single structure may occupy more than one land parcel and have more than one street address assigned to it, but would have only one record associated with a single Parcel Identifier in the REMF.

Based on REMF data, the proportion of county residential addresses with basements is 0.602. This value was taken to be the population parameter for the study attribute.

Of the 30 cluster samples (Table 1) produced by the RATP, 90% (n = 27) had 300 addresses as intended by the design of the program. Three of the samples had slightly less than 300 because some clusters (precincts) contain fewer than 10 residential addresses. Availability of attribute data from the REMF averaged 84.34% (range = 75.67–92.67%) for the 30 samples. Point estimates of the proportion of addresses with the study attribute ranged from 0.433–0.752.

As intended by the sampling method design, all of the sample proportions had 95% confidence intervals within ±10% of the point estimate (Figure 1). In 46.7% (n = 14) of the samples, the 95% confidence interval included the true proportion of addresses with basements. In 63.0% (n = 19) of the samples, the 95% confidence interval extended beyond ±10 absolute percentage points of the true proportion. The sample proportion was within ±10 points of the true pro-

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	RATP Sample			Simple Random Sample			
Sample	Proportion	SE	Variance	Proportion	SE	Variance	Design Effect
1	0.5798	0.0320	0.0010	0.5770	0.0285	0.0008	1.2582
2	0.6680	0.0303	0.0009	0.6330	0.0278	0.0008	1.1883
3	0.5075	0.0305	0.0009	0.6330	0.0278	0.0008	1.2044
4	0.6471	0.0310	0.0010	0.6470	0.0276	0.0008	1.2604
5	0.5764	0.0327	0.0011	0.5970	0.0283	0.0008	1.3295
6	0.4332	0.0336	0.0011	0.6170	0.0281	0.0008	1.4365
7	0.5145	0.0322	0.0010	0.5630	0.0286	0.0008	1.2638
8	0.6087	0.0307	0.0009	0.6230	0.0280	0.0008	1.2025
9	0.6518	0.0303	0.0009	0.6030	0.0282	0.0008	1.1515
10	0.6191	0.0301	0.0009	0.5900	0.0284	0.0008	1.1247
11	0.7520	0.0271	0.0007	0.6100	0.0282	0.0008	0.9260
12	0.6824	0.0292	0.0008	0.6330	0.0278	0.0008	1.0977
13	0.7121	0.0279	0.0008	0.6170	0.0281	0.0008	0.9858
14	0.5731	0.0311	0.0010	0.6330	0.0278	0.0008	1.2488
15	0.6908	0.0286	0.0008	0.5870	0.0284	0.0008	1.0088
16	0.5690	0.0320	0.0010	0.5770	0.0285	0.0008	1.2612
17	0.5296	0.0314	0.0010	0.6070	0.0282	0.0008	1.2383
18	0.5516	0.0313	0.0010	0.6030	0.0282	0.0008	1.2300
19	0.7158	0.0271	0.0007	0.6230	0.0280	0.0008	0.9346
20	0.6398	0.0297	0.0009	0.6200	0.0280	0.0008	1.1243
21	0.6245	0.0295	0.0009	0.6100	0.0282	0.0008	1.0993
22	0.5902	0.0315	0.0010	0.5930	0.0284	0.0008	1.2322
23	0.6705	0.0289	0.0008	0.5800	0.0285	0.0008	1.0307
24	0.6696	0.0312	0.0010	0.5670	0.0286	0.0008	1.1909
25	0.5935	0.0295	0.0009	0.6000	0.0283	0.0008	1.0848
26	0.6629	0.0289	0.0008	0.6100	0.0282	0.0008	1.0554
27	0.6375	0.0303	0.0009	0.5900	0.0284	0.0008	1.1419
28	0.4889	0.0304	0.0009	0.5730	0.0286	0.0008	1.1348
29	0.5385	0.0317	0.0010	0.5900	0.0284	0.0008	1.2478
30	0.7206	0.0285	0.0008	0.6000	0.0283	0.0008	1.0188

Table 2—Design effect for cluster sample of Louisville metro addresses (SE = standard error)

portion in 80.0% (n = 24) of the samples. In 93.3% (n = 28) of the samples, the point estimate was within ±12.5% and 96.7% (n = 29) fell within ±15%. All of the point estimates fell within ±20% of the true proportion. Estimates of the design effect ranged from 0.926 to 1.436 (mean = 1.157, median = 1.170) over the 30 samples (Table 2).

Discussion

Taking advantage of the detailed data available through the LOJIC, the RATP was designed as a locally deployable tool for rapid needs assessments. The sampling procedures of the RATP strike a balance between the EPI sampling methodology. It is designed for use in situations where no sampling frame is available, and more methodologically rigorous sampling methodologies, which generally are too difficult, expensive. However, it is too time consuming to be of practical use in large-scale emergencies.

The original EPI method for cluster sampling involved the random selection of 30 population-weighted sites called "clusters" within the geographic area of interest, fol-

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lowed by the selection of seven consecutive households from a randomly selected starting point within each cluster.[27,29,30] The rationale for this method is based on the fact that, for a binary variable, a maximum sample size of 96 is required to produce an estimate with a precision of +/-10 absolute percentage points from the population mean at the 95% confidence level. Sampling from clusters rather than from the entire population makes the survey easier to manage logistically, but means that the sample is less dispersed. Individuals within clusters tend to share characteristics, reducing the precision of the sample. To compensate, the EPI method doubles the calculated sample size and, to allow for an equal number of subjects to be selected from each cluster, arrives at the sample size of 210.

The EPI cluster sampling methodology originally was designed for use in developing countries where enumeration of all sampling units, whether housing units, households, or individuals, in a town or village would be impractical. The method addresses this issue by selecting a random starting point near the center of the village and sampling subsequent adjacent houses until seven subjects were accumulated for that cluster. Sequential sampling makes the EPI method well-suited for use in situations in which no reliable sampling frame is available, but the tendency for adjacent sampling units to share characteristics reduces the precision of the sample. The RATP, however, makes use of a sampling frame generated using a detailed and essentially complete enumeration and mapping of the second-stage sampling units—housing units—that are intended as a proxy for households and are operationalized as residential addresses. This allows for the random sampling of addresses within each cluster. In this way, the logistical advantages of cluster sampling (i.e., subjects are less dispersed, requiring less travel by survey teams) are preserved, while the design effect is mitigated. This is reflected in the estimates of the design effect in this study, which were very close to one. Of course, the magnitude of the design effect will depend on the geographic distribution of the values of a given variable and estimates of attributes with higher intraclass (cluster) correlations will be more severely affected.

Less than 95% of the sample proportions fell within ±10% of the true proportion. However, the true proportion of the study attribute in this case was 60.2%. The RATP was tested under conditions for which it would be expected to perform least well; that is, a population proportion approaching 50%. It is to be expected, on theoretical grounds and based on experience from previous computer simulations,[27,31] that the precision of sample estimates would decrease as the population proportion approaches 50% and increase as it approaches 0 or 100%.

This suggests that the RATP can produce sufficient population-based estimates of the prevalence of binary attributes associated with households in order to inform the initial decisions of local public health and other officials regarding relief efforts in response to a disaster or other mass emergency. For example, if a large majority of households sampled in an affected area report having vehicle access, local officials might decide to provide relief supplies through a few regionally located distribution centers. However, if a significant number of households report having no vehicle access, officials might decide to provide relief supplies through a large number of neighborhood centers or to deliver them directly. Additionally, the quantitative nature of these estimates allows for the establishment of relief priorities based on the relative prevalence of problems, which would not be possible using only qualitative survey methods. For example, in a situation in which disruptions to both water and power supplies were reported, but 15% of households were without running water and 70% were without power, officials might prioritize the restoration of electric utilities over the repair of water lines and provide bottled water in the interim, especially if temperature extremes were a concern.

The Louisville Metro Health Department is fortunate in that it has geographic information system capabilities, as well as access to an advanced geospatial data infrastructure through the LOJIC, while most local health departments do not.[32] However, even without these capabilities, RATP-style automated cluster sampling still could be utilized using geographic and population data available from the United States Census Bureau by operationalizing primary sampling units (clusters) as census tracts or block groups. Indeed, since 1998, rapid needs assessments typically have been conducted using sampling frames derived from census data.

While its sole use precludes the complete enumeration of residential addresses and the random selection of secondary sampling units, the use of census data has important advantages. Population and housing data can be used to weigh selection probabilities in proportion to cluster size, and to make projections of the total number of households or persons affected in the entire area covered by the sample and within geographic and demographic substrata.[7] However, if significant population displacement has occurred because of a disaster, basing such projections on census counts could result in distorted estimates of the total number of households with disaster needs.

While population and demographic estimates have been produced for Louisville Metro Council districts,[33] none are available for election precincts. Consequently, such projected totals cannot be calculated validly, based on samples produced by the current version of the RATP. For the same reason, the RATP does not select primary sampling units with probability proportional to population size. Each cluster has an equal probability of being included in the sample, as was the case with the surveys conducted following Hurricane Andrew.[1] However, by law, election precincts in Jefferson County are designed with the intent to include approximately the same number of registered voters,[34] so the assumption that the clusters have roughly equivalent populations is not unreasonable.

Like those of census geographies, election precinct boundaries are subject to periodic adjustments to reflect shifts and changes in the distribution of the population (of registered voters in the case of election precincts). When this occurs, the tables that comprise the RATP's sampling frame can be updated easily. All that is required is to reassign the addresses to the appropriate precinct based on the new boundaries. This is accomplished using GIS software, and the updated table can be imported back into the RATP. Because the table of residential addresses is derived

from tax assessor records, not voter registration records, the foundation of the sampling frame remains unchanged by political redistricting. Of course, as new residential addresses are created, they can be added to the table.

Still, while households that do not include a registered voter are not excluded from the sampling frame, geographic differences in voter registration rates would skew the probability that a particular household would be sampled because the precincts are drawn to include approximately equal numbers of voters, not total population. Differential voter registration rates violate the assumption of equal precinct populations, and tend to introduce a bias, leading to the over-representation of households that include a registered voter. Because households that do not include a registered voter are more likely to be minority and less wealthy, they may be at greater risk for disaster needs and their under-representation could result in an underestimation of needs.

Similarly vulnerable groups, such as migrants and the homeless, who may not have a fixed residential address, will be missed by this sampling methodology. Additional, focused surveys of these populations may be necessary to assess their needs fully.

The use of political districts rather than census geographies, as primary sampling units for the RATP, was based on the desire to have a higher-level aggregation of geographic subunits so that geographic areas of interest smaller than the entire county could be defined easily. Census tracts, of which there are 170 in Jefferson County, were deemed too small for this purpose. Metro Council Districts, of which there are 26, are a convenient size for this purpose, but they overlap census geographies. Election precincts, on the other hand, nest within council districts and have suitable population size and area to serve as primary sampling units.

Defining a geographic area of interest below the county level is important for at least two reasons. First, in the case of a highly localized disaster, a sample drawn from the entire county would produce skewed estimates by including many unaffected areas. Second, the ability to draw samples from at least two different areas is necessary for comparison studies.

To preserve the advantages of using a census-based primary sampling frame, future versions of the RATP will use predefined, contiguous aggregations of census tracts instead of Metro Council Districts as a tool for defining sub-county level areas of interest and census block groups as primary sampling units (clusters).

As it is currently configured, the RATP produces samples of 300 addresses, while the original EPI method calls for only 210; the RATP selects 10, rather than seven, addresses from each cluster. For rapid assessment surveys, the smallest sample that can yield statistically reliable results generally is preferred in order to conserve both time and resources. In field settings, therefore, it is anticipated that data will be collected only from the first seven addresses where responses are obtained. The number of addresses selected from each cluster easily can be increased or decreased, depending on the anticipated household response rate for the area of interest.

By increasing the number of addresses selected from each sample to 30, the RATP also can be used to produce 30 x 30 cluster samples of the sort commonly used in nutrition surveys.[13,35] While sampling 900 households obviously is more demanding, follow-up surveys of this type may be necessary to demonstrate any impact of relief efforts. Depending on the initial proportion estimate, surveys using the 30 x 7 scheme may require large changes in measured variable proportions in order to demonstrate statistical significance.[27] For this reason, surveys using larger sample sizes could play an important role tracking progress in the recovery phase of disaster relief efforts.

Conclusions

This study suggests that locally designed and deployed solutions for disaster rapid needs assessments, such as the RATP, may provide population-based estimates of community needs and the extent of disaster-related effects. These estimates are precise enough to serve as the basis for the initial decisions regarding relief efforts for a sudden-onset disaster.

Results from the analysis of the 30 computer-simulated test samples indicate that the cluster samples generated by the RATP can produce suitable, population-based estimates of the prevalence of binary attributes. These estimates could inform the initial decisions of local public health and other officials regarding relief efforts in response to a disaster or another mass emergency.

Prospective evaluation of the performance of the RATP performance in field trials or an actual emergency will be required to confirm its utility as a local disaster response tool.

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