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Access to care and social/community characteristics and for people diagnosed and living with HIV in California, 2014

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Access to care and social/community characteristics and for people diagnosed and living with HIV in California, 2014

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Abstract

Advances in HIV care and treatment continue to prolong the lives of people diagnosed and living with HIV (PDLWH). The National HIV/AIDS Strategy mobilizes national, state, and local efforts toward ensuring equitable access to care, reducing disparities, and improving continuum of HIV care outcomes. A social/community-based factor that contributes to sub-optimal HIV outcomes for PDLWH – all of whom require regular visits to a medical facility – is access to accommodating, affordable, and acceptable HIV care providers. Employing case surveillance data to analyze relationships between social/community-based factors and HIV disease outcomes is an opportunity to identify underserved PDLWH. This analytic approach, linking individual case-level epidemiologic surveillance data with macro-level community measures, provides public health departments a more precise estimate of priority geographic zones and subpopulation clusters whereby limited public health resources can be directed for maximal impact and efficiency.

This dissertation analyzed California HIV surveillance system (CHSS) data to characterize PDLWH in terms of residential census tract characteristics related to income, poverty, unemployment, vehicle access, population density, travel duration from residence to care facility, and access to care. The primary study population was 60,979 PDLWH as of 2014 who had recent, geocoded residential addresses collected in CHSS. Access to care was measured using a novel enhanced two-step floating catchment area (E2SFCA) method developed for this dissertation. We also assessed whether community characteristics, trip duration, and access to care were associated with suppressed viral load, an indicator of successful disease management. Several significant relationships were found between suppressed viral load and where people lived, how long they drove for care, and their E2SFCA-measured access to care. This analysis identifies new methods for state and local health jurisdictions to: investigate factors associated with HIV-specific health disparities, improve the capacity to direct resources for improving health outcomes for PDLWH, and enhance transmission prevention efforts.

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Disclaimer

The findings and conclusions in this dissertation are those of the authors and do not necessarily represent the views of the Centers for Disease Control and Prevention, nor the California Department of Health, Office of AIDS.

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CHAPTER 1: Introduction and Statement of Purpose

Background

Regular care and adherence to an antiretroviral (ARV) regimen have been shown to increase survival for people diagnosed and living with HIV (PDLWH) and decrease likelihood of infecting others, leading to better clinical outcomes for individuals and fewer new infections in communities (1–4). Both individual sociodemographic and transmission risk characteristics, along with neighborhood and community effects, are related in a multifaceted way to linkage to care, adherence to ARV, and viral load suppression (i.e., continuum of care outcomes). Although researchers have used individual sociodemographic and transmission risk characteristics to characterize these relationships for many years, security and confidentiality concerns have limited the use of surveillance data to analyze how the neighborhood environment affects disease and care outcomes among PDLWH. A limited number of new studies have demonstrated that the residential locations of PDLWH have an impact on their overall health, management of HIV, and rates of transmission (5–11). Geocoded locations from residences and facilities where PDLWH seek care may help us better understand how community and neighborhood characteristics impact continuum of care outcomes for PDLWH. This approach may also suggest opportunities to mobilize geographically informed resources and interventions for improving HIV and other health related outcomes and identify distal causes of health disparities (12).

Most existing studies involving spatial aspects of HIV surveillance data are ecological in nature, meaning that the associations are based on using aggregated census tract characteristics as proxies for individual or community level socioeconomic data (8–11). This approach can be informative to a degree, but is also subject to methodological limitations (13–15). However, by using geocoded locations of the residences and care facilities of PDLWH, it is possible to more precisely characterize the effect neighborhood characteristics have on HIV care outcomes.

National statistics indicate that 51% of people who had been diagnosed with HIV and were still alive at the end of 2010 were retained in care and only 35% had suppressed viral loads (16). PDLWH identify barriers to care that are generally characterized as being structural (e.g., transportation, ability to pay), psychological (e.g., stigma, social support), or clinic specific (e.g., scheduling, follow-up assistance, patient-provider relationships [17,18]). These barriers differ across socioeconomic circumstances and also among PDLWH who are engaged in care compared to those out of care (19). Findings from qualitative studies of barriers to care suggest themes that are generally consistent with those from quantitative studies of health care access. Specifically, Penchansky and Thomas described access to care as a multi-dimensional concept involving accessibility, availability, affordability, acceptability, and accommodation (20). Accessibility, which refers to the distance required to travel to the nearest care facilities, availability, which is the number of services in a given area, and affordability are structural barriers to care. Acceptability, which refers to the relationship between providers and patient preferences (e.g., language concordance), and accommodation, meaning the ability of the providers to enroll patients (e.g., having appointments available after work hours to accommodate patient work schedules), are clinic-specific barriers. Psychological factors cited in these qualitative studies, such as stigma associated with HIV and positive relationships with facility staff, were the only concepts that don't lend themselves well to Penchansky and Thomas' model.

As advances in HIV care and treatment continue to prolong the lives of PDLWH, ensuring equitable access to care is becoming increasingly important. It is important in general health care, but perhaps even more so for HIV care (for which stigma is often an additional barrier), that people have access to a choice of care providers to reduce barriers to receiving regular care. Geocoding residential and care facility addresses will allow HIV care access to be analyzed with more specificity than was previously possible. For example, quantifying whether PDLWH reside in areas where many other PDLWH live, compared to areas where PDLWH are sparse, while controlling for the overall size of the population, could be used as an approximate measure of level of social support and other psychological influences.

Statement of Purpose

For this dissertation research I propose three studies:

Study 1: Describe the distribution of PDLWH in California in terms of social determinant of health and community characteristics from aggregated census tract data including percent of population living in households with income below the federal poverty level, median income, population density, urbanicity, percent with no health insurance, percent with less than a high school degree, percent without vehicle access, and percent who are unemployed. We will look for associations between these characteristics and whether PDLWH are in care and have suppressed viral load.

Study 2: Describe the trip duration from place of residence to care facility as a function of individual and neighborhood characteristics and whether suppressed viral load is associated with travel time using for California PDLWH in 2014.

Study 3: Propose a framework for studying HIV-related health care accessibility by estimate statewide HIV-specific care accessibility using an enhanced two step floating catchment area method, employing empirically derived variable catchment sizes and trip duration decay, to generate a provider to population ratio for each California census tract as a measure of HIV care accessibility. The variable catchment size and decay function will be derived using data for PDLWH who have a current, valid, residential address and have an event for which a provider of care, with a valid address, is recorded. We will then describe PDLWH in California in terms of their access to HIV care.

This proposed study, including the protocols developed to collect and refine the associated data, support Office of AIDS (OA) efforts to measure progress toward National HIV/AIDS Strategy (NHAS) goals (16). Specifically, these data will greatly enhance OA's ability to inform indicators and programmatic responses for actions associated with NHAS Goal 2, Step A, which encourages systems for linking PDLWH to care immediately and supporting retention in care, and also Step B, which encourages increased capacity and diversity of available providers of care and service for PDLWH. Further, this study will improve continuum of care outcomes for California by updating current address information and performing complete death ascertainment for stale cases that would otherwise be assumed to be alive and still living in California.

Data and Methods

The primary source of data for this research will be HIV surveillance data in California. HIV surveillance data is collected to inform public health response to the epidemic for the purposes of preventing new HIV infections and identifying gaps that contribute to lack of access to care for PDLWH. For the proposed study, no primary data will be collected from the individuals in the California HIV surveillance system; only publically available data or information already collected through routine surveillance processes will be used. The risk that confidential identifiable data might be inadvertently disclosed is the reason this should be considered human-subjects research. An official Institutional Review Board application for expedited human-subjects research review has been submitted through the Georgia State University Research Services Administration for approval.

This study will use HIV surveillance data to determine individual level characteristics of PDLWH (e.g., current age, transmission category, and years since HIV diagnosis) and locations of residences and HIV care facilities. Data from the U.S. Census Bureau—in particular data from the American Community Survey—will be used to determine contextual characteristics of neighborhoods of residence for PDLWH. The source data and coding procedures are described in more detail in the following subsections.

Case Surveillance Data: The state of California has conducted confidential, name-based HIV surveillance since 2006, and name-based AIDS surveillance since March 1983. Prior to 2006, HIV case surveillance was code-based, meaning that an anonymous code was assigned to each person with a newly diagnosed HIV infection. OA made significant efforts to re-ascertain name-based records for all previously code-based HIV cases. A person who is newly diagnosed with an HIV infection is reported to the Local Health Jurisdiction (LHJ) by the diagnosing provider or the laboratory that performed the confirmatory HIV test according to California statute. The LHJ then collects information on the person and completes the case report form, which includes diagnostic and clinical laboratory tests, clinical information such as previous tests and opportunistic infections, and personal information such as transmission risk, demographic characteristics, and address information. California law also requires that HIV-related laboratory tests be reported to the jurisdiction of the provider in a timely manner. Most often, investigation of a new case of HIV infection is triggered by an HIV-related laboratory test report. The case report form is transmitted to OA for entry into the California HIV Surveillance System (CHSS), a browser-based software application developed by CDC for conducting HIV surveillance. Rigorous data quality assurance procedures are executed by LHJ and OA staff to ensure data received and entered into CHSS are accurate and complete.

This study will use with HIV surveillance data for cases diagnosed with HIV prior to January 1st, 2015 who are presumed to be alive and living in California as of this date in a non-institutionalized setting (e.g., not in a prison or hospital) and who are not deemed to be homeless (institutionalized and homeless persons have different access to care issues than most PDLWH). This is the most recently available HIV surveillance data for California, because OA policy requires 12 months maturation for case information to be reported publicly (data analysis will not commence until after January 1st, 2016). The location of the best available address of residence as of January 1st, 2015 for each PDLWH, as collected by the LHJ and recorded in CHSS, will be geocoded. There is a substantial range in HIV morbidity among the 59 counties in California, ranging from fewer than five PDLWH in six sparsely populated counties (21) to over 60,000 in Los Angeles County (22). The processes for collecting address data also vary to a great degree across counties. In high morbidity counties, residential address is collected at the time of diagnosis, but it would take substantial effort to follow up on address changes for all cases. Most high morbidity counties proceed with passive procedures for collecting updated addresses, such as updating addresses only when a new laboratory report is received with a different address (Tracy Martin, Health Program Specialist, CA Office of AIDS, personal communication, October 2015). Some larger morbidity counties use other sources of personal information, such as LexisNexis Accurint (a subscription service for tracking information on individuals), to retrieve current address information on individuals who are out of care (Rebecca Mares, MPH; Senior Epidemiologist; HIV/AIDS Surveillance and Monitoring, County of Orange, Health Care Agency; personal communication; November 2015). Smaller morbidity counties are more likely to actively follow up regularly with cases in their county to update addresses. Medium morbidity counties may have programs or processes in place to follow up regularly on address changes, however not all counties are able to do this (Tracy Martin, personal communication). As a result of the variation in address follow-up procedures, outdated address information may exist for a substantial number of cases in California, especially in high morbidity, densely populated areas.

All addresses entered into CHSS will be standardized, geocoded and verified against the database of U.S. Postal Service registered addresses using the subscription service geocoder from Melissa Data (23). In addition, addresses will be spatially matched with institutional addresses that are often used in place of residential addresses such as the address of the public health department, public health lab, care facility, or temporary shelter. The residential locations of PDLWH who are homeless are identified by recording the zip code of the local public health department and specifying an address type of "Homeless" (Cullen Fowler-Riggs, Surveillance Coordinator, Office of AIDS, personal conversation, November 2015). Some LHJs record the full address of the health department or sometimes the provider. For the purposes of this study, PDLWH who are in institutional settings, including correctional, health care-related, and education settings, will be excluded because it is presumed that their health care is provided by the institution where they reside. Homeless PDLWH will also be excluded from this analysis because care accessibility challenges are likely different for homeless people compared to other PDLWH as access to adequate shelter, food, physical and mental health care, is probably a higher priority for this group. Research elucidating challenges and barriers incurred by homeless PDLWH in California is critical, but is beyond the scope of this study.

Other Contextual Data: Population data from the 2010 decennial census at the block group level will be used to calculate population density and, if necessary, to interpolate HIV case residence information for cases where only zip code is available. Block-group level data will also be used to determine burden on health care facilities within catchment areas. This study will use the most recent 5-year estimates of American Community Survey data aggregated at the block group level to approximate neighborhood characteristics that we hypothesize may be associated with HIV care access. The block group level is more likely to be homogenous in terms of community demographic characteristics than the census tract, and therefore a better representation of neighborhood characteristics. In areas where block group level data is not available, most likely because of low population density where heterogeneity is less of a concern, we will use census tract as a proxy for neighborhood. For each block group in California, we will determine the proportion of the population that lives in households with income below the federal poverty level, without personal transportation, without health insurance, and with public health insurance coverage. We will also determine the proportion of the population age 16 years and older without a job, the proportion of vacant houses, and median income for each block group.

We will use the U.S. Department of Agriculture Rural-Urban Commuting Area classification system based on data from the 2010 decennial Census and American Community Survey to classify census tracts along the spectrum ranging from urban core to isolated rural (24). Specifically, this research study will use the consolidation scheme proposed by the Washington State Department of Health, which combines the Rural/Urban Commuting Area (RUCA) codes into four categories: Urban Core, Sub-Urban, Large Rural

Town and Small Town/Isolated Rural Area (25) (this will henceforth be referred to as CRUCA – Table 2). This method was chosen to account for the high likelihood that whether individuals commute from an area of residence to an urban core is likely associated with access to care. For example, an individual who lives in a remote area with few care resources, but who commutes to a city for employment near many care resources, may not have the same challenges in access to care as others in his/her area of residence. Not having information about location of employment is a weakness of this analysis, however defining urbanicity using the CRUCA classification scheme will help minimize any potential bias.

While analysis of address data will be performed using individual locations in order to calculate distance between a residential address and a facility address (a strength of this study's method compared to prior studies), the findings will be aggregated by either geographic or demographic characterizations of PDLWH for reporting purposes to protect confidentiality.

Outcome variables: We will use two components of the continuum of care outlined in the National HIV/AIDS Strategy to measure HIV care related outcomes: in care and viral suppression (3,26). PDLWH will be considered to be in care if they had at least one documented viral load, genotype, or CD4+ test during 2014. They will be characterized as being virally suppressed if the result of their most recent viral load during the year of observation was less than 200 copies/mL which indicates successful disease management. Tests of CD4 levels are a clinical indicator used to determine progression of disease and viral genotype tests are used to identify drug resistance; both are also considered to be proxies for being in HIV care.

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Chapter 2: **Spatial Characterization of residential community and social determinants of health among Californians diagnosed and living with HIV in 2014**

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Abstract

Background: Individual sociodemographic characteristics and community characteristics are related in a multifaceted way to individuals obtaining regular care, using antiretroviral therapy (ART), and maintaining a suppressed viral load. Identifying and addressing the community and social determinants of health (SDH) that adversely affect HIV-related health outcomes may advance efforts towards reducing disparities in prevalence of HIV infection and viral suppression rates among populations.
Methods: We used geocoded, current, residential addresses from the California HIV Surveillance System (CHSS) to describe the distribution of people diagnosed and living with HIV (PDLWH) in California in terms of residential SDH characteristics. Community SDH characteristics were derived using census tract-level American Community Survey 5-year-estimate data. We calculated prevalence ratios of unsuppressed viral load (UVL) among PDLWH with viral load results using separate log-binomial models for each SDH category, population density, and urbanicity adjusting for gender, race/ethnicity, transmission risk category, and age.
Results: We found PDLWH in California were more likely to live in census tracts with higher percentages of people in households with income below poverty, without health insurance, with comparatively low median incomes, with high population density, and categorized as urban-center. Overall, 51,907 (85%) of the 60,979 PDLWH were in care and 43,298 (71%) were virally suppressed. Higher risk quintile census tracts had higher prevalence ratio of UVL for all of the SDH measures except percent of households without access to a vehicle. The prevalence of UVL among PDLWH was higher for census tracts with high poverty (quintile 5 prevalence ratio [PR] = 1.69; confidence interval [95% CI]: 1.51, 1.90), low median household income, (quintile 5 PR = 1.78; 95% CI: 1.60, 1.98), high percent of lower than high school education (quintile 5 PR = 1.73; 95% CI: 1.57, 1.91), without health insurance (quintile 5 PR = 1.65; 95% CI: 1.47, 1.84), and high unemployment (quintile 5 PR = 1.19; 95% CI: 1.08, 1.31).
Discussion: Because of the extent of missing address data, this analysis provides a framework for future analyses of SDH and HIV disease outcomes. This information can assist public health departments in identifying disproportionately high percentages of PDLWH with unsuppressed viral load or who are out of care.

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Background

Regular care, adherence to an antiretroviral therapy (ART) regimen, and viral load suppression have been shown to increase survival for persons diagnosed and living with HIV (PDLWH) and decrease likelihood of infecting others, leading to better clinical outcomes for individuals and fewer new infections (1–4). Both individual sociodemographic and behaviors associated with transmission, along with effects associated with community characteristics, are related in a multifaceted way to individuals obtaining regular care, using ART, and maintaining a suppressed viral load (5,6). Although researchers have used individual sociodemographic and transmission risk characteristics to study these relationships for many years, only a few studies have used HIV surveillance data to analyze how community characteristics affect disease and care outcomes among PDLWH. A limited number of new studies have demonstrated that the community characteristics near residential locations of PDLWH are associated with measures of overall health, management of HIV, and rates of transmission (1,2,7–9). These studies tend to analyze geographically small areas such as metropolitan areas (7,10–13) or geographically large areas, but with much less geographic resolution (2,6,14). However, this approach holds promise for identifying opportunities to mobilize interventions informed by a geographic or community-based prospective to improve HIV clinical outcomes, reduce new infections, and identify distal causes of HIV-specific health disparities (15).

The state of California was home to 126,241 PDLWH at the end of 2014 with a rate of 327.5 per 100,000 population, which is the second highest absolute HIV morbidity and tenth highest prevalence rate among U.S. states and the District of Columbia (16). In 2014, there were 5,002 people with newly-reported HIV infections in California and the rate of newly-reported HIV infections was 13.0 per 100,000 population, which ranked highest for number of newly-reported infections (16). Among all PDLWH in California who have been diagnosed and reported with HIV infection, an estimated 64% were in care and 49% were retained in care during 2014 (17).

This study describes the distribution of PDLWH in California in terms of residential community social determinants of health (SDH) characteristics and examines whether suppressed viral load is associated with these characteristics. Social determinants of health are community-level social and economic systems that contribute to health inequities (18). Identifying and addressing the SDH that adversely affect HIV-related health outcomes may advance efforts towards reducing disparities in prevalence of HIV infection and viral suppression rates among populations. We focused on suppressed viral load because it is both a key HIV-related positive health outcome (4,19–21) and it is associated with lower risk of HIV-1 secondary transmission (22,23). Better information about how community SDH characteristics are related to HIV care outcomes is an important first step for identifying community characteristics associated with high risk of poor disease outcomes, thereby allowing state and local health departments, and policymakers to efficiently focus resources on specific geographic areas of need. Using the geocoded location of residential addresses allowed for an analysis at a significantly higher resolution than has been previously published for PDLWH.

We primarily used the community SDH framework used by Centers for Disease Control and Prevention (CDC) to characterize census tracts according to their population attributes. We used measures of percent living in households with incomes below the federal poverty line, median household income, percent with less than a high school diploma, percent with no health insurance, percent unemployed, and percent without access to a vehicle (24). This study area covers a large and diverse geographic area, including several of the largest metropolitan areas in the U.S. and a number of medium and low population density cities and rural areas. For this reason, we elected to also examine measures of population density and urbanicity of community of residence.

Methods

Case Surveillance Data - The state of California has conducted confidential, name-based HIV surveillance since 2006, and name-based AIDS surveillance since March 1983. Prior to 2006, HIV case surveillance was code-based, meaning that an anonymous code was assigned to each person with a newly-diagnosed HIV infection. California law mandates that each person who is newly diagnosed with an HIV infection be reported to the local health jurisdiction (LHJ) by the diagnosing provider and the laboratory that performed the confirmatory HIV test. LHJ staff collect information on the person and complete the case report form, which includes diagnostic and clinical laboratory test results, clinical information such as previous test results and opportunistic infections, and personal information such as transmission category, demographic characteristics, and address information. Most often, LHJ investigations of new cases of HIV infection are triggered by HIV-related laboratory test reports.

The study included people aged 13 and older who were diagnosed with HIV, reported to California HIV surveillance system (CHSS) on or before December 31, 2014, alive and living in California as of this date, and had no evidence reported to the CHSS that their current residence was in an institutionalized setting (e.g., not in a prison or hospital) or that they were homeless. Community SDH characteristics for neighborhoods surrounding institution locations would not necessarily apply to the population living in the institution. Homeless persons likely did not have address information recorded in the CHSS that reflected where they resided; therefore the community SDH characteristics could not be determined for the purposes of this study. Data from 2014 are the most recently available HIV surveillance data for California; OA policy requires 12 months maturation for surveillance information to be available for analysis.

Additional inclusion criteria were based on recency of residential address as of December 31, 2014. Residential address information for PDLWH was collected in the CHSS from Case Report Forms (CRF) completed at diagnosis, from reports of changes in disease status, and from additional reports that included location information, such as laboratory reports of diagnostic and clinical tests. We included cases that met one of the following criteria: (1) the most recent residential address in the CHSS was from a document (CRF, laboratory report, death report, etc.) dated between January 1, 2013 – December 31, 2014; (2) the most recent residential address in the CHSS was dated prior to January 1, 2013, but a laboratory document or ACRF (without updated address information) was added to the CHSS between January 1, 2013 – December 31, 2014; (3) the most recent residential address in CHSS was from a document received after December 31, 2014, but it matched the residential address on record, even if that address would have been considered out-of-date. The dataset was created using the OA's 2014 end-of-year surveillance dataset. The 2015 end-of-year dataset was used to confirm address information for inclusion criteria three.

HIV care outcome variables included whether or not a person was in care and whether they were virally suppressed. "In care" was defined as having had at least one clinical visit during 2014, represented by a reported viral load, CD4, or genotype test (25). Individuals were classified as having suppressed viral loads if their most recent viral load test during 2014 was undetectable or had a result of less than 200 copies/ml. Those without a viral load test during 2014 were included in the dataset but excluded from the regression analyses.

Geographic Data - The address of residence for each PDLWH was standardized, geocoded, and verified against the database of U.S. Postal Service registered addresses using the subscription service geocoder from Melissa Data (26). Resulting latitude and longitude for point locations were spatially merged with a polygon data file of California census tracts to determine census tract of residence. All geographic data were projected using the California (Teale) Albers North American Datum 1983.

Community SDH characteristics were derived from American Community Survey 2010—2014 5-year estimate using census tract-level data from the U.S. Census Tigerline Shape Files for geographic characteristics. We calculated community-based risk level (CBRL) quintiles for the following seven census tract characteristics: percent of residents living in households with incomes lower than the federal poverty line within the 12 months prior to the survey response, median household income, population density(population/square kilometer), percent of residents with less than a high school diploma or equivalent, percent of residents without health insurance, percent of workforce-eligible residents ages 16 years and older who were unemployed, and percent of residents without household access to a privately-owned vehicle (24).

For characterizing urbanicity of census tracts, we used the U.S. Department of Agriculture Rural-Urban Commuting Area (RUCA) classification system based on data from the 2010 decennial Census and American Community Survey to classify census tracts along a spectrum ranging from urban core to isolated rural (27). Specifically, we used the consolidation scheme proposed by the Washington State Department of Health, which combines the RUCA codes into four categories: Urban Core, Sub-Urban, Large Rural Town, and Small Town/Isolated Rural Area (28) (this will henceforth be referred to as CRUCA). This is an appropriate measure of urbanicity because it includes information on commuting patterns when categorizing the census tracts.

Statistical Analysis - We used chi square goodness-of-fit tests to determine whether the residences of PDLWH were equally distributed among the quintiles for each SDH category, population density, and urbanicity. Analyses were conducted separately for all PDLWH, only those in care, and only those with a suppressed viral load. We then calculated crude prevalence ratios for unsuppressed viral load among the PDLWH with viral load results using separate log-binomial models for each social determinant of health, population density, and urbanicity. We then re-estimated these models after adjusting for gender, race/ethnicity, transmission risk category, and age. Years since diagnosis was also considered as a potential covariate, but was ultimately not found to be a significant confounder. Individual demographic and outcome variables from the surveillance dataset were created using SAS © version 9.4 (29). The spatial dataset was created and all merges and analyses were performed using R version 3.3.1 (30).

Results

Among the 118,842 non-institutionalized, non-homeless PDLWH in California as of December 31, 2014, 60,979 (51%) had residential addresses that were determined to be current, were successfully validated and geocoded, and were therefore included in the analyses (Table 1). There were 12,634 (11%) PDLWH who had residential addresses in the CHSS that were not valid because of an invalid address number, street name, city, or zip code, and could therefore not be geocoded or included in the analyses. An additional 45,229 (38%) PDLWH were excluded because they had an out-of-date residential address in the CHSS (i.e., the address did not meet one of the three criteria described earlier).

The distributions of PDLWH with current/valid addresses were similar to those with current/invalid addresses and out-of-date addresses with regard to gender, race/ethnicity, and age (Table 1). However, a slightly higher percentage of PDLWH who had current/valid addresses were in the male to male sexual contact (MSM) transmission category (69%) than was the case among PDLWH who had current/invalid addresses (64%). There were substantial differences in the distributions of PDLWH who had current/valid, current/invalid, and out-of-date addresses across the categories of years since diagnosis, in care status, and viral load suppression. Specifically, higher percentages of PDLWH who had current/invalid addresses (84%) or out-of-date addresses (84%) were more than 5 years removed from diagnosis compared to those having current/valid addresses (76%). Eighty-five percent of PDLWH with a current/valid address were in care compared to 81% of those with a current/invalid address, and 41% of PDLWH with an out-of-date address. PDLWH who had current/invalid addresses (81%) or out-of-date addresses (41%) were less likely to be in care than those with current/valid addresses (85%), and they were also more likely to have unknown viral suppression status (26% and 62% versus 20%, respectively). People with current/valid addresses were also more likely to have be virally suppressed (71%) compared to those with current/invalid addresses (65%) and out-of-date addresses (32%).

Californians diagnosed living with HIV were more likely to live in higher CBRL quintile census tracts for most SDH measures (Table 2). Specifically, PDLWH were more likely to reside in CBRL quintile census tracts with a higher percent of residents below poverty (10% in quintile 1 versus 27% in quintile 5, p-value < 0.001), lower household median income (14% in quintile 1 versus 28% in quintile 5, p-value < 0.001), a higher percent of residents without health insurance (13% in quintile 1 versus 27% in quintile 5, p-value < 0.001), a higher percent of unemployed residents (17% in quintile 1 versus 22% in quintile 4, p-value < 0.001), and lower household access to a vehicle (p < 0.001). The only exception was with regard to the percent of residents with less than a high school diploma, for which the PDLWH were not distributed significantly differently than the expected distribution among CBRL quintiles. PDLWH were also more likely to live in higher population density census tracts (44% in quintile 1 versus 8% in quintile 5, p < 0.001) and 97% of PDLWH live in urban-center census tracts compared to sub-urban (2%) or rural census tracts (<1%, p-value < 0.001).

Overall, 51,907 (85%) of the 60,979 PDLWH with current/valid addresses were in care and 43,298 (71%) had a suppressed viral load (Table 2). The percentages of PDLWH who were in care were consistent across CBRL quintile census tracts for all SDH measures and population density, ranging from 82% to 87% for all categories. The one exception was for urban/rural classification, where 85% of PDLWH living in the urban center category were in care, compared to 82% in the sub-urban category, 73% in large rural town category, and 71% in the small town/isolated category (p-value = 0.02). Although in care status was high and consistent across all the CBRL SDH measures, viral suppression was not. Specifically, PDLWH with suppressed viral load were significantly less likely to live in CBRL quintile census tracts with a higher percent of residents below poverty (75% in quintile 1 versus 67% in quintile 5, p-value < 0.001), lower household median income (76% in quintile 1 versus 68% in quintile 5, p-value < 0.001), a higher percent of residents without a high school diploma (76% in quintile 1 versus 66% in quintile 5, p-value < 0.001), and a higher percent of residents without health insurance (76% in quintile 1 versus 68% in quintile 4, p-value < 0.001). The percentages of virally suppressed PDLWH were not significantly different across SDH quintiles for unemployment and household access to a privately owned vehicle. In addition, PDLWH with suppressed viral load were significantly more likely to live in CBRL quintile census tracts with a higher population density (71% in quintile 1 versus 68% in quintile 5, p-value < 0.001) and an urban center classification (71% in urban-center tracts versus 53% in small town/isolated tracts, p-value < 0.001).

Because 12,078 (20%) of the 60,979 PDLWH with current/valid addresses were missing viral load results in 2014, the crude (bivariate) and adjusted prevalence ratio models were estimated among only the 48,901 (80%) PDLWH with current/valid addresses who also had viral load results. After adjusting for differences in gender, race/ethnicity, transmission risk category, and age, PDLWH who have unsuppressed viral loads were more likely to live in higher CBRL quintile census tracts for all of the SDH measures except percent of households without access to a vehicle (Table 3). Furthermore, the increases in unsuppressed viral load prevalence were monotonic across the CBRL quintile census tracts for all these SDH measures except unemployment. Specifically, the prevalence of unsuppressed viral load among PDLWH generally increased as function of census tract poverty, ranging from 25% higher in quintile 3 (prevalence ratio [PR] = 1.25; 95%

confidence interval [95% CI]: 1.10, 1.41) to 69% higher in quintile 5 (PR = 1.69; 95% CI: 1.51, 1.90). Similarly, the prevalence of unsuppressed viral load among PDLWH increased as function of lower median household income, ranging from 23% higher in quintile 2 (PR = 1.23; 95% CI: 1.09, 1.39) to 78% higher in quintile 5 (PR = 1.78; 95% CI: 1.60, 1.98). Unsuppressed viral loads also increased as a function of census tract percent of residents with less than a high school diploma, ranging from 22% higher in quintile 2 (PR = 1.22; 95% CI: 1.10, 1.36) to 73% higher in quintile 5 (PR = 1.73; 95% CI: 1.57, 1.91). Finally, higher census tract percent of residents without health insurance was also monotonically related to higher prevalence of unsuppressed viral load among PDLWH, ranging from 19% higher in quintile 2 (PR = 1.19; 95% CI: 1.05, 1.34) to 65% higher in quintile 5 (PR = 1.65; 95% CI: 1.47, 1.84). Although unemployment was not monotonically related to higher prevalence of unsuppressed viral load, those who lived in census tracts in the highest unemployment quintile had 19% higher prevalence of unsuppressed viral load compared to the lowest quintile (PR = 1.19; 95% CI: 1.08, 1.31). Interestingly, the prevalence of unsuppressed viral load was 13% lower for PDLWH who lived in census tracts with a higher percentage of residents without access to a vehicle (PR = 0.87; 95% CI: 0.80, 0.94). Population density and CRUCA were not related to unsuppressed viral load prevalence in any systematic manner in the adjusted model, with the exception that the prevalence of unsuppressed viral load was 9% lower among PDLWH in quintile 2 of population density than those living in quintile 1 (PR = 0.91, 95% CI: 0.84, 0.98).

Discussion

This analysis sought to describe the distribution of Californians diagnosed living with HIV in the context of community SDH characteristics and to determine if CBRL measures for neighborhood of residence were associated with unsuppressed viral load, a measure associated with successful HIV disease management. We found that higher percentages of PDLWH in California lived in higher CBRL quintile census tracts for all of the selected SDH measures except percent of residents with less than a high school diploma. Consistent with previous literature, PDLWH in California were more likely to live in census tracts with higher percentages of people in households with income below poverty, without health insurance, and in areas with comparatively low median incomes (24). Californian PDLWH also reside predominantly in densely populated, urban areas which is consistent with previous findings in the United States (31). It is important to note that while less than 5% of PDLWH live in non-urban center census tracts, this represents nearly 2000 among only PDLWH in California with addresses, which is a higher HIV prevalence than in fourteen U.S. states.

Residents of higher CBRL quintile census tracts had significantly higher prevalence of unsuppressed viral load compared to the lowest CBRL quintile tracts. The odds of PDLWH having a unsuppressed viral load significantly increased monotonically as CBRL quintiles increased for percent of population below poverty, lower median household income, percent of the population with less than a high school diploma, and percent of the population without health insurance. Only very the highest unemployment quintile was associated with higher prevalence of unsuppressed viral load. The measures for percent of households without access to a vehicle showed a marginally protective effect, as the prevalence of unsuppressed viral load was lower among those in census tracts with greater than average percent of households without access to a vehicle. No systematic relationship was found between unsuppressed viral load prevalence and population density or CRUCA urban/rural classification, after adjusting for demographic and risk factors. Overall, these findings indicate that there is an association between community level SDH and poorer HIV health outcomes as measured by unsuppressed viral load.

This association was evident using a dataset of only PDLWH with a current, valid address recorded in the CHSS. Address information is typically updated in the CHSS from laboratory reports; therefore not having a current address is an indicator for not having had a recent care visit. Given that having a laboratory test reported to the CHSS is an indicator that an individual is in care, and viral load tests are ordered as part of standard care, it was expected that individuals with current and valid addresses were more likely to be in care and have viral load results. Indeed this appeared to be the case given that 71% of the 2014 PDLWH with a current/valid address had a suppressed viral load versus 65% of those with a current/invalid address, and 32% of those with an out-of-date address. With improved collection of residential address information on people who are out of care, we hypothesize that there may be an even stronger association found between higher CBRL quintile census tracts and prevalence of unsuppressed viral load.

Because this is a cross-sectional, ecological analysis, the results should be interpreted with caution; it cannot be determined from this study whether living in a community with lower SDH is causing poorer HIV health outcomes. To help determine the causal nature of the association found in the present study, future research should analyze longitudinal data including residential relocation patterns to determine if disease outcomes change for those moving into higher or lower SDH areas. Future analysis should also examine interactions between individual and SDH characteristics, as well as interactions and collinearity among SDH measures. If such interactions exist, which is likely, they may indicate areas where systemic interventions could be especially efficient for improving care outcomes. Finally, generalizations from the present analysis may be hindered by the fact that PDLWH without a current, valid residential address were excluded, which was a substantial percentage (49%) of the original sample. In order to better represent the entire population of PDLWH in terms of community SDH, future efforts should seek to obtain current and valid residential address information from sources external to the HIV surveillance system for individuals with out-of-date or invalid addresses. For example, other U.S. HIV surveillance programs have used commercial external address locator services to improve address information for PDLWH. The use of these in future efforts is recommended; the cost of these services was prohibitive for the present effort.

Several limitations should be considered when interpreting these results. Current, valid address information was not available for 49% of the PDLWH, which likely biased the results toward people who were in care and therefore who were likely to have better disease outcomes. Forty-one percent of PDLWH in California with an out-of-date address in the CHSS were characterized as being in care, while roughly one-third had suppressed viral loads. This is significantly fewer compared with PDLWH who have a current/valid address, or even those with a current/invalid address. This discrepancy suggests that, while informative, the present analysis likely missed those at highest risk for poorer HIV health outcomes. The measure of suppressed viral load may also be underreported because while HIV viral load tests were required to be reported by California statute, some laboratory results may not have been reported to the CHSS. However, the extent to which this occurs is expected to decrease in the future as an increasing number of laboratories report electronically to OA. This is also expected to improve the recency and completeness of address information for PDLWH in California.

We used quintiles to delineate different levels of SDH. If census tract SDH characteristics cluster in meaningful ways relevant to the present analysis, this method may mask important differences by moderating distinctions. There may be better ways to characterize socioeconomic characteristics of geographic units according to pertinent features (such as where tract characteristics cluster in percentage of population below poverty). Census tract of residence is used as a proxy for neighborhood/environmental influences on disease outcomes, but may not correctly represent neighborhood boundaries and therefore may miss critical influences on disease outcomes related to people's' environments (32). Census block groups represent smaller geographic areas and therefore may better represent neighborhood characteristics, especially in areas with heterogeneous populations with respect to SDH characteristics; however, we elected to use census tracts because American Community Survey estimates are more stable for tracts compared to block groups. In addition, place of residence may not accurately represent SDH/community barriers to having suppressed viral load if an individual commutes to work regularly and seeks care near to the location of employment. We chose to use CRUCA as an urban/rural classification scheme to account for this, however having residential and work locations would provide a better measure of care access. Discerning contextual or interactive effects between individual factors and SDH factors is an important facet to explore, but we deemed this to be beyond the scope of the current study.

This is the first analysis of PDLWH residential address distribution among community SDH characteristics in California. It is also the first analysis of suppressed viral load as a function of SDH characteristics in a large geographic area using a high level of spatial definition with a diverse population of PDLWH. We anticipate that the recent adoption of electronic laboratory reporting in California will substantially increase the number of cases in the CHSS that have current and valid address information. This will allow for greater representation of the population at higher risk for poor HIV disease outcomes and increase our knowledge of where to mobilize care resources. This and future analyses will allow state and local health jurisdictions in California to focus resources on geographic areas with high CBRL and disproportionately high percentages of PDLWH with unsuppressed viral load or who are out of care.

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Tables

Table 1: Address-type distribution among persons diagnosed and living with HIV[1] by demographic characteristic and continuum of care measures: California, 2014

Characteristic or Care Indicator	Current[2], Valid Address n (%)	Current, Invalid[3] Address n (%)	Out-of-date Address n %	Total People Living with HIV n (%)
Gender				
Male	52,926 (87)	10,887 (86)	39,646 (88)	103,459 (87)
Female	7,414 (12)	1,635 (13)	5,004 (11)	14,053 (12)
Transgender: Male-to-Female	622 (1)	107 (<1)	568 (1)	1,297 (1)
Transgender: Female-to-Male	15 (<1)	5 (<1)	10 (<1)	30 (<1)
Alternative designation	2 (<1)	0 (<1)	1 (<1)	3 (<1)
Race/Ethnicity[4]				
Hispanic/Latino	21,853 (36)	3,978 (32)	14,176 (32)	40,007 (34)
American Indian/Alaska Native	184 (<1)	61 (<1)	190 (<1)	435 (<1)
Asian and Asian Pacific Islander	2,552 (4)	407 (3)	1,432 (3)	4,391 (4)
Black/African American	10,297 (17)	2,316 (19)	8,492 (19)	21,105 (18)
White	24,969 (42)	5,658 (45)	20,114 (45)	50,741 (43)
Native Hawaiian/Other Pacific Island	139 (<1)	35 (<1)	117 (<1)	291 (<1)
Multiple Races	980 (2)	179 (1)	702 (2)	1,861 (2)
Unknown Race	5 (<1)	0 (<1)	6 (<1)	11 (<1)
Age in Years (at end of 2014)				
13-18	112 (<1)	30 (<1)	71 (<1)	213 (<1)
19-24	1,199 (2)	219 (2)	721 (2)	2,139 (2)
25-34	7,687 (13)	1,192 (10)	5,187 (12)	14,066 (12)
35-44	12,301 (20)	2,449 (20)	8,839 (20)	23,589 (20)
45-54	21,858 (36)	4,672 (37)	16,575 (37)	43,105 (37)
55-64	13,418 (22)	3,045 (24)	10,196 (23)	26,659 (23)
65-74	3,739 (6)	884 (7)	3,042 (7)	7,665 (7)
75+	665 (1)	143 (1)	598 (1)	1,406 (1)
Transmission Category[5]				
Male-to-male sexual contact (MSM)	41,378 (69)	7,942 (64)	29,244 (66)	78,564 (67)
Injection drug use (IDU)	3,383 (6)	1,085 (9)	3,526 (8)	7,994 (7)
MSM and IDU	4,090 (7)	976 (8)	3,890 (9)	8,956 (8)
High-risk heterosexual contact	5,795 (10)	1,399 (11)	3,699 (8)	10,893 (9)
Perinatal	273 (<1)	86 (<1)	206 (<1)	565 (<1)
Heterosexual contact (non-high-risk)	3,476 (6)	672 (5)	2,408 (5)	6,556 (6)
Unknown risk	2,378 (4)	418 (3)	2,087 (5)	4,883 (4)
Other	206 (<1)	56 (<1)	169 (<1)	431

1 Persons living with HIV at the end of 2014.

2 Current address is an address reported to the California HIV surveillance system (CHSS) from a document (case report form, laboratory report, or death report) during 2013-2014, an address reported prior to 2013, but there were documents that did not include address reported to the CHSS during 2013-2014, or an address reported after 2014 that confirmed the address on the CHSS record that would have otherwise been considered out-of-date.

3 Invalid addresses include addresses recorded with non-existent building numbers, streets, city, or zip codes.

4 Hispanic/Latino(a) persons can be of any race. Race/ethnicity was collected using Asian/Native Hawaiian/Pacific Islander as a single category until 2003; therefore cases reported prior to 2003 are classified as Asian above because they cannot be disaggregated.

5 High-risk Heterosexual contact includes persons who reported engaging in heterosexual intercourse with a person of the opposite sex of their sex-at-birth, and that partner was known to be HIV positive or engage an activity that put them at high risk for HIV (e.g., MSM, IDU). Heterosexual contact (non-high-risk) includes persons with no other identified risk who reported engaging in heterosexual intercourse with a person of the opposite sex of their sex-at-birth. Perinatal includes persons who were exposed immediately before, during, or after birth due to breastfeeding. 'Other' risk includes having hemophilia, receiving a blood transfusion, or experiencing an occupational exposure.

Table 1 (continued): Address-type distribution among persons diagnosed and living with HIV[1] by demographic characteristic and continuum of care measures: California, 2014

Characteristic or Care Indicator	Current[2], Valid Address n (%)	Current, Invalid[3] Address n (%)	Out-of-date Address n %	Total People Living with HIV n (%)
Years since diagnosis				
More than 5 years	46,070 (76)	10,670 (84)	37,923 (84)	94,663 (80)
3-5 years	8,735 (14)	1,180 (9)	4,932 (11)	14,847 (12)
1-2 years	6,174 (10)	784 (6)	2,374 (5)	9,332 (8)
Continuum of Care Indicators				
In care	51,907 (85)	10,179 (81)	18,501 (41)	80,587 (68)
Not in care	9,072 (15)	2,455 (19)	26,728 (59)	38,255 (32)
Unsuppressed viral load	5,603 (9)	1,109 (9)	2,912 (6)	9,624 (8)
Supressed viral load	43,298 (71)	8,186 (65)	14,371 (32)	65,855 (55)
Unknown viral load suppression statu	12,078 (20)	3,339 (26)	27,946 (62)	43,363 (36)
Total	**60,979 (51)**	**12,634 (11)**	**45,229 (38)**	**118,842 (100)**

1 Persons living with HIV at the end of 2014.

2 Current address is an address reported to the California HIV surveillance system (CHSS) from a document (case report form, laboratory report, or death report) during 2013-2014, an address reported prior to 2013, but there were documents that did not include address reported to the CHSS during 2013-2014, or an address reported after 2014 that confirmed the address on the CHSS record that would have otherwise been considered out-of-date.

3 Invalid addresses include addresses recorded with non-existent building numbers, streets, city, or zip codes.

4 Hispanic/Latino(a) persons can be of any race. Race/ethnicity was collected using Asian/Native Hawaiian/Pacific Islander as a single category until 2003; therefore cases reported prior to 2003 are classified as Asian above because they cannot be disaggregated.

5 High-risk Heterosexual contact includes persons who reported engaging in heterosexual intercourse with a person of the opposite sex of their sex-at-birth, and that partner was known to be HIV positive or engage an activity that put them at high risk for HIV (e.g., MSM, IDU). Heterosexual contact (non-high-risk) includes persons with no other identified risk who reported engaging in heterosexual intercourse with a person of the opposite sex of their sex-at-birth. Perinatal includes persons who were exposed immediately before, during, or after birth due to breastfeeding. 'Other' risk includes having hemophilia, receiving a blood transfusion, or experiencing an occupational exposure.

Table 2: Census tract of residence social determinants of health, population density, and urbanicity of people diagnosed and living with HIV with current[2]/valid[3] addresses by continuum of care measures California, 2014

Census Tract Characteristic	People Living with HIV[1] n (%)	In Care[4] n (%)	Suppressed Viral Load[5] n (%)
Percent of residents living in households with income below poverty			
Quintile 1 (0-6.2)	6,379 (10)	5,554 (87)	4,784 (75)
Quintile 2 (6.2-10.6)	10,652 (17)	9,219 (87)	8,000 (75)
Quintile 3 (10.6-16.6)	13,588 (22)	11,446 (84)	9,649 (71)
Quintile 4 (16.6-26.1)	14,160 (23)	12,037 (85)	9,966 (70)
Quintile 5 (26.1-100)	16,200 (27)	13,651 (84)	10,899 (67)
Median household income			
Quintile 1 ($90,700-250,000)	8,570 (14)	7,466 (87)	6,541 (76)
Quintile 2 ($68,000-90,700)	10,988 (18)	9,236 (84)	7,861 (72)
Quintile 3 ($52,700-68,000)	11,834 (19)	10,176 (86)	8,590 (73)
Quintile 4 ($39,500-52,700)	12,655 (21)	10,761 (85)	8,856 (70)
Quintile 5 (0-39,500)	16,932 (28)	14,268 (84)	11,450 (68)
Population Density (population per square kilometer)			
Quintile 1 (4,750-62,400)	26,999 (44)	22,857 (85)	19,287 (71)
Quintile 2 (2,980-4,750)	13,147 (22)	11,374 (87)	9,454 (72)
Quintile 3 (1,850-2,980)	8,632 (14)	7,410 (86)	6,107 (71)
Quintile 4 (682-1,850)	7,417 (12)	6,314 (85)	5,214 (70)
Quintile 5 (0-682)	4,784 (8)	3,952 (83)	3,236 (68)
Percent Less than high school diploma			
Quintile 1 (0-18.4)	13,999 (23)	12,107 (86)	10,696 (76)
Quintile 2 (18.4-29.4)	10,613 (17)	9,165 (86)	7,718 (73)
Quintile 3 (29.4-41.9)	10,366 (17)	8,859 (85)	7,369 (71)
Quintile 4 (41.9-57.4)	12,809 (21)	10,901 (85)	8,798 (69)
Quintile 5 (57.4-100)	13,192 (22)	10,875 (82)	8,717 (66)
Percent having no health insurance			
Quintile 1 (0-7.6)	7,794 (13)	6,744 (87)	5,909 (76)
Quintile 2 (7.6-12.4)	10,500 (17)	9,080 (86)	7,708 (73)
Quintile 3 (12.4-17.7)	12,014 (20)	10,254 (85)	8,607 (72)
Quintile 4 (17.7-24.6)	14,157 (23)	11,833 (84)	9,623 (68)
Quintile 5 (24.6-65.5)	16,514 (27)	13,996 (85)	11,451 (69)
Urban/Rural Classification (CRUCA)			
Urban center	59106 (97)	50407 (85)	42070 (71)
Sub-urban	1489 (2)	1224 (82)	1015 (68)
Large rural town	165 (<1)	120 (73)	96 (58)
Small town/isolated	219 (<1)	156 (71)	117 (53)
Percent unemployed residents age 16 and older			
Quintile 1 (0-4.3)	10,216 (17)	8,377 (82)	7,050 (69)
Quintile 2 (4.3-5.8)	10,777 (18)	9,271 (86)	7,836 (73)
Quintile 3 (5.8-7.4)	13,906 (23)	11,956 (86)	10,092 (73)
Quintile 4 (7.4-9.6)	13,224 (22)	11,318 (86)	9,455 (71)
Quintile 5 (9.6-100)	12,856 (21)	10,985 (85)	8,865 (69)
Percent of households without access to a vehicle			
Greater than mean plus 1 SD	9,511 (16)	8,165 (86)	6,944 (73)
Less than mean plus 1 SD	51,468 (84)	43,742 (85)	36,354 (71)
Total	**60,979 (100)**	**51,907 (85)**	**43,298 (71)**

1 Persons diagnosed and living with HIV at the end of 2014 having evidence a recent, valid address in the California HIV surveillance system

2 Current address is an address reported to the California HIV surveillance system (CHSS) from a document (case report form, laboratory report, or death report) during 2013-2014, an address reported prior to 2013, but there were documents that did not include address reported to the CHSS during 2013-2014, or an address reported after 2014 that confirmed the address on the CHSS record that would have otherwise been considered out-of-date.

3 Invalid addresses include addresses recorded with non-existent building numbers, streets, city, or zip codes.

4 Defined as at least one CD4, viral load, or genotype test performed during 2014.

5 Viral load test with collection date during 2014 and a result of undetectable or <200 copies/µL.

Table 3: Associations between unsuppressed HIV viral load and census tract of residence social determinants of health, population density, and urbanicity of of people living and diagnosed with HIV[1] with current[2]/valid addresses[3] and viral load results[4]: California, 2014

CensusTract Characteristic	Crude Model[5] PR[7] 95% CI	Adjusted Model[6] PR[7] 95% CI
Percent of residents living in households with income below poverty		
Quintile 1 (0-6.2)	Ref	Ref
Quintile 2 (6.2-10.6)	1.12 (0.98, 1.27)	1.08 (0.95, 1.23)
Quintile 3 (10.6-16.6)	1.37 (1.22, 1.55)	1.25 (1.1, 1.41)
Quintile 4 (16.6-26.1)	1.55 (1.38, 1.75)	1.30 (1.15, 1.46)
Quintile 5 (26.1-100)	2.27 (2.03, 2.54)	1.69 (1.51, 1.9)
Median household income		
Quintile 1 ($90,700-250,000)	Ref	Ref
Quintile 2 ($68,000-90,700)	1.35 (1.21, 1.52)	1.23 (1.09, 1.39)
Quintile 3 ($52,700-68,000)	1.51 (1.35, 1.69)	1.30 (1.16, 1.45)
Quintile 4 ($39,500-52,700)	1.75 (1.57, 1.96)	1.42 (1.27, 1.59)
Quintile 5 (0-39,500)	2.43 (2.19, 2.69)	1.78 (1.6, 1.98)
Population Density (population per square kilometer)		
Quintile 1 (4,750-62,400)	Ref	Ref
Quintile 2 (2,980-4,750)	0.89 (0.83, 0.96)	0.91 (0.84, 0.98)
Quintile 3 (1,850-2,980)	0.89 (0.81, 0.97)	0.93 (0.85, 1.02)
Quintile 4 (682-1,850)	0.83 (0.76, 0.91)	0.94 (0.86, 1.04)
Quintile 5 (0-682)	0.85 (0.76, 0.95)	0.91 (0.81, 1.02)
Percent Less than high school diploma		
Quintile 1 (0-18.4)	Ref	Ref
Quintile 2 (18.4-29.4)	1.35 (1.22, 1.49)	1.22 (1.1, 1.36)
Quintile 3 (29.4-41.9)	1.61 (1.46, 1.77)	1.31 (1.19, 1.45)
Quintile 4 (41.9-57.4)	2.06 (1.88, 2.25)	1.57 (1.43, 1.73)
Quintile 5 (57.4-100)	2.31 (2.11, 2.52)	1.73 (1.57, 1.91)
Percent having no health insurance		
Quintile 1 (0-7.6)	Ref	Ref
Quintile 2 (7.6-12.4)	1.34 (1.19, 1.5)	1.19 (1.05, 1.34)
Quintile 3 (12.4-17.7)	1.40 (1.25, 1.57)	1.21 (1.08, 1.36)
Quintile 4 (17.7-24.6)	1.83 (1.64, 2.04)	1.43 (1.28, 1.6)
Quintile 5 (24.6-65.5)	2.18 (1.96, 2.42)	1.65 (1.47, 1.84)
Urban/Rural Classification (CRUCA)		
Urban center	Ref	Ref
Sub-urban	0.91 (0.74, 1.09)	0.95 (0.78, 1.15)
Large rural town	0.88 (0.45, 1.58)	0.85 (0.42, 1.54)
Small town/isolated	1.65 (1.05, 2.5)	1.48 (0.93, 2.27)

1 Persons living with HIV at the end of 2014.

2 Current address is an address reported to the California HIV surveillance system (CHSS) from a document (case report form, laboratory report, or death report) during 2013-2014, an address reported prior to 2013, but there were documents that did not include address reported to the CHSS during 2013-2014, or an address reported after 2014 that confirmed the address on the CHSS record that would have otherwise been considered out-of-date.

3 Invalid addresses include addresses recorded with non-existent building numbers, streets, city, or zip codes.

4 12,078 PLWH with recent/valid addresses were excluded due to missing viral load results (included n = 48,901)

5 Crude model: non-suppressed viral load = social determinant of health factor (SDH).

6 Adjusted model: non-suppressed viral load = SDH factor + gender + race/ethnicity + mode of transmission + age category.

7 Prevalence Ratio

Table 3 (continued): Associations between unsuppressed HIV viral load and census tract of residence social determinants of health, population density, and urbanicity of of people living and diagnosed with HIV[1] with current[2]/valid addresses[3] and viral load results[4]: California, 2014

Census Block Group/Tract Characteristic	Crude Model[5] PR[7] 95% CI	Adjusted Model[6] PR[7] 95% CI
Percent unemployed residents age 16 and older		
Quintile 1 (0-4.3)	Ref	Ref
Quintile 2 (4.3-5.8)	0.97 (0.88, 1.08)	0.98 (0.89, 1.09)
Quintile 3 (5.8-7.4)	1.06 (0.97, 1.17)	1.02 (0.93, 1.13)
Quintile 4 (7.4-9.6)	1.14 (1.04, 1.26)	1.02 (0.93, 1.13)
Quintile 5 (9.6-100)	1.45 (1.32, 1.59)	1.19 (1.08, 1.31)
Percent of households without access to a vehicle		
Greater than mean plus 1 SD	Ref	Ref
Less than mean plus 1 SD	0.86 (0.79, 0.93)	0.87 (0.8, 0.94)

1 Persons living with HIV at the end of 2014.

2 Current address is an address reported to the California HIV surveillance system (CHSS) from a document (case report form, laboratory report, or death report) during 2013-2014, an address reported prior to 2013, but there were documents that did not include address reported to the CHSS during 2013-2014, or an address reported after 2014 that confirmed the address on the CHSS record that would have otherwise been considered out-of-date.

3 Invalid addresses include addresses recorded with non-existent building numbers, streets, city, or zip codes.

4 12,078 PLWH with recent/valid addresses were excluded due to missing viral load results (included n = 48,901)

5 Crude model: non-suppressed viral load = social determinant of health factor (SDH).

6 Adjusted model: non-suppressed viral load = SDH factor + gender + race/ethnicity + mode of transmission + age category.

7 Prevalence Ratio

Chapter 3: Estimated trip duration from residence to care facility by individual and neighborhood characteristics for People Living with HIV in California, 2014.

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Abstract

Background: Among the factors that contribute to sub-optimal HIV treatment and disease outcomes, proximity to accommodating, affordable, and acceptable providers of HIV care is a key social/community-based factor for PDLWH. A greater understanding of how proximity influences care provider choice is crucial for public health departments to effectively use limited resources for the greatest public health impact.

Methods: We used California HIV Surveillance System (CHSS) data to describe trip duration of PLDWH from place of residence to care provider. We characterized geometric mean trip duration (GMTD) using a pessimistic traffic model to reflect real-world travel duration. We modeled GMTD and viral load suppression as a function individual demographic, clinical, residential community social determinants of health (SDH), urbanicity, and population density characteristics.

Results: 10,451 PDLWH included in our analysis had a GMTD of 20.7 minutes. We found significantly shorter GMTD among higher risk census tract quintiles for percent below poverty and median income, while controlling for population density. We also found higher GMTD as population density decreased and in large rural towns and sub-urban areas compared to urban core areas. We found little association between GMTD and unsuppressed viral load.

Conclusions: This work represents the first state-wide analysis of residence to care trip duration and how it is associated with HIV disease outcomes. It will be necessary to analyze trip duration within socio-economic strata to elucidate findings from which public health departments can intervene. Because of the extent of missing data, this analysis provides a framework for future analyses of GMTD and HIV disease outcomes.

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Background

Advances in HIV care and treatment continue to prolong the lives of people diagnosed and living with HIV (PDLWH) (1). Regular care and adherence to an antiretroviral (ARV) regimen have been shown to contribute to viral load suppression, increased survival for PDLWH, and decreased likelihood of transmitting the virus to others (2–5). The National HIV/AIDS Strategy has mobilized national, state, and local efforts toward ensuring equitable access to care, reducing disparities, and improving HIV continuum of care outcomes (diagnosis, retention in regular medical care, prescription of ARV, and viral suppression) to prevent HIV transmission (6). However, among people who were aware of their HIV infection, only an estimated 45% of PDLWH in the U.S. and 49% of PDLWH in California (7,8) are retained in regular HIV care. There are a number of individual and structural barriers to achieving regular care including poverty, unemployment, ability to pay for care with either health insurance or other means, intimate partner violence, unstable housing, food insecurity, and lack of access to transportation (6,9,10). Previous research has shown differences in HIV disease outcomes by race/ethnicity, gender, age, and community-based characteristics (2,11–14).

Among the factors that contribute to sub-optimal HIV treatment and disease outcomes, proximity to accommodating, affordable, and acceptable providers of HIV care (15) is a key social/community-based factor for PDLWH, all of whom require regular visits to a medical provider. Proximity to HIV care is associated with engagement and retention in care (2,16). How people select a care facility and why people miss care appointments are complex behavioral phenomena and can be influenced by both individual preferences and external factors, such as ability to pay and transportation availability among others (13,15,17,18). A greater understanding of how proximity to facilities influences care provider choice may help public health departments determine the optimal distribution and characteristics of HIV care providers in order to have the greatest public health impact.

Most research studies regarding factors associated with care provider choices have used data from very large samples with low geographic resolution (2,3,19–21), or have used data for small, relatively homogenous geographic areas which may not be representative of other areas of the country (17,19,22–24). Additionally, proximity to care has most often been characterized using Euclidean or "as the crow flies" distances–either using exact points representing origin and destination, or approximate locations such as using residential and care facility zip code or census tract centroid locations (14,25,26). Research in the U.S. using road networks to calculate travel distance or trip duration from places of residence to HIV care facilities is limited. Road network analysis better reflects real-world distance or travel duration, especially in a heterogeneous study area with respect to population density and other factors that influence travel time. Using trip duration, rather than distance makes it easier to combine different categories of urbanicity in one analysis. While people in rural areas tend to driver farther, road speeds are generally faster; whereas people in urban areas have less distance to cover, but they often have to contend with slower road speeds and traffic (27).

The present study uses California HIV Surveillance System (CHSS) data to describe the trip duration of PLDWH from place of residence to facility of HIV care in terms of individual demographic and clinical characteristics, and residential community social determinants of health (SDH), urbanicity, and population density characteristics. We characterize trip duration using road network data and a pessimistic traffic model to better reflect real-world travel duration times. Using geocoded residential addresses allows for analysis at a significantly higher resolution than has been previously published for PDLWH.

This study presents the first state-wide analysis of trip duration applied to a heterogeneous sample with respect to a number of factors including population density, HIV morbidity, and demographic makeup. We examine whether trip duration is associated with viral suppression, a measure of successful HIV disease management and an indirect measure of engagement in care. The results of this analysis will enhance the ability of health departments and policymakers to effectively allocate HIV care resources to individuals and geographic areas at the highest risk for poor HIV disease outcomes.

We primarily follow the community SDH framework used by the Centers for Disease Control and Prevention (CDC) in that we characterize census tracts according to their population percent below poverty, median income, percent with less than a high school diploma, percent with public or no health insurance, percent unemployed, and percent without vehicle ownership (9). This study covers a large and diverse geographic area, including several of the largest metropolitan areas in the U.S. and a number of medium and low population density cities. For this reason, we elected to also include measures of population density and urbanicity of community of residence.

Methods

Data Source and Study Population: The state of California has conducted confidential, name-based HIV surveillance since 2006, and name-based AIDS surveillance since March 1983. Surveillance data collection methods in California have been described in greater detail previously (11). This study included people aged 13 and older who were diagnosed with HIV on or before December 31, 2014, alive and living in California as of this date, reported to CHSS on or before December 31, 2015, and had no evidence reported to the

CHSS that their current residence is in an institutionalized setting (e.g., a prison or hospital) or homeless.

We used best available evidence of address of residence recorded in CHSS as of December 31, 2014. Address information for PDLWH in California was collected in the CHSS from case report forms (CRF) completed at diagnosis, when there were changes in disease status, or at other times when updated demographic or location information were available. CHSS also collects address information from laboratory reports from diagnostic and clinical tests. For the purpose of this study, all addresses for PDLWH that did not have at least one document (e.g., CRF, laboratory report, death report) added to CHSS within the 12 months prior to December 31, 2014 were considered not current. However, PDLWH with out-of-date addresses were included if CHSS received at least one laboratory document or adult case reporting form (CRF) in 2013 or 2014, indicating that the individual was likely in care. Addresses were geocoded and validated against the database of U.S. Postal Service registered addresses using the subscription service geocoder from Melissa Data (28). For residential addresses that were out of range (for example having a 1700 house number on a street that ended on the 1500 block) and therefore could only be geocoded to a zip code, we used the population-weighted centroid location of the zip code to estimate residential location for the purpose of determining trip duration to care facility (29).

The study population was limited to PDLWH with current, valid, and geocoded residential addresses that had a report of a laboratory test during 2014 that identified a care provider with a valid, geocoded address. We also excluded all individuals who were newly diagnosed with HIV during 2014 because measures for care status is determined differently and there was insufficient observation time to correctly classify individuals as attaining viral suppression. We included only PDLWH for whom both the residence and care facility could be resolved to valid, geocoded addresses or zip codes. Finally, in many local jurisdictions, the address of the care facility is routinely recorded as the residential address for people who are homeless or whose residential address is unknown. To remove any potential bias due to such cases, we excluded any PDLWH that had calculated trip duration of fewer than 5 minutes.

Outcome Variables: We conducted two analyses; one with trip duration between the location of residence and the location of care facility as the dependent variable and one with viral suppression as the dependent variable. The trip duration between place of residence and facility of care was obtained through Google Distance Matrix API (30), which accounts for speed limits, traffic, and one-way streets to calculate travel time using a pessimistic traffic model. To protect confidentiality of residential location, we applied a random offset distance and randomly selected direction as a function of population density from 100-200 meters in high density areas, and 800-1000 meters in low density areas. The offset was only applied to calculate the travel duration from residence to facility of care; SDH characteristics of residential location were derived using exact residential location points. Individuals were classified as having suppressed viral loads if the result of their most recent viral load test during 2014 was undetectable or less than 200 copies/ml. Those without a viral load test during 2014 were classified as having a missing viral load status. People with missing viral load status were excluded from the regression analyses, but included in analyses comparing those with a viral load status against those without.

Individual-level Factors: We reported current gender, age, race/ethnicity, HIV transmission risk category, and number of years since diagnosis as of December 31st, 2014 for each

PDLWH in the dataset using standard classification schemes. The high-risk heterosexual contact transmission risk category includes persons who reported engaging in heterosexual intercourse with a person of the opposite sex of their sex-at-birth, if that partner was known to be HIV positive or engage an activity that put them at high risk for contracting HIV (e.g., injection drug use). The heterosexual contact (non-high-risk) transmission risk category includes persons with no other identified risk who reported engaging in heterosexual intercourse with a person of the opposite sex of their sex-at-birth. Perinatal includes persons who were exposed to HIV before, during, or after birth due to breastfeeding. “Other” risk includes persons with hemophilia, who received a blood transfusion, or who experienced an occupational exposure.

Community-level factors: To calculate SDH characteristics, non-offset point locations of residence were spatially merged with a California census tracts polygon data file. Community SDH characteristics were derived from American Community Survey 2010-2014 5-year estimate data using census tract-level data from the U.S. Census Tigerline Shape Files for geographic characteristics. We calculated community-based risk level (CBRL) quintiles for the following seven census tract characteristics: percent of residents living in households with incomes lower than the poverty line within the 12 months prior to the survey response, median household income, population density (population/square kilometer), percent of residents with less than a high school diploma or equivalent, percent of residents without health insurance, percent of workforce-eligible residents ages 16 years and older who were unemployed, and percent of residents without household access to a privately-owned vehicle (9).

For characterizing urbanicity of census tracts, we used the U.S. Department of Agriculture Rural-Urban Commuting Area (RUCA) classification system based on data from the 2010 decennial Census and American Community Survey to classify census tracts along the spectrum ranging from urban core to isolated rural (31). Specifically, we used the consolidation scheme proposed by the Washington State Department of Health, which combines the RUCA codes into four categories: Urban Core, Sub-Urban, Large Rural Town, and Small Town/Isolated Rural Area (32) (this will henceforth be referred to as CRUCA). This is a particularly appropriate measure of urbanicity because it is derived using information on commuting patterns when categorizing the census tracts.

Statistical Analysis: We found the distribution of trip duration from the random offset residential locations to the facility of care locations produced by the Google Distance Matrix pessimistic traffic model (30) to be skewed. Therefore we used geometric means and standard deviations for trip duration to characterize central tendency and dispersion, a transformation which caused the trip durations to more closely approximate normality. Crude linear regression models were used to estimate and compare trip duration across categories for each individual demographic characteristic, viral suppression status, social determinant of health, population density, and urbanicity measure. Population density for the census tract of residence was determined to be an important confounder and was therefore included as a covariate in all adjusted models. We then re-ran the models for all demographic characteristics and viral suppression status adjusting for gender, race/ethnicity, age group, transmission category, and a continuous measure of population density in the census tract of residence. Years since diagnosis was also considered as a potential covariate for this model, but was ultimately excluded because it was not found to be a significant confounder. Similarly, we re-ran the models for all social determinants of health, population density, and urbanicity adjusting for population density (population per square kilometer), gender, race/ethnicity, age group, and transmission category. Percent with less than a high school diploma, percent having no health insurance, and urban/rural classification (CRUCA), median household income, percent of unemployed residents age 16 and older, and percent of households with no access to a vehicle were assessed as potential confounders for these analyses, but ultimately rejected because they were highly correlated with each other. The intercept coefficients in all regression models, which indicate the log-transformed average duration for the referent category, along with the regression coefficient for each non-referent category, were re-transformed to yield meaningful results in minutes of trip duration. The p-values ($\alpha = 0.05$) reflect comparisons of the mean trip duration estimate for each non-referent category to that for the referent category. Finally, additional linear models were used to compare average trip duration between PDLWH having suppressed viral load versus unsuppressed viral load, and also between PDLWH with and without a reported viral load test in 2014. Viral load status was the outcome variable in these models, log-transformed trip duration, and community or individual category of interest were predictor variables; population density was included as a potential confounder, and an interaction term with viral load status and the SDH, community characteristic, or demographiccategory of interest was also included. Statistical significance was determined using the p-value associated with the interaction term, which indicates the significance of the effect of the variable of interest on the change in log of trip duration minutes associated with changing levels of viral load status.

Individual demographic and outcome variables from the surveillance dataset were created using SAS version 9.4 (33). The trip duration and geographic variable datasets were created and all analyses were performed using R version 3.3.1 (34).

Results

Among the 118,842 not institutionalized or homeless PDLWH in California as of December 31, 2014, 69,907 (59%) were not newly diagnosed during 2014, and had residential addresses that were determined to be current and were successfully validated and geocoded, or had valid zip codes (Table 1). There were 11,102 (9% of the total) PDLWH who had a lab test with a recorded provider with valid, geocoded addresses in CHSS. However, 651 (5.9%) of the 11,102 PDLWH were excluded from analysis because the trip durations between the offset residential locations and care facilities were less than 5 minutes, indicating likely institutional, unknown, or homeless addresses. This yielded a final sample of 10,451 PDWLH who had laboratory reports from 365 care providers.

The distributions of PDLWH with current/valid addresses were similar to those with only zip code available, those that were excluded because the short trip duration indicated likely institutional, unknown, or homeless address, and all PDLWH in California with regard to gender, race/ethnicity, and age (table 1). However, a higher percentage of PDLWH who had current/valid addresses were in the men who have sex with men (MSM) transmission category (72%) than was the case among PDLWH who had current/zip code-only addresses (67%), excluded (68%), and all PDLWH in California (66%). In addition, fewer PDLWH who had current/valid addresses and all PDLWH in California were in the more than 5 years since diagnosis category (80%) than was the case among PDLWH who had current/zip code-only addresses (85%). There were substantial differences in the distributions of viral load suppression among PDLWH who had current/valid addresses, current/zip code-only addresses, and all PDLWH in California. Specifically, PDLWH who had current/valid addresses (87%), current/zip code-only addresses (81%), or were excluded (80%) were more likely to have a suppressed viral load compared to all PDLWH in California (55%).

The 10,451 PDLWH included in our analysis had an average trip duration between residence and care facility of 20.7 minutes (Table 2). After adjusting for gender, race/ethnicity, age, transmission category, and population density for the census tract of residence, there were statistically significant differences in average trip duration with regard to individual demographic characteristics including race/ethnicity, transmission category and viral suppression status. There were not statistically significant differences for gender, age, and years since diagnosis. Specifically, the average trip duration time for non-Hispanic blacks (22.2 minutes, p<0.001),Hispanics/Latinos (24.0 minutes p=.058), and Native Hawaiian/Other Pacific Islander PDLWH (14.6 minutes, p=0.03) were significantly or marginally significantly shorter than non-Hispanic whites (25.0 minutes). The average trip duration of PDLWH in the MSM transmission category (25.2 minutes) was longer than for those PDLWH in the injection drug use (IDU; 20.3 minutes, p<0.001), MSM-IDU (22.6 minutes, p=0.005), and high-risk heterosexual contact (22.8 minutes, p=0.028) categories, but lower than for PDLWH in the perinatal transmission category (40.3 minutes, p<0.001). Finally, the average trip duration of PDLWH with unknown viral load status (24.9 minutes) was longer than that for PDLWH who had suppressed viral load status (23.0 minutes, p=0.004) and shorter compared to PDLWH with unknown viral load status (35.1 minutes, p<0.001).

We found that average trip duration of PDLWH between residence and care facility was lower in higher CBRL census tracts for the following SDH characteristics: percent of residents in households with incomes below the poverty line, median income, percent having no health insurance, and percent of households with no access to a vehicle. Specifically, when adjusting for individual demographic characteristics and population density, the average trip duration decreased monotonically as a function of percent of residents living in households with income below poverty (32.8 minutes in quintile 1 to 21.2 minutes in quintile 5, ($p<0.001$) and percent having no health insurance (30.5 in quintile 1 to 25.6 in quintile 5 $p<0.001$). For median income, only quintile 5 (21.1 minutes, $p<0.001$) was significantly different than quintile 1 (32.3 minutes). The average trip duration monotonically increased for each quintile of decreasing population density, ranging from a low of 23.3 minutes for quintile 1 to a high of 38.5 minutes in quintile 5 ($p<0.001$). Average trip duration was only significantly higher for PDLWH in quintile 2 (27.3 minutes ($p=0.006$) and quintile 3 (30.1 minutes, $p<0.001$) for percent of residents with less than a high school diploma compared with 25.2 minutes for quintile 1. PDLWH who were residents of urban cores had the lowest average trip duration (26.3 minutes) compared to those who live in sub-urban census tracts (44.4 minutes, $p<0.001$), large rural town census tracts (52.3 minutes, $p<0.001$), and small town/isolated census tracts (52.6 minutes, $p<0.001$). For the census tract measure of unemployed residents aged 16 and over, quintile 3 (25.6 minutes, $p=0.007$) had shorter average trip duration and quintile 4 (30.2 minutes, $p=0.014$) had longer average trip duration compared to quintile 1 (27.8 minutes). Finally, with regard to percent of households with no access to a vehicle, all CBRL levels had statistically significantly longer trip durations compared to the lowest quintile for percentage of no access to a vehicle; the largest difference was between quintile 4 (29.1 minutes, p<0.001) and quintile 1 (24.4 minutes).

When stratifying by SDH and individual characteristics that showed at least some significant association with trip duration in the adjusted models, the majority of CBRL quintiles showed no significant association between virally suppression or presence of viral load test (Table 4). Any categories with five or fewer PDLWH with non-suppressed or missing viral load were not displayed in Table 4. There were insufficient PDLWH living in sub-urban, large rural town or small town/isolated CRUCA categories, and among American Indian/Alaska Native and Native Hawaiian/Other Pacific Islander race/ethnicity categories to include those categories in this analysis. There were also insufficient PDLWH with missing viral load status to be included in high-risk heterosexual contact, non-high risk heterosexual contact and unknown risk/other risk transmission categories, and Asian/Asian Pacific Islander and multiple race categories.

Comparing average trip duration minutes with virally suppression, PDLWH with unsuppressed viral load in the least dense CBRL quintile for population density had an average trip duration of 29.3 minutes versus 35.7 minutes for people with suppressed viral load (p=0.03). PDLWH with suppressed viral load had a longer average trip duration (22.7 minutes) compared to those with an unsuppressed viral load (21.74 minutes, p=0.036) in quintile 4 in the median income category.

Comparing PDLWH with a missing viral load (MVL) status to those with a viral load status, there were marginally significant differences in the percent of residents living in households below poverty quintile 1 (missing viral load = 35.0 minutes versus 24.1 minutes, p=0.047), in the highest population density quintile (MVL = 21.9 minutes versus 18.0 minutes, p=0.054), and in the percent of households with no access to a vehicle, quintile 1 (MVL = 28.1 minutes versus 19.3 minutes, p=0.01). There was a significant difference in trip duration minutes among PDLWH living in urban core census tracts (MVL=25.5 minutes versus 20.3 minutes, p=0.001). Finally, there were significant differences among MSM (MVL = 25.5 minutes compared to 21.0 minutes, p=0.014) and among white PDLWH (MVL = 29.9 minutes versus 21.6 minutes, p=0.057).

Discussion

This analysis sought to describe differences in trip duration between PDLWH residential location and care facility by individual and community characteristics, and determine whether trip duration between location of residence and care facility was associated with viral suppression and missing viral load status. For individual demographic and clinical characteristics, we found significantly longer average trip duration using an adjusted model among PDLWH in the perinatal transmission category compared to MSM and people with unknown viral load status versus people with suppressed viral load. We found, using an adjusted model, significantly shorter average trip duration among Native Hawaiian/Other Pacific Islanders, black/African Americans, and Hispanics/Latinos compared to whites; IDU, MSM/IDU and high-risk heterosexual contact transmission categories compared to MSM transmission category; and among PDLWH with unsuppressed viral load compared to those with suppressed viral load.

There was significantly shorter average trip duration among higher CBRL quintiles for percent of residents living in households with income below poverty and median income, even when population density was included in the model. It may be the case that people residing in census tracts with lower median income and higher percent of households in poverty are more likely to be found in higher population density areas. However, seeing the effect persist while controlling for population density was surprising. Further analysis on a larger sample of PDLWH in California is required to determine if this represents real-world behavior. There are several reasons why these finding should be interpreted with caution. Because Los Angeles (LA) County collected a majority of laboratory reports electronically during 2014 and care facility information (including location addresses) are included on a larger percentage of electronic laboratory reports compared to paper reports, a disproportionate number of PDLWH (77%) and facilities (81%) in our sample are from LA County. If there are differences in care seeking behavior between LA County and other areas of California, our sample would under-represent care-seeking behavior for populations outside of LA County. Our sample also contained approximately 600 PDLWH residing in high median income, high population density areas who patronized facilities in rural areas that resulted in a trip duration of between 180-220 minutes. Our relatively small sample size may have resulted in this sub-population having a substantial effect on our results. Electronic laboratory reporting was implemented statewide in November 2015 and was broadened to over 75% of laboratory reports by March 2016. This will greatly improve the representativeness of future analyses for PDLWH who live in other parts of California. It may also be necessary to find ways to stratify by socio-economic characteristics and analyze trip duration within strata, to elucidate characteristics on which public health departments can intervene.

We also found significantly higher trip duration times as population density decreased and large rural towns and sub-urban areas compared to urban core areas. This is consistent with previous research showing that people in rural areas tend to travel further for medical care than people in urban areas (27). There were significantly longer trip durations for PDLWH living in quintiles two through four compared to quintile one for percent of household with no access to a vehicle. Future research should examine the relationship between trip duration using other modes of transportation including public transportation and HIV engagement in care and suppressed viral loads in populations with higher transportation vulnerability. Analyzing trip duration across quintiles measuring percent unemployed residents over age 16, compared to quintile one, there were significantly longer trip duration for quintile 3 and significantly shorter average trip duration in quintile 4. It may be that the use of quintiles to define SDH categories masks fundamental relationships between unemployment levels and trip duration. The quintile cut points for percent of unemployed residents age 16 and older are tightly distributed; examining the use of tertiles or dichotomous category might have been more appropriate. A population-weighted cluster or factor analysis should also be explored as a method to elucidate more meaningful SDH category cut-points.

Finally, our findings indicate that there is little association between trip duration length and HIV-related disease outcomes, represented by viral load suppression. There were only marginally significant differences in trip duration time comparing PDLWH having unsuppressed viral loads with those with suppressed viral loads, stratified by community-based SDH or individual characteristics. Specifically, people living in low population density quintile with suppressed viral load had a longer trip duration compared to people with non-suppressed viral load. However, further investigation into this relationship is warranted, as PDLWH with unsuppressed viral load were substantially under-represented in this analysis. There were only 62 people who had non-suppressed viral load in this category, which may not be a large enough sample to yield a result that adequately represents this population in California.

Finally, there were significant differences in trip duration time among people with no viral load test during 2014 compared to those with a viral load test, however these results should be interpreted with caution. PDLWH who are seeing a provider and getting a prescription for ART should get a viral load test (35). Some of these individuals may be obtaining ARV medication from non-clinical sources or they may have been seen in an ER or urgent care where they had a CD4 test to help with the diagnostic work up, but no viral load. These were kept as a separate group for analysis purposes, but a larger sample size including more PDLWH with information about the facility of care is needed before inferences can be made. Better ascertainment of residential addresses from PDLWH who are out of care and of care facilities where tests were ordered will have a positive impact on future ability to analyze these relationships.

Several limitations should be considered when interpreting these results. Because this is a cross-sectional, ecological analysis, the results should be interpreted with caution; it cannot be determined from this study if a causal relationships exists among living in a community with lower SDH, longer trip durations from residence to care facility, and poorer HIV health outcomes. To help determine the causal nature of the association found in the present study, future research should analyze longitudinal data including residential relocation patterns to determine if disease outcomes change for those moving to places with closer or further proximity to care facility. The percent of PDLWH in California with current/ valid residential and recorded facility address information was available for only 9% of the population, which may have under-represented some population subgroups and likely biased the results toward people who are engaged in care and therefore who are likely to have better disease outcomes. We excluded any PDLWH that had calculated trip duration of fewer than 5 minutes because we suspected these people had either institutional, homeless, or unknown addresses and their residential address was recorded as their care provider's address. This may not be appropriately conservative and has the potential to bias the results by excluding individuals who live very close to their providers. Future analyses should determine more precise methods for determining institutional, homeless, and unknown residences.

Forty-one percent of PDLWH in California with an out-of-date address in the CHSS are characterized as being in care, while roughly one-third had suppressed viral loads. This is significantly fewer compared with PDLWH who have a current/valid address or those with a current address where only a zip code was available. While informative, the present analysis likely missed those at highest risk for poorer HIV health outcomes. In order to better examine trip duration from residence to care facility for the entire population of PDLWH, future efforts should seek to obtain current and valid residential address information from sources external to the HIV surveillance system for individuals with out-of-date addresses, or with invalid addresses. For example, other U.S. HIV surveillance jurisdictions have used commercial external address locator services to improve address information for PDLWH. The use of these in future efforts is recommended. In addition, as statewide electronic laboratory reports become available for analysis, the proportion of cases with a residential address, a reported facility, and a valid facility address will increase substantially. The measure of suppressed viral load may also be underreported. While HIV viral load tests are required to be reported by California statute, not all laboratory results may have been reported to the CHSS. However, the extent to which this occurs is expected to decrease in the future as an increasing number of laboratories report electronically to OA. This is also expected to improve the recency and completeness of address information for PDLWH in California. Finally, the CHSS does not collect any information on place of occupation. If a person lives a great distance from their care facility, but that person's place of work is shorter duration trip from the care facility location, the residence to care facility duration would not accurately reflect trip duration as a barrier to care.

Conclusion

This is the first statewide analysis of trip duration between residential address and facility of care address among PDLWH in the U.S. It is also the first analysis of suppressed viral load as a function of trip duration, using a high level of spatial definition, with a diverse population of PDLWH. We anticipate that the recent adoption of electronic laboratory reporting in California will substantially increase the number of cases in the CHSS that have current and valid address information and recorded facility information including facility address. This will allow for greater representation of the population at higher risk for poor HIV disease outcomes and increase our knowledge of where to target care resources. With more data, we can determine if trip duration has a differential effect on viral suppression within SDH strata, whether trip duration is associated with engagement in care, and whether public transportation trip duration affects disease outcomes in populations with limited access to transportation.

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Tables

Table 1: Persons diagnosed and living with HIV[1] with current, valid address by demographic characteristic and continuum of care indicators: California, 2014

Characteristic or Care Indicator	Current, Valid Address n (%)	Address (zip code centroid)[2] n (%)	Duration <5 Minutes[3] n (%)	PDLWH in California n %
Gender				
Male	8,724 (89)	510 (86)	579 (89)	103,459 (87)
Female	999 (10)	78 (13)	59 (9)	14,053 (12)
Transgender male-to-female	134 (1)	4 (<1)	13 (2)	1,297 (1)
Transgender female-to-male	2 (<1)	0 (<1)	0 (<1)	30 (<1)
Alternative designation	0 (<1)	0 (<1)	0 (<1)	3 (<1)
Race/Ethnicity[4]				
American Indian/Alaska Native	17 (<1)	1 (<1)	5 (<1)	40,007 (34)
Asian and Asian Pacific Islander	378 (4)	21 (4)	22 (3)	50,741 (43)
Black/African American	1,602 (16)	97 (16)	105 (16)	435 (<1)
Hispanic/Latino	3,565 (36)	219 (37)	239 (37)	4,391 (4)
Native Hawaiian/Other Pacific Island	19 (<1)	0 (<1)	1 (<1)	21,105 (18)
White	4,078 (41)	243 (41)	274 (42)	291 (<1)
Multiple Races	200 (2)	11 (2)	5 (<1)	1,861 (2)
UnKnown Race	0 (<1)	0 (<1)	0 (<1)	11 (<1)
Age in Years (at end of 2014)				
13-24	146 (1)	17 (3)	9 (1)	2,352 (2)
25-44	3,055 (31)	198 (33)	184 (28)	37,655 (32)
45-64	5,952 (60)	329 (56)	413 (63)	69,764 (59)
65+	706 (7)	48 (8)	45 (7)	9,071 (8)
Transmission Category[5]				
Male-to-male sexual contact (MSM)	7,056 (72)	395 (67)	442 (68)	78,564 (66)
Injection drug use (IDU)	395 (4)	24 (4)	35 (5)	7,994 (7)
MSM and IDU	657 (7)	52 (9)	82 (13)	8,956 (8)
High-risk heterosexual contact (HRH)	698 (7)	56 (9)	45 (7)	10,893 (9)
Perinatal	37 (<1)	8 (1)	1 (<1)	565 (<1)
Heterosexual contact (Non-HRH)	527 (5)	36 (6)	22 (3)	6,556 (6)
Unknown risk	462 (5)	19 (3)	23 (4)	4,883 (4)
Other	27 (<1)	2 (<1)	1 (<1)	431 (<1)
Years Since Diagnosis				
More than 5 years	7,893 (80)	501 (85)	540 (83)	94,663 (80)
3-5 years	1,218 (12)	42 (7)	73 (11)	14,847 (12)
1-2 years	748 (8)	49 (8)	38 (6)	9,332 (8)
Viral Suppression Status				
Suppressed viral load	8,599 (87)	479 (81)	519 (80)	65,855 (55)
Unsuppressed viral load	1,142 (12)	102 (17)	122 (19)	9,624 (8)
Unknown viral load status	118 (1)	11 (2)	10 (2)	43,363 (36)
Total	**9,859 (8.3)**	**592 (0.5)**		**118,842 (100)**

1 Persons living with HIV at the end of 2014.

2 Invalid addresses include addresses recorded with non-existent building numbers, streets, cities, or zip codes.

3 In some jurisdictions, addresses for PLDLWH with unknown or who are known to be homeless are recorded using the provider address. These are addresses not identified as institutional address or homeless, but were excluded because the trip duration between residence and care provider location was less than five minutes and therefore suspected to be unknown addresses or homeless.

4 Hispanic/Latino(a) persons can be of any race. Race/ethnicity was collected using Asian/Native Hawaiian/Pacific Islander as a single category until 2003; therefore cases reported prior to 2003 are classified as Asian above because they cannot be disaggregated.

5 High-risk Heterosexual contact includes persons who reported engaging in heterosexual intercourse with a person of the opposite sex of their sex-at-birth, and that partner was known to be HIV positive or engage an activity that put them at high risk for HIV (e.g., MSM, IDU). Heterosexual contact (non-high-risk) includes persons with no other identified risk who reported engaging in heterosexual intercourse with a person of the opposite sex of their sex-at-birth. Perinatal includes persons who were exposed immediately before, during, or after birth due to breastfeeding. 'Other' risk includes having hemophilia, receiving a blood transfusion, or experiencing an occupational exposure.

Table 2: Geometric mean travel duration from residence to facility of care and 95% confidence intervals using crude and adjusted linear models by individual demographic characteristics among Californians living with HIV[1] with recent/valid addresses[2] and recorded/geocoded facility of care, 2014

Characteristic or Care Indicator	n	Crude Models[5] GM[3]	95% C.I.[4]	p-value	Adjusted Models[6] GM[3]	95% C.I.[4]	p-value
Gender							
Male (Referent)	9,234	20.75	(20.46,21.05)		24.88	(24.25,25.53)	
Female	1,077	20.79	(19.89,21.7)	0.934	25.43	(23.63,27.23)	0.548
Transgender male-to-female	138	18.36	(15.94,20.78)	0.052	22.02	(17.99,26.04)	0.164
Transgender female-to-male[7]	2	--	--	--	--	--	--
Race/Ethnicity[8]							
White (Referent)	4,321	21.70	(21.26,22.16)		25.04	(24.33,25.77)	
Hispanic/Latino	3,784	19.91	(19.25,20.56)	<0.001	23.99	(22.91,25.08)	0.058
American Indian/Alaska Native	18	16.56	(9.61,23.51)	0.147	18.68	(8.37,29.00)	0.227
Asian and Asian Pacific Islander	399	20.63	(19.09,22.17)	0.173	23.83	(21.5,26.16)	0.308
Black/African American	1,699	19.85	(19,20.69)	<0.001	22.22	(20.88,23.55)	<0.001
Native Hawaiian/Other Pacific Islander	19	14.63	(7.87,21.4)	0.041	14.60	(5.06,24.14)	0.032
Multiple Races	211	22.23	(20.16,24.31)	0.619	24.90	(21.80,28.00)	0.927
Age in Years (at end of 2014)							
45-64 (Referent)	6,281	20.78	(20.42,21.14)		24.86	(24.2,25.55)	
13-24	163	25.77	(23.53,28.01)	<0.001	28.27	(23.97,32.57)	0.120
25-44	3,253	20.11	(19.51,20.72)	0.033	24.09	(23.06,25.11)	0.139
65+	754	21.81	(20.72,22.9)	0.062	25.61	(23.91,27.31)	0.389
Transmission Category[9]							
Male-to-male sexual contact (MSM) (Referent)	7,451	21.01	(20.68,21.34)		25.15	(24.48,25.84)	
Injection drug use (IDU)	419	18.36	(16.93,19.79)	<0.001	20.30	(18.03,22.56)	<0.001
MSM and IDU	709	18.88	(17.76,20.00)	<0.001	22.56	(20.77,24.35)	0.005
High-risk heterosexual contact (HRH)	754	20.07	(18.99,21.16)	0.092	22.83	(20.77,24.9)	0.028
Perinatal	45	33.58	(29.33,37.84)	<0.001	40.34	(31.64,49.05)	<0.001
Heterosexual contact (Non-HRH)	563	20.93	(19.69,22.18)	0.908	24.04	(21.61,26.47)	0.370
Unknown risk	481	20.31	(18.97,21.65)	0.308	24.61	(22.09,27.14)	0.678
Other	29	25.89	(20.59,31.18)	0.071	29.39	(21.57,37.22)	0.287
Years Since Diagnosis							
More than 5 years (Referent)	8,394	20.87	(20.57,21.18)		24.90	(24.25,25.57)	
3-5 years	1,260	20.33	(19.48,21.19)	0.217	23.82	(22.4,25.23)	0.132
1-2 years	797	19.76	(18.7,20.81)	0.037	23.50	(21.73,25.27)	0.120
Viral Suppression Status							
Supressed viral load (Referent)	9,078	20.76	(20.46,21.05)		24.93	(24.28,25.59)	
Unsuppressed viral load	1,244	19.97	(19.12,20.82)	0.071	22.95	(21.61,24.28)	0.004
Unknown viral load status	129	25.76	(23.26,28.26)	<0.001	35.14	(30.57,39.71)	<0.001
Total	**10,451**						

1 Persons diagnosed and living with HIV at the end of 2014.

2 Invalid addresses include addresses recorded with non-existent building numbers, streets, city, or zip codes. If zip code was available, the population-weighted zip

3 Geometric mean (re-transformed mean of log-transformed trip duration)

4 95% confidence interval

5 Crude model: log of trip duration minutes = characteristic in the leftmost column.

6 Adjusted model: log of trip duration minutes = characteristic in leftmost column + gender + race/ethnicity + age group + transmission category + population density of residential census tract.

7 Transgender: female to male did not have sufficient sample to include in the model

8 Hispanic/Latino(a) persons can be of any race. Race/ethnicity was collected using Asian/Native Hawaiian/Pacific Islander as a single category until 2003; therefore cases reported prior to 2003 are classified as Asian above because they cannot be disaggregated.

9 High-risk Heterosexual contact includes persons who reported engaging in heterosexual intercourse with a person of the opposite sex of their sex-at-birth, and that partner was known to be HIV positive or engage an activity that put them at high risk for HIV (e.g., MSM, IDU). Heterosexual contact (non-high-risk) includes persons with no other identified risk who reported engaging in heterosexual intercourse with a person of the opposite sex of their sex-at-birth. Perinatal includes persons who were exposed immediately before, during, or after birth due to breastfeeding. 'Other' risk includes having hemophilia, receiving a blood

Table 3: Geometric mean travel duration from residence to facility of care and 95% confidence intervals using crude and adjusted linear models by comunity social determinant of health characteristics among Californians living with HIV[1] with recent/valid addresses[2] and recorded facility of care , 2014

		Crude Models[5]		Adjusted Models[6]	
Social Determinant of Health/Characteristic	**N**	**GM[3] 95% C.I.[4]**	**p-value**	**GM[3] 95% C.I.[4]**	**p-value**
Percent of Residents Living in Households with Income Below Poverty					
Quintile 1 (0-6.2) - Referent	928	24.28 (23.23,25.38)		32.84 (28.82,37.43)	
Quintile 2 (6.2-10.6)	1656	22.57 (21.23,23.91)	0.012	34.40 (31.65,37.14)	0.267
Quintile 3 (10.6-16.6)	2354	21.15 (19.88,22.42)	<0.001	29.26 (26.71,31.8)	0.006
Quintile 4 (16.6-26.1)	2368	20.69 (19.42,21.95)	<0.001	28.56 (26.09,31.02)	<0.001
Quintile 5 (26.1-100)	3145	17.45 (16.23,18.67)	<0.001	21.20 (18.79,23.61)	<0.001
Median Income					
Quintile 1 ($90,700-250,000) - Referent	1180	22.59 (21.72,23.49)		32.27 (28.46,36.58)	
Quintile 2 ($68,000-90,700)	1725	21.69 (20.54,22.83)	0.123	30.99 (28.58,33.4)	0.298
Quintile 3 ($52,700-68,000)	1986	21.53 (20.41,22.65)	0.063	30.90 (28.6,33.21)	0.247
Quintile 4 ($39,500-52,700)	2178	22.64 (21.54,23.74)	0.934	30.78 (28.38,33.18)	0.224
Quintile 5 (0-39,500)	3382	17.62 (16.6,18.65)	<0.001	21.11 (19.02,23.2)	<0.001
Population Density (population per square kilometer)					
Quintile 1 (4,750-62,400) - Referent	5558	18.04 (17.72,18.36)		23.33 (20.76,26.21)	
Quintile 2 (2,980-4,750)	2186	21.73 (21.13,22.33)	<0.001	27.11 (22,32.21)	0.146
Quintile 3 (1,850-2,980)	1154	22.71 (21.94,23.48)	<0.001	35.94 (28.72,43.16)	<0.001
Quintile 4 (682-1,850)	1082	24.57 (23.78,25.35)	<0.001	36.36 (32.19,40.53)	<0.001
Quintile 5 (0-682)	471	30.00 (28.86,31.13)	<0.001	38.46 (36.1,40.82)	<0.001
Percent with Less than High School Diploma					
Quintile 1 (0-18.4) - Referent	2531	19.58 (19.06,20.12)		25.17 (22.26,28.46)	
Quintile 2 (18.4-29.4)	1702	22.02 (21.19,22.86)	<0.001	27.31 (25.78,28.83)	0.006
Quintile 3 (29.4-41.9)	1642	21.50 (20.66,22.34)	<0.001	30.14 (28.55,31.74)	<0.001
Quintile 4 (41.9-57.4)	2188	20.56 (19.79,21.34)	0.013	26.09 (24.65,27.54)	0.212
Quintile 5 (57.4-100)	2388	20.48 (19.72,21.24)	0.02	26.22 (24.7,27.75)	0.177
Percent having No Health Insurance					
Quintile 1 (0-7.62) - Referent	1044	22.31 (21.39,23.27)		30.47 (26.78,34.67)	
Quintile 2 (7.6-12.4)	1772	20.48 (19.3,21.66)	0.002	26.13 (23.97,28.29)	<0.001
Quintile 3 (12.4-17.7)	2002	20.92 (19.76,22.07)	0.018	25.42 (23.32,27.53)	<0.001
Quintile 4 (17.7-24.6)	2212	21.64 (20.51,22.78)	0.248	27.07 (24.91,29.23)	0.002
Quintile 5 (24.6-65.5)	3421	19.48 (18.41,20.55)	<0.001	25.56 (23.41,27.7)	<0.001

1 Persons diagnosed and living with HIV at the end of 2014.

2 Invalid addresses include addresses recorded with non-existent building numbers, streets, city, or zip codes. If zip code was available, the population-weighted zip code centroid was used as an approximation of residential address

3 Geometric mean

4 95% Confidence Interval

5 Crude model: log of trip duration minutes = characteristic in leftmost column.

6 Adjusted model: log of trip duration minutes = characteristic in leftmost column + percent of residents living in households with income below poverty + population density + percent with less than high school diploma + no health insurance + urban/rural classification.

Table 3 (continued): Geometric mean travel duration from residence to facility of care and 95% confidence intervals using crude and adjusted linear models by comunity social determinant of health characteristics among Californians living with HIV[1] with recent/valid addresses[2] and recorded facility of care , 2014

		Crude Models[5]		Adjusted Models[6]	
Social Determinant of Health/Characteristic	**N**	**GM[3] 95% C.I.[4]**	**p-value**	**GM[3] 95% C.I.[4]**	**p-value**
Urban/rural Classification (CRUCA)					
Urban core - Referent	10262	20.39 (20.13,20.67)		26.30 (23.45,29.5)	
Sub-Urban	159	36.97 (34.79,39.15)	<0.001	44.44 (41.21,47.68)	<0.001
Large rural town	23	47.19 (41.49,52.88)	<0.001	52.34 (43.23,61.45)	<0.001
Small town/isolated	7	42.28 (31.97,52.6)	<0.001	52.56 (35.55,69.56)	0.002
Percent Unemployed Residents Age 16 and Older					
Quintile 1 (0-4.28) - Referent	1334	20.70 (19.94,21.48)		27.83 (24.58,31.53)	
Quintile 2 (4.3-5.84)	1751	22.25 (21.23,23.27)	0.003	27.95 (26.22,29.68)	0.896
Quintile 3 (5.8-7.37)	2533	20.14 (19.19,21.09)	0.249	25.56 (23.9,27.23)	0.007
Quintile 4 (7.4-9.61)	2526	20.68 (19.73,21.63)	0.972	30.23 (28.32,32.15)	0.014
Quintile 5 (9.6-100)	2307	20.26 (19.3,21.23)	0.378	26.39 (24.55,28.22)	0.122
Percent of Households with No Access to a Vehicle					
Quintile 1 (0-0.232) - Referent	2481	19.35 (18.83,19.89)		24.41 (21.65,27.53)	
Quintile 2 (0.2-0.799)	1922	20.68 (19.88,21.48)	0.001	27.81 (26.34,29.28)	<0.001
Quintile 3 (0.8-1.41)	1962	20.99 (20.2,21.78)	<0.001	27.10 (25.76,28.45)	<0.001
Quintile 4 (1.4-2.29)	2008	21.78 (20.99,22.56)	<0.001	29.08 (27.61,30.55)	<0.001
Quintile 5 (2.3-13.6)	2078	20.90 (20.12,21.68)	<0.001	27.94 (26.58,29.29)	<0.001
Total	**10451**				

1 Persons diagnosed and living with HIV at the end of 2014.

2 Invalid addresses include addresses recorded with non-existent building numbers, streets, city, or zip codes. If zip code was available, the population-weighted zip code centroid was used as an approximation of residential address

3 Geometric mean

4 95% Confidence Interval

5 Crude model: log of trip duration minutes = characteristic in leftmost column.

6 Adjusted model: log of trip duration minutes = characteristic in leftmost column + percent of residents living in households with income below poverty + population density + percent with less than high school diploma + no health insurance + urban/rural classification.

Table 4: Geometric mean travel duration from residence to facility of care by viral load status and community social determinant of health and individual demographic characteristics among eligible[1] people diagnosed and living with HIV in California, 2014

	Not suppressed viral load		Suppressed viral load			Missing viral load		Present viral load		
	N (# Facilities)	Mean duration[2]	N (# Facilities)	Mean duration[2]	p-value[3]	N (# Facilities)	Mean duration[2]	N (# Facilities)	Mean duration[2]	p-value[3]
Total	**1244 (176)**	**22.24**	**9078 (304)**	**24.28**	**0.001**	**129 (58)**	**26.41**	**10322 (348)**	**20.66**	**<0.001**
Percent of Residents Living in Households with Income Below Poverty										
Quintile 1 (0-6.2)	84 (45)	23.24	826 (121)	24.20	0.809	18 (13)	35.01	910 (131)	24.11	0.037
Quintile 2 (6.2-10.6)	135 (58)	23.86	1498 (147)	22.54	0.886	23 (15)	21.30	1633 (158)	22.65	0.114
Quintile 3 (10.6-16.6)	212 (72)	21.05	2110 (169)	21.26	0.726	32 (17)	30.43	2322 (181)	21.24	0.897
Quintile 4 (16.6-26.1)	287 (80)	21.33	2057 (173)	20.83	0.836	24 (19)	26.02	2344 (192)	20.89	0.484
Quintile 5 (26.1-100)	526 (105)	17.62	2587 (162)	18.42	0.519	32 (24)	23.10	3113 (198)	18.28	0.536
Median Income										
Quintile 1 ($90,700-250,000)	108 (42)	22.38	1052 (123)	22.52	0.196	20 (11)	27.74	1160 (132)	22.51	0.168
Quintile 2 ($68,000-90,700)	134 (56)	22.19	1562 (168)	21.56	0.445	29 (18)	27.87	1696 (177)	21.61	0.874
Quintile 3 ($52,700-68,000)	184 (77)	21.21	1776 (159)	21.54	0.174	26 (19)	25.43	1960 (181)	21.51	0.937
Quintile 4 ($39,500-52,700)	250 (78)	21.74	1902 (155)	22.66	0.036	26 (17)	31.00	2152 (175)	22.55	0.600
Quintile 5 (0-39,500)	568 (103)	18.04	2786 (172)	18.12	0.252	28 (20)	21.54	3354 (200)	18.11	0.736
Population Density (population per square kilometer)										
Quintile 1 (4,750-62,400)	705 (112)	17.94	4797 (202)	18.01	0.620	56 (30)	21.85	5502 (232)	18.00	0.054
Quintile 2 (2,980-4,750)	233 (85)	20.67	1924 (170)	22.29	0.097	29 (21)	24.51	2157 (189)	22.11	0.666
Quintile 3 (1,850-2,980)	113 (49)	22.81	1027 (145)	23.44	0.646	14 (9)	22.81	1140 (154)	23.38	0.344
Quintile 4 (682-1,850)	131 (48)	25.03	931 (127)	25.78	0.671	20 (16)	40.65	1062 (137)	25.69	0.110
Quintile 5 (0-682)	62 (29)	29.34	399 (89)	35.67	0.030	10 (7)	49.28	461 (101)	34.74	0.224

1 Persons living with HIV at the end of 2014 having a recent/valid residential address or an address recorded with non-existent building numbers, streets, city, or zip codes. If zip code was available, the population-weighted zip code centroid was used as an approximation of residential address. Eligible people also had a recorded facility of care with a valid address that had trip duration between residence and care facility of longer than five minutes to exclude people who are homeless or with unknown address

2 Geometric mean

3 P-value was calculated from a linear model: log of trip duration minutes = viral load status + community SDH or individual characteristic of interest + population density + an interaction term of viral load status * community SDH or individual characteristic of interest. The p-value associated with the interaction term, which measures the significance of the effect of the variable of interest on the change in log of trip duration minutes associated with changing levls of viral load status.

4 High-risk Heterosexual contact includes persons who reported engaging in heterosexual intercourse with a person of the opposite sex of their sex-at-birth, and that partner was known to be HIV positive or engage an activity that put them at high risk for HIV (e.g., MSM, IDU). Heterosexual contact (non-high-risk) includes persons with no other identified risk who reported engaging in heterosexual intercourse with a person of the opposite sex of their sex-at-birth. 'Other/Unknown' risk includes perinatal exposure (includes persons who were exposed immediately before, during, or after birth due to breastfeeding), having hemophilia, receiving a blood transfusion, experiencing an occupational exposure, or unknown risk.

5 There were small numbers of people in sub-urban, large rural town and small town/isolated urban/rural classification category and with perinatal, other and unknown transmission category when stratified by suppressed viral load and missing viral load status. For the urban/rural classification, these were included in the analysis but excluded from the table. For transmission category, they were aggregated into the other/unknown for the analysis and the table.

6 Hispanic/Latino(a) persons can be of any race. Race/ethnicity was collected using Asian/Native Hawaiian/Pacific Islander as a single category until 2003; therefore cases reported prior to 2003 are classified as Asian above because they cannot be disaggregated.

Table 4 (continued): Geometric mean travel duration from residence to facility of care by viral load status and community social determinant of health and individual demographic characteristics among eligible[1] people diagnosed and living with HIV in California, 2014

	Not suppressed viral load		Suppressed viral load			Missing viral load		Present viral load		
	N (# Facilities)	Mean duration[2]	N (# Facilities)	Mean duration[2]	p-value[3]	N (# Facilities)	Mean duration[2]	N (# Facilities)	Mean duration[2]	p-value[3]
Percent with Less than High School Diploma										
Quintile 1 (0-18.4)	200 (71)	19.94	2283 (158)	19.48	0.464	48 (24)	23.40	2483 (176)	19.52	0.076
Quintile 2 (18.4-29.4)	175 (58)	20.47	1511 (145)	22.27	0.128	16 (14)	36.58	1686 (160)	22.08	0.073
Quintile 3 (29.4-41.9)	179 (59)	19.78	1440 (150)	21.68	0.124	23 (15)	33.31	1619 (165)	21.46	0.314
Quintile 4 (41.9-57.4)	312 (85)	19.86	1859 (162)	20.65	0.526	17 (14)	28.57	2171 (185)	20.53	0.528
Quintile 5 (57.4-100)	378 (81)	19.99	1985 (147)	20.60	0.364	25 (21)	20.73	2363 (168)	20.50	0.220
Percent having No Health Insurance										
Quintile 1 (0-7.62)	98 (35)	24.36	925 (128)	21.98	0.148	21 (15)	28.38	1023 (137)	22.20	0.171
Quintile 2 (7.6-12.4)	187 (72)	19.76	1561 (141)	20.50	0.118	24 (10)	32.22	1748 (159)	20.42	0.246
Quintile 3 (12.4-17.7)	182 (60)	19.38	1789 (158)	21.10	0.109	31 (21)	22.60	1971 (168)	20.94	0.425
Quintile 4 (17.7-24.6)	254 (83)	21.32	1933 (174)	21.64	0.158	25 (20)	26.65	2187 (195)	21.60	0.954
Quintile 5 (24.6-65.5)	523 (97)	18.94	2870 (172)	19.74	0.105	28 (21)	24.89	3393 (198)	19.61	0.986
Urban/rural classification										
Urban core	1228 (175)	19.82	8911 (298)	20.41	0.834	123 (55)	25.53	10139 (342)	20.34	0.001
Sub-Urban	--	--	--	--		--	--	--	--	
Large rural town	--	--	--	--		--	--	--	--	
Small town/isolated	--	--	--	--		--	--	--	--	

1 Persons living with HIV at the end of 2014 having a recent/valid residential address or an address recorded with non-existent building numbers, streets, city, or zip codes. If zip code was available, the population-weighted zip code centroid was used as an approximation of residential address. Eligible people also had a recorded facility of care with a valid address that had trip duration between residence and care facility of longer than five minutes to exclude people who are homeless or with unknown address

2 Geometric mean

3 P-value was calculated from a linear model: log of trip duration minutes = viral load status + community SDH or individual characteristic of interest + population density + an interaction term of viral load status * community SDH or individual characteristic of interest. The p-value associated with the interaction term, which measures the significance of the effect of the variable of interest on the change in log of trip duration minutes associated with changing levls of viral load status.

4 High-risk Heterosexual contact includes persons who reported engaging in heterosexual intercourse with a person of the opposite sex of their sex-at-birth, and that partner was known to be HIV positive or engage an activity that put them at high risk for HIV (e.g., MSM, IDU). Heterosexual contact (non-high-risk) includes persons with no other identified risk who reported engaging in heterosexual intercourse with a person of the opposite sex of their sex-at-birth. 'Other/Unknown' risk includes perinatal exposure (includes persons who were exposed immediately before, during, or after birth due to breastfeeding), having hemophilia, receiving a blood transfusion, experiencing an occupational exposure, or unknown risk.

5 There were small numbers of people in sub-urban, large rural town and small town/isolated urban/rural classification category and with perinatal, other and unknown transmission category when stratified by suppressed viral load and missing viral load status. For the urban/rural classification, these were included in the analysis but excluded from the table. For transmission category, they were aggregated into the other/unknown for the analysis and the table.

6 Hispanic/Latino(a) persons can be of any race. Race/ethnicity was collected using Asian/Native Hawaiian/Pacific Islander as a single category until 2003; therefore cases reported prior to 2003 are classified as Asian above because they cannot be disaggregated.

Table 4 (continued): Geometric mean travel duration from residence to facility of care by viral load status and community social determinant of health and individual demographic characteristics among eligible[1] people diagnosed and living with HIV in California, 2014

	Not suppressed viral load		Suppressed viral load			Missing viral load		Present viral load		
	N (# Facilities)	Mean duration[2]	N (# Facilities)	Mean duration[2]	p-value[3]	N (# Facilities)	Mean duration[2]	N (# Facilities)	Mean duration[2]	p-value[3]
Percent Unemployed Residents Age 16 and Older										
Quintile 1 (0-7.62)	98 (35)	24.36	925 (128)	21.98	0.148	21 (15)	28.38	1023 (137)	22.20	0.171
Quintile 2 (7.6-12.4)	187 (72)	19.76	1561 (141)	20.50	0.118	24 (10)	32.22	1748 (159)	20.42	0.246
Quintile 3 (12.4-17.7)	182 (60)	19.38	1789 (158)	21.10	0.109	31 (21)	22.60	1971 (168)	20.94	0.425
Quintile 4 (17.7-24.6)	254 (83)	21.32	1933 (174)	21.64	0.158	25 (20)	26.65	2187 (195)	21.60	0.954
Quintile 5 (24.6-65.5)	523 (97)	18.94	2870 (172)	19.74	0.105	28 (21)	24.89	3393 (198)	19.61	0.986
Percent of Households with No Access to a Vehicle										
Quintile 1 (0-0.232)	333 (88)	19.14	2123 (166)	19.30	0.310	25 (21)	28.10	2456 (187)	19.28	0.010
Quintile 2 (0.2-0.799)	221 (80)	20.45	1677 (160)	20.77	0.533	24 (16)	20.56	1898 (183)	20.73	0.034
Quintile 3 (0.8-1.41)	213 (74)	19.54	1723 (151)	21.15	0.090	26 (18)	29.65	1936 (167)	20.97	0.798
Quintile 4 (1.4-2.29)	244 (69)	21.74	1738 (168)	21.92	0.458	26 (19)	25.07	1982 (186)	21.90	0.316
Quintile 5 (2.3-13.6)	233 (71)	19.45	1817 (140)	21.06	0.046	28 (17)	29.20	2050 (156)	20.87	0.712

1 Persons living with HIV at the end of 2014 having a recent/valid residential address or an address recorded with non-existent building numbers, streets, city, or zip codes. If zip code was available, the population-weighted zip code centroid was used as an approximation of residential address. Eligible people also had a recorded facility of care with a valid address that had trip duration between residence and care facility of longer than five minutes to exclude people who are homeless or with unknown address

2 Geometric mean

3 P-value was calculated from a linear model: log of trip duration minutes = viral load status + community SDH or individual characteristic of interest + population density + an interaction term of viral load status * community SDH or individual characteristic of interest. The p-value associated with the interaction term, which measures the significance of the effect of the variable of interest on the change in log of trip duration minutes associated with changing levls of viral load status.

4 High-risk Heterosexual contact includes persons who reported engaging in heterosexual intercourse with a person of the opposite sex of their sex-at-birth, and that partner was known to be HIV positive or engage an activity that put them at high risk for HIV (e.g., MSM, IDU). Heterosexual contact (non-high-risk) includes persons with no other identified risk who reported engaging in heterosexual intercourse with a person of the opposite sex of their sex-at-birth. 'Other/Unknown' risk includes perinatal exposure (includes persons who were exposed immediately before, during, or after birth due to breastfeeding), having hemophilia, receiving a blood transfusion, experiencing an occupational exposure, or unknown risk.

5 There were small numbers of people in sub-urban, large rural town and small town/isolated urban/rural classification category and with perinatal, other and unknown transmission category when stratified by suppressed viral load and missing viral load status. For the urban/rural classification, these were included in the analysis but excluded from the table. For transmission category, they were aggregated into the other/unknown for the analysis and the table.

6 Hispanic/Latino(a) persons can be of any race. Race/ethnicity was collected using Asian/Native Hawaiian/Pacific Islander as a single category until 2003; therefore cases reported prior to 2003 are classified as Asian above because they cannot be disaggregated.

Table 4 (continued): Geometric mean travel duration from residence to facility of care by viral load status and community social determinant of health and individual demographic characteristics among eligible[1] people diagnosed and living with HIV in California, 2014

	Not suppressed viral load		Suppressed viral load			Missing viral load		Present viral load		
	N (# Facilities)	Mean duration[2]	N (# Facilities)	Mean duration[2]	p-value[3]	N (# Facilities)	Mean duration[2]	N (# Facilities)	Mean duration[2]	p-value[3]
Transmission Category[4,5]										
Male-to-male sexual contact (MSM)	776 (136)	20.63	6578 (244)	20.99	0.963	97 (47)	25.53	7354 (279)	20.95	0.014
Injection drug use (IDU)	76 (30)	17.05	336 (71)	18.73	0.316	7 (6)	26.14	412 (83)	18.41	0.611
MSM and IDU	136 (34)	18.08	564 (76)	19.05	0.943	9 (8)	32.64	700 (86)	18.85	0.196
High-risk heterosexual contact (HI	106 (40)	17.43	643 (100)	20.48	0.059	--	--	--	--	
Heterosexual contact (Non-HRH)	76 (41)	20.75	484 (101)	20.92	0.773	--	--	--	--	
Unknown risk/Other	38 (27)	20.88	171 (59)	22.48	0.716	--	--	--	--	
Race/Ethnicity[6]										
Hispanic/Latino	429 (80)	19.07	3320 (166)	20.09	0.459	35 (25)	21.06	3749 (181)	19.97	0.796
White	395 (98)	21.44	3861 (216)	21.61	0.475	65 (25)	29.94	4256 (239)	21.60	0.057
American Indian/Alaska Native	--	--	--	--		--	--	--	--	
Asian and Asian Pacific Islander	23 (17)	16.12	373 (81)	20.80	0.222	--	--	--	--	
Black/African American	356 (88)	19.71	1321 (158)	19.94	0.663	22 (20)	22.91	1677 (183)	19.89	0.617
Native Hawaiian/Other Pacific Isla	--	--	--	--		--	--	--	--	
Multiple Races	38 (27)	20.88	171 (59)	22.48	0.716	--	--	--	--	

1 Persons living with HIV at the end of 2014 having a recent/valid residential address or an address recorded with non-existent building numbers, streets, city, or zip codes. If zip code was available, the population-weighted zip code centroid was used as an approximation of residential address. Eligible people also had a recorded facility of care with a valid address that had trip duration between residence and care facility of longer than five minutes to exclude people who are homeless or with unknown address

2 Geometric mean

3 P-value was calculated from a linear model: log of trip duration minutes = viral load status + community SDH or individual characteristic of interest + population density + an interaction term of viral load status * community SDH or individual characteristic of interest. The p-value associated with the interaction term, which measures the significance of the effect of the variable of interest on the change in log of trip duration minutes associated with changing levls of viral load status.

4 High-risk Heterosexual contact includes persons who reported engaging in heterosexual intercourse with a person of the opposite sex of their sex-at-birth, and that partner was known to be HIV positive or engage an activity that put them at high risk for HIV (e.g., MSM, IDU). Heterosexual contact (non-high-risk) includes persons with no other identified risk who reported engaging in heterosexual intercourse with a person of the opposite sex of their sex-at-birth. 'Other/Unknown' risk includes perinatal exposure (includes persons who were exposed immediately before, during, or after birth due to breastfeeding), having hemophilia, receiving a blood transfusion, experiencing an occupational exposure, or unknown risk.

5 There were small numbers of people in sub-urban, large rural town and small town/isolated urban/rural classification category and with perinatal, other and unknown transmission category when stratified by suppressed viral load and missing viral load status. For the urban/rural classification, these were included in the analysis but excluded from the table. For transmission category, they were aggregated into the other/unknown for the analysis and the table.

6 Hispanic/Latino(a) persons can be of any race. Race/ethnicity was collected using Asian/Native Hawaiian/Pacific Islander as a single category until 2003; therefore cases reported prior to 2003 are classified as Asian above because they cannot be disaggregated.

Chapter 4: Ratio of HIV care provider to California population diagnosed and living with HIV from an enhanced two-step floating catchment area method, 2014

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Abstract

Background: Among the factors that contribute to sub-optimal HIV treatment and disease outcomes, proximity to accommodating, affordable, and acceptable providers of HIV care is a key social/community-based factor for people diagnosed and living with HIV (PDLWH). A greater understanding of how proximity influences care provider choice is crucial for public health departments to effectively use limited resources for the greatest public health impact.

Methods: We used California HIV Surveillance System (CHSS) data to derive statewide HIV-specific care accessibility using an enhanced two step floating catchment area method (E2SFCA). We enhanced previous methods by employing empirically derived variable catchment sizes to represent the provider service area and trip duration decay to account for decreased probability of patronization as trip duration increased. We then calculated provider to population ratio (PPR) for each California census tract using E2SFCA methods.

Results: We determined these enhancements were feasible additions to the 2SFCA method to determine access to care as well as a new use for HIV surveillance data in helping identify areas for intervention. The geometric mean PPR in California was 6.02 providers per 100 PDLWH and ranged from 0.1 to 42.8 providers per 100 PDLWH. Among PDLWH in California in 2014, 2,982 (6%) lived in census tracts with fewer than two providers per 100 PDLWH and 34,841 (64%) lived in census tracts with fewer than five providers per 100 population.

Discussion: This analysis represents an important methodological improvement in measuring PPR in a geographically large, demographically heterogeneous area. It also represents a framework for a considerable step forward in being able to measure access to care for PDLWH. These methods will allow state and local health jurisdictions to: investigate factors associated with HIV-specific health disparities, improve the capacity to direct resources for improving health outcomes for PDLWH, and enhance transmission prevention efforts.

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Background

Regular care, adherence to an antiretroviral (ARV) regimen, and viral load suppression have been shown to increase survival for persons diagnosed and living with HIV (PDLWH) and decrease their likelihood of infecting others, leading to better clinical outcomes for individuals and fewer new infections [1–4]. he National HIV/AIDS Strategy has mobilized national, state, and local efforts toward ensuring equitable access to care, reducing disparities, and improving HIV continuum of care outcomes (diagnosis, retention in regular medical care, prescription of ARV, and viral suppression) to prevent HIV transmission [5]. However, among people who were aware of their HIV infection, only an estimated 45% of PDLWH in the U.S. and 49% of PDLWH in California [6,7] are retained in regular HIV care, meaning two visits in a calendar year at least three months apart. There are a number of individual and structural barriers to obtaining regular care including poverty, unemployment, intimate partner violence, unstable housing, food insecurity, and lack of access to transportation [5,8,9]. Previous research has shown differences in HIV continuum of care outcomes by race/ethnicity, gender, age, and community-based characteristics [1,10–13].

A primary factor that contributes to sub-optimal HIV treatment and disease outcomes is lack of access to accommodating, affordable, and acceptable providers of HIV care [31]. The simplest method for measuring health care access has been to calculate the ratio of service providers to the potential service population within a given area, usually for a locally relevant or politically drawn area, such as neighborhoods, counties, or zip codes. However, determining access to care using these boundaries is not ideal, because these boundaries are often arbitrary, defined by non-local entities, and generally do not prohibit members of the potential service population from seeking care from care providers outside these boundaries [14]. The two-step floating catchment area (2SFCA) was developed to address these weaknesses by calculating a provider to population ratio (PPR) using a unique geographic buffer, or catchment area, for each provider location [15,16]. This measure can be calculated using GIS data in two steps. For step one, at each provider location, identify all population locations (either individual residences or populations aggregated to a geographic point such as a census tract centroid) that are within an expected maximum travel time, or catchment area, from the provider location. The number of care providers (i.e. physicians, licensed practical nurses, etc.) at the identified location is then divided by the total population within the catchment area to compute the PPR for the provider location. For step two, for each population location of interest (again, either individual residences or census tract centroids), identify all provider locations that are within an expected maximum travel time, and sum the provider PPR derived in step one. This yields an easy to understand ratio of supply and demand for care services in the form of a PPR[15].

However, this method has two major weaknesses: first it does not account for the decreasing probability of patronizing providers as travel distance or duration from home increases, and second it may not necessarily accurately characterize the size and shape of service areas from which providers draw their patrons [14–17]. We can apply an impedance-based decay function to our analysis to account for the former. (This is usually called a distance decay function in the literature. However, since we considered both travel distance and duration and because are both forms of impedance in geographic network parlance, we will refer to this as impedance-based decay). Previous literature has indicated that impedance-based decay varies by population density, urbanicity, availability of public transportation, and income [14-17]. Urban areas tend to have higher densities of care providers, but also more vehicle traffic, so the probability of persons living in highly urban areas patronizing a given provider might decrease sharply with only small increases in impedance-based from residence to provider location. Residents of sub-urban and rural areas, which usually have lower care provider density, may be more accustomed to longer travel distances compared to residents of densely populated urban areas, so the impedance-based decay function may have a more shallow slope. Additionally, while using a fixed catchment size could be sufficient for characterizing catchments for small geographic areas with relatively homogenous populations with respect to predictors of health, it does not adequately characterize differences between rural, suburban, and urban areas, or differences between areas with high versus low vehicle access [18,19]. California is a geographically large and demographically diverse state, including several of the largest metropolitan areas in the U.S., a number of medium and low population density cities, and large rural areas. It also has the second highest absolute HIV morbidity and tenth highest HIV prevalence rate among U.S. states and the District of Columbia (D.C.) [20]. Given the wide geographic and demographic variation in the California, it would be inadequate to attempt to model access to HIV care among the state's PDLWH using a fixed catchment area or without accounting for impedance-based decay.

While it is generally agreed that adding impedance-based decay and variable catchment area size would improve the utility of 2SFCA, there is limited precedent for how to include these components. Regarding the latter, McGrail and colleague [19] developed a variable catchment area size schema based on urbanicity for a national analysis of health-care accessibility in Australia. While several other researchers have included impedance-based decay functions in 2SFCA, there has been not been agreement on how to best model the decay. For example, one proposal is to use a step decay function, which uses weighted values based on several discrete travel distance or duration zones (e.g. <10 minutes, 11-30 minutes, 30-45 minutes, >45 minutes) from residence to service provider locations [14,15]. Other researchers have proposed establishing travel decay as a continuous Gaussian function of travel time or distance [17]. However, while both of these methods improve over a 2SFCA method that assumes no impedance-based decay, it has been difficult for researchers to determine whether the time zone or continuous method best characterizes the influence of travel time or distance on patient behavior [14]. Ideally, both the decay function and the catchment size would be empirically derived based on observed behavior of people; however access to national or state level data with the degree of precision required to perform this analysis is difficult to secure.

This present study builds upon our prior work to improve 2SFCA and therefore represents the next step in quantitatively characterizing access to care. In the present study, we hypothesized that it is feasible to characterize access to care using continuous, empirically derived impedance-based decay functions and variable catchment sizes using California HIV surveillance system (CHSS) data. Specifically, we employed data comprised of addresses of residence and care providers patronized by PDLWH statewide. Trip duration from residence to patronized providers was modeled as a function of population density of care provider addresses to determine HIV-specific enhanced two-step floating catchment areas (E2SFCA). Associations between access to care based on the proposed model and viral suppression would potentially identify modifiable causes of low care access. This information could be used by policymakers and health department staff to reduce these factors and increase PDLWH in care, leading to better overall health among PDLWH and lower HIV infection rates in the future.

Methods

We calculated an HIV care provider to PDLWH ratio (PPR) using an empirically derived enhanced two-factor floating catchment area (E2SFCA) in two phases (Figure 1) and applied it to the population of PDLWH in California. In the first phase we calculated the variable catchment area size scheme and impedance-based function for providers (E2SFCA step one) and places of residence (E2SFCA step two). We used a limited study population to derive the catchment area sizes and decay functions, including only PDLWH with residential addresses that were recent, valid, and geocodable, and for whom there also existed a report of a laboratory test that identified a testing or care facility that had a valid, geocodable address. These exclusions allowed for a sub-sample of PDLWH with known, selected care providers, and calculable trip durations from residences to care provider locations, which were needed for deriving the functions. In phase two we applied the catchment and decay functions developed in phase one to calculated the E2SFCA-derived PPR for each California census tract that had at least one PDLWH residing in it. For phase two, we used a dataset including all PDLWH in California with valid/geocodable addresses and also included all HIV care providers in California with valid/geocodable addresses. Each phase is described in more detail in the paragraphs that follow. Finally, we described PDLWH in California in terms of the PPR for the census tract of residence.

Enhanced Two-Factor Floating Catchment Area Calculation Processes - In phase one, we first separately derived variable catchment sizes for each care provider location (step one) and residential population location (step 2) based on the 90th percentile trip duration from residence to the care provider location based on PDLWH in a limited sample of PDLWH. The provider variable catchment sizes capture the trip durations of most people who patronized each provider, while excluding outliers. Step one and step two catchment area size calculations are necessary because step one measures the duration for most PDLWH who patronize a provider, and step two measures the duration for most PDLWH in a residential location. We then aggregated and stratified the individual catchment areas by HIV surveillance project area and population density quintile. The three HIV surveillance project areas in California are Los Angeles County, San Francisco County, and all other counties in California; the latter is referred to as the California Project Area (CPA). The 90th percentile was used to represent the catchment area for all providers within each combination of project area by population density quintile. Note that because the same population density quintile strata were used across all project areas, and all San Francisco county-based providers were located in the highest density quintile (quintile 1) areas, there was only one step one stratum for the San Francisco project area.

Using the stratified provider catchment sizes, we then derived provider and residence decay functions, which were defined as the probability that PDLWH residing within a catchment area patronized the provider of interest, as a function of the trip durations from the provider to the residential location (or from the residential location to the providers within a step two catchment area). In general, as trip duration from an origin to a destination increases, the probability of patronizing that destination decreases. We calculated this probability using a general linear model with a binary outcome of whether each individual in the catchment area did or did not patronize the provider. Because we found the distribution of trip duration produced by the Google Distance Matrix pessimistic traffic model (30) to be skewed, we used log-transformed trip duration as the primary predictor variable—this transformation caused the trip durations to more closely approximate normality. The model included the log of the trip duration, population density quintile, and a multiplicative interaction term of trip duration by population density quintile. The coefficients from the model allowed us to calculate the probability of patronization for a given travel duration between two points located in a census tract with a given population density quintile. We assumed that trip duration was not a barrier to patronization for any provider within 10 minutes of a residence. Therefore, a probability weight value of one was applied to any trip duration of less than 10 minutes, which improved the efficiency of model estimation. For any trip duration value greater than 10 minutes, we applied the probability of patronization at a given trip duration divided by the probability calculated for trip duration at 10 minutes as the maximum probability, which standardized all trip durations to the patronization probability for a duration of 10 minutes. Weights were separately calculated using this method for each population density quintile (weight plots for simulated data is shown in figures two and three).

For phase two, we applied the catchment sizes and decay functions to all PDLWH with valid/geocoded residential address and all eligible HIV providers to determine the E2SFCA step one provider to population ratio (PPR). Calculating PPR using each residential and provider location was determined to be too computationally intensive, so we elected to aggregate by census tracts with locations being represented by the census tract centroid (the geographic center of the census tract polygon). For each census tract centroid that had at least one eligible provider, we applied the appropriate catchment area size for the population density and surveillance jurisdiction to create a spatial buffer. We calculated the trip duration from provider centroid location to all census tract centroids that were located within the buffer. The decay function weight was then applied to each population tract centroid based on the measured trip duration between the provider centroid and the population centroid, and the population density in the provider census tract. We multiplied the weight by the number of PDLWH in the population census tract which represented a population weighted by the likelihood that they would patronize the provider. For example, if 25 PDLWH lived in a lowest quintile population density census tract with a centroid that was 100 minutes from the provider census tract centroid, the decay weight for this tract would be approximately 0.15, indicating that the probability of patronization was low, but greater than zero. The weighted population that this census tract would contribute to the provider demand would be 25 PDLWH x 0.15 = 3.75 PDWLH. Adding together all census tract weighted population values within the catchment area yielded the service population for the providers in the selected census tract. To calculate the step-one PPR for the provider census tract, we divided the number of providers in the census tract by the service population.

For each census tract centroid that had at least one eligible provider, we applied the appropriate catchment area size for the population density and surveillance jurisdiction to create a spatial buffer. We calculated the trip duration from the selected residence centroid location to all census tract centroids that had at least one eligible provider located within the buffer. The residence decay function weight was then applied to each provider tract centroid within the catchment based on the trip duration between the provider centroid, the population centroid, and the population density in the residence census tract. For each provider census tract in the residential catchment, we multiplied the step one PPR by the decay function weight which represented a PPR weighted by the likelihood that the PDLWH in the selected census tract would patronize a provider in the provider census tract. Finally, we summed all step one weighted PPR values associated with providers within the catchment area to yield the E2SFCA derived PPR for the census tract.

Finally, we described the population of PDLWH in California with current, valid, geocodeable address from the CHSS in terms of the E2SFCA derived PPR for the census tract of residence. We reported the number and percent of PDLWH living in each category of PPR (0-2, 2-5, 5-10, 10-15, and 15 providers per 100 PDLWH) and the geometric mean PPR for each demographic, clinical, community, and population density characteristic category. Individual demographic and outcome variables from the surveillance dataset were created using SAS © version 9.4 [26]. The trip duration and geographic variable datasets were created, and all analyses were performed, using R version 3.3.1 [27].

Data Source and Study Population: The state of California has conducted confidential, name-based HIV surveillance since 2006, and name-based AIDS surveillance since March 1983. Surveillance data collection methods in California have been described in greater detail previously (11). This study included people aged 13 and older who were diagnosed with HIV on or before December 31, 2014, alive and living in California as of this date, reported to CHSS on or before December 31, 2015, and had no evidence reported to the CHSS that their current residence is in an institutionalized setting (e.g., a prison or hospital) or homeless.

We used best available evidence of address of residence recorded in CHSS as of December 31, 2014. Address information for PDLWH in California was collected in the CHSS from case report forms (CRF) completed at diagnosis, when there were changes in disease status, or at other times when updated demographic or location information were available. CHSS also collects address information from laboratory reports from diagnostic and clinical tests. For the purpose of this study, all addresses for PDLWH that did not have at least one document (e.g., CRF, laboratory report, death report) added to CHSS within the

12 months prior to December 31, 2014 were considered not current. However, PDLWH with out-of-date addresses were included if CHSS received at least one laboratory document or adult case reporting form (CRF) in 2013 or 2014, indicating that the individual was likely in care. Addresses were geocoded and validated against the database of U.S. Postal Service registered addresses using the subscription service geocoder from Melissa Data [21]. For residential addresses that were out of range (for example having a 1700 house number on a street that ended on the 1500 block) and therefore could only be geocoded to a zip code, we used the population-weighted centroid location of the zip code to estimate residential location for the purpose of determining trip duration to care facility [22].

The trip duration between place of residence and facility of care was obtained through Google Distance Matrix API [23], which accounts for speed limits, traffic, and one-way streets to calculate travel time using a pessimistic traffic model. To protect confidentiality of residential location, we applied a random offset distance and randomly selected direction as a function of population density from 100-200 meters in high density areas, and 800-1000 meters in low density areas. The offset was only applied to calculate the travel duration from residence to facility of care; SDH characteristics of residential location were derived using exact residential location points. Because the address of the care provider is routinely used by local surveillance staff in some jurisdictions as the residential address for people who are homeless or whose residential address is unknown, we excluded any PDLWH that had calculated trip duration of fewer than 5 minutes to avoid any potential bias due to such cases.

HIV Care Providers - HIV care providers are medical care professionals licensed to order HIV-related clinical tests in California, as derived from electronic laboratory reports (ELR) in the CHSS since ELR was instituted in California (November 2015). We used data on HIV care providers from two different sources for phases one and two. For phase one, we needed to know the travel duration of trips that actually took place. To determine the impedance-based decay function, we also needed to know provider locations that were potentially under consideration for patronization by an individual, but not selected. Therefore, for phase one, we used provider locations specified in CHSS laboratory reports for eligible PDLWH. For phase two, we were interesting in extrapolating empirically derived findings from phase one to understand hypothetical trips from residence to care provider. However, we needed to know the precise number of providers at each location to correctly calculate the PPR. Individual provider information is not explicitly collected in CHSS laboratory reports. Therefore, for phase two, we used data from the electronic laboratory reports before it is imported into the CHSS, which does include specific provider names and addresses. Providers in the ELR database were de-duplicated based on first name, last name, and the name of the facilities for which they provided care. Provider addresses were geocoded using the subscription service geocoder from Melissa Data [21]. Any addresses that were not valid according to Melissa were geocoded using Google Geocoding API web-service. Because we were interested in providers who specialize in HIV care, we included only providers who had five or more ELRs for tests routinely associated with HIV care (i.e., CD4, viral load, and genotype tests). The criterion of requiring five ELR test results to be considered an HIV care provider was used to differentiate between providers who routinely cared for PDLWH versus other medical care professionals, such as emergency department or primary care physicians, who do not specialize in caring for HIV patients. Some providers work at multiple locations (e.g., both a community clinic and a private office), but we were unable to discern what percentage of time providers work at each location. It was therefore necessary to assume that all providers worked full time at the location they were associated with, even though that meant some providers were counted as offering care at two places at once. Providers were then aggregated to the census tract level, using census tract centroid to approximate the provider location, in order to reduce the processing resources required to estimate the model.

Individual-level Factors: We reported current gender, age, race/ethnicity, HIV transmission risk category, and number of years since diagnosis as of December 31st, 2014 for each PDLWH in the dataset using standard classification schemes. The high-risk heterosexual contact transmission risk category includes persons who reported engaging in heterosexual intercourse with a person of the opposite sex of their sex-at-birth, if that partner was known to be HIV positive or engage an activity that put them at high risk for contracting HIV (e.g., injection drug use). The heterosexual contact (non-high-risk) transmission risk category includes persons with no other identified risk who reported engaging in heterosexual intercourse with a person of the opposite sex of their sex-at-birth. Perinatal includes persons who were exposed to HIV before, during, or after birth due to breastfeeding. "Other" risk includes persons with hemophilia, who received a blood transfusion, or who experienced an occupational exposure.

Community-level factors: To calculate SDH characteristics, non-offset point locations of residence were spatially merged with a California census tracts polygon data file. Community SDH characteristics were derived from American Community Survey 2010-2014 5-year estimate data using census tract-level data from the U.S. Census Tigerline Shape Files for geographic characteristics. We calculated community-based risk level (CBRL) quintiles for the following seven census tract characteristics: percent of residents living in households with incomes lower than the poverty line within the 12 months prior to the survey response, median household income, population density (population/square kilometer), percent of residents with less than a high school diploma or equivalent, percent of residents without health insurance, percent of workforce-eligible residents ages 16 years and older who were unemployed, and percent of residents without household access to a privately-owned vehicle (9).

For characterizing urbanicity of census tracts, we used the U.S. Department of Agriculture Rural-Urban Commuting Area (RUCA) classification system based on data from the 2010 decennial Census and American Community Survey to classify census tracts along the spectrum ranging from urban core to isolated rural (31). Specifically, we used the consolidation scheme proposed by the Washington State Department of Health, which combines the RUCA codes into four categories: Urban Core, Sub-Urban, Large Rural Town, and Small Town/Isolated Rural Area (32) (this will henceforth be referred to as CRUCA). This is a particularly appropriate measure of urbanicity because it is derived using information on commuting patterns when categorizing the census tracts.

Results

Among the 126,241 PDLWH in California as of December 31, 2014, 60,478 (48%) had residential addresses that were determined to be recent, were successfully validated and geocoded, and were therefore included in the analyses. There were 12,634 (10%) PDLWH who had residential addresses in the CHSS that were not valid because of an invalid address number, street name, city, or zip code, and could therefore not be geocoded or included in the analyses. An additional 52,268 (41%) PDLWH were excluded because they had no recent residential address in the CHSS (i.e., the address did not meet one of the four criteria described earlier) or had an otherwise ineligible address type (e.g., they lived in an institution or were homeless). The distributions of PDLWH with recent/valid addresses were similar to those with recent/invalid addresses and no recent addresses with regard to gender, race/ethnicity, and age and have been reported previously [10]. The reduced dataset for calculating the catchment areas and decay functions included 11,102 (9%) PDLWH who had a lab test with a recorded provider with a valid and geocoded address among the 8,590 unique facilities with valid addresses in CHSS. However, 651 (5.9%) of the 11,102 PDLWH were excluded from analysis because the trip durations between the offset residential locations and care facilities were less than 5 minutes, indicating likely institutional, unknown, or homeless addresses. This yielded a final sample of 10,451 PDWLH who had laboratory reports from 365 care providers.

The distributions of PDLWH with recent/valid addresses were similar to those with only zip code available, those that were excluded because the short trip duration indicated likely institutional, unknown, or homeless address, and all PDLWH in California with regard to gender, race/ethnicity, and age. However, a higher percentage of PDLWH who had recent/valid addresses were in the men who have sex with men (MSM) transmission category (72%) than was the case among PDLWH who had recent/zip code-only addresses (67%), excluded (68%) and all PDLWH in California (66%). In addition, fewer PDLWH who had recent/valid addresses and all PDLWH in California were in the more than 5 years since diagnosis category (80%) than was the case among PDLWH who had recent/zip code-only addresses (85%). There were substantial differences in the distributions of viral load suppression among PDLWH who had recent/valid addresses, recent/zip code-only addresses, and all PDLWH in California. Specifically, PDLWH who had recent/valid addresses (87%), recent/zip code-only addresses (81%), or were excluded (80%) were more likely to have a suppressed viral load compared to all PDLWH in California (55%), and were also much less likely to have unknown viral suppression status (1%, 2%, and 2% versus 36%, respectively). People with recent/zip code-only addresses (17%) and those who were excluded (19%) were also more likely to have an unsuppressed viral load compared to those with recent/valid addresses (12%) and all PDLWH in California (8%).

For providers in phase one analyses, there were 11, 983 eligible providers recorded in the CHSS of which 8,590 had valid, geocodable addresses. There were 365 that matched with the 10,451 PDWLH with current, valid, and geocodable addresses. For phase two analyses, there were 685,144 laboratory reports submitted via ELR to CHSS between November 2015 and October 2016 which were submitted by 24,126 unique providers. Among these 20,498 were eliminated because the provider had submitted fewer than five HIV-related clinical tests. The final provider dataset included 3,628 HIV care providers in California, located in 823 California census tracts.

We calculated variable catchment area for care facilities using the 90th percentile travel duration using the pessimistic traffic model stratifying by surveillance project area and population density (Table 1). For the Los Angeles County project area, we found the 90th percentile travel duration ranged between 60.1 minutes for the least population dense areas (quintile five), to 37.6 minutes for moderate population density areas (quintile three), and 55.9 minutes for most dense areas (quintile one). In the San Francisco project area, care facilities were only located in the highest density quintile and the 90th percentile travel time was 20.7 minutes. For California project area, we found the 90th percentile travel duration ranged between 136.1 minutes for least population dense areas (quintile five), to 52.1 minutes for moderate population density areas (quintile three), and 86.7 minutes for most dense areas (quintile one).

The step-one provider decay function stratified by population density quintile yielded a 0.002 reduction in probability of patronization for 1 log-transformed minute increase in travel duration. Population density had a significant effect on the function slope (figure 2). Census tracts in the lowest population density quintiles had the most shallow slope, followed by the most dense quintile (quintile one) tracts, and quintile three. Quintiles two and four both had the steepest slopes. Simulated patronization probability weight curves by trip duration stratified by population density quintile to be applied in E2SFCA step 1 are presented in Figure 2.

For the E2SFCA step two variable catchment area schema, we used census tract centroids to represent residential population locations. We use the 90th percentile travel duration using the pessimistic traffic model stratified by surveillance project area and population density (table 2). For Los Angeles County project area, we found the 90th percentile travel duration ranged between 71.7 minutes for residents least population dense areas (quintile five), to 43.7 minutes for residents of most dense areas (quintile one). In the San Francisco County project area the 90th percentile travel duration ranged between 18.8 minutes for residents least population dense areas (quintile five), to 19.9 minutes for residents of most dense areas (quintile one) For California project area, we found the 90th percentile travel duration ranged between 123.2 minutes for residents in least population dense areas (quintile five), to 98.8 minutes for moderate population density areas (quintile three), and 138.3 minutes for most dense areas (quintile one).

The step-two provider impedance decay function stratified by population density quintile yielded a 0.019 reduction in probability of patronization for 1 log-transformed minute increase in travel duration. Population density had a significant effect on the function slope. Census tracts in the highest population density quintiles had the steepest slope, and the remaining quintiles had similar, more shallow slopes. Simulated patronization probability weight curves by trip duration stratified by population density quintile to be applied in E2SFCA step 2 are presented in Figure 3.

The geometric mean PPR in California was 6.02 providers per 100 PDLWH population and ranged from 0.1 PPM per 100 population to 42.8 providers per 100 population. Among PDLWH in California in 2014, 2,982 (6%) lived in census tracts with fewer than two providers per 100 population and 34,841 (64%) lived in census tracts with fewer than five providers per 100 population (table 3). Among demographic and clinical factors, female PDLWH had a greater average PPR (5.2) compared to males (4.8), transgender male-female (4.2) and transgender female to male (3.4). Native Hawaiian/Other Pacific Islander PDLWH had the highest PPR (6.8) and Hispanic/Latino PDLWH had the lowest (4.2). Among transmission categories, injection drug use had the highest average PPR (6.5) compared to MSM and non-high-risk heterosexual contact which had the lowest average PPR (4.8). Finally PDWLH with suppressed viral load had the lowest PPR (4.8) and PDLWH with unknown viral load status had the highest average PPR (5.7).

Geometric mean providers per 100 PDLWH increased as risk increased for SDH measures (table 4). For percent of residents living in households with income below the federal poverty line, the average providers per 100 PDLWH population was 6.2 for the lowest percentage quintile and 4.0 for the highest percentage quintile. Similar patterns were found for median income (quintile one average PPR= 5.8, quintile five PPR = 4.1), percent of residents with no health insurance (quintile one average PPR = 5.9, quintile five average PPR = 3.0), and percent of unemployed residents age 16 and older (quintile one average PPR = 5.3, quintile four average PPM = 4.5). For the measure of population density, the average PPR highest density quintile was 3.4 compared to the lowest density quintile at 5.9. The CRUCA category did not show a monotonic relationship with average PPR, however large rural town census tract had the highest average PPR of 7.4 and small town/isolated census tracts had an average PPR of 4.6.

Discussion

This analysis proposed an empirical enhancement to the 2SFCA method for calculating PPR, applied the enhanced method to HIV care in California, and described California PDLWH in terms of the derived PPR. We determined these enhancements were feasible additions to the 2SFCA method to determine access to care as well as a new use for HIV surveillance data in helping identify areas for intervention. Including impedance decay functions in the method also likely increased the degree to which our model reflected care seeking behavior by incorporating the notion that as duration to destination increases, the probability of patronization decreases. Additionally, catchment area sizes reflected that some individuals traveled two to three times longer in some population density strata than had been used in previous literature [15,16]. This analysis quantified suspicions among HIV practitioners that some Californians travel a long way for HIV care.

Among PDLWH in California in 2014, 2,982 (6%) lived in census tracts with fewer than two providers per 100 population and 34,841 (64%) lived in census tracts with fewer than five providers per 100 population. There were 1,219 PDLWH living in highest poverty quintile census tracts where there were fewer than two providers per 100 PDLWH. There was a similar relationship between numbers of PDLWH in low median income and high lack of health insurance census tracts with fewer than to providers per 100 PDLWH. There were also 1,338 Hispanic/Latino, 496 black/African American, and 56 multiple race PDLWH living in census tracts with fewer than two providers per 100 PDLWH. These groups also had relatively large proportions of PDLWH in census tracts with fewer than five providers per 100 PDWLH.

While this model does represent a substantial refinement in examining access to care for PDLWH, there are still issues that should be addressed to make it more useful. The decay function model and weighting are likely oversimplified and would benefit from further analyses using a larger sample, which would also support examining additional stratifications. Future analysis should also consider performing sensitivity analyses to examine the impact of specific assumptions, such as assigning full weight to trip durations of less than 10 minutes for the decay functions, as well as whether the E2SFCA is sensitive to real-world changes in census tract PPR. In other words, if health departments add locations for HIV specialists to provide service in low-access areas, will the E2SFCA-derived PPR measures reflect this change. Additionally, it was beyond the scope of this study to determine whether PPR measures were associated with HIV disease outcomes. This is obviously critical to examine since if PPR does not correctly measure barriers associated with poor disease outcomes or is for other reasons not associated with poor disease outcomes, then it is not a useful approach for examining access to care. It is also important to know the degree to which differences in PPR affect disease outcomes. For example, we do not know if the difference between 2 PPR and 5 PPR is has a meaningful effect on disease outcomes, nor do we know if there is a PPR threshold below which community disease outcomes are impacted.

In previous research, PLDWH have identified barriers to care that are generally characterized as being structural (e.g., transportation, ability to pay), psychological (e.g., stigma, social support), or clinic specific (e.g., scheduling, follow-up assistance, patient-provider relationships [28–30]. These barriers differ across socioeconomic circumstances and also among PDLWH who are engaged in care compared to those out of care [31]. The methodology presented in this study measures primarily structural barriers, however there are opportunities to adapt the methods to measure other psychological and clinic-specific barriers as well. Additional information could be collected from providers regarding whether hours of business extend into after-work hours, if medical assistance is accepted, if pre-exposure prophylaxis medicine is available, and if providers are bilingual, we can determine access to specific services especially for populations in need of these services. Finally, we measured accessibility exclusively using driving travel duration; however, other modes of transportation, including walking, biking, and public transportation, should also be considered, particularly for examining access to care in urban areas.

Because this is a cross-sectional, ecological analysis, the results should be interpreted with caution; it cannot be determined from this study whether living in a community with a lower PPR leads to lower access to care. Generalizations from the present analysis may be hindered by the fact that PDLWH without a current, valid residential address were excluded, which was a substantial percentage (49%) of the original sample. In order to better represent the entire population of PDLWH in terms of community SDH, future efforts should seek to obtain current and valid residential address information from sources external to the HIV surveillance system for individuals with out-of-date or invalid addresses. For example, other U.S. HIV surveillance programs have used commercial external address locator services to improve address information for PDLWH. The use of these in future efforts is recommended; the cost of these services was prohibitive for the present effort.

Several limitations should be considered when interpreting these results. Recent, valid address information was not available for 49% of the PDLWH, which may not represent the population of PDLWH living in California. However, an increasing number of laboratories report electronically to OA which is expected to improve the percentage of people with current address information in CHSS. The percent of PDLWH in California with recent, valid residential and recorded provider address information which we used for phase one analysis was available for only 9% of the population. In addition, this sample included a disproportionate number of PDLWH (77%) and facilities (81%) from Los Angeles County, which has been conducting electronic laboratory reporting for longer than San Francisco or the CPA and therefore the sample is likely not representative of these areas. In addition, our findings may be affected by clustering for PDLWH and facilities that are in the CPA, but are near Los Angeles County. For example, roughly 600 (48%) of CPA PDLWH were from one facility in Southern California located in a rural area of CPA that draws PDLWH from long distances. This likely affected catchment sizes, decay function results, and potentially the PPR. We were also limited to stratifying only by population density because any further stratification would significantly affect the power to make inferences on the effect of trip duration on the probability of patronization. In the near future, we will be able to use statewide ELR and have a representative sample as well as explore more complex modeling strategies that better explain provider selection behavior for deriving the PPR. Finally, we made the assumption that all providers are accessible to all people. Future studies should classify providers as available to all or limited availability, based on such factors as ability to pay, and insurance status and provider.

We used quintiles to delineate different levels of SDH. If census tract population density or other characteristics associated with care seeking behavior cluster in meaningful ways relevant to the present analysis, this method may mask important differences by moderating distinctions. There may be better ways to examine characteristics of geographic units according to pertinent features. Census tract of residence is used as a proxy for neighborhood/environmental influences on access to care but may not correctly represent neighborhood boundaries and therefore may miss critical influences on disease outcomes related to people's' environments [32]. Census block groups represent smaller geographic areas and therefore may better represent neighborhood characteristics, especially in areas with heterogeneous populations with respect to SDH, density, or urbanicity characteristics.

This analysis represents an important methodological improvement in measuring PPR in a geographically large, demographically heterogeneous area. It also represents a framework for a considerable step forward in being able to measure access to care for PDLWH. As advances in HIV care and treatment continue to prolong the lives of PDLWH, access to accommodating, affordable, and acceptable HIV care providers becomes ever more critical. These methods will allow state and local health jurisdictions to: investigate factors associated with HIV-specific health disparities, improve the capacity to direct resources for improving health outcomes for PDLWH, and enhance transmission prevention efforts. We anticipate that the recent adoption of electronic laboratory reporting in California will substantially increase the number of cases in the CHSS that have current and valid address information. This will allow for greater representation of the population at higher risk for poor HIV disease outcomes and increase our knowledge of where to mobilize care resources.

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Tables and Figures

Table 1: Fiftieth percentile, ninetieth percentile, and maximum trip duration between care provider location and residence by California HIV jurisdiction and population density quintile *of provider facility location* for people diagnosed and living with HIV in California[1], 2014

Project Area	Population density (population/km^{2})	n	Number of Provider Facilities	Duration in minutes (pessimistic traffic model) 50th percentile	90th percentile	Maximum
Los Angeles County	Quintile 5 (0-682)	108	11	18.6	60.1	128.1
	Quintile 4 (682-1,850)	749	42	22.3	52.3	180.3
	Quintile 3 (1,850-2,980)	2327	51	17.7	37.6	187.8
	Quintile 2 (2,980-4,750)	1359	63	24.0	59.1	193.8
	Quintile 1 (4,750-62,400)	3555	131	23.4	55.9	198.8
San Francisco County	Quintile 1 (4,750-62,400)	1106	5	13.9	20.7	148.8
California project area	Quintile 5 (0-682)	439	14	23.7	136.1	177.8
	Quintile 4 (682-1,850)	223	22	16.8	58.6	197.6
	Quintile 3 (1,850-2,980)	23	12	19.6	52.1	103.3
	Quintile 2 (2,980-4,750)	32	11	14.8	76.1	146.8
	Quintile 1 (4,750-62,400)	530	3	16.1	86.7	180.2
Total		**10451**	**368**			

1 People diagnosed and living with HIV with current, valid, geocodable address and laboratory record reported during 2014 with a valid provider address incuded. Current address is an address reported to the California HIV surveillance system (CHSS) from a document (case report form, laboratory report, or death report) during 2013-2014, an address reported prior to 2013, but there were documents that did not include address reported to the CHSS during 2013-2014, or an address reported after 2014 that confirmed the address on the CHSS record that would have otherwise been considered out-of-date.

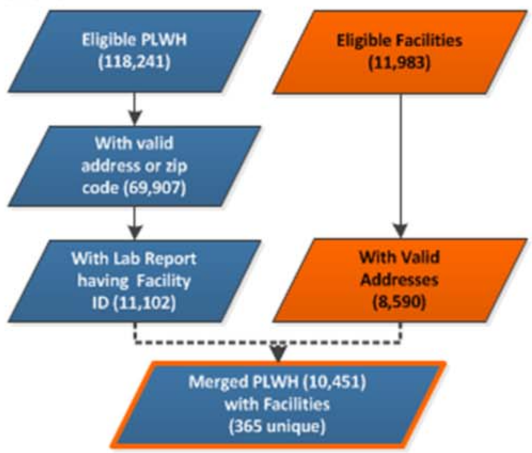
Table 2: Fiftieth percentile, ninetieth percentile, and maximum trip duration between residence and care provider location by California HIV surveillance jurisdiction and population density quintile *of residence* for people diagnosed and living with HIV in California[1], 2014

Project Area	Population density (population/km^{2})	n	Number of Provider Facilities	Duration in minutes (pessimistic traffic model) 50th percentile	90th percentile	Maximum
Los Angeles	Quintile 5 (0-682)	155	59	32.4	71.7	149.5
	Quintile 4 (682-1,850)	581	110	26.3	58.6	144.7
	Quintile 3 (1,850-2,980)	806	131	23.2	58.8	147.0
	Quintile 2 (2,980-4,750)	1872	168	22.7	52.5	157.4
	Quintile 1 (4,750-62,400)	4432	224	18.7	43.7	145.3
San Francisco	Quintile 5 (0-682)	5	1	18.0	18.8	19.2
	Quintile 4 (682-1,850)	12	1	15.3	19.0	19.2
	Quintile 3 (1,850-2,980)	14	1	18.0	19.8	20.5
	Quintile 2 (2,980-4,750)	50	2	13.7	18.7	21.3
	Quintile 1 (4,750-62,400)	991	9	13.8	19.9	108.7
California project area	Quintile 5 (0-682)	330	72	30.8	123.2	205.7
	Quintile 4 (682-1,850)	492	75	22.9	118.2	204.6
	Quintile 3 (1,850-2,980)	335	58	18.0	98.8	219.4
	Quintile 2 (2,980-4,750)	250	53	16.9	101.7	187.8
	Quintile 1 (4,750-62,400)	126	40	28.4	138.3	199.9
Total		**10451**	**365**			

1 People diagnosed and living with HIV with current, valid, geocodable address and laboratory record reported during 2014 with a valid provider address incuded. Current address is an address reported to the California HIV surveillance system (CHSS) from a document (case report form, laboratory report, or death report) during 2013-2014, an address reported prior to 2013, but there were documents that did not include address reported to the CHSS during 2013-2014, or an address reported after 2014 that confirmed the address on the CHSS record that would have otherwise been considered out-of-date.

Figure 1: Analytic process flow for calculating empirically derived catchment size schema, decay function, and enhanced two-step floating catchment area provider to population ratio

Phase 1: Calculate FACILITY and RESIDENCE Variable Catchment Sizes and Decay Functions



$$Patronize = \beta_0 * Pop_{density} + \beta_1 * Trip_{duration} * Pop_{density} + \varepsilon$$

$$Decay\_Wgt_j = \frac{Prob_{patronize_j}}{Max(Prob_{patronize})}$$

Phase 1a: Calculate FACILITY Variable Catchment Sizes and Decay Functions

Calculate trip duration for each PLWH-Facility match

Aggregate trip duration by population density quintile and CA project area of the location of the facility and calculate the 90th Percentile trip duration. This is the facility catchment size

Calculate the probability of each PLWH within each facility catchment area patronizing the selected facility as a function of trip duration, stratified by population density quintile

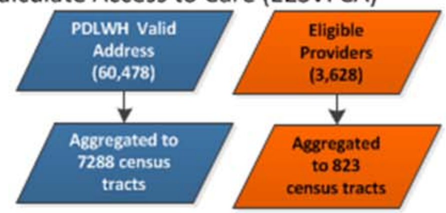
Phase 1b: Calculate RESIDENCE Variable Catchment Sizes and Decay Functions

Calculate trip duration for each PLWH-Facility match

Aggregate trip duration by population density quintile and CA project area of the location of the facility and calculate the 90th Percentile trip duration. This is the facility catchment size

Calculate the probability of each PLWH patronizing each facility in the residence catchment area as a function of duration, stratified by population density quintile

Phase 2: Apply Phase 1 findings to All CA PLWH and Facilities with Addresses to Calculate Access to Care (E2SVFCA)



E2SFCA Step 1

Create a trip duration derived spatial buffer around each facility (represented by 823 census tract centroids) using the identified catchment size specified from phase 1. **This is the facility catchment area**

Spatially merge PLWH addresses of residence (represented by 7288 census tract centroids) that are located within the catchment area and measure trip duration from facility centroid to residence centroid

For each population centroid within the catchment area, multiply the number of PDLWH by the decay function weight associated with the population density for the trip duration between the provider centroid and the residential centroid

Sum the weighted PLWH count within the catchment and divide by the number of providers at the in the current provider census tract. **This is the step1 provider to patient ratio for the current census tract.**

E2SFCA Step 2

Create a trip duration derived spatial buffer around each facility (represented by 823 census tract centroids) using the identified catchment size specified from phase 1. **This is the residence catchment area**

Spatially merge provider locations (represented by 823 census tract centroids) that are located within the residence catchment area and measure trip duration from residence centroid to provider centroid

For each population centroid within the catchment area, multiply the step one provider to population ratio by the decay function weight associated with the population density for the trip duration between the residential centroid and the provider centroid

Sum the weighted provider to patient ratio within the catchment. **This is the E2SFCA provider to population ratio measure for the selected census tract.**

Figure 2: HIV provider patronization probability weights for residential locations as a function of trip duration minutes among people diagnosed and living with HIV in California having a current/valid residential address, 2014

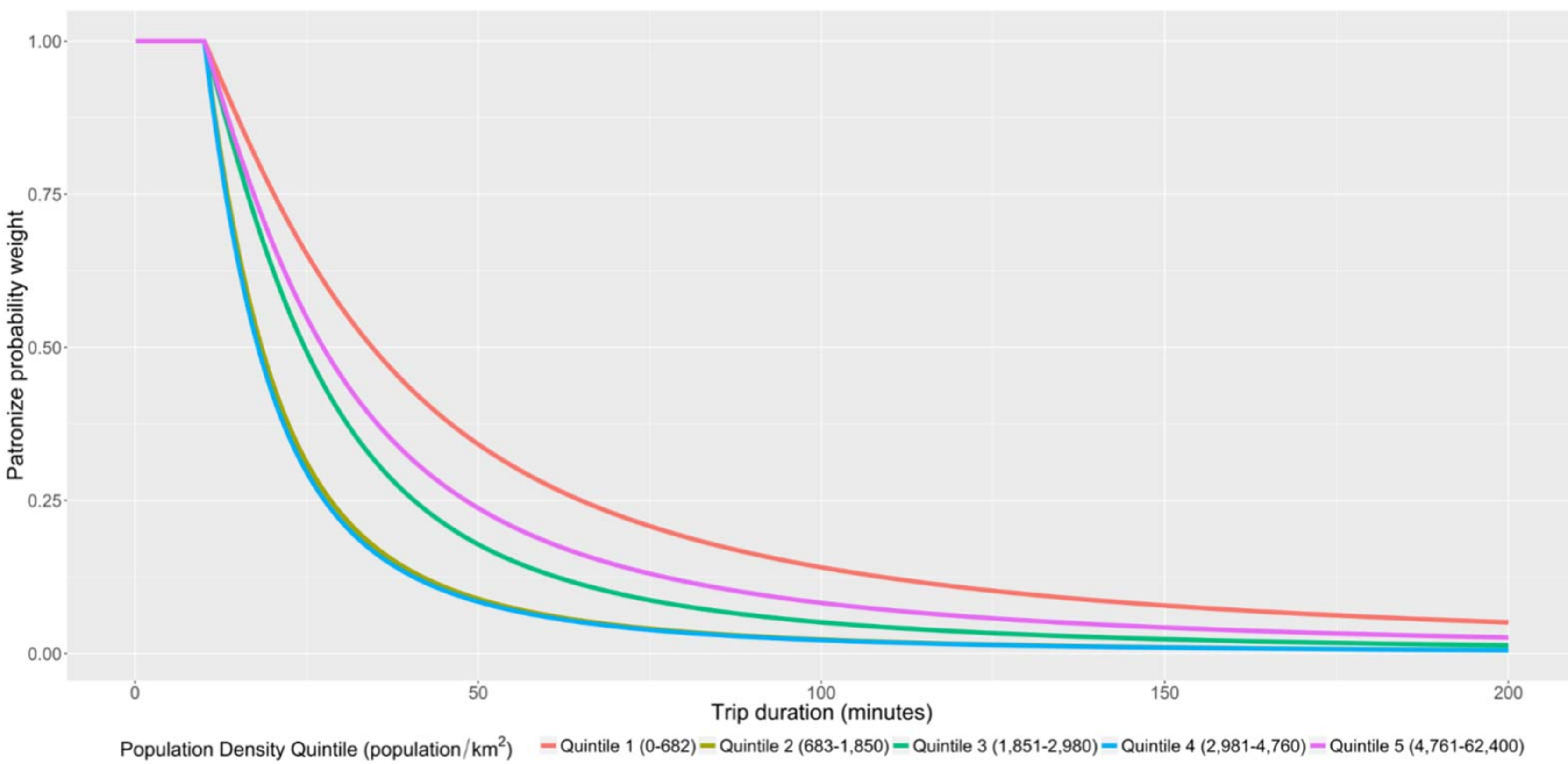


Figure 3: HIV provider patronization probability weights for residential locations as a function of trip duration minutes among people diagnosed and living with HIV in California having a current/valid residential address, 2014

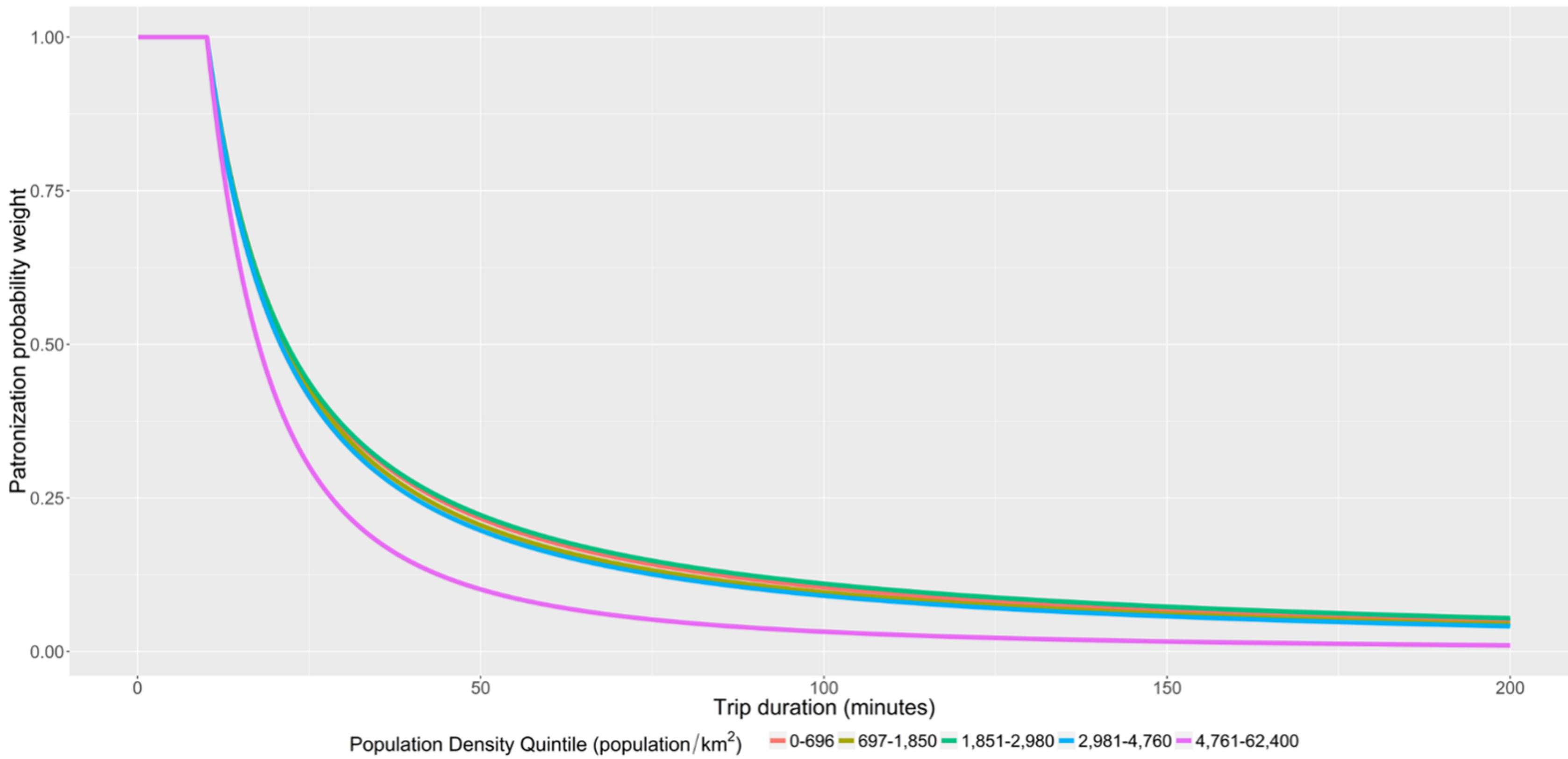


Table 3: Provider to population ratio for people diagnosed and living with HIV[1] with recent/valid addresses[2] by demographic characteristic and continuum of care indicators: California, 2014

Characteristic or Care Indicator	n	Geometric Mean	0-2 PPR[3] n (row %)	2-5 PPR[3] n (row %)	5-10 PPR[3] n (row %)	10-15 PPR[3] n (row %)	15+ PPR[3] n (row %)
Gender							
Male	52,496	4.83	2,588 (5)	28,085 (54)	13,681 (26)	6,685 (13)	1,444 (3)
Female	7,347	5.23	357 (5)	3,395 (46)	1,914 (26)	1,430 (19)	248 (3)
Transgender male-to-female	618	4.23	36 (6)	366 (59)	156 (25)	45 (7)	15 (2)
Transgender female-to-male	15	3.41	0 (<1)	12 (80)	3 (20)	0 (<1)	0 (<1)
Alternative designation	2		1 (50)	1 (50)	0 (<1)	0 (<1)	0 (<1)
Race/Ethnicity[3]							
Hispanic/Latino	21,659	4.20	1,338 (6)	12,968 (60)	5,097 (24)	1,960 (9)	293 (1)
White	24,750	5.30	983 (4)	11,722 (47)	7,488 (30)	3,661 (15)	885 (4)
American Indian/Alaska Native	184	6.01	5 (3)	74 (40)	62 (34)	35 (19)	8 (4)
Asian and Asian Pacific Islander	2,532	5.31	100 (4)	1,196 (47)	695 (27)	496 (20)	45 (2)
Black/African American	10,236	5.04	496 (5)	5,254 (51)	2,192 (21)	1,842 (18)	450 (4)
Native Hawaiian/Other Pacific Islander	138	6.77	6 (4)	39 (28)	35 (25)	46 (33)	12 (9)
Multiple Races	974	4.23	54 (6)	605 (62)	181 (19)	120 (12)	14 (1)
UnKnown Race	5	6.03	0 (<1)	1 (20)	4 (80)	0 (<1)	0 (<1)
Age in Years (at end of 2014)							
13-18	128	5.89	10 (9)	35 (31)	29 (26)	36 (32)	2 (2)
19-24	1,191	5.11	42 (4)	588 (49)	334 (28)	192 (16)	35 (3)
25-34	7,611	4.72	393 (5)	4,156 (55)	1,893 (25)	966 (13)	203 (3)
35-44	12,201	4.66	627 (5)	6,838 (56)	2,966 (24)	1,483 (12)	287 (2)
45-54	21,686	4.83	1,106 (5)	11,539 (53)	5,528 (25)	2,903 (13)	610 (3)
55-64	13,290	5.05	627 (5)	6,663 (50)	3,651 (27)	1,916 (14)	433 (3)
65-74	3,713	5.28	151 (4)	1,720 (46)	1,141 (31)	576 (16)	125 (3)
75+	658	5.10	26 (4)	320 (49)	212 (32)	88 (13)	12 (2)

1 Persons living with HIV at the end of 2014.

2 Invalid addresses include addresses recorded with non-existent building numbers, streets, city, or zip codes.

3 Hispanic/Latino(a) persons can be of any race. Race/ethnicity was collected using Asian/Native Hawaiian/Pacific Islander as a single category until 2003; therefore cases reported prior to 2003 are classified as Asian above because they cannot be disaggregated.

4 High-risk Heterosexual contact includes persons who reported engaging in heterosexual intercourse with a person of the opposite sex of their sex-at-birth, and that partner was known to be HIV positive or engage an activity that put them at high risk for HIV (e.g., MSM, IDU). Heterosexual contact (non-high-risk) includes persons with no other identified risk who reported engaging in heterosexual intercourse with a person of the opposite sex of their sex-at-birth. Perinatal includes persons who were exposed immediately before, during, or after birth due to breastfeeding. 'Other' risk includes having hemophilia, receiving a blood transfusion, or experiencing an occupational exposure.

Table 3 (continued): Provider to population ratio for people diagnosed and living with HIV[1] with recent/valid addresses[2] by demographic characteristic and continuum of care indicators: California, 2014

Characteristic or Care Indicator	n	Geometric Mean	0-2 PPR[3] n (row %)	2-5 PPR[3] n (row %)	5-10 PPR[3] n (row %)	10-15 PPR[3] n (row %)	15+ PPR[3] n (row %)
Transmission Category[4]							
Male-to-male sexual contact (MSM)	41,062	4.77	2,017 (5)	22,428 (55)	10,774 (26)	4,784 (12)	1,052 (3)
Injection drug use (IDU)	3,359	6.48	130 (4)	1,273 (38)	1,033 (31)	772 (23)	149 (4)
MSM and IDU	4,061	5.66	182 (4)	1,961 (48)	1,248 (31)	529 (13)	138 (3)
High-risk heterosexual contact (HRH)	5,739	6.41	240 (4)	2,238 (39)	1,636 (29)	1,344 (23)	279 (5)
Perinatal	272	5.75	17 (6)	120 (44)	73 (27)	57 (21)	5 (2)
Heterosexual contact (Non-HRH)	3,431	4.75	214 (6)	2,059 (60)	626 (18)	480 (14)	50 (1)
Unknown risk	2,348	3.89	174 (7)	1,697 (72)	305 (13)	146 (6)	26 (1)
Other	206	6.42	8 (4)	83 (40)	59 (29)	48 (23)	8 (4)
Years since diagnosis							
More than 5 years	45,692	4.83	2,314 (5)	24,298 (53)	11,742 (26)	6,014 (13)	1,310 (3)
3-5 years	8,654	5.39	381 (4)	4,541 (52)	2,236 (26)	1,267 (15)	228 (3)
1-2 years	6,132	5.56	287 (5)	3,020 (49)	1,776 (29)	879 (14)	169 (3)
Viral Load Status							
Suppressed Viral Load	42,917	4.81	2,247 (5)	22,857 (53)	10,986 (26)	5,662 (13)	1,158 (3)
Not Suppressed Viral Load	5,573	5.16	298 (5)	3,042 (55)	1,379 (25)	675 (12)	178 (3)
Unknown Viral Load	11,988	5.68	437 (4)	5,960 (50)	3,389 (28)	1,823 (15)	371 (3)
Total	**60478**	**6.12**	**2,982 (5)**	**31,859 (53)**	**15,754** (37)	**8,160** (19)	**1,707** (4)

1 Persons living with HIV at the end of 2014.

2 Invalid addresses include addresses recorded with non-existent building numbers, streets, city, or zip codes.

3 Hispanic/Latino(a) persons can be of any race. Race/ethnicity was collected using Asian/Native Hawaiian/Pacific Islander as a single category until 2003; therefore cases reported prior to 2003 are classified as Asian above because they cannot be disaggregated.

4 High-risk Heterosexual contact includes persons who reported engaging in heterosexual intercourse with a person of the opposite sex of their sex-at-birth, and that partner was known to be HIV positive or engage an activity that put them at high risk for HIV (e.g., MSM, IDU). Heterosexual contact (non-high-risk) includes persons with no other identified risk who reported engaging in heterosexual intercourse with a person of the opposite sex of their sex-at-birth. Perinatal includes persons who were exposed immediately before, during, or after birth due to breastfeeding. 'Other' risk includes having hemophilia, receiving a blood transfusion, or experiencing an occupational exposure.

Table 4: Enhanced two-step floating catchment area-derived provider to population ratio for people diagnosed and living with HIV[1] with recent/valid addresses[2] by community characteristics: California, 2014

Social Determinant of Health/Characteristic	n	Geometric Mean	0-2 PPR[3] n (row %)	2-5 PPR[3] n (row %)	5-10 PPR[3] n (row %)	10-15 PPR[3] n (row %)	15+ PPR[3] n (row %)
Percent of Residents Living in Households with Income Below Poverty							
Quintile 1 (0-6.2)	6253	6.23	61 (<1)	2,767 (44)	1,624 (26)	1,610 (26)	190 (3)
Quintile 2 (6.2-10.6)	10523	5.05	393 (4)	5,728 (54)	2,548 (24)	1,724 (16)	129 (1)
Quintile 3 (10.6-16.6)	13493	4.60	525 (4)	7,227 (54)	3,788 (28)	1,703 (13)	246 (2)
Quintile 4 (16.6-26.1)	14074	4.67	784 (6)	7,205 (51)	3,967 (28)	1,615 (11)	497 (4)
Quintile 5 (26.1-100)	16135	3.97	1,219 (8)	8,932 (55)	3,827 (24)	1,508 (9)	645 (4)
Median Income							
Quintile 1 ($90,700-250,000)	8430	5.75	103 (1)	4,582 (54)	1,766 (21)	1,855 (22)	124 (1)
Quintile 2 ($68,000-90,700)	10847	5.27	296 (3)	5,244 (48)	3,292 (30)	1,810 (17)	204 (2)
Quintile 3 ($52,700-68,000)	11750	4.78	461 (4)	6,323 (54)	3,240 (28)	1,384 (12)	337 (3)
Quintile 4 ($39,500-52,700)	12549	4.63	885 (7)	6,379 (51)	3,434 (27)	1,527 (12)	320 (3)
Quintile 5 (0-39,500)	16902	4.14	1,237 (7)	9,331 (55)	4,022 (24)	1,584 (9)	722 (4)
Population Density (population per square kilometer)							
Quintile 1 (4,750-62,400)	26929	3.36	2,753 (10)	19,529 (73)	4,277 (16)	370 (1)	0 (<1)
Quintile 2 (2,980-4,750)	13003	5.15	100 (<1)	6,653 (51)	3,214 (25)	2,495 (19)	541 (4)
Quintile 3 (1,850-2,980)	8474	5.81	64 (<1)	2,901 (34)	2,682 (32)	2,288 (27)	537 (6)
Quintile 4 (682-1,850)	7345	5.99	18 (<1)	1,697 (23)	3,370 (46)	1,793 (24)	457 (6)
Quintile 5 (0-682)	4727	5.92	47 (<1)	1,079 (23)	2,211 (47)	1,214 (26)	172 (4)

1 Persons living with HIV at the end of 2014.

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3 Providers per 100 people diagnosed and living with HIV

Table 4 (continued): Enhanced two-step floating catchment area-derived provider to population ratio for people diagnosed and living with HIV[1] with recent/valid addresses[2] by community characteristics: California, 2014

Social Determinant of Health/Characteristic	n	Geometric Mean	0-2 PPR[3] n (row %)	2-5 PPR[3] n (row %)	5-10 PPR[3] n (row %)	10-15 PPR[3] n (row %)	15+ PPR[3] n (row %)
Percent with Less than High School Diploma							
Quintile 1 (0-18.4)	13877	4.76	530 (4)	7,982 (58)	3,598 (26)	1,404 (10)	363 (3)
Quintile 2 (18.4-29.4)	10494	5.64	331 (3)	4,508 (43)	3,340 (32)	1,873 (18)	434 (4)
Quintile 3 (29.4-41.9)	10281	5.59	417 (4)	4,434 (43)	2,983 (29)	1,920 (19)	519 (5)
Quintile 4 (41.9-57.4)	12709	4.86	709 (6)	6,633 (52)	3,012 (24)	2,036 (16)	319 (3)
Quintile 5 (57.4-100)	13117	3.82	995 (8)	8,302 (63)	2,821 (22)	927 (7)	72 (<1)
Percent having No Health Insurance							
Quintile 1 (0-7.6)	7675	5.93	107 (1)	3,751 (49)	1,936 (25)	1,718 (22)	163 (2)
Quintile 2 (7.6-12.4)	10403	5.75	326 (3)	4,416 (42)	3,072 (30)	2,244 (22)	340 (3)
Quintile 3 (12.4-17.7)	11904	5.43	429 (4)	5,295 (44)	3,735 (31)	1,938 (16)	507 (4)
Quintile 4 (17.7-24.6)	14062	4.89	733 (5)	7,012 (50)	4,095 (29)	1,658 (12)	554 (4)
Quintile 5 (24.6-65.5)	16434	3.00	1,387 (8)	11,385 (69)	2,916 (18)	602 (4)	143 (<1)
Urban/rural classification							
Urban core	58647	4.83	2,893 (5)	31,341 (53)	14,921 (25)	7,819 (13)	1,673 (3)
Sub-Urban	1447	6.27	51 (4)	356 (25)	717 (50)	318 (22)	5 (<1)
Large rural town	165	7.38	6 (4)	47 (31)	63 (42)	11 (7)	23 (15)
Small town/isolated	219	4.59	32 (15)	115 (53)	53 (24)	12 (6)	6 (3)

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3 Providers per 100 people diagnosed and living with HIV

Table 4 (continued): Enhanced two-step floating catchment area-derived provider to population ratio for people diagnosed and living with HIV[1] with recent/valid addresses[2] by community characteristics: California, 2014

Social Determinant of Health/Characteristic	n	Geometric Mean	0-2 PPR[3] n (row %)	2-5 PPR[3] n (row %)	5-10 PPR[3] n (row %)	10-15 PPR[3] n (row %)	15+ PPR[3] n (row %)
Percent Unemployed Residents Age 16 and Older							
Quintile 1 (0-4.3)	10111	5.33	278 (3)	4,906 (49)	3,245 (32)	1,453 (14)	229 (2)
Quintile 2 (4.3-5.8)	10640	5.10	536 (5)	5,237 (49)	3,177 (30)	1,414 (13)	271 (3)
Quintile 3 (5.8-7.4)	13765	4.66	565 (4)	7,678 (56)	3,546 (26)	1,601 (12)	369 (3)
Quintile 4 (7.4-9.6)	13160	4.46	839 (6)	7,366 (56)	2,955 (22)	1,682 (13)	313 (2)
Quintile 5 (9.6-100)	12802	4.85	764 (6)	6,672 (52)	2,831 (22)	2,010 (16)	525 (4)
Percent of Households with No Access to a Vehicle							
Quintile 1 (0-0.2)	13093	4.11	934 (7)	8,263 (63)	2,652 (20)	1,013 (8)	231 (2)
Quintile 2 (0.2-0.8)	11435	4.97	619 (5)	5,428 (47)	3,129 (27)	1,905 (17)	351 (3)
Quintile 3 (0.8-1.4)	11769	5.05	544 (5)	5,604 (48)	3,459 (29)	1,700 (14)	460 (4)
Quintile 4 (1.4-2.3)	11930	5.05	577 (5)	5,524 (46)	3,646 (31)	1,837 (15)	339 (3)
Quintile 5 (2.3-13.6)	12251	4.93	308 (3)	7,040 (57)	2,868 (23)	1,705 (14)	326 (3)
	60478						
Total			**2,982 (6)**	**31,859 (58)**	**15,754 (36)**	**8,160 (18)**	**1,707 (5)**

1 Persons living with HIV at the end of 2014.

2 Invalid addresses include addresses recorded with non-existent building numbers, streets, city, or zip codes.

3 Providers per 100 people diagnosed and living with HIV

Chapter 5: Integrated Discussion

This dissertation study demonstrated the feasibility and utility of incorporating geo-spatial data into analyses of disease outcomes for people diagnosed and living with HIV (PDLWH). Including geo-spatial data gives health departments and partners the capacity to mobilize geographically informed resources and interventions for improving HIV and other health related outcomes and identify distal causes of health disparities. In paper 1, we identified community and social determinants of health (SDH) and determined whether they are associated with negative HIV-related health outcomes. We found PDLWH in California were more likely to live in census tracts with higher percentages of people in households with income below poverty, without health insurance, with comparatively low median incomes, with high population density, and categorized as urban-center. Additionally, higher risk quintile census tracts were more likely to have unsuppressed viral load in most community and SDH characteristics. In paper two, we examined travel time from residence to care provider as a measure of proximity and whether increased travel time is associated with sub-optimal HIV treatment and disease outcomes. We found mixed results; this was likely due to influential outliers that had a greater effect due to a only 9% of PDLWH having enough data to make them eligible for the analysis. A greater understanding of how proximity influences care provider choice is important for public health departments to effectively use limited resources for the greatest public health impact as well as evaluate interventions that aim to reduce trip duration from residence to care providers. Finally, paper three proposed an empirical enhancement to the 2SFCA method for calculating PPR, applied the enhanced method to HIV care in California, and described California PDLWH in terms of the derived PPR. We determined these enhancements were feasible additions to the 2SFCA method to determine access to care as well as a new use for HIV surveillance data in helping identify areas for intervention.

This dissertation represents a start; however there is much more work that should be pursued. Records from the California HIV Surveillance System (CHSS) in 2014 had a high percentage of missing or out-of-date address information; analysis of more recent years will benefit systemic changes in how CHSS data are collected which will yield more current address information. While paper three showed that an Enhanced Two-Step Floating Catchment Area method using empirically derived catchment area size and decay function was feasible using HIV surveillance data, the next step is to compare this method with existing methods and refine with additional data to improve the precision with which we can model real-life access to care and care-seeking behavior among PDLWH. In addition, reliance on Google Distance Matrix API may be cost prohibitive for public health surveillance jurisdictions, so alternatives employing open source, freely available road network datasets and software capable of analyzing road networks should be explored. Future analysis should also examine interactions between individual , social determinants of health (SDH), and access to care characteristics, as well as interactions and collinearity among SDH and community measures. Systemic interactions should also be explored, as they may indicate areas where interventions could be especially efficient for improving care outcomes. The methodology presented in this study measures primarily structural barriers, however there are opportunities to adapt the methods to measure other psychological and clinic-specific barriers as well. If additional information could be collected from providers regarding the degree to which they can accommodate patrons' needs, such as flexible hours, payment assistance, and other services such as pre-exposure prophylaxis, we can determine proximity to specific services especially for populations in need of these services. We should use data from supplemental surveillance projects to explore differences between individuals' perceived access to care and objective measures of access to care as a way to elucidate additional barriers to care. Efforts to measure access to care using other modes of transportation, including walking, biking, and public transportation, should also be considered, particularly for examining access to care in urban areas and in areas where a relatively large proportion of the population lacks access to a vehicle.