Using Geographic Information Systems and Local Food Store Data in California's Low-Income Neighborhoods to Inform Community Initiatives and Resources

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As the obesity epidemic continues to escalate across the nation,[1–5] community factors most likely to reverse the trend become increasingly important. The Centers for Disease Control and Prevention recently recommended community strategies to prevent obesity, including improving access to healthy local foods, providing incentives for food retailers to carry healthier options, and limiting advertisements of less healthy foods.[6] The American Reinvestment and Recovery Act seeks to mobilize communities to create neighborhoods that sustainably support healthy lifestyles and ameliorate the obesity epidemic.[7]

Reliable data on the local food environment can inform decisions about which actions are appropriate at the community level and which neighborhoods are at highest need for resources. Local data derived from geographic information system (GIS) mapping and field surveys that describe the neighborhood environment and the types of food available in neighborhoods can help guide local efforts. The Network for a Healthy California (the Network) of the California Department of Public Health uses GIS mapping and store surveys to examine food store conditions in low-income neighborhoods as part of the program Communities of Excellence in Nutrition, Physical Activity and Obesity Prevention (CX^3).

The Network for a Healthy California

The Network is a social marketing initiative serving California's estimated 7 million parents and children in households with incomes below 185% of the federal poverty level[8] through local assistance contracts. The Network's contractors carry out public campaigns, community-level classes, and nutrition programs, such as the Network for a Healthy California Retail Program, which provides direct technical assistance, marketing strategies, and materials to help qualifying retailers use point-of-sale marketing to promote fruit and vegetable consumption.[9]

Objectives. We examined conditions in California low-income neighborhoods that affect obesity to inform program planning, nutrition education, community participation, investment of resources, and involvement of stakeholders.

Methods. Staff members in 18 local health departments were trained to use an online geographic information system (GIS) and conduct field surveys. GIS data were aggregated from 68 low-income neighborhoods of 1 or more census tracts. Data were collected in 2007 to 2009 from 473 grocery stores in 62 neighborhoods.

Results. Thirty-one percent of neighborhoods mapped had no supermarket within any of their census tract boundaries, but health department staff members estimated that 74.2% of residents had access to a large grocery store within 1 mile. Eighty-one percent of small markets sold produce, and 67.6% offered 4 or more types of fresh vegetables.

Conclusions. Small markets and corner stores in California's low-income neighborhoods often have fresh produce available for sale. Stores providing healthy options in typically underserved areas can be part of community efforts to promote healthy eating behaviors. (*Am J Public Health.* 2010;100:2156–2162. doi:10.2105/AJPH.2010.192757)

The Network also maintains a statewide GIS with online interactive mapping capability and more than 100 geocoded database layers.[10] The map's main purpose is to enable contractors to identify qualifying areas and locations to provide nutrition education. Features of the map, such as streets, highways, rivers, and parks, can be overlaid with census tracts or zip codes and locations such as schools, worksites, retail food outlets, and nutrition-related local programs. The GIS is the first step in program planning: it identifies local amenities, services, and physical attributes.

The Network developed CX^3 to help local health departments appraise environmental conditions that affect obesity in low-income neighborhoods and to inform local strategies for program planning, nutrition education, community participation, and involvement of stakeholders. CX^3 was initiated to build the capacity of local health departments to collect and use community-level data linked to a series of standardized community benchmarks for healthy communities known as indicators and assets. The CX^3 indicators are used to assess conditions expected to promote healthy food and physical activity environments. CX^3 assets measure the extent of local support from community members, stakeholders, media, and organizations. Local health departments are trained with CX^3 standardized methods to use the GIS and field surveys that link to specific indicators and assets.

Geographic Information Systems and the Retail Food Environment

GIS studies have sparked interest in using this technology to examine spatial relationships of the food environment and capture disparities in food access.[11–14] GIS mapping provides a quick and cost-effective way to examine neighborhood differences without sending researchers in to survey the area. The accuracy of GIS mapping is limited, however, by the variable nature of businesses and by misclassification of data. Maps created with GIS technology may provide only a cursory view of environmental relationships. Although a map view provides an

indication of the types of food that could be present, the view does not provide information about the availability, quality, or cost of foods in stores or other retail food sources.

Grocery stores set the tone for healthy neighborhoods. Supermarkets with the greatest variety and lowest prices are more accessible in middle- and higher-income neighborhoods.[14–19] Access to food sources is important to consider in low-income areas, where car ownership rates are low.[20,21] A positive connection has been identified between proximity to supermarkets and healthy eating,[17,22] and the importance of small neighborhood food stores has also been recognized.[23,24] Point-of-sale nutrition information and targeted marketing strategies to increase the selection of healthy choices are generally successful.[25,26] Documentation of community food environments in low-income neighborhoods and of disparities in access to healthy food is needed to inform the strategies of health leaders and community members.

METHODS

State-level staff working on CX[3] started by developing instruments that could assess the community benchmarks in the neighborhood food environment. Their goal was to create surveys and tracking methods that could be used by local health department staff members working with community members and youths. Among the instruments developed were a series of GIS mapping procedures and field surveys for gathering on-the-ground neighborhood data.

The GIS mapping procedures identified access to supermarkets or large grocery stores, transportation to supermarkets or large grocery stores, access to fast food in a neighborhood and within a half mile of schools, farmers markets in a neighborhood and within 5 miles, and access to small markets and convenience stores within a half mile of schools. The field instruments were surveys dealing with food stores, walkability within 2 blocks of stores, fast-food outlets, outdoor marketing, and food banks and emergency food outlets. Additional methods to identify alternative food sources, such as farm stands, community gardens, and community-supported agriculture, were part of the process. The standardized instruments and methods were developed to capture a complete

perspective of the neighborhood food environment to determine whether communities were meeting neighborhood indicators and what community assets were available.

In 2006, all survey instruments and GIS procedures were pilot tested by 6 local health departments in areas ranging from dense urban to rural. Local health departments used their own staff, community residents, or young people to test the store survey in 181 stores. A field protocol was developed for surveyor reference and to improve the quality of data collection. In 2007 to 2009, health departments examined the food store environment in their areas.

Geographic Information System Mapping

GIS mapping provided visual depiction of retail food availability within the overall context of residential areas and in relation to other public infrastructure, such as schools and roads. We trained local health department staff members to use the online system and interpret the maps. The online system used ArcIMS 9.2 and ArcSDE 9.2 (Environmental Systems Research Institute, Redlands, CA). We procured databases represented in the retail food layers from Dun & Bradstreet, Inc (Short Hills, NJ). We considered inaccuracies of retail databases during the mapping process. Local health department staff used other online mapping interfaces to update the mapping data collected when possible and to verify locations identified for the survey phase of implementation. Interpretation of the maps was guided by a series of instruments to record information present on the map viewer from downloaded maps and related data. The initial map views guided many health departments in deciding which areas should receive ground-level survey work.

Census tracts provided the boundaries to identify low-income–qualifying areas with 50% or more of their population (identified from 2000 US Census data[27]) living in households with incomes at or below 185% of the federal poverty level[8] and to designate neighborhoods recognized by residents. Occasionally census block groups were used to incorporate areas that better defined natural neighborhoods. Residential and mixed-use areas were mapped, but zoning designations were not part of neighborhood identification.

A circle with a half-mile radius was drawn that centered on each supermarket and large grocery store (≥20 employees) in neighborhoods to estimate the percentage of residents within walking distance to healthy food. Estimation was roughly calculated by determining the proportion of a census tract's geographic area captured within this defined circle or within several circles and summing for each census tract's geographic area. If no supermarkets or large grocery stores were present, the travel distance needed to access one was estimated by expanding a circular buffer from a center point in the neighborhood. Resident access via public transit routes was mapped separately by overlaying routes found through Internet searching. The number of small markets (<20 employees) and convenience stores located in the neighborhood and within a circle with a half-mile radius centered on schools was also determined.

Each local health department used map data findings and federal poverty level designations in census tracts to select 3 or 4 low-income neighborhoods in which to conduct store surveys. In some cases, other neighborhood characteristics were considered for selecting neighborhoods, such as obesity rates, population density, race/ethnicity, and existence of established partnerships with community organizations. From the GIS map viewer, store information—addresses, store type, and number of employees—was downloaded to develop a list of locations to survey. To address inaccuracies in the retail databases in the GIS, lists were refined and revised as needed from such sources as environmental health data from the local health department, other search engines, and online mapping interfaces such as Google or Yahoo.

Store Surveys

All types of retail food stores were surveyed in the selected neighborhoods. Store types were verified upon data collection. Small markets and convenience stores were confirmed by the presence of fewer than 4 cash registers. Data collection centered on several main topics: exterior and interior marketing, produce quality and availability, and the presence of healthy foods other than fresh fruit and vegetables. To develop the list of other healthy foods, we selected items

that contributed 2 to 3 basic foods from the food groups in the 2005 Dietary Guidelines for Americans[28] that are part of a healthy diet, excluding fats, oils, and sweets. We also considered the US Department of Agriculture's Thrifty Food Plan[29] during development and consulted the California Women, Infants and Children (WIC) program to include certain foods for the revised federal nutrition package on the store survey's list of other healthy foods (oral and e-mail communications with program staff, 2007).

Measures of exterior marketing conditions included the number, size, and type of food-related advertisements posted in windows and doors; the types of ads and food displayed on other parts of the property; and the presence of produce bins on the sidewalk in front of the store. Measures of interior marketing included the presence of ads and of healthy and less healthy foods next to the checkout counter. Participation in the Supplemental Nutrition Assistance Program (SNAP) and WIC, as well as the presence of exterior signage to let customers know whether a vendor accepted the 2 federal programs, was recorded.

We ascertained the availability and quality of fresh fruit and vegetables with a scale adapted from the Food Stores Survey developed as part of the Girls Health Enrichment Multi-Site Study.[30] We coded availability by the number of types of fruit or vegetables (0, 1–3, 4–6, ≥7). A type was defined as an individual form of fruit or vegetable; different varieties of the same form were not considered different types. We coded descriptive assessments for overall fruit and vegetable quality on a scale of 1 to 4, with 4 being the best quality. We collected prices of 7 common, nutritious produce items and recorded the lowest-priced item for each. We also coded the presence or absence of other items from our healthy foods list.

Data from field surveys were collected by local health department staff or by community members. We trained staff members in quality control methods for data collection and provided field practice. Trainees also viewed photographs depicting various types of store conditions. To improve their judgment of the quality of fruit and vegetables, trainees were shown photographs and introduced to terms for spoilage of produce; we developed these materials with guidance from the Postharvest Technology Research and Information Center at the University

of California, Davis.[31] We tested the survey instrument for interrater reliability in 2008, and results will be reported in future publications.

Aggregated Samples

GIS data samples. Because the mapping process informed the selection of neighborhoods to examine in depth, we mapped a greater number of neighborhoods than were surveyed. We combined reports from 18 local health departments, which recorded data interpreted from GIS mapping procedures in 71 low-income neighborhoods. Fifty-two neighborhoods composed the sample for the study of small markets and convenience stores located around 133 schools. We compiled a smaller sample for small markets and convenience stores because this mapping procedure was not added until 2008.

Store survey sample. We combined data from 18 health departments, 62 neighborhoods, and 473 stores. Surveys were conducted in 2007–2009 in all stores within neighborhood boundaries defined by census tracts or block groups, thereby providing a relatively complete picture of food markets in 62 low-income neighborhoods across California. Survey data were entered at a central location by state-level Network staff, who used double-entry crosschecking procedures and followed additional quality control protocols to reduce inaccurate or missing data.

Analysis

GIS and store surveys. The Network's research staff analyzed the combined GIS data and store survey data with SPSS/PASW[32] to obtain basic frequencies and cross-tabulations. We tested statistical significance with Pearson χ^2 for cross-tabulations. We entered both fully and partially completed surveys of retail food stores in our analysis. Only 4 surveys were partially completed (0.8%). An α level of .001 was used for all statistical tests unless otherwise stated.

Store scores. To help local health departments with interpretation of survey results and communication to stores, community members, partners, and stakeholders, we developed standardized scoring criteria for all stores surveyed. During score development, a roundtable discussion between the Network's staff and the local health departments implementing CX^3 helped to refine the scoring structure

initially developed by the Network's research team. Scores were weighted to reflect specific store conditions considered most likely to influence or support healthy eating behaviors, such as the availability and quality of fresh fruit and vegetables. We used algorithms to calculate scores from the raw data for a localized analysis specific to each store and each neighborhood. Stores could receive a total score of 0 to 100 points. A score of 75 points or higher indicated that a store carried healthy foods and limited the marketing of less healthy food products. Categories in which stores could make improvements were highlighted.

Stores received points for desired conditions and positive attributes, such as carrying more fresh fruit or vegetables, maintaining quality produce, and carrying other healthy foods, as well as for the types and sizes of interior or exterior advertisements and product placement next to the checkout counter. We awarded points for reasonable produce prices if the stores charged less than a calculated price, which we created for each of 7 produce items by analyzing retail scanner data for a designated county. For presentation here, we combined scores from data spanning 2008 to 2009. Because scoring criteria were modified from 2007 to 2008, data variables could not be matched. The scoring analysis was derived from the store surveys, but we compiled and analyzed the aggregated scoring and survey data sets separately. We analyzed scores from 338 stores with descriptive statistics in SPSS/PASW.[32] Description of store scoring criteria and development will be reported in future publications.

RESULTS

Seventy-six percent of the neighborhoods were defined by local health departments as containing 1 or 2 census tracts; a maximum of 5 census tracts defined a neighborhood. Thirty percent of the neighborhoods had no supermarket within neighborhood boundaries, but local health departments reported from GIS mapping that residents of 42.4% of the neighborhoods had access to a supermarket or large grocery store within an estimated half mile and 76.3% had access within 1 mile. Combined estimates of travel distance to a supermarket or large grocery store for most residents

showed a mean distance of 0.86 miles (SD=0.51 with an outlier of 17 miles removed).

Only 9.6% of neighborhoods mapped had no small markets or convenience stores within half a mile of schools. Thirty-one percent had 1 to 3 of these types of stores within a half mile, 46.1% had 4 to 9 stores, and 13.4% had 10 stores or more. Four of the neighborhoods mapped had more than 14 small markets and convenience stores within walking distance of their neighborhood schools; only 2 of those neighborhoods were in dense urban areas.

Store Survey

Stores surveyed in the 62 low-income neighborhoods were predominantly small markets—known as corner stores or mom and pops—and convenience stores (Figure 1). We included other stores, such as dollar stores, drug stores, and WIC-only establishments, as food sources in neighborhoods; store types in this category (other) composed more of the sample than did either supermarkets or large grocery stores. Nearly 23% of stores were WIC vendors, and 65.1% were SNAP vendors. A few small markets and convenience stores were recorded as WIC vendors (16.7% and 6.5%, respectively), but many more were SNAP vendors (66.2% and 56.5%, respectively). Thirty-six stores (7.9%) participated in the Network for a Healthy California Retail Program, with most participating in the retail program being supermarkets (47.2%) or large grocery stores (13.9%).

About two thirds of the stores sampled sold fresh fruit or vegetables. Nearly all (98.1%) supermarkets and large grocery stores carried 7 or more types of produce, and of those stores selling produce, quality was rated as all or most good-quality for the majority (75.9% of supermarkets and 69.2% of large grocery stores for fruit, 75.9% and 73.1% for vegetables, respectively). Most convenience stores carried either limited fruit or vegetables (1–3 types) or none at all (90.9%; Table 1).

Contrary to conventional belief, 81.2% of small markets sold fresh produce, and 67.6% contained moderate or better variety (≥4 types) of fresh vegetables. Many small markets (58.8%) carried 7 or more types of vegetables. Fifty-four percent of small markets carried a moderate variety or better (≥4 types) of fresh fruit. Just over 40% carried 7 or more types of
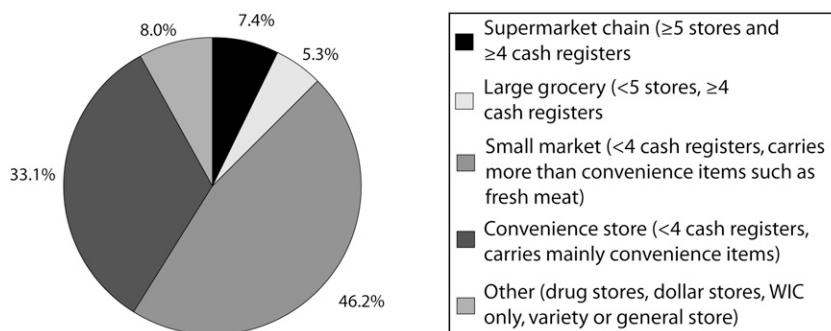
Note. WIC = Special Supplemental Nutrition Program for Women, Infants, and Children. A low-income neighborhood is a neighborhood having ≥50% of its residents living in households with income at or below 185% of the federal poverty level, as listed in the 2000 US census.

FIGURE 1—Food store types in 62 low-income neighborhoods in California: CX³ Food Availability and Marketing Survey, 2007–2009.

fruit. Among small markets that sold produce, the quality of fresh produce was somewhat variable, with only about one third carrying all or most good-quality fruit. The combined categories of more good- than poor-quality and all or most good-quality totaled 69.0%. Overall vegetable quality in small markets selling produce was rated better; 76.0% had more good- than poor-quality or all or most good-quality (Table 2).

Store Scores

The mean score was 43.7 (SD=23.8) total points out of a maximum of 100 possible points. Scores ranged from a high of 90.0 points to a low of 2.5 points. The majority of stores (66.9%) received scores below 60 points; only 14.2% were designated as quality stores, with scores of 75 or above. Nearly all supermarkets (95.7%) received 75 points or higher, as did most large grocery stores (73.7%), but only a few small markets (7.1%), and no convenience stores received a quality score. Small markets had room for improvement: 58.4% of the small markets scored lower than 60 points, and 24% scored under 25 points. However, more than one third of small markets (34.4%) approached the quality standard, with scores over 60 but under 75 points.

DISCUSSION

CX³ store data revealed that a surprising number of small markets in low-income

neighborhoods carried produce, that the quality of fruit and vegetables in those markets was variable, and that these types of stores generally did not reach a standard that could be considered as quality stores in low-income neighborhoods. These markets are important targets for local health departments and community groups with marketing efforts and as partners in promoting healthy behaviors. Previous research supports the importance of making healthy foods available in both supermarkets and small grocery stores and of marketing strategies that influence consumption behaviors, as part of the effort to reduce obesity and chronic disease.[33]

Limitations

CX³ is limited to collection of data in neighborhoods where 50% or more of the residents live in households with incomes at or below 185% of the federal poverty level. Because the 2000 US Census data on which these figures are based are outdated, some areas that were known within the community to have poor access to healthy foods may have been excluded. Because only low-income–qualifying census tracts were surveyed and stores in neighboring census tracts were not considered, our data may not have given a complete picture of access. The census tract qualification requirement for data collection also limited the ability to demonstrate disparities in access between neighborhoods of higher income levels.

TABLE 1—Availability of Fresh Fruit and Vegetables in Stores Selling Produce, by Store Type in Low-Income Neighborhoods in California: CX[3] Food Availability and Marketing Survey, 2007–2009

Availability of Fresh Produce[a]	Store Type[b]				
	Supermarket Chain Store, No. (%)	Large Grocery Store,[a] No. (%)	Small Market, No. (%)	Convenience Store, No. (%)	Other, No. (%)
Fruit					
None	0 (0.0)	0 (0.0)	58 (26.7)	98 (63.6)	26 (72.2)
Limited	0 (0.0)	0 (0.0)	42 (19.4)	42 (27.3)	3 (8.3)
Moderate	0 (0.0)	1 (3.8)	29 (13.4)	12 (7.8)	0 (0.0)
Wide	29 (100.0)	25 (96.2)	88 (40.6)	2 (1.3)	7 (19.4)
Total	29 (100.0)	26 (100.0)	217 (100.0)	154 (100.0)	36 (100.0)
Vegetables					
None	0 (0.0)	0 (0.0)	44 (20.4)	125 (81.2)	19 (52.8)
Limited	0 (0.0)	0 (0.0)	26 (12.0)	12 (7.8)	9 (25.0)
Moderate	0 (0.0)	0 (0.0)	19 (8.8)	11 (7.1)	2 (5.6)
Wide	29 (100.0)	26 (100.0)	127 (58.8)	6 (3.9)	6 (16.7)
Total	29 (100.0)	26 (100.0)	216 (100.0)	154 (100.0)	36 (100.0)

Note. A low-income neighborhood is a neighborhood having ≥ 50% of its residents living in households with income at or below 185% of the federal poverty level, as listed in the 2000 US census. Numbers of stores vary because of missing data. Percentages may not total to 100 because of rounding.
[a]Limited variety = 1–3 types of fruit; moderate = 4–6 types; wide = ≥ 7 types.
[b]Large grocery stores had > 20 employees or ≥ 4 registers but were not part of a large chain; small markets had < 4 registers and were not part of a large chain; convenience stores sold food items and snacks and possibly gasoline, but no fresh meats.

Crime and safety issues often create a fear of violence that can affect perceived access to food and walkability of a neighborhood.[34]

Walkability and safety were evaluated in CX[3] measures within 2 blocks of stores, as part of its assessment of safe routes to healthy foods, but

only organizations with funding outside of the Network for a Healthy California were able to address any recognized issues.

TABLE 2—Quality of Fresh Fruit and Vegetables in Stores Selling Produce, by Store Type in Low-Income Neighborhoods in California: CX[3] Food Availability and Marketing Survey, 2007–2009

Quality of Fresh Produce[a]	Store Type[b]				
	Supermarket Chain Store, No. (%)	Large Grocery Store,[a] No. (%)	Small Market, No. (%)	Convenience Store, No. (%)	Other, No. (%)
Fruit					
None sold	0 (0.0)	0 (0.0)	12 (6.9)	1 (1.8)	7 (41.2)
Poor	0 (0.0)	1 (3.8)	11 (6.3)	8 (14.0)	2 (11.8)
Mixed, more poor than good	1 (3.4)	0 (0.0)	31 (17.8)	14 (24.6)	4 (23.5)
Mixed, more good than poor	6 (20.7)	7 (26.9)	69 (39.7)	16 (28.1)	2 (11.8)
Good	22 (75.9)	18 (69.2)	51 (29.3)	18 (31.6)	2 (11.8)
Total	29 (100.0)	26 (100.0)	174 (100.0)	57 (100.0)	17 (100.0)
Vegetables					
None sold	0 (0.0)	0 (0.0)	1 (0.6)	19 (39.6)	0 (0.0)
Poor	0 (0.0)	1 (3.8)	10 (5.7)	2 (4.2)	3 (16.7)
Mixed, more poor than good	0 (0.0)	0 (0.0)	31 (17.7)	7 (14.6)	4 (22.2)
Mixed, more good than poor	7 (24.1)	6 (23.1)	78 (44.6)	10 (20.8)	2 (11.1)
Good	22 (75.9)	19 (73.1)	55 (31.4)	10 (20.8)	9 (50.0)
Total	29 (100.0)	26 (100.0)	175 (100.0)	48 (100.0)	18 (100.0)

Note. Low-income neighborhood = neighborhood having ≥ 50% of its residents living in households with income at or below 185% of the federal poverty level, as listed in the 2000 US Census. Numbers of stores vary because of missing data. Percentages may not total to 100 because of rounding.
[a]Poor = all or most of poor quality; good = all or most of good quality.
[b]Large grocery stores had > 20 employees or ≥ 4 registers but were not part of a large chain; small markets had < 4 registers and were not part of a large chain; convenience stores sold food items and snacks and possibly gasoline, but no fresh meats.

Future Community Initiatives

Experts have recommended that health departments help direct local resources and create partnerships among city, county, and local organizations to improve the community food environment.[35] Already, corner store conversions (from selling and promoting predominantly unhealthy products to offering more healthy foods) are supported through the Healthy Corner Store Network, a collaboration among the Community Food Security Coalition, the Food Trust, and Public Health Law and Policy.[36,37] Shelf space will inevitably be an issue in persuading stores to carry healthier products,[38,39] but campaigns should be created and incentives offered to encourage stores to carry—and consumers to buy—more healthy products.

CX^3 surveys and methods have extended beyond the Network. They have been used by the Central California Regional Obesity Prevention Program funded by the California Endowment, by the California Convergence, and by projects funded through the California Rural Indian Health Board. The store survey has also been adapted for use in other studies. Altogether, more than half the local health departments in California have used all or some portion of CX^3. With CX^3 data, local health departments can facilitate connections to communities and help provide perspective on the type and level of need. ∎

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Contributors

A. Ghirardelli was lead researcher with CX^3, participated in developing tools and methods and designing the study, trained health departments in data collection methods, managed the data entry process and quality control, conducted the analysis, interpreted findings, and led the writing of the article. V. Quinn provided the main conceptual design for CX^3, contributed to developing tools and methods, training of health departments, interpreting findings, and writing. S. B. Foerster participated in the conceptual design for CX^3 and contributed to writing the article.

Human Participant Protection

No protocol approval was required because no human participants were involved.

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