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Surveillance of the Social Determinants of Health in California Communities: Racial, Ethnic, and Geographic Disparities

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Title: **Surveillance of the Social Determinants of Health in California Communities: Racial, Ethnic, and Geographic Disparities**

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ABSTRACT

Objective

To study the magnitude and direction of city level racial and ethnic differences in poverty and education to examine health equity and social determinants of health in California communities.

Design

We used data from the American Community Survey, United States Census Bureau, 2006-2010, and calculated differences in the prevalence of poverty and low educational attainment in adults by race/ethnicity and by census tracts within California cities. For race/ethnicity comparisons, when the referent group (p_2) to calculate the difference (p_1-p_2) was the non-Hispanic White population (considered a historically advantaged group), a positive difference was considered a health inequity. Differences with a non-White reference group were considered health disparities.

Setting

Cities and towns of the State of California, United States.

Results

Within-city differences in the prevalence of poverty and low educational attainment disfavored Black and Latinos compared to Whites in over 78% of cities. Compared to Whites, the median within-city poverty difference was 7.0% for Latinos and 6.2% for Blacks. For education, median within-city difference was 26.6% for Latinos compared to Whites. In a small, but not negligible proportion of cities, historically disadvantaged race/ethnicity groups had better social determinants of health outcomes than Whites. The median difference between the highest and lowest census tracts within cities was 14.3% for poverty and 15.7% for low educational attainment. Overall city poverty rate was weakly, but positively correlated with within-city racial/ethnic differences.

Conclusions

Disparities and inequities are widespread in California. Local health departments can partner with cities in their jurisdiction on strategies to reduce racial, ethnic and geographic differences in economic and educational outcomes.

ARTICLE SUMMARY

STRENGTHS AND LIMITATIONS OF THIS STUDY

- To our knowledge, this is the first comprehensive tabulation of pairwise within-city SDOH differences between major race/ethnic groups and neighbourhoods across California's cities.
- Most multi-level, place-based research, examines individual and neighborhood impacts, but often bypasses city as a "place": racial and ethnic differences in health outcomes and their social determinants are widely reported in the United States at the national, state, and county scale, with non-Hispanic White populations usually experiencing the best outcomes.
- This article fills a geographic gap in current public health surveillance by documenting the glaring disparities in poverty and low educational attainment by race/ethnicity and neighborhood that exist within nearly every California city.
- Examination of the geographical extent and magnitude of disparities in the social determinants is essential to engage local government in "health in all policies" and collaborations with public health agencies.
- As a univariate analysis, our findings have several limitations including lack of examination of other social determinants that could mediate the outcomes, timeperiod of the study that coincides with high levels of economic instability during the Great Recession, 2007-2009, and use of aggregated data that masks the heterogeneity of Asian and other sub-populations.

INTRODUCTION

Differences in health outcomes or their determinants are widely reported between racial and ethnic groups in the United States at the national, state, and county scale.[1-3] Differences that are avoidable, unfair and rooted in historical social disadvantage are defined as health inequities. Differences with biological or other underlying causes are health disparities.[4] County and city local health departments (LHDs) increasingly recognise their role in addressing the social determinants of health (SDOH) that underlie health inequities. LHDs are also reaching out to non-health sectors in their communities to impact the root causes of health inequities through "Health in All Policies".[5]

Geographic analysis of SDOH is used to reveal health inequities, and prioritise public health interventions and target community engagement. While an increasing number of LHDs examine health inequities at small geographies, most rely on county level data that masks important differences within counties. The surveillance of SDOH at small geographies poses methodological challenges and opportunities for taking data to action. In assessing racial and ethnic inequities, non-Hispanic Whites are often considered the socially advantaged referent group. It has been posited that it is relatively rare for the most privileged group not to have the best outcome.[4, p187]

We explore racial, ethnic, and geographic differences in poverty and low educational attainment. Poverty reduction, increasing educational attainment, and the elimination of health disparities are national health goals of the United States[6]; these two SDOH may account for 18% of the national burden of mortality.[7]

We examined 1) the magnitude and direction of racial, ethnic and geographical differences in these SDOH within and between California cities, 2) the relationship between overall community disadvantage and health inequities, and 3) possible actions that LHDs may consider based on surveillance findings.

METHODS

Data Source

We used data from the American Community Survey (ACS),[8 9] a continuous prevalence survey based on a probability sample of households throughout the United States. ACS publishes data in 5-year tabulations for cities and census tracts. We used ACS Selected Population Tables (2006-2010), which stratify the tabulations by mutually exclusive race and ethnicity categories: Hispanic or Latino, and non-Hispanic persons of the following races: White, Black, Asian, Native Hawaiian and Other Pacific Islander, Other, Multiple, and American Indian/Alaskan Native. For California, the ACS reported on 8,057 census tracts, 480 incorporated cities, and 1,043 non-incorporated places. The prevalence of poverty and its standard error were obtained from ACS Table DP03, and educational attainment in adults and its standard error were obtained from Table DP02. The California Department of Public Health compiled these data (www.cdph.ca.gov/programs/pages/healthycommunityindicators.aspx).

ACS Definition of Poverty and Educational Attainment

The prevalence of poverty was defined as the 5-year annual average percentage of all individuals whose household income in the past 12 months was below the federal poverty level. Total household income was calculated from eight questions on the ACS-1 form about wages, self-employment, securities, rental property, retirement and disability payments, and public assistance. Households were classified as poor when total income of the householder's family was below an income threshold, taking into account the size of the family, number of related children, and, for 1- and 2-person families, age of householder.[8] The prevalence of educational attainment less than high school was defined as the 5-year annual average percentage of adults aged 25 years or older whose maximum educational attainment was 0 to 11 years of grade school.

Between-City, Within-City, and Neighbourhood Level Racial and Ethnic Disparities and Inequities and Statistical Methods

We calculated between-city, within-city, and neighbourhood level differences for combinations of White, Asian, Latino, and Black subgroups.

Differences in the 5-year percentage of poverty or low educational attainment, p, were calculated between pairs of racial/ethnic groups, $p_1 - p_2$. Differences have a positive or negative sign based on the referent group (p_2). When the referent group, p_2, was White, a positive difference represents a health inequity. Differences with a non-White reference group were considered health disparities. For cities with two or more census tracts, neighbourhood disparities were defined as the absolute difference of census tracts with the highest and lowest 5-year percentage.

Mean and medians of between- and within-city differences and their standard deviation were calculated. The between-city mean difference was defined as the difference of the mean prevalence of two specified race/ethnicity groups across all cities:

$$\text{Between-city mean difference} = \frac{\sum_{i,j} p_{i,j}}{N_{\text{Total (j)}}} - \frac{\sum_{i,k} p_{i+1,k}}{N_{\text{Total(k)}}}$$

where *i* is the i^{th} race/ethnicity group and *j* is the j^{th} of N total cities of group_i, and *k* is the k^{th} of N total cities of group_{i+1}.

The within-city mean difference was defined as:

$$\text{Within-city mean difference} = \frac{\sum_{i.j} (p_{i,j} - p_{i+1,j})}{N_{\text{Total(j)}}},$$

where *i* is the *ith* race/ethnicity group and *j* is the *jth* of city of N_{Total} cities where data on both of the race/ethnicity pairs are available.

Within-city differences were plotted as cumulative frequency distributions of cities for each pairwise race/ethnicity comparison in order to assess the magnitude and direction

of racial and ethnic inequities or disparities in cities across the state. For each city, Z-tests were carried out to determine whether the within-city difference was statistically significant. We followed U.S. Census Bureau guidelines for pooling standard errors of percents, which is the square root of the sum of the squares of the two individual standard errors ($se = \sqrt{se_1^2 + se_2^2}$). A p value of 0.10 was considered statistically significant. R software was used for the calculations.[10]

SDOH differences are often interpreted in the context of the range of their absolute values. For example, in some very poor communities there may be no demonstrable differences between groups and "everyone is poor together". In other communities, there is a small, but statistically significantly difference between groups, but each group is relatively well off (e.g., has a SDOH value far above the mean.) To contextualise a city's disparities or inequities on a backdrop of high or low rate of poverty or educational attainment, we plotted within-city disparities or inequities, as a function of the between-city poverty rate (or educational attainment). Simple linear correlation (Pearson, r) assessed the strength of association.

Calculation of Neighbourhood Disparities

Census tract and city boundaries are not always congruent; therefore, for neighbourhood analyses, census tracts were associated with the city into which its centroid fell. We used ArcGIS 10.3 (ESRI, Redlands, CA) to calculate and associate centroids with cities. In some cases, portions of census tracts outside of city limits were included in neighbourhood comparisons. This introduces some potential misclassification if the outlying portion of the census tract has different poverty or educational attainment. We also calculated the mean linear distance in miles between the centroids of the census tracts with the highest and lowest poverty and educational outcomes.

Exclusions

The ACS does not publish data for geographic areas with fewer than 50 respondents. Of 1,523 cities the number available for within-city pairwise comparisons varied by race/ethnicity subgroup: 221 cities had data for Black-Asian comparisons, 280 for Asian-White, 245 for Black-White, 364 for Latino-Asian, 252 for Latino-Black, and 611 for Latino-White. We did not have sufficient data to carry out pairwise comparisons that included American Indian/Native Alaskans, Native Hawaiians and Other Pacific Islanders, Multiple races, and Other. Analyses of poverty at the census tract level excluded economically dependent populations in colleges, correctional facilities, and other group quarters and institutions. Two census tracts with a population less than 500 inhabitants was also excluded.

RESULTS

Between- and Within-City Racial and Ethnic Disparities and Inequities

The poverty rate of Latinos (18.6%) and Blacks (17.4%) averaged over California cities was nearly twice that of Whites (9.2%) and Asians (9.5%) (table 1).

Table 1 Between and Within-City Means and Race-Ethnicity Specific Pairwise Differences in Poverty Rate and Educational Attainment, California, 2006-2010

	Percent below the federal poverty level			Percent of adults aged ≥25 years without a high school education		
Between cities	Mean	SD	Median	Mean	SD	Median
White	9.2	6.9	7.5	8.7	7.3	6.7
Black	17.4	12.9	14.6	11.0	8.9	8.8
Asian	9.5	8.7	7.1	12.4	9.8	9.7
Latino	18.6	11.4	16.8	39.6	18.4	39.9

Pairwise differences (p_1-p_2)	Between city		Within city		Between city		Within city	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Black-White	8.2	7.1	8.5	6.2	2.3	2.1	2.0	0.6
Asian-White	0.3	-0.4	1.7	0.9	3.7	3.0	4.4	2.7
Latino-White	9.4	9.3	7.6	7.0	30.9	33.2	26.2	26.6
Black-Asian	7.9	7.5	6.5	4.8	-1.4	-0.9	-3.3	-3.1
Latino-Asian	9.1	9.7	5.1	4.8	27.2	30.2	19.0	19.2
Latino-Black	1.2	2.2	0.3	0.5	28.6	31.1	24.9	25.4

The city average percentage of adults with low educational attainment was 3-4 times higher in Latinos compared to Whites, Asians, or Blacks. The largest mean between-city educational inequity (30.9%) was between Latinos and Whites.

The distribution of within-city differences of race/ethnicity pairs is presented for poverty and low educational attainment (Figure 1). In a large percentage of cities, Asians and Whites had better poverty outcomes than Latinos or Blacks. The largest inequities occurred between Blacks and Whites (8.5% mean difference) and Latinos and Whites (7.6%). In approximately 40% of cities, these differences were statistically significant. Latinos had better poverty outcomes than Asians or Whites in 26% and 18% of cities, respectively. Likewise, Blacks had better outcomes than Asians or Whites in approximately 20% of cities. The average differences in within-city poverty rates between Blacks and Latinos were small (0.3%), but there was considerable variation.

For low educational attainment (Figure 1 b), the largest mean difference was between Latinos and other groups (Latino-Whites, 26.2%; Latino-Blacks, 24.9%; Latino-Asians, 19.0%). Whites tended to have better outcomes than Asians or Blacks. Blacks tended to have better outcomes than Asians. Latinos had poorer outcomes than the other groups in almost all cities (94% or higher). An overwhelming majority of within-city differences between Latinos and other groups were statistically significant.

Supplemental materials include maps of California cities depicting the race/ethnicity with the largest disparity for poverty or educational attainment.

Between- and Within-City Racial and Ethnicity Correlations

Within-city racial/ethnic differences in poverty and overall city poverty rate (Figure 2 a), appear to be correlated for all race/ethnicity combinations with White or Asian referents, but exhibit considerable variability (scatter). Black and Latino inequities (White referents) tended to be larger at higher levels of overall poverty ($r = 0.37$, $P < 0.01$). A

weaker association (r = 0.20, *P* <0.01) was observed for Black or Latinos with Asian referents.

In a large proportion of California cities, Latinos experience both large educational disparities and live in cities with low overall educational attainment. Within-city education differences between Latinos and other groups were strongly associated (r range: 0.48 to 0.60) with overall city low educational attainment (Figure 2 b).

Neighbourhood Disparities

The distribution of within-city differences of poverty and educational attainment between the highest and lowest census tract is presented in Figure 3. The median difference was 14.3% for poverty and 15.7% for educational attainment. Disparities of 25% or greater were observed in 25% of cities for poverty and 33% of cities for educational attainment. In approximately 73% of 500 cities with two or more census tracts, the differences were statistically significant. For the 174 cities with 10 or more census tracts, 99% of differences were statistically significant. The median straight-line distance between the highest and lowest census tracts was 2.6 km (SD, 3.2) for poverty and 2.9 km (SD, 3.04) for educational attainment.

DISCUSSION

We found widespread racial, ethnic, and geographic differences in educational attainment and poverty within California cities. Comparisons between Whites and Blacks and Whites and Latinos generally conformed to a health inequities model – that historically, socially disadvantaged groups had poorer outcomes than Whites. This was less frequent in comparisons between Asians and Whites. In a small, but not negligible proportion of cities, historically disadvantaged race/ethnicity groups had better SDOH outcomes than Whites. We found a correlation between a community's underlying level of poverty (or educational attainment) and racial/ethnic disparities. Neighbourhood level differences within cities were also ubiquitous. On average, a mere 2.6 km separates a city's census tracts with the highest and lowest poverty rate or educational attainment.

Strengths and Limitations

To our knowledge, this is the first comprehensive tabulation of pairwise within-city SDOH differences between major race/ethnic groups and neighbourhoods across California's cities.

As a univariate analysis, our findings have several limitations. Racial/ethnic differences may be related other SDOHs which mediate the outcome. For example, recency of immigration profoundly influences poverty and educational attainment, and may explain, in part, the educational inequities we observed in Latinos and Whites. Moreover, SDOH are themselves interrelated. Conducting a multivariate analysis to establish the independence of racial/ethnicity disparities[4], is not feasible using pre-tabulated ACS tables. Other U.S. Census Bureau products (Public Use Microdata Sample) and surveys may serve this purpose, but do not provide reliable estimates at small geographies.

For a small percentage of cities, socially disadvantaged groups had significantly better outcomes than Whites. Further research of these cities may reveal whether this finding

is associated with community "resiliency", confounded by other sociodemographic factors, or has another explanation.

The Asian category includes subpopulations whose poverty and educational attainment are heterogeneous. Valuable information may have been lost by aggregation.

Differences in SDOH between geographic units such as census tracts may be disparities or inequities, depending on the history of social disadvantage. Long-standing patterns of racial discrimination and economic segregation within California cities[11] undoubtedly underlie some of the differences that we labeled disparities.

Data suppression in the ACS impacts numerically small, geographically dispersed racial/ethnic populations, creating information bias towards areas with greater racial concentration or segregation. Small rural communities account for a disproportionate number of exclusions in our analysis. Nonetheless, depending on the race/ethnicity comparison, the cities included in our analysis contain between 68% and 88% of the California population.

Cross-sectional data cannot be used to establish causal relationships or directionality. Our finding that a community's poverty rate and its racial/ethnic disparities are interrelated will require longitudinal, confirmatory studies. Studies in the United States and western countries suggest that income inequality inhibits overall economic development and economic mobility.[12]

The time period of this study coincided with high levels of economic instability during the Great Recession, 2007-2009. Cities and regions might have since experienced economic recovery, gentrification, population displacement, and community succession. Due to lags in reporting, ACS data may not reflect current conditions.

What Can Cities Do?

While cities alone cannot be expected to solve economic and educational disparities, they play an important role in shaping the social determinants of health through people- and place-based strategies.[13] In the United States local government plays an active role in recruiting and retaining employers, establishing preferences for minority-owned businesses, adopting local first-hire policies, and legislating minimum wages. School districts and boards exert local control over school policy and funding, whether the bulk of funds are from state or local taxes. Through local zoning, urban revitalization, and the creation of enterprise zones, local government shapes the built environment and the availability of resources for the basics of living (e.g., food outlets, housing, jobs, transportation). Local housing authorities implement federal and state policies that influence the availability and placement of affordable housing. Several health impact assessments and health studies document the likely and actual health promoting impacts of minimum wage ordinances[14 15] and housing vouchers that relocate renters from neighbourhoods with concentrated poverty to those with low poverty.[16 17] Many cities are examining their own internal policies and practices with regard to hiring, procurement, and building capacity through authentic deep community engagement.

Local elected officials often comprise the governing bodies of regional associations of government, which make decisions on regional transportation, housing, and economic investments. Economic development strategies forged at a regional level have a wide ranging impact at the local level.[18] There is evidence that some strategies that promote overall regional economic development may exacerbate economic disparities.[19]

What Can Local Health Departments Do?

Data and Surveillance

In general, SDOH indicators have not been institutionalised in public health surveillance at the state and local level in the same manner as mortality surveillance, communicable

disease reporting, and behavioral risk factor surveillance. Monitoring SDOH geographic variation, time trends, and population subgroups help assess the magnitude of the problem, identify high risk groups, monitor progress toward meeting goals, set priorities, and target resources for intervention. Several U.S. states have offices of health equity, which issue periodic reports.[20 21] Due to requirements of the Affordable Care Act (ACA), LHDs in partnership with nonprofit hospitals and community coalitions are producing community health needs assessments and improvement plans [US IRS Code Title IX, §6033(b)], frequently framing health disparities in terms of SDOH.[22 23] ACA implementation supports the institutionalization of surveillance of the SDOH at geographically resolved areas throughout the United States.

Health departments can also use the distribution of within-city inequities to identify specific cities that share socioeconomic and demographic similarities, but differ on health inequities. Fostering exchanges like learning collaboratives or intervention trials between peer cities may be but one mechanism to engage cities and identify successful strategies to reduce inequities.

Some LHDs are taking systematic approaches to link SDOH surveillance data to action in the form of how-to guides,[24] internal capacity building, and setting explicit goals and activities to reduce disparities.[25]

Internal Capacity Building on Racial and Health Equity

Efforts to examine and counter structural racism in health inequities are being integrated into public health practice by identifying upstream causes,[21 26] and conducting assessments of organizational behavior in health departments. Educational and action-oriented workshops, training, and toolkits are increasingly part of public health workforce development, program design, policy development, and evaluation[27 28] and should touch areas relevant to public health department accreditation.

Health in All Policies

With the ascendance of Health in All Policies (HiAP),[5] public health departments have opportunities to play an active and direct role in educating policy makers on the SDOH and health equity. Because different sectors may frame equity in profoundly different ways,[29] public health practitioners can convene and constructively engage partners, including those central to economic development and education. HiAP-related actions include health impact assessments, advising and participating in cross-sector planning (e.g., land use, transportation, food systems), and developing tools that non-health planners can use to quantify the health benefits or harms of various policies or programs.[27]

Service Environment

Overcoming fragmented social services delivery is highly desirable and underpins comprehensive models of service delivery that may have collective impact and address SDOHs.[30 31] Building on city-level data of poverty and educational inequities, health departments can play a role in monitoring and evaluating the equitable access and distribution of services provided by the health department and other social service agencies.

Conclusions

Racial, ethnic, and geographic disparities in poverty and educational attainment in adults are widespread within and between California cities. Given that public health practice is increasingly focused upstream, surveillance of the social determinants of health may afford opportunities for engagement with neighbourhoods, cities, and regional government to be an active partner in strategies that promote health and reduce poverty and low educational attainment.

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CONTRIBUTORS

DB and NM shared responsibilities in the design, analysis, and write up of this research.

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COMPETING INTERESTS

None declared.

PROTECTION OF HUMAN SUBJECTS IN RESEARCH

This study used publicly available data and did not involve human subjects in research.

DATA SHARING STATEMENT

This study used publicly available data. Data sets used in this analysis can be downloaded from: http://www.cdph.ca.gov/programs/Pages/HealthyCommunityIndicators.aspx.

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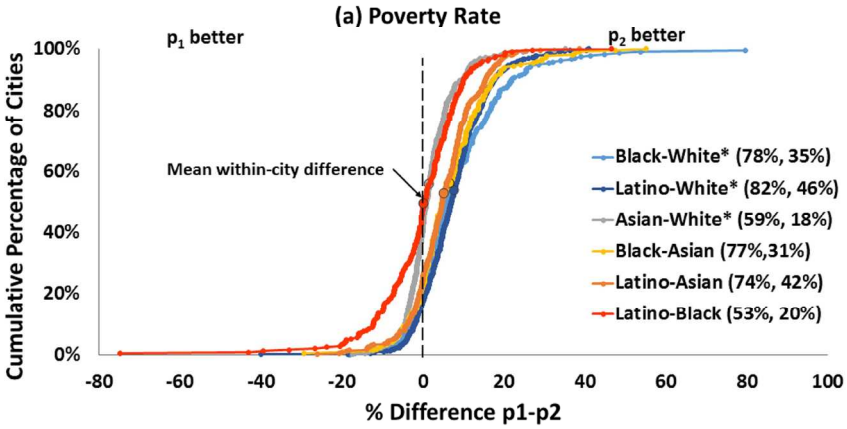
FIGURES LEGENDS

Figure 1. Distribution of Within-City Differences in (a) Poverty Rate and (b) Low Educational Attainment for Pairwise Comparisons of California Whites, Blacks, Latinos, and Asians, 2006-2010. *Considering Whites as a socially advantaged reference group, the differences that favor Whites are considered inequities. The legends show the percent of cities in which the p_2 race/ethnicity group has a better outcome and the percent of cities in which the outcome is statistically significant ($p < 0.1$). For instance, "Black-Asian (77%, 31%)" indicates that 77% of the cities in which the comparison is possible have a better outcome for the Asian group and 31% of those cities have a significantly better outcome.

Figure 2. Within-City Poverty Rate Differences and Overall City Poverty Rate (a) and Low Educational Attainment and Overall City Low Educational Attainment (b), California Cities, 2006-2010. r is the Pearson correlation coefficient between within city differences and the overall city value. *Considering Whites as a socially advantaged reference group, the differences that favor Whites are considered inequities.

Figure 3. Distribution of Within-City Differences in the Highest and Lowest Census Tract Rates for Educational Attainment and Poverty, California, 2006-2010.



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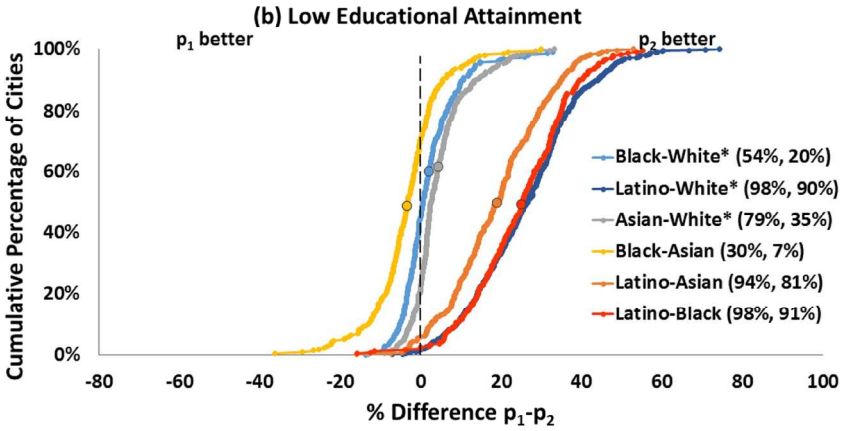

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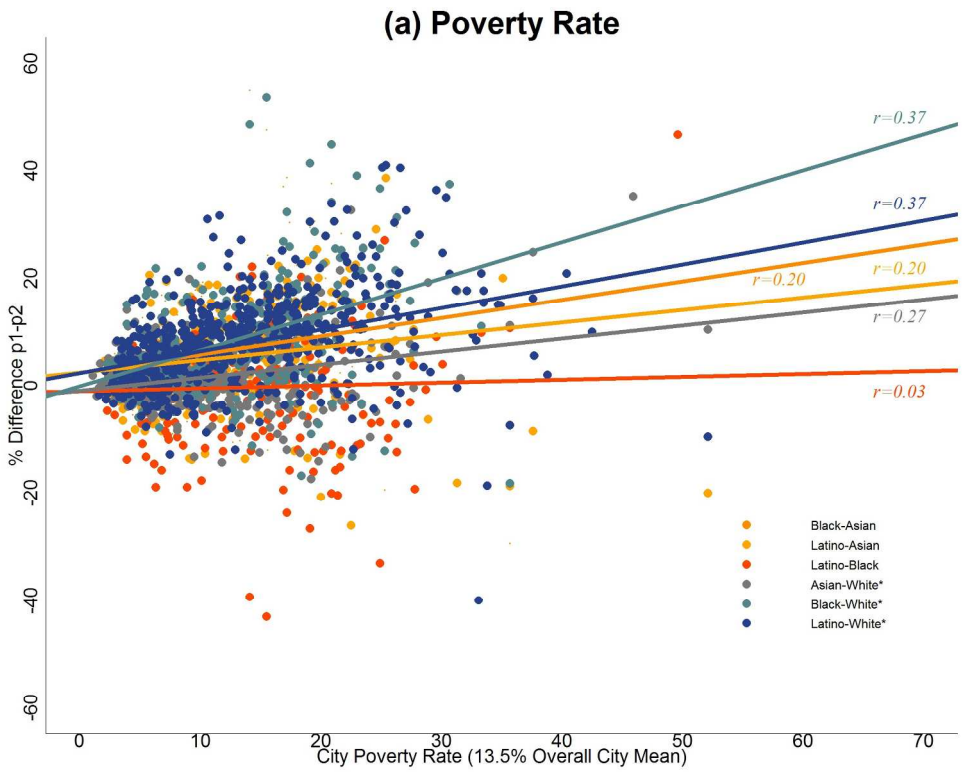

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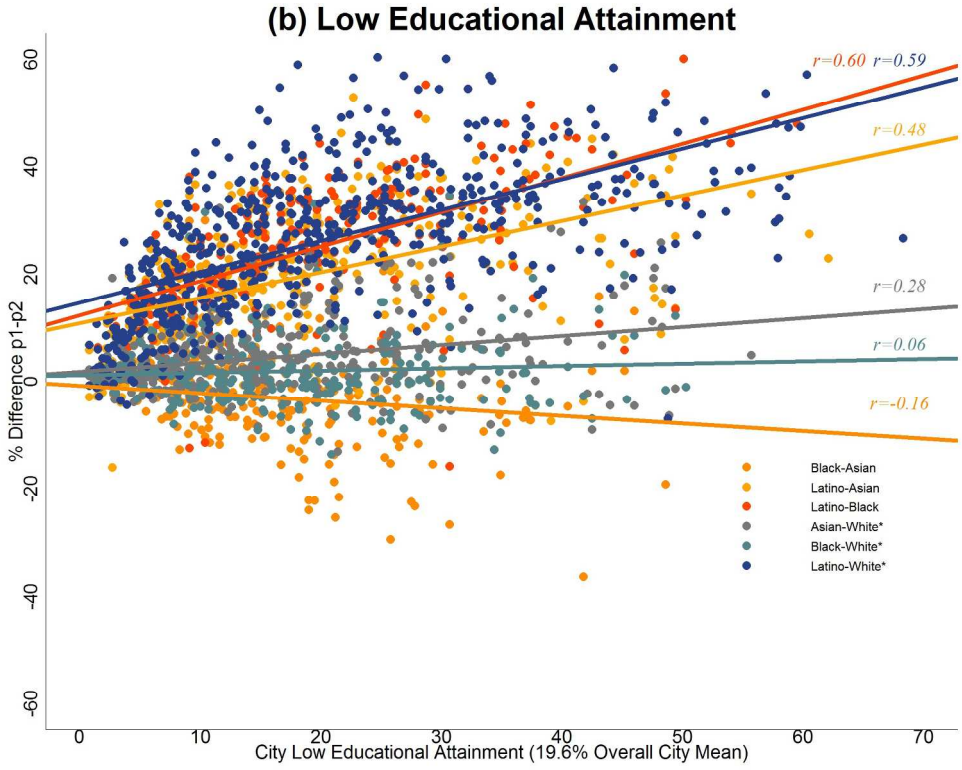

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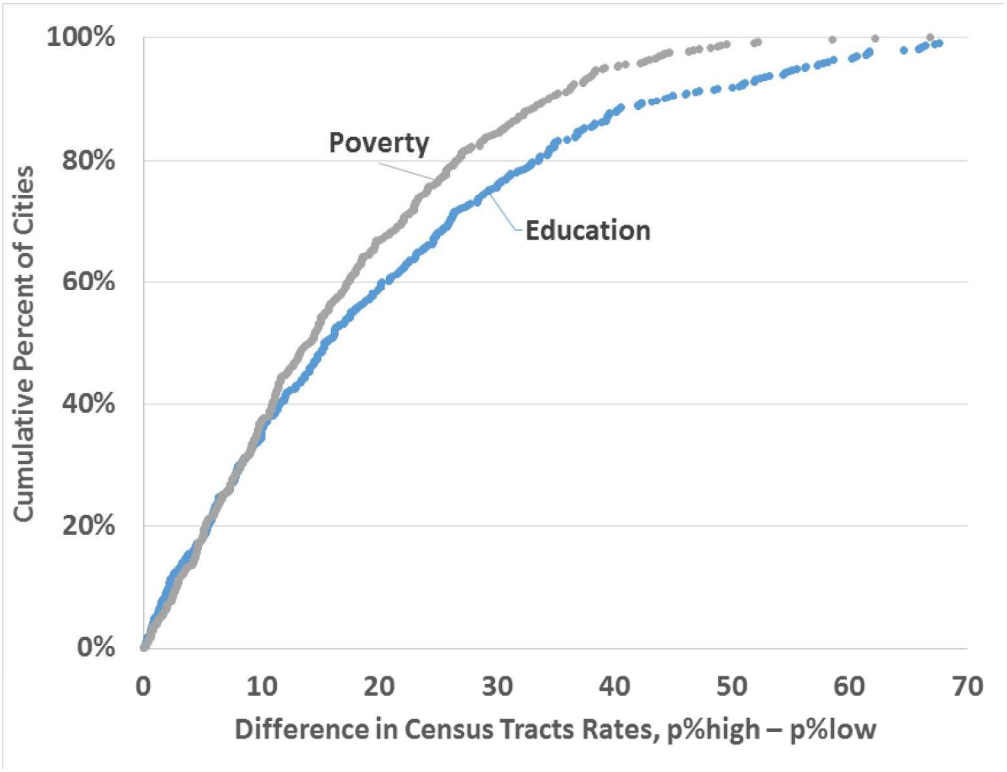

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Surveillance of the Social Determinants of Health in California Communities: Racial, Ethnic, and Geographic Disparities

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Title: **Surveillance of the Social Determinants of Health in California Communities: Racial, Ethnic, and Geographic Disparities**

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ABSTRACT

Objective

To study the magnitude and direction of city level racial and ethnic differences in poverty and education to examine health equity and social determinants of health in California communities.

Design

We used data from the American Community Survey, United States Census Bureau, 2006-2010, and calculated differences in the prevalence of poverty and low educational attainment in adults by race/ethnicity and by census tracts within California cities. For race/ethnicity comparisons, when the referent group (p_2) to calculate the difference (p_1-p_2) was the non-Hispanic White population (considered a historically advantaged group), a positive difference was considered a health inequity. Differences with a non-White reference group were considered health disparities.

Setting

Cities and towns of the State of California, United States.

Results

Within-city differences in the prevalence of poverty and low educational attainment disfavored Black and Latinos compared to Whites in over 78% of cities. Compared to Whites, the median within-city poverty difference was 7.0% for Latinos and 6.2% for Blacks. For education, median within-city difference was 26.6% for Latinos compared to Whites. In a small, but not negligible proportion of cities, historically disadvantaged race/ethnicity groups had better social determinants of health outcomes than Whites. The median difference between the highest and lowest census tracts within cities was 14.3% for poverty and 15.7% for low educational attainment. Overall city poverty rate was weakly, but positively correlated with within-city racial/ethnic differences.

Conclusions

Disparities and inequities are widespread in California. Local health departments can partner with cities in their jurisdiction on strategies to reduce racial, ethnic and geographic differences in economic and educational outcomes.

ARTICLE SUMMARY

STRENGTHS AND LIMITATIONS OF THIS STUDY

- To our knowledge, this is the first comprehensive tabulation of pairwise within-city SDOH differences between major race/ethnic groups and neighbourhoods across California's cities.
- Most multi-level, place-based research, examines individual and neighborhood impacts, but often bypasses city as a "place": racial and ethnic differences in health outcomes and their social determinants are widely reported in the United States at the national, state, and county scale, with non-Hispanic White populations usually experiencing the best outcomes.
- This article fills a geographic gap in current public health surveillance by documenting the glaring disparities in poverty and low educational attainment by race/ethnicity and neighborhood that exist within nearly every California city.
- Examination of the geographical extent and magnitude of disparities in the social determinants is essential to engage local government in "health in all policies" and collaborations with public health agencies.
- As a univariate analysis, our findings have several limitations including lack of examination of other social determinants that could mediate the outcomes, time period of the study that coincides with high levels of economic instability during the Great Recession, 2007-2009, and use of aggregated data that masks the heterogeneity of sub-populations within the racial and ethnic groups studied.

INTRODUCTION

Differences in health outcomes or their determinants are widely reported between racial and ethnic groups in the United States at the national, state, and county scale.[1-3] Differences that are avoidable, unfair and rooted in historical social disadvantage are defined as health inequities. Differences with biological or other underlying causes are health disparities.[4] County and city local health departments (LHDs) increasingly recognise their role in addressing the social determinants of health (SDOH) that underlie health inequities. LHDs are also reaching out to non-health sectors in their communities to impact the root causes of health inequities through "Health in All Policies".[5]

Geographic analysis of SDOH is used to reveal health inequities, and prioritise public health interventions and target community engagement. While an increasing number of LHDs examine health inequities at small geographies, most rely on county level data that masks important differences within counties. The surveillance of SDOH at small geographies poses methodological challenges and opportunities for taking data to action. In assessing racial and ethnic inequities, non-Hispanic Whites are often considered the socially advantaged referent group. It has been posited that it is relatively rare for the most privileged group not to have the best outcome.[4, p187]

We explore racial, ethnic, and geographic differences in poverty and low educational attainment. Poverty reduction, increasing educational attainment, and the elimination of health disparities are national health goals of the United States[6]; these two SDOH may account for 18% of the national burden of mortality.[7]

We examined 1) the magnitude and direction of racial, ethnic and geographical differences in these SDOH within and between California cities, 2) the relationship between overall community disadvantage and SDOH disparities and inequities, and 3) possible actions that LHDs may consider based on surveillance findings.

METHODS

Data Source

We used data from the American Community Survey (ACS),[8, 9] a continuous prevalence survey based on a probability sample of households throughout the United States. ACS publishes data in 5-year tabulations for cities and census tracts. We used ACS Selected Population Tables (2006-2010), which stratify the tabulations by mutually exclusive race and ethnicity categories: Hispanic or Latino, and non-Hispanic persons of the following races: White, Black, Asian, Native Hawaiian and Other Pacific Islander, Other, Multiple, and American Indian/Alaskan Native. For California, the ACS reported on 8,057 census tracts, 480 incorporated cities, and 1,043 non-incorporated places. The prevalence of poverty and its standard error were obtained from ACS Table DP03, and educational attainment in adults and its standard error were obtained from Table DP02. The California Department of Public Health compiled these data (www.cdph.ca.gov/programs/pages/healthycommunityindicators.aspx).

ACS Definition of Poverty and Educational Attainment

The prevalence of poverty was defined as the 5-year annual average percentage of all individuals whose household income in the past 12 months was below the federal poverty level. Total household income was calculated from eight questions on the ACS-1 form about wages, self-employment, securities, rental property, retirement and disability payments, and public assistance. Households were classified as poor when total income of the householder's family was below an income threshold, taking into account the size of the family, number of related children, and, for 1- and 2-person families, age of householder.[8] The prevalence of educational attainment less than high school was defined as the 5-year annual average percentage of adults aged 25 years or older whose maximum educational attainment was 0 to 11 years of grade school.

Between-City, Within-City, and Neighbourhood Level Racial and Ethnic Disparities and Inequities and Statistical Methods

We calculated between-city, within-city, and neighbourhood level differences for combinations of White, Asian, Latino, and Black subgroups.

Differences in the 5-year percentage of poverty or low educational attainment, p, were calculated between pairs of racial/ethnic groups, $p_1 - p_2$. Differences have a positive or negative sign based on the referent group (p_2). When the referent group, p_2, was White, a positive difference represents a health inequity. Differences with a non-White reference group were considered health disparities. For cities with two or more census tracts, neighbourhood disparities were defined as the absolute difference of census tracts with the highest and lowest 5-year percentage.

Mean and medians of between- and within-city differences and their standard deviation were calculated. The between-city mean difference was defined as the difference of the mean prevalence of two specified race/ethnicity groups across all cities:

$$\text{Between-city mean difference} = \frac{\sum_{i,j} p_{i,j}}{N_{\text{Total (j)}}} - \frac{\sum_{i,k} p_{i+1,k}}{N_{\text{Total(k)}}}$$

where *i* is the i^{th} race/ethnicity group and *j* is the j^{th} of N total cities of group_i, and *k* is the k^{th} of N total cities of group_{i+1}.

The within-city mean difference was defined as:

$$\text{Within-city mean difference} = \frac{\sum_{i.j} (p_{i,j} - p_{i+1,j})}{N_{\text{Total(j)}}},$$

where *i* is the *ith* race/ethnicity group and *j* is the *jth* of city of N_{Total} cities where data on both of the race/ethnicity pairs are available.

Within-city differences were plotted as cumulative frequency distributions of cities for each pairwise race/ethnicity comparison in order to assess the magnitude and direction

of racial and ethnic inequities or disparities in cities across the state. For each city, Z-tests were carried out to determine whether the within-city difference was statistically significant. We followed U.S. Census Bureau guidelines for pooling standard errors of percents, which is the square root of the sum of the squares of the two individual standard errors ($se = \sqrt{se_1^2 + se_2^2}$). A p value of 0.10 was considered statistically significant. R software was used for the calculations.[10]

SDOH differences are often interpreted in the context of the range of their absolute values. For example, in some very poor communities there may be no demonstrable differences between groups and "everyone is poor together". In other communities, there is a small, but statistically significantly difference between groups, but each group is relatively well off (e.g., has a SDOH value far above the mean.) To contextualise a city's disparities or inequities on a backdrop of high or low rate of poverty or educational attainment, we plotted within-city disparities or inequities, as a function of the between-city poverty rate (or educational attainment). Simple linear correlation (Pearson, r) assessed the strength of association.

Calculation of Neighbourhood Disparities

Census tract and city boundaries are not always congruent; therefore, for neighbourhood analyses, census tracts were associated with the city into which its centroid fell. We used ArcGIS 10.3 (ESRI, Redlands, CA) to calculate and associate centroids with cities. In some cases, portions of census tracts outside of city limits were included in neighbourhood comparisons. This introduces some potential misclassification if the outlying portion of the census tract has different poverty or educational attainment. We also calculated the mean linear distance in miles between the centroids of the census tracts with the highest and lowest poverty and educational outcomes.

Exclusions

The ACS does not publish data for geographic areas with fewer than 50 respondents. Of 1,523 cities the number available for within-city pairwise comparisons varied by race/ethnicity subgroup: 221 cities had data for Black-Asian comparisons, 280 for Asian-White, 245 for Black-White, 364 for Latino-Asian, 252 for Latino-Black, and 611 for Latino-White. We did not have sufficient data to carry out pairwise comparisons that included American Indian/Native Alaskans, Native Hawaiians and Other Pacific Islanders, Multiple races, and Other. Analyses of poverty at the census tract level excluded economically dependent populations in colleges, correctional facilities, and other group quarters and institutions. Two census tracts with a population less than 500 inhabitants were also excluded.

Association between Within-City Geographic Disparities in Educational Attainment and Poverty with Within-City Disparities in Life Expectancy at Birth

To illustrate the association between SDOH and health outcomes within California cities we calculated the correlation coefficient between census tract level life expectancy at birth (LEB) and the two social determinants. The LEB data for California census tracts is publically available through the Health Disadvantage Index Project (http://phasocal.org/ca-hdi/). The census tracts with the highest and lowest education educational attainment and those with the highest and lowest poverty rates were matched with their LEB. Within cities, the differences between minimum and maximum (min-max) SDOH and health outcomes, respectively, was calculated. Census tract differences in educational attainment and poverty were scaled so that positive differences indicated greater disparities. Census tract difference in LEB were scaled so that positive differences indicated increases in life expectancy, and conversely, negative differences indicated a lower life expectancy. The correlation coefficient between the differences (min-max) was calculated in R.

RESULTS

Between- and Within-City Racial and Ethnic Disparities and Inequities

The poverty rate of Latinos (18.6%) and Blacks (17.4%) averaged over California cities was nearly twice that of Whites (9.2%) and Asians (9.5%) (Table 1).

Table 1 Between and Within-City Means and Race-Ethnicity Specific Pairwise Differences in Poverty Rate and Educational Attainment, California, 2006-2010

	Percent below the federal poverty level			Percent of adults aged ≥25 years without a high school education		
Between cities	Mean	SD	Median	Mean	SD	Median
White	9.2	6.9	7.5	8.7	7.3	6.7
Black	17.4	12.9	14.6	11.0	8.9	8.8
Asian	9.5	8.7	7.1	12.4	9.8	9.7
Latino	18.6	11.4	16.8	39.6	18.4	39.9

Pairwise differences (p_1-p_2)	Between city		Within city		Between city		Within city	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Black-White	8.2	7.1	8.5	6.2	2.3	2.1	2.0	0.6
Asian-White	0.3	-0.4	1.7	0.9	3.7	3.0	4.4	2.7
Latino-White	9.4	9.3	7.6	7.0	30.9	33.2	26.2	26.6
Black-Asian	7.9	7.5	6.5	4.8	-1.4	-0.9	-3.3	-3.1
Latino-Asian	9.1	9.7	5.1	4.8	27.2	30.2	19.0	19.2
Latino-Black	1.2	2.2	0.3	0.5	28.6	31.1	24.9	25.4

The city average percentage of adults with low educational attainment was 3-4 times higher in Latinos compared to Whites, Asians, or Blacks. The largest mean between-city educational inequity (30.9%) was between Latinos and Whites.

The distribution of within-city differences of race/ethnicity pairs is presented for poverty and low educational attainment (Figure 1). In a large percentage of cities, Asians and Whites had better poverty outcomes than Latinos or Blacks. The largest inequities occurred between Blacks and Whites (8.5% mean difference) and Latinos and Whites (7.6%). In approximately 40% of cities, these differences were statistically significant. Latinos had better poverty outcomes than Asians or Whites in 26% and 18% of cities, respectively. Likewise, Blacks had better outcomes than Asians or Whites in approximately 20% of cities. The average differences in within-city poverty rates between Blacks and Latinos were small (0.3%), but there was considerable variation.

For low educational attainment (Figure 1 b), the largest mean difference was between Latinos and other groups (Latino-Whites, 26.2%; Latino-Blacks, 24.9%; Latino-Asians, 19.0%). Whites tended to have better outcomes than Asians or Blacks. Blacks tended to have better outcomes than Asians. Latinos had poorer outcomes than the other groups in almost all cities (94% or higher). An overwhelming majority of within-city differences between Latinos and other groups were statistically significant.

Supplemental materials include maps of California cities depicting the race/ethnicity with the largest disparity for poverty or educational attainment.

Between- and Within-City Racial and Ethnicity Correlations

Within-city racial/ethnic differences in poverty and overall city poverty rate (Figure 2 a), appear to be correlated for all race/ethnicity combinations with White or Asian referents, but exhibit considerable variability (scatter). Black and Latino inequities (White referents) tended to be larger at higher levels of overall poverty ($r = 0.37$, $P < 0.01$). A

weaker association (r = 0.20, *P* <0.01) was observed for Black or Latinos with Asian referents.

In a large proportion of California cities, Latinos experience both large educational disparities and live in cities with low overall educational attainment. Within-city education differences between Latinos and other groups were strongly associated (r range: 0.48 to 0.60) with overall city low educational attainment (Figure 2 b).

Neighbourhood Disparities

The distribution of within-city differences of poverty and educational attainment between the highest and lowest census tract is presented in Figure 3. The median difference was 14.3% for poverty and 15.7% for educational attainment. Disparities of 25% or greater were observed in 25% of cities for poverty and 33% of cities for educational attainment. In approximately 73% of 500 cities with two or more census tracts, the differences were statistically significant. For the 174 cities with 10 or more census tracts, 99% of differences were statistically significant. The median straight-line distance between the highest and lowest census tracts was 2.6 km (SD, 3.2) for poverty and 2.9 km (SD, 3.04) for educational attainment.

Within-City Associations between Disparities in Life Expectancy at Birth and Disparities in the SDOH

Within cities, increasing disparities in educational attainment between census tracts with the highest and lowest levels were significantly correlated with increasing disparities in which life expectancy decreased (Pearson r=-0.24, p< 0.001). A similar significant correlation was found for poverty disparities and life expectancy (Pearson r=-0.28). In simple linear regression analyses, 0.08 years of life expectancy was lost for each percent of educational disparity and 0.05 years of life expectancy was lost for each percent of poverty disparity.

DISCUSSION

We found widespread racial, ethnic, and geographic differences in educational attainment and poverty within California cities. Comparisons between Whites and Blacks and Whites and Latinos generally conformed to a health inequities model – that historically, socially disadvantaged groups had poorer outcomes than Whites. This was less frequent in comparisons between Asians and Whites. In a small, but not negligible proportion of cities, historically disadvantaged race/ethnicity groups had better SDOH outcomes than Whites. We found a correlation between a community's underlying level of poverty (or educational attainment) and racial/ethnic disparities. Neighbourhood level differences within cities were also ubiquitous. On average, a mere 2.6 km separates a city's census tracts with the highest and lowest poverty rate or educational attainment. An illustrative analysis showed that increases in within-city disparities in poverty and educational attainment are associated with reductions in life expectancy, providing support for the relevance of the monitoring of SDOH.

Strengths and Limitations

To our knowledge, this is the first comprehensive tabulation of pairwise within-city SDOH differences between major race/ethnic groups and neighbourhoods across California's cities.

As a univariate analysis, our findings have several limitations. Racial/ethnic differences may be related to other SDOHs which mediate the outcome. For example, recency of immigration profoundly influences poverty and educational attainment,[11] and may explain, in part, the educational inequities we observed in Latinos and Whites. Moreover, SDOH are themselves interrelated. Conducting a multivariate analysis to establish the independence of racial/ethnicity disparities,[4] is not feasible using pre-tabulated ACS tables. Other U.S. Census Bureau products (Public Use Microdata Sample) and surveys may serve this purpose, but do not provide reliable estimates at small geographies.

For a small percentage of cities, socially disadvantaged groups had significantly better outcomes than Whites. Further research of these cities may reveal whether this finding is associated with community "resiliency", confounded by other sociodemographic factors, or has another explanation.

We acknowledge that the race categories included in the analysis are composed of subpopulations whose poverty and educational attainment are heterogeneous (for instance, differences between Asian ethnic groups). Valuable information may have been lost by aggregation.

Differences in SDOH between geographic units such as census tracts may be disparities or inequities, depending on the history of social disadvantage. Long-standing patterns of racial discrimination and economic segregation within California cities[12] undoubtedly underlie some of the differences that we labeled disparities.

Data suppression in the ACS impacts numerically small, geographically dispersed racial/ethnic populations, creating information bias towards areas with greater racial concentration or segregation. Small rural communities account for a disproportionate number of exclusions in our analysis. Nonetheless, depending on the race/ethnicity comparison, the cities included in our analysis contain between 68% and 88% of the California population.

Cross-sectional data cannot be used to establish causal relationships or directionality. Our finding that a community's poverty rate and its racial/ethnic disparities are interrelated will require longitudinal, confirmatory studies. Studies in the United States and western countries suggest that income inequality inhibits overall economic development and economic mobility.[13]

The time period of this study coincided with high levels of economic instability during the Great Recession, 2007-2009. Cities and regions might have since experienced

economic recovery, gentrification, population displacement, and community succession. Due to lags in reporting, ACS data may not reflect current conditions.

What Can Cities Do?

While cities alone cannot be expected to solve economic and educational disparities, they play an important role in shaping the social determinants of health through people- and place-based strategies.[14] In the United States local government plays an active role in recruiting and retaining employers, establishing preferences for minority-owned businesses, adopting local first-hire policies, and legislating minimum wages. School districts and boards exert local control over school policy and funding, whether the bulk of funds are from state or local taxes. Through local zoning, urban revitalization, and the creation of enterprise zones, local government shapes the built environment and the availability of resources for the basics of living (e.g., food outlets, housing, jobs, transportation). Local housing authorities implement federal and state policies that influence the availability and placement of affordable housing. Several health impact assessments and health studies document the likely and actual health promoting impacts of minimum wage ordinances[15, 16] and housing vouchers that relocate renters from neighbourhoods with concentrated poverty to those with low poverty.[17, 18] Many cities are examining their own internal policies and practices with regard to hiring, procurement, and building capacity through authentic deep community engagement.

Local elected officials often comprise the governing bodies of regional associations of government, which make decisions on regional transportation, housing, and economic investments. Economic development strategies forged at a regional level have a wide ranging impact at the local level.[19] There is evidence that some strategies that promote overall regional economic development may exacerbate economic disparities.[20]

What Can Local Health Departments Do?

Data and Surveillance

In general, SDOH indicators have not been institutionalised in public health surveillance at the state and local level in the same manner as mortality surveillance, communicable disease reporting, and behavioral risk factor surveillance. Monitoring SDOH geographic variation, time trends, and population subgroups help assess the magnitude of the problem, identify high risk groups, monitor progress toward meeting goals, set priorities, and target resources for intervention. Several U.S. states have offices of health equity, which issue periodic reports.[21, 22] Due to requirements of the Affordable Care Act (ACA), LHDs in partnership with nonprofit hospitals and community coalitions are producing community health needs assessments and improvement plans [US IRS Code Title IX, §6033(b)], frequently framing health disparities in terms of SDOH.[23, 24] ACA implementation supports the institutionalization of surveillance of the SDOH at geographically resolved areas throughout the United States.

Health departments can also use the distribution of within-city inequities to identify specific cities that share socioeconomic and demographic similarities, but differ on health inequities. Fostering exchanges like learning collaboratives or intervention trials between peer cities may be but one mechanism to engage cities and identify successful strategies to reduce inequities.

Some LHDs are taking systematic approaches to link SDOH surveillance data to action in the form of how-to guides,[25] internal capacity building, and setting explicit goals and activities to reduce disparities.[26]

Internal Capacity Building on Racial and Health Equity

Efforts to examine and counter structural racism in health inequities are being integrated into public health practice by identifying upstream causes,[22, 27] and conducting assessments of organizational behavior in health departments. Educational and action-

oriented workshops, training, and toolkits are increasingly part of public health workforce development, program design, policy development, and evaluation[28, 29] and should touch areas relevant to public health department accreditation.

Health in All Policies

With the ascendance of Health in All Policies (HiAP),[5] public health departments have opportunities to play an active and direct role in educating policy makers on the SDOH and health equity. Because different sectors may frame equity in profoundly different ways,[30] public health practitioners can convene and constructively engage partners, including those central to economic development and education. HiAP-related actions include health impact assessments, advising and participating in cross-sector planning (e.g., land use, transportation, food systems), and developing tools that non-health planners can use to quantify the health benefits or harms of various policies or programs.[28]

Service Environment

Overcoming fragmented social services delivery is highly desirable and underpins comprehensive models of service delivery that may have collective impact and address SDOHs.[31,32] Building on city-level data of poverty and educational inequities, health departments can play a role in monitoring and evaluating the equitable access and distribution of services provided by the health department and other social service agencies.

Conclusions

Racial, ethnic, and geographic disparities in poverty and educational attainment in adults are widespread within and between California cities. Given that public health practice is increasingly focused upstream, surveillance of the social determinants of

health may afford opportunities for engagement with neighbourhoods, cities, and regional government to be an active partner in strategies that promote health and reduce poverty and low educational attainment.

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CONTRIBUTORS

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COMPETING INTERESTS

None declared.

PROTECTION OF HUMAN SUBJECTS IN RESEARCH

This study used publicly available data and did not involve human subjects in research.

DATA SHARING STATEMENT

This study used publicly available data. Data sets used in this analysis can be downloaded from:
http://www.cdph.ca.gov/programs/Pages/HealthyCommunityIndicators.aspx.

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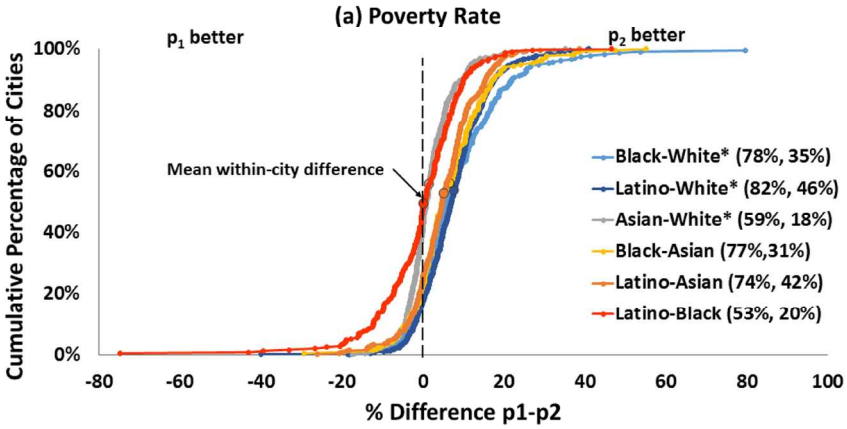
FIGURES LEGENDS

Figure 1. Distribution of Within-City Differences in (a) Poverty Rate and (b) Low Educational Attainment for Pairwise Comparisons of California Whites, Blacks, Latinos, and Asians, 2006-2010. *Considering Whites as a socially advantaged reference group, the differences that favor Whites are considered inequities. The legends show the percent of cities in which the p_2 race/ethnicity group has a better outcome and the percent of cities in which the outcome is statistically significant ($p < 0.1$). For instance, "Black-Asian (77%, 31%)" indicates that 77% of the cities in which the comparison is possible have a better outcome for the Asian group and 31% of those cities have a significantly better outcome.

Figure 2. Within-City Poverty Rate Differences and Overall City Poverty Rate (a) and Low Educational Attainment and Overall City Low Educational Attainment (b), California Cities, 2006-2010. r is the Pearson correlation coefficient between within city differences and the overall city value. *Considering Whites as a socially advantaged reference group, the differences that favor Whites are considered inequities.

Figure 3. Distribution of Within-City Differences in the Highest and Lowest Census Tract Rates for Educational Attainment and Poverty, California, 2006-2010.



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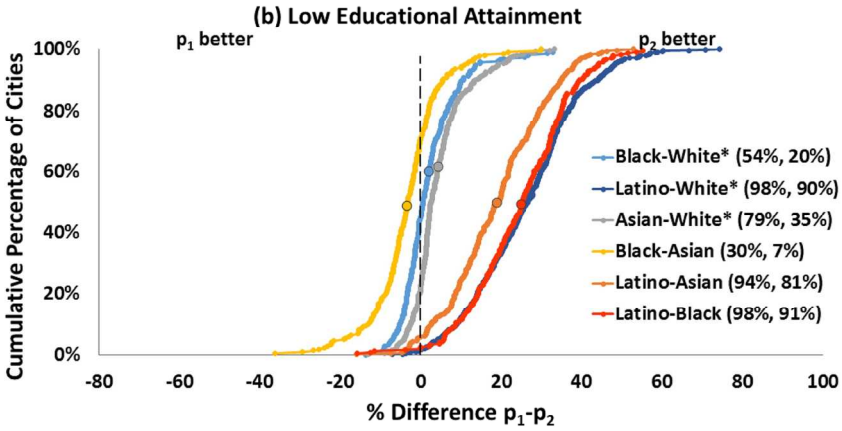

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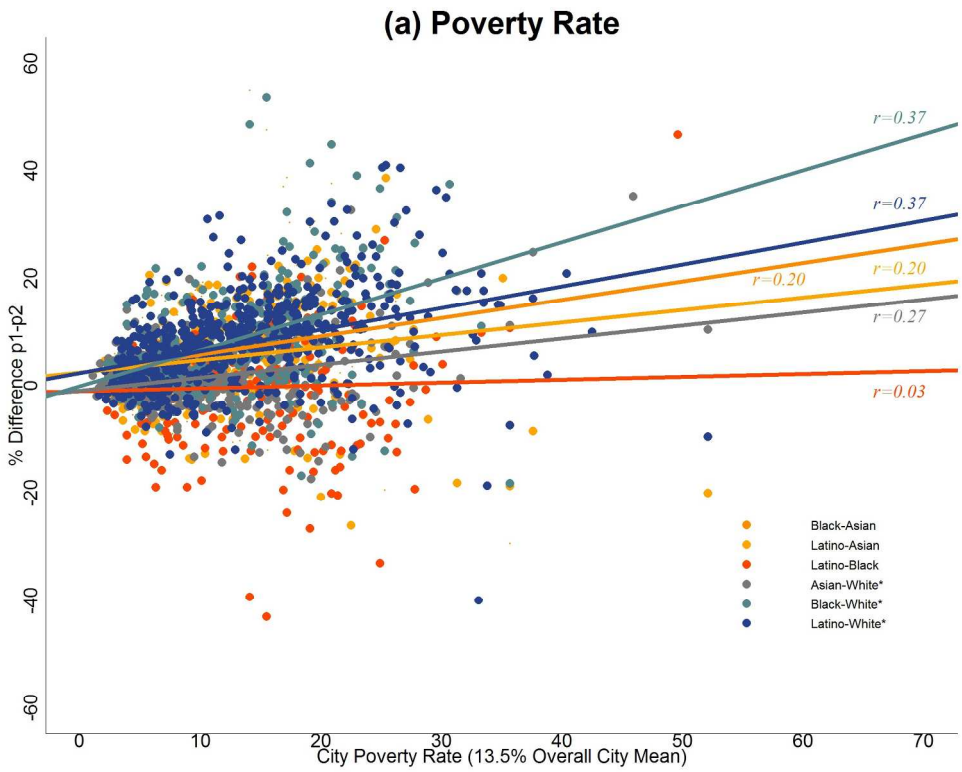

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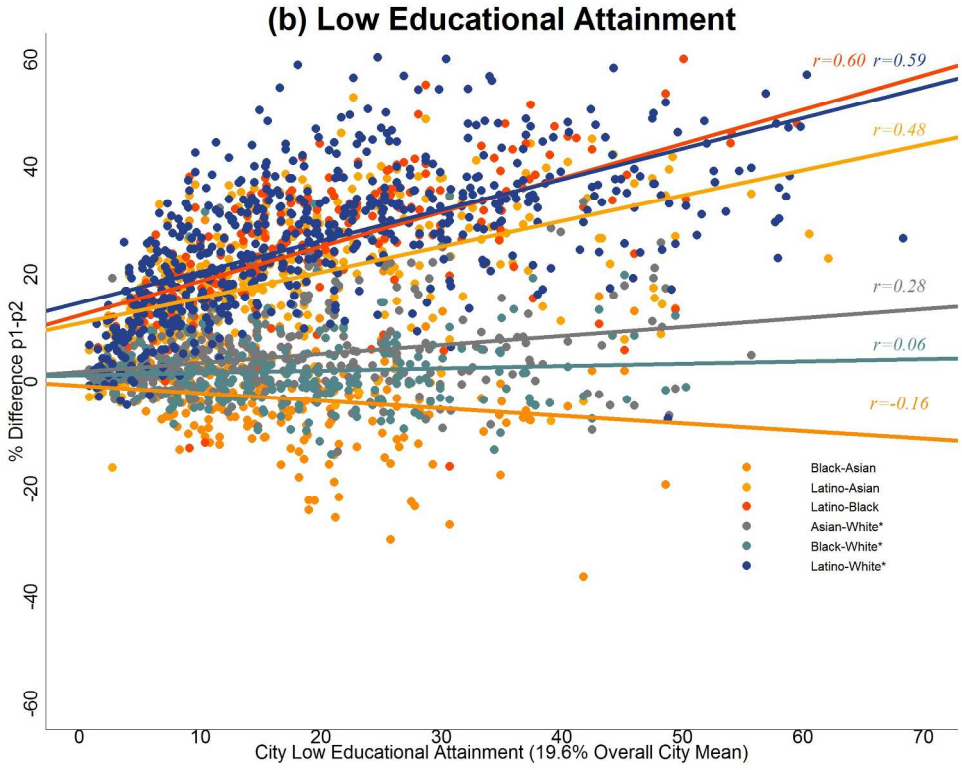

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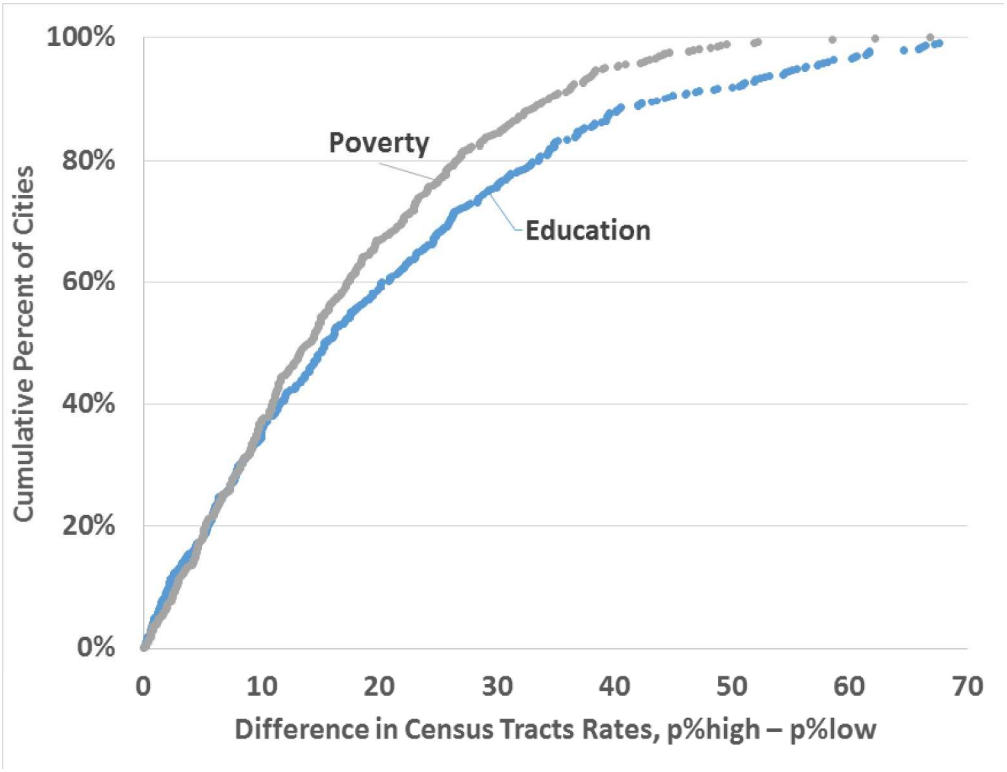

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Cross Sectional Analysis of the Social Determinants of Health in California Cities: Racial, Ethnic, and Geographic Disparities

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Title: **Cross Sectional Analysis of the Social Determinants of Health in California Cities: Racial, Ethnic, and Geographic Disparities**

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Word Count: 3,436

ABSTRACT

Objective

To study the magnitude and direction of city level racial and ethnic differences in poverty and education to examine health equity and social determinants of health in California cities.

Design

We used data from the American Community Survey, United States Census Bureau, 2006-2010, and calculated differences in the prevalence of poverty and low educational attainment in adults by race/ethnicity and by census tracts within California cities. For race/ethnicity comparisons, when the referent group (p_2) to calculate the difference (p_1-p_2) was the non-Hispanic White population (considered a historically advantaged group), a positive difference was considered a health inequity. Differences with a non-White reference group were considered health disparities.

Setting

Cities of the State of California, United States.

Results

Within-city differences in the prevalence of poverty and low educational attainment disfavored Black and Latinos compared to Whites in over 78% of cities. Compared to Whites, the median within-city poverty difference was 7.0% for Latinos and 6.2% for Blacks. For education, median within-city difference was 26.6% for Latinos compared to Whites. In a small, but not negligible proportion of cities, historically disadvantaged race/ethnicity groups had better social determinants of health outcomes than Whites. The median difference between the highest and lowest census tracts within cities was 14.3% for poverty and 15.7% for low educational attainment. Overall city poverty rate was weakly, but positively correlated with within-city racial/ethnic differences.

Conclusions

Disparities and inequities are widespread in California. Local health departments can use these findings to partner with cities in their jurisdiction and design strategies to reduce racial, ethnic and geographic differences in economic and educational outcomes. These analytic methods could be used in a surveillance system to monitor these determinants of health.

ARTICLE SUMMARY

STRENGTHS AND LIMITATIONS OF THIS STUDY

- To our knowledge, this is the first comprehensive tabulation of pairwise within-city SDOH differences between major race/ethnic groups and neighbourhoods across California's cities.
- Most multi-level, place-based research, examines individual and neighborhood impacts, but often bypasses city as a "place": racial and ethnic differences in health outcomes and their social determinants are widely reported in the United States at the national, state, and county scale, with non-Hispanic White populations usually experiencing the best outcomes.
- This article contributes to fill a geographic gap in current public health surveillance methods by documenting the glaring disparities in poverty and low educational attainment by race/ethnicity and neighborhood that exist within nearly every California city.
- This analysis provides both between and within city-level estimates that can be more effective for targeting interventions to where they are most needed.
- As a univariate analysis, our findings have several limitations including lack of examination of other social determinants that could mediate the outcomes, time period of the study that coincides with high levels of economic instability during the Great Recession, 2007-2009, and use of aggregated data that masks the heterogeneity of sub-populations within the racial and ethnic groups studied.

INTRODUCTION

Differences in health outcomes or their determinants are widely reported between racial and ethnic groups in the United States at the national, state, and county scale.[1-3] Differences that are avoidable, unfair and rooted in historical social disadvantage are defined as health inequities. Differences with biological or other underlying causes are health disparities.[4] County and city local health departments (LHDs) increasingly recognise their role in addressing the social determinants of health (SDOH) that underlie health inequities. LHDs are also reaching out to non-health sectors in their communities to impact the root causes of health inequities through "Health in All Policies".[5]

Geographic analysis of SDOH is used to reveal health inequities, and prioritise public health interventions and target community engagement. While an increasing number of LHDs examine health inequities at small geographies, most rely on county level data that masks important differences within counties. The surveillance of SDOH at small geographies poses methodological challenges and opportunities for taking data to action. In assessing racial and ethnic inequities, non-Hispanic Whites are often considered the socially advantaged referent group. It has been posited that it is relatively rare for the most privileged group not to have the best outcome.[4, p187]

We explore racial, ethnic, and geographic differences in poverty and low educational attainment. Poverty reduction, increasing educational attainment, and the elimination of health disparities are national health goals of the United States[6]; these two SDOH may account for 18% of the national burden of mortality.[7]

We examined 1) the magnitude and direction of racial, ethnic and geographical differences in these SDOH within and between California cities, 2) the relationship between overall city disadvantage and SDOH disparities and inequities, and 3) possible actions that LHDs may consider based on surveillance findings produced with the research methods suggested in this study.

METHODS

Data Source

We used data from the American Community Survey (ACS),[8, 9] a continuous prevalence survey based on a probability sample of households throughout the United States. ACS publishes data in 5-year tabulations for cities and census tracts. We used ACS Selected Population Tables (2006-2010), which stratify the tabulations by mutually exclusive race and ethnicity categories: Hispanic or Latino, and non-Hispanic persons of the following races: White, Black, Asian, Native Hawaiian and Other Pacific Islander, Other, Multiple, and American Indian/Alaskan Native. For California, the ACS reported on 8,057 census tracts, 480 incorporated cities and towns, and 1,043 non-incorporated places (from here on towns and non-incorporated places will be referred on as cities). The prevalence of poverty and its standard error were obtained from ACS Table DP03, and educational attainment in adults and its standard error were obtained from Table DP02. The California Department of Public Health compiled these data (www.cdph.ca.gov/programs/pages/healthycommunityindicators.aspx).

ACS Definition of Poverty and Educational Attainment

The prevalence of poverty was defined as the 5-year annual average percentage of all individuals whose household income in the past 12 months was below the federal poverty level. Total household income was calculated from eight questions on the ACS-1 form about wages, self-employment, securities, rental property, retirement and disability payments, and public assistance. Households were classified as poor when total income of the householder's family was below an income threshold, taking into account the size of the family, number of related children, and, for 1- and 2-person families, age of householder.[8] The prevalence of educational attainment less than high school was defined as the 5-year annual average percentage of adults aged 25 years or older whose maximum educational attainment was 0 to 11 years of grade school.

Between-City, Within-City, and Neighbourhood Level Racial and Ethnic Disparities and Inequities and Statistical Methods

We calculated between-city, within-city, and neighbourhood level differences for combinations of White, Asian, Latino, and Black subgroups.

Differences in the 5-year percentage of poverty or low educational attainment, p, were calculated between pairs of racial/ethnic groups, $p_1 - p_2$. Differences have a positive or negative sign based on the referent group (p_2). When the referent group, p_2, was White, a positive difference represents a health inequity. Differences with a non-White reference group were considered health disparities. For cities with two or more census tracts, neighbourhood disparities were defined as the absolute difference of census tracts with the highest and lowest 5-year percentage.

Mean and medians of between- and within-city differences and their standard deviation were calculated. The between-city mean difference was defined as the difference of the mean prevalence of two specified race/ethnicity groups across all cities:

$$\text{Between-city mean difference} = \frac{\sum_{i,j} p_{i,j}}{N_{\text{Total (j)}}} - \frac{\sum_{i,k} p_{i+1,k}}{N_{\text{Total(k)}}}$$

where *i* is the i^{th} race/ethnicity group and *j* is the j^{th} of N total cities of group_i, and *k* is the k^{th} of N total cities of group_{i+1}.

The within-city mean difference was defined as:

$$\text{Within-city mean difference} = \frac{\sum_{i,j} (p_{i,j} - p_{i+1,j})}{N_{\text{Total(j)}}},$$

where *i* is the *ith* race/ethnicity group and *j* is the *jth* of city of N_{Total} cities where data on both of the race/ethnicity pairs are available.

Within-city differences were plotted as cumulative frequency distributions of cities for each pairwise race/ethnicity comparison in order to assess the magnitude and direction of racial and ethnic inequities or disparities in cities across the state. For each city, Z-tests were carried out to determine whether the within-city difference was statistically significant. We followed U.S. Census Bureau guidelines for pooling standard errors of percents, which is the square root of the sum of the squares of the two individual standard errors ($se = \sqrt{se_1^2 + se_2^2}$). A p value of 0.10 was considered statistically significant. R software was used for the calculations.[10]

SDOH differences are often interpreted in the context of the range of their absolute values. For example, in some very poor cities there may be no demonstrable differences between groups and "everyone is poor together". In other cities, there is a small, but statistically significantly difference between groups, but each group is relatively well off (e.g., has a SDOH value far above the mean.) To contextualise a city's disparities or inequities on a backdrop of high or low rate of poverty or educational attainment, we plotted within-city disparities or inequities, as a function of the between-city poverty rate (or educational attainment). Simple linear correlation (Pearson, r) assessed the strength of association.

Calculation of Neighbourhood Disparities

Census tract and city boundaries are not always congruent; therefore, for neighbourhood analyses, census tracts were associated with the city into which its centroid fell. We used ArcGIS 10.3 (ESRI, Redlands, CA) to calculate and associate centroids with cities. In some cases, portions of census tracts outside of city limits were included in neighbourhood comparisons. This introduces some potential misclassification if the outlying portion of the census tract has different poverty or educational attainment. We also calculated the mean linear distance in miles between the centroids of the census tracts with the highest and lowest poverty and educational outcomes.

Exclusions

The ACS does not publish data for geographic areas with fewer than 50 respondents. Of 1,523 cities the number available for within-city pairwise comparisons varied by race/ethnicity subgroup: 221 cities had data for Black-Asian comparisons, 280 for Asian-White, 245 for Black-White, 364 for Latino-Asian, 252 for Latino-Black, and 611 for Latino-White. We did not have sufficient data to carry out pairwise comparisons that included American Indian/Native Alaskans, Native Hawaiians and Other Pacific Islanders, Multiple races, and Other. Analyses of poverty at the census tract level excluded economically dependent populations in colleges, correctional facilities, and other group quarters and institutions. Two census tracts with a population less than 500 inhabitants were also excluded.

Association between Within-City Geographic Disparities in Educational Attainment and Poverty with Within-City Disparities in Life Expectancy at Birth

To illustrate the association between SDOH and health outcomes within California cities we calculated the correlation coefficient between census tract level life expectancy at birth (LEB) and the two social determinants. The LEB data for California census tracts is publically available through the Health Disadvantage Index Project (http://phasocal.org/ca-hdi/). The census tracts with the highest and lowest education educational attainment and those with the highest and lowest poverty rates were matched with their LEB. Within cities, the differences between minimum and maximum (min-max) SDOH and health outcomes, respectively, was calculated. Census tract differences in educational attainment and poverty were scaled so that positive differences indicated greater disparities. Census tract difference in LEB were scaled so that positive differences indicated increases in life expectancy, and conversely, negative differences indicated a lower life expectancy. The correlation coefficient between the differences (min-max) was calculated in R.

RESULTS

Between- and Within-City Racial and Ethnic Disparities and Inequities

The poverty rate of Latinos (18.6%) and Blacks (17.4%) averaged over California cities was nearly twice that of Whites (9.2%) and Asians (9.5%) (Table 1).

Table 1 Between and Within-City Means and Race-Ethnicity Specific Pairwise Differences in Poverty Rate and Educational Attainment, California, 2006-2010

	Percent below the federal poverty level			Percent of adults aged ≥25 years without a high school education		
Between cities	Mean	SD	Median	Mean	SD	Median
White	9.2	6.9	7.5	8.7	7.3	6.7
Black	17.4	12.9	14.6	11.0	8.9	8.8
Asian	9.5	8.7	7.1	12.4	9.8	9.7
Latino	18.6	11.4	16.8	39.6	18.4	39.9

Pairwise differences (p_1-p_2)	Between city		Within city		Between city		Within city	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Black-White	8.2	7.1	8.5	6.2	2.3	2.1	2.0	0.6
Asian-White	0.3	-0.4	1.7	0.9	3.7	3.0	4.4	2.7
Latino-White	9.4	9.3	7.6	7.0	30.9	33.2	26.2	26.6
Black-Asian	7.9	7.5	6.5	4.8	-1.4	-0.9	-3.3	-3.1
Latino-Asian	9.1	9.7	5.1	4.8	27.2	30.2	19.0	19.2
Latino-Black	1.2	2.2	0.3	0.5	28.6	31.1	24.9	25.4

The city average percentage of adults with low educational attainment was 3-4 times higher in Latinos compared to Whites, Asians, or Blacks. The largest mean between-city educational inequity (30.9%) was between Latinos and Whites.

The distribution of within-city differences of race/ethnicity pairs is presented for poverty and low educational attainment (Figure 1). In a large percentage of cities, Asians and Whites had better poverty outcomes than Latinos or Blacks. The largest inequities occurred between Blacks and Whites (8.5% mean difference) and Latinos and Whites (7.6%). In approximately 40% of cities, these differences were statistically significant. Latinos had better poverty outcomes than Asians or Whites in 26% and 18% of cities, respectively. Likewise, Blacks had better outcomes than Asians or Whites in approximately 20% of cities. The average differences in within-city poverty rates between Blacks and Latinos were small (0.3%), but there was considerable variation.

For low educational attainment (Figure 1 b), the largest mean difference was between Latinos and other groups (Latino-Whites, 26.2%; Latino-Blacks, 24.9%; Latino-Asians, 19.0%). Whites tended to have better outcomes than Asians or Blacks. Blacks tended to have better outcomes than Asians. Latinos had poorer outcomes than the other groups in almost all cities (94% or higher). An overwhelming majority of within-city differences between Latinos and other groups were statistically significant.

Supplemental materials include maps of California cities depicting the race/ethnicity with the largest disparity for poverty or educational attainment.

Between- and Within-City Racial and Ethnicity Correlations

Within-city racial/ethnic differences in poverty and overall city poverty rate (Figure 2 a), appear to be correlated for all race/ethnicity combinations with White or Asian referents, but exhibit considerable variability (scatter). Black and Latino inequities (White referents) tended to be larger at higher levels of overall poverty ($r = 0.37$, $P < 0.01$). A

weaker association (r = 0.20, *P* <0.01) was observed for Black or Latinos with Asian referents.

In a large proportion of California cities, Latinos experience both large educational disparities and live in cities with low overall educational attainment. Within-city education differences between Latinos and other groups were strongly associated (r range: 0.48 to 0.60) with overall city low educational attainment (Figure 2 b).

Neighbourhood Disparities

The distribution of within-city differences of poverty and educational attainment between the highest and lowest census tract is presented in Figure 3. The median difference was 14.3% for poverty and 15.7% for educational attainment. Disparities of 25% or greater were observed in 25% of cities for poverty and 33% of cities for educational attainment. In approximately 73% of 500 cities with two or more census tracts, the differences were statistically significant. For the 174 cities with 10 or more census tracts, 99% of differences were statistically significant. The median straight-line distance between the highest and lowest census tracts was 2.6 km (SD, 3.2) for poverty and 2.9 km (SD, 3.04) for educational attainment.

Within-City Associations between Disparities in Life Expectancy at Birth and Disparities in the SDOH

Within cities, increasing disparities in educational attainment between census tracts with the highest and lowest levels were significantly correlated with increasing disparities in which life expectancy decreased (Pearson r=-0.24, p< 0.001). A similar significant correlation was found for poverty disparities and life expectancy (Pearson r=-0.28). In simple linear regression analyses, 0.08 years of life expectancy was lost for each percent of educational disparity and 0.05 years of life expectancy was lost for each percent of poverty disparity.

DISCUSSION

We found widespread racial, ethnic, and geographic differences in educational attainment and poverty within California cities. Comparisons between Whites and Blacks and Whites and Latinos generally conformed to a health inequities model – that historically, socially disadvantaged groups had poorer outcomes than Whites. This was less frequent in comparisons between Asians and Whites. In a small, but not negligible proportion of cities, historically disadvantaged race/ethnicity groups had better SDOH outcomes than Whites. We found a correlation between a city's underlying level of poverty (or educational attainment) and racial/ethnic disparities. Neighbourhood level differences within cities were also ubiquitous. On average, a mere 2.6 km separates a city's census tracts with the highest and lowest poverty rate or educational attainment. An illustrative analysis showed that increases in within-city disparities in poverty and educational attainment are associated with reductions in life expectancy, providing support for the relevance of the monitoring of SDOH.

Strengths and Limitations

To our knowledge, this is the first comprehensive tabulation of pairwise within-city SDOH differences between major race/ethnic groups and neighbourhoods across California's cities.

As a univariate analysis, our findings have several limitations. Racial/ethnic differences may be related to other SDOHs which mediate the outcome. For example, recency of immigration profoundly influences poverty and educational attainment,[11] and may explain, in part, the educational inequities we observed in Latinos and Whites. Moreover, SDOH are themselves interrelated. Conducting a multivariate analysis to establish the independence of racial/ethnicity disparities,[4] is not feasible using pre-tabulated ACS tables. Other U.S. Census Bureau products (Public Use Microdata Sample) and surveys may serve this purpose, but do not provide reliable estimates at small geographies.

For a small percentage of cities, socially disadvantaged groups had significantly better outcomes than Whites. Further research of these cities may reveal whether this finding is associated with community "resiliency", confounded by other sociodemographic factors, or has another explanation.

We acknowledge that the race categories included in the analysis are composed of subpopulations whose poverty and educational attainment are heterogeneous (for instance, differences between Asian ethnic groups). Valuable information may have been lost by aggregation.

Differences in SDOH between geographic units such as census tracts may be disparities or inequities, depending on the history of social disadvantage. Long-standing patterns of racial discrimination and economic segregation within California cities[12] undoubtedly underlie some of the differences that we labeled disparities.

Data suppression in the ACS impacts numerically small, geographically dispersed racial/ethnic populations, creating information bias towards areas with greater racial concentration or segregation. Small rural cities account for a disproportionate number of exclusions in our analysis. Nonetheless, depending on the race/ethnicity comparison, the cities included in our analysis contain between 68% and 88% of the California population.

Cross-sectional data cannot be used to establish causal relationships or directionality. Our finding that a city's poverty rate and its racial/ethnic disparities are interrelated will require longitudinal, confirmatory studies. Studies in the United States and western countries suggest that income inequality inhibits overall economic development and economic mobility.[13]

The time period of this study coincided with high levels of economic instability during the Great Recession, 2007-2009. Cities and regions might have since experienced

economic recovery, gentrification, population displacement, and community succession. Due to lags in reporting, ACS data may not reflect current conditions.

What Can Cities Do?

While cities alone cannot be expected to solve economic and educational disparities, they play an important role in shaping the social determinants of health through people- and place-based strategies.[14] In the United States local government plays an active role in recruiting and retaining employers, establishing preferences for minority-owned businesses, adopting local first-hire policies, and legislating minimum wages. School districts and boards exert local control over school policy and funding, whether the bulk of funds are from state or local taxes. Through local zoning, urban revitalization, and the creation of enterprise zones, local government shapes the built environment and the availability of resources for the basics of living (e.g., food outlets, housing, jobs, transportation). Local housing authorities implement federal and state policies that influence the availability and placement of affordable housing. Several health impact assessments and health studies document the likely and actual health promoting impacts of minimum wage ordinances[15, 16] and housing vouchers that relocate renters from neighbourhoods with concentrated poverty to those with low poverty.[17, 18] Many cities are examining their own internal policies and practices with regard to hiring, procurement, and building capacity through authentic deep community engagement.

Local elected officials often comprise the governing bodies of regional associations of government, which make decisions on regional transportation, housing, and economic investments. Economic development strategies forged at a regional level have a wide ranging impact at the local level.[19] There is evidence that some strategies that promote overall regional economic development may exacerbate economic disparities.[20]

What Can Local Health Departments Do?

Data and Surveillance

In general, SDOH indicators have not been institutionalised in public health surveillance at the state and local level in the same manner as mortality surveillance, communicable disease reporting, and behavioral risk factor surveillance. Monitoring SDOH geographic variation, time trends, and population subgroups help assess the magnitude of the problem, identify high risk groups, monitor progress toward meeting goals, set priorities, and target resources for intervention. Several U.S. states have offices of health equity, which issue periodic reports.[21, 22] Due to requirements of the Affordable Care Act (ACA), LHDs in partnership with nonprofit hospitals and community coalitions are producing community health needs assessments and improvement plans [US IRS Code Title IX, §6033(b)], frequently framing health disparities in terms of SDOH.[23, 24] ACA implementation supports the institutionalization of surveillance of the SDOH at geographically resolved areas throughout the United States.

Health departments can also use the distribution of within-city inequities to identify specific cities that share socioeconomic and demographic similarities, but differ on health inequities. Fostering exchanges like learning collaboratives or intervention trials between peer cities may be but one mechanism to engage cities and identify successful strategies to reduce inequities.

Some LHDs are taking systematic approaches to link SDOH surveillance data to action in the form of how-to guides,[25] internal capacity building, and setting explicit goals and activities to reduce disparities.[26]

Internal Capacity Building on Racial and Health Equity

Efforts to examine and counter structural racism in health inequities are being integrated into public health practice by identifying upstream causes,[22, 27] and conducting assessments of organizational behavior in health departments. Educational and action-oriented workshops, training, and toolkits are increasingly part of public health

workforce development, program design, policy development, and evaluation[28, 29] and should touch areas relevant to public health department accreditation.

Health in All Policies

With the ascendance of Health in All Policies (HiAP),[5] public health departments have opportunities to play an active and direct role in educating policy makers on the SDOH and health equity. Because different sectors may frame equity in profoundly different ways,[30] public health practitioners can convene and constructively engage partners, including those central to economic development and education. HiAP-related actions include health impact assessments, advising and participating in cross-sector planning (e.g., land use, transportation, food systems), and developing tools that non-health planners can use to quantify the health benefits or harms of various policies or programs.[28]

Service Environment

Overcoming fragmented social services delivery is highly desirable and underpins comprehensive models of service delivery that may have collective impact and address SDOHs.[31,32] Building on city-level data of poverty and educational inequities, health departments can play a role in monitoring and evaluating the equitable access and distribution of services provided by the health department and other social service agencies.

Conclusions

Racial, ethnic, and geographic disparities in poverty and educational attainment in adults are widespread within and between California cities. Given that public health practice is increasingly focused upstream, surveillance of the social determinants of health may afford opportunities for engagement with neighbourhoods, cities, and

regional government to be an active partner in strategies that promote health and reduce poverty and low educational attainment.

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CONTRIBUTORS

DB and NM shared responsibilities in the design, analysis, and write up of this research.

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COMPETING INTERESTS

None declared.

PROTECTION OF HUMAN SUBJECTS IN RESEARCH

This study used publicly available data and did not involve human subjects in research.

DATA SHARING STATEMENT

This study used publicly available data. Data sets used in this analysis can be downloaded from: http://www.cdph.ca.gov/programs/Pages/HealthyCommunityIndicators.aspx.

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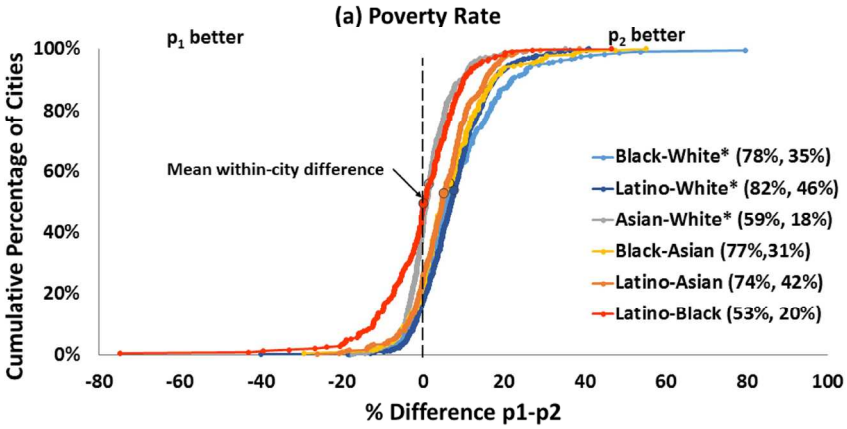
FIGURES LEGENDS

Figure 1. Distribution of Within-City Differences in (a) Poverty Rate and (b) Low Educational Attainment for Pairwise Comparisons of California Whites, Blacks, Latinos, and Asians, 2006-2010. *Considering Whites as a socially advantaged reference group, the differences that favor Whites are considered inequities. The legends show the percent of cities in which the p_2 race/ethnicity group has a better outcome and the percent of cities in which the outcome is statistically significant ($p < 0.1$). For instance, "Black-Asian (77%, 31%)" indicates that 77% of the cities in which the comparison is possible have a better outcome for the Asian group and 31% of those cities have a significantly better outcome.

Figure 2. Within-City Poverty Rate Differences and Overall City Poverty Rate (a) and Low Educational Attainment and Overall City Low Educational Attainment (b), California Cities, 2006-2010. r is the Pearson correlation coefficient between within city differences and the overall city value. *Considering Whites as a socially advantaged reference group, the differences that favor Whites are considered inequities.

Figure 3. Distribution of Within-City Differences in the Highest and Lowest Census Tract Rates for Educational Attainment and Poverty, California, 2006-2010.



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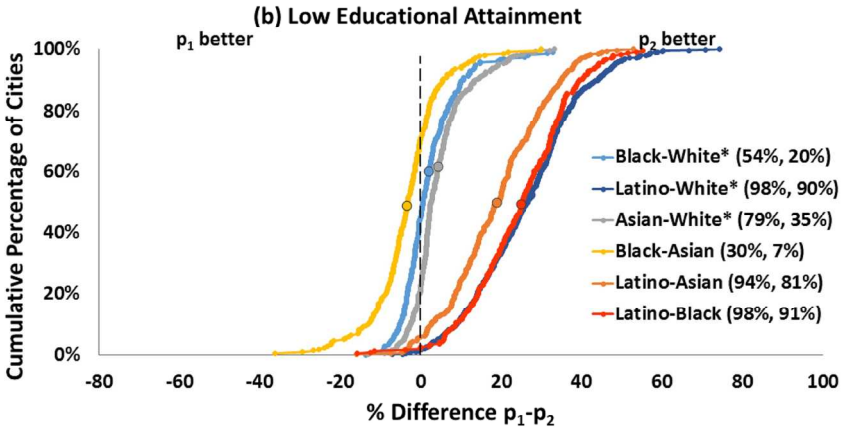

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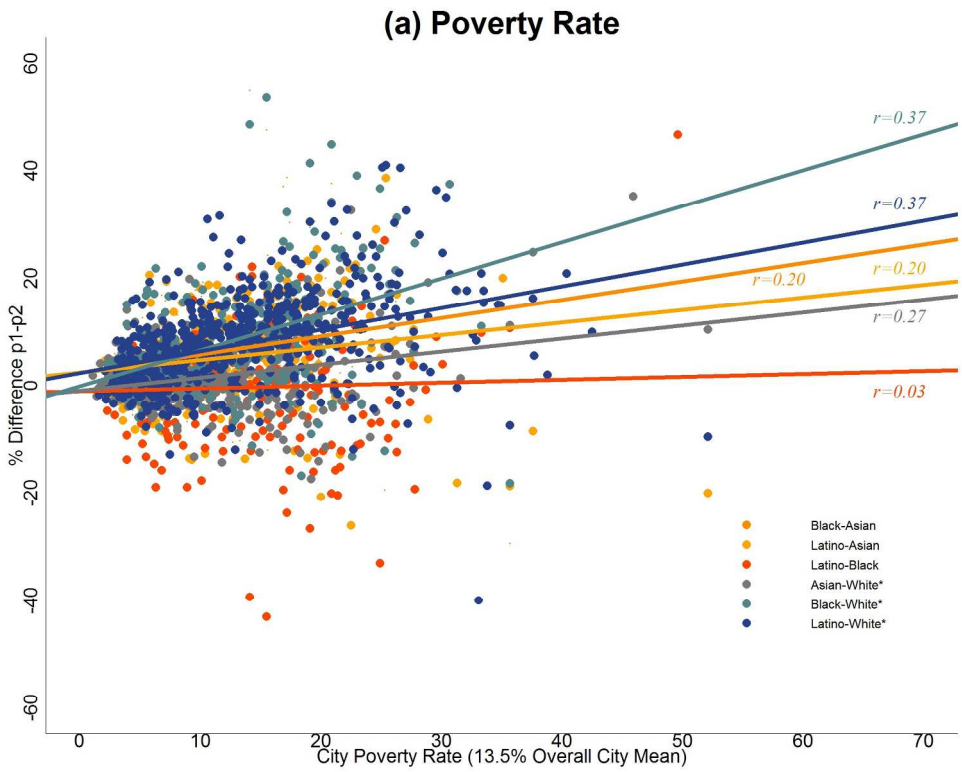

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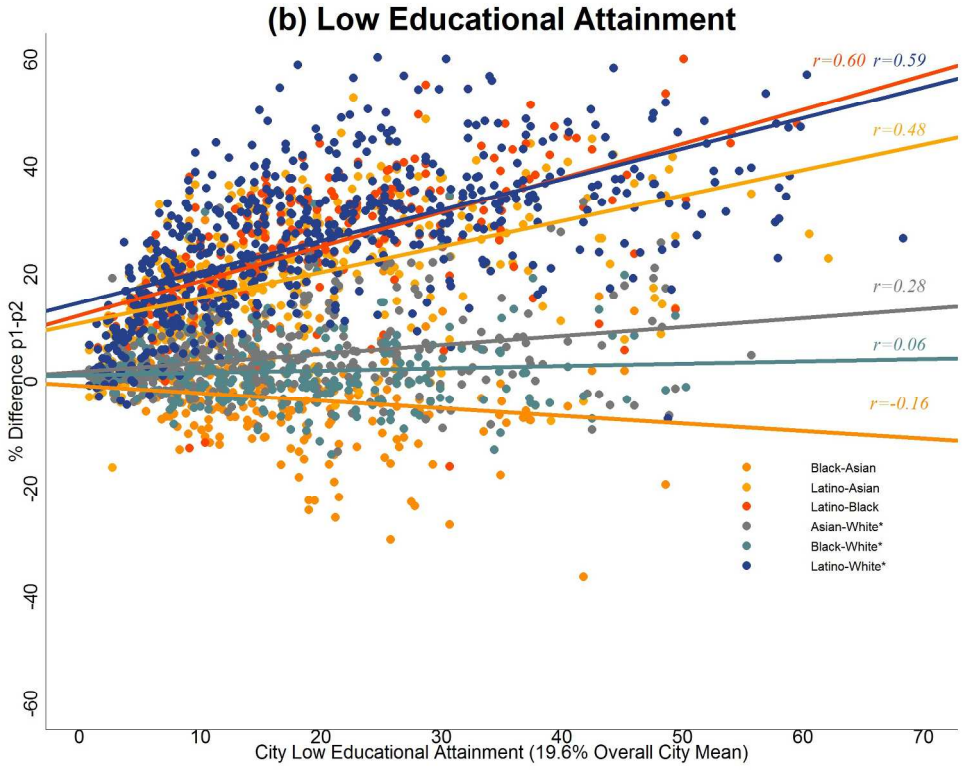

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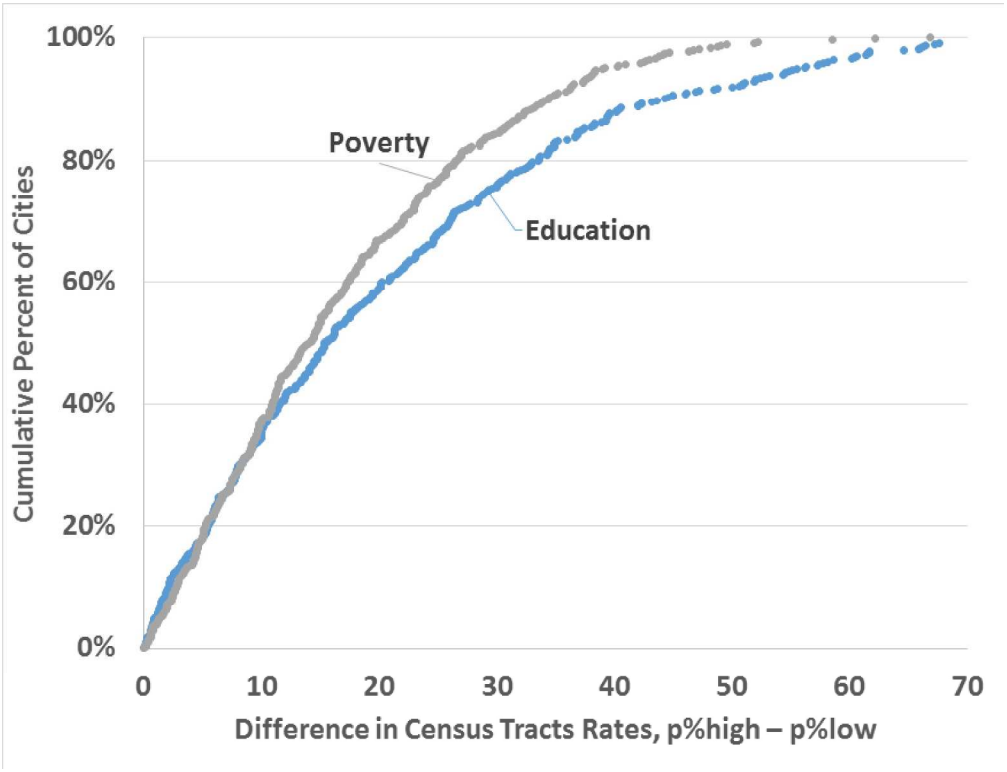

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STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract Page 1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found Pages 2-3
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported Page 5
Objectives	3	State specific objectives, including any prespecified hypotheses Page 5
Methods		
Study design	4	Present key elements of study design early in the paper Pages 7-8, 9
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection Page 6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants Page 6 (cities in California)
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable Pages 7-8, 9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group Sources of data, page 6
Bias	9	Describe any efforts to address potential sources of bias Page 9
Study size	10	Explain how the study size was arrived at Page 6 (data available from U.S. Census)
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why Pages 7-8, 9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
		(*c*) Explain how missing data were addressed
		(*d*) If applicable, describe analytical methods taking account of sampling strategy
		(*e*) Describe any sensitivity analyses Pages 7-8, 9
Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		(b) Give reasons for non-participation at each stage

		(c) Consider use of a flow diagram Page 9
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest
Outcome data	15*	Report numbers of outcome events or summary measures Pages 10-12, Figures 1-3
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period Pages 10-12, Figures 1-3
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses Pages 10-12, Figures 1-3
Discussion		
Key results	18	Summarise key results with reference to study objectives Page 13
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias Pages 13-14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence Page 13
Generalisability	21	Discuss the generalisability (external validity) of the study results Not relevant
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based Page 18

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Cross Sectional Analysis of Two Social Determinants of Health in California Cities: Racial, Ethnic, and Geographic Disparities

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Word Count: 3,447

ABSTRACT

Objective

To study the magnitude and direction of city level racial and ethnic differences in poverty and education to characterize health equity and social determinants of health in California cities.

Design

We used data from the American Community Survey, United States Census Bureau, 2006-2010, and calculated differences in the prevalence of poverty and low educational attainment in adults by race/ethnicity and by census tracts within California cities. For race/ethnicity comparisons, when the referent group (p_2) to calculate the difference (p_1-p_2) was the non-Hispanic White population (considered a historically advantaged group), a positive difference was considered a health inequity. Differences with a non-White reference group were considered health disparities.

Setting

Cities of the State of California, United States.

Results

Within-city differences in the prevalence of poverty and low educational attainment disfavored Black and Latinos compared to Whites in over 78% of cities. Compared to Whites, the median within-city poverty difference was 7.0% for Latinos and 6.2% for Blacks. For education, median within-city difference was 26.6% for Latinos compared to Whites. In a small, but not negligible proportion of cities, historically disadvantaged race/ethnicity groups had better social determinants of health outcomes than Whites. The median difference between the highest and lowest census tracts within cities was 14.3% for poverty and 15.7% for low educational attainment. Overall city poverty rate was weakly, but positively correlated with within-city racial/ethnic differences.

Conclusions

Disparities and inequities are widespread in California. Local health departments can use these findings to partner with cities in their jurisdiction and design strategies to reduce racial, ethnic and geographic differences in economic and educational outcomes. These analytic methods could be used in an ongoing surveillance system to monitor these determinants of health.

ARTICLE SUMMARY

STRENGTHS AND LIMITATIONS OF THIS STUDY

- To our knowledge, this is the first comprehensive tabulation of pairwise within-city SDOH differences between major race/ethnic groups and neighbourhoods across California's cities.
- Most multi-level, place-based research, examines individual and neighborhood impacts, but often bypasses city as a "place": racial and ethnic differences in health outcomes and their social determinants are widely reported in the United States at the national, state, and county scale, with non-Hispanic White populations usually experiencing the best outcomes.
- This article contributes to fill a geographic gap in current public health surveillance methods by documenting the glaring disparities in poverty and low educational attainment by race/ethnicity and neighborhood that exist within nearly every California city.
- This analysis provides both between and within city-level estimates that can be more effective for targeting interventions to where they are most needed.
- As a univariate analysis, our findings have several limitations including lack of examination of other social determinants that could mediate the outcomes, time period of the study that coincides with high levels of economic instability during the Great Recession, 2007-2009, and use of aggregated data that masks the heterogeneity of sub-populations within the racial and ethnic groups studied.

INTRODUCTION

Differences in health outcomes or their determinants are widely reported between racial and ethnic groups in the United States at the national, state, and county scale.[1-3] Differences that are avoidable, unfair and rooted in historical social disadvantage are defined as health inequities. Differences with biological or other underlying causes are health disparities.[4] County and city local health departments (LHDs) increasingly recognise their role in addressing the social determinants of health (SDOH) that underlie health inequities. LHDs are also reaching out to non-health sectors in their communities to impact the root causes of health inequities through "Health in All Policies".[5]

Geographic analysis of SDOH is used to reveal health inequities, and prioritise public health interventions and target community engagement. While an increasing number of LHDs examine health inequities at small geographies, most rely on county level data that masks important differences within counties. The surveillance of SDOH at small geographies poses methodological challenges and opportunities for taking data to action. In assessing racial and ethnic inequities, non-Hispanic Whites are often considered the socially advantaged referent group. It has been posited that it is relatively rare for the most privileged group not to have the best outcome.[4, p187]

We explore racial, ethnic, and geographic differences in poverty and low educational attainment. Poverty reduction, increasing educational attainment, and the elimination of health disparities are national health goals of the United States[6]; these two SDOH may account for 18% of the national burden of mortality.[7]

We examined 1) the magnitude and direction of racial, ethnic and geographical differences in these SDOH within and between California cities, 2) the relationship between overall city disadvantage and SDOH disparities and inequities, and 3) possible actions that LHDs may consider based on surveillance findings produced with the research methods suggested in this study.

METHODS

Data Source

We used data from the American Community Survey (ACS),[8, 9] a continuous prevalence survey based on a probability sample of households throughout the United States. ACS publishes data in 5-year tabulations for cities and census tracts. We used ACS Selected Population Tables (2006-2010), which stratify the tabulations by mutually exclusive race and ethnicity categories: Hispanic or Latino, and non-Hispanic persons of the following races: White, Black, Asian, Native Hawaiian and Other Pacific Islander, Other, Multiple, and American Indian/Alaskan Native. For California, the ACS reported on 8,057 census tracts, 480 incorporated cities and towns, and 1,043 non-incorporated places (from here on towns and non-incorporated places will be referred on as cities). The prevalence of poverty and its standard error were obtained from ACS Table DP03, and educational attainment in adults and its standard error were obtained from Table DP02. The California Department of Public Health compiled these data (www.cdph.ca.gov/programs/pages/healthycommunityindicators.aspx).

ACS Definition of Poverty and Educational Attainment

The prevalence of poverty was defined as the 5-year annual average percentage of all individuals whose household income in the past 12 months was below the federal poverty level. Total household income was calculated from eight questions on the ACS-1 form about wages, self-employment, securities, rental property, retirement and disability payments, and public assistance. Households were classified as poor when total income of the householder's family was below an income threshold, taking into account the size of the family, number of related children, and, for 1- and 2-person families, age of householder.[8] The prevalence of educational attainment less than high school was defined as the 5-year annual average percentage of adults aged 25 years or older whose maximum educational attainment was 0 to 11 years of grade school.

Between-City, Within-City, and Neighbourhood Level Racial and Ethnic Disparities and Inequities and Statistical Methods

We calculated between-city, within-city, and neighbourhood level differences for combinations of White, Asian, Latino, and Black subgroups.

Differences in the 5-year percentage of poverty or low educational attainment, p, were calculated between pairs of racial/ethnic groups, $p_1 - p_2$. Differences have a positive or negative sign based on the referent group (p_2). When the referent group, p_2, was White, a positive difference represents a health inequity. Differences with a non-White reference group were considered health disparities. For cities with two or more census tracts, neighbourhood disparities were defined as the absolute difference of census tracts with the highest and lowest 5-year percentage.

Mean and medians of between- and within-city differences and their standard deviation were calculated. The between-city mean difference was defined as the difference of the mean prevalence of two specified race/ethnicity groups across all cities:

$$\text{Between-city mean difference} = \frac{\sum_{i,j} p_{i,j}}{N_{\text{Total (j)}}} - \frac{\sum_{i,k} p_{i+1,k}}{N_{\text{Total(k)}}}$$

where *i* is the i^{th} race/ethnicity group and *j* is the j^{th} of N total cities of $group_i$, and *k* is the k^{th} of N total cities of $group_{i+1}$.

The within-city mean difference was defined as:

$$\text{Within-city mean difference} = \frac{\sum_{i.j} (p_{i,j} - p_{i+1,j})}{N_{\text{Total(j)}}},$$

where *i* is the *ith* race/ethnicity group and *j* is the *jth* of city of N_{Total} cities where data on both of the race/ethnicity pairs are available.

Within-city differences were plotted as cumulative frequency distributions of cities for each pairwise race/ethnicity comparison in order to assess the magnitude and direction of racial and ethnic inequities or disparities in cities across the state. For each city, Z-tests were carried out to determine whether the within-city difference was statistically significant. We followed U.S. Census Bureau guidelines for pooling standard errors of percents, which is the square root of the sum of the squares of the two individual standard errors ($se = \sqrt{se_1^2 + se_2^2}$). A p value of 0.10 was considered statistically significant. R software was used for the calculations.[10]

SDOH differences are often interpreted in the context of the range of their absolute values. For example, in some very poor cities there may be no demonstrable differences between groups and "everyone is poor together". In other cities, there is a small, but statistically significantly difference between groups, but each group is relatively well off (e.g., has a SDOH value far above the mean.) To contextualise a city's disparities or inequities on a backdrop of high or low rate of poverty or educational attainment, we plotted within-city disparities or inequities, as a function of the between-city poverty rate (or educational attainment). Simple linear correlation (Pearson, r) assessed the strength of association.

Calculation of Neighbourhood Disparities

Census tract and city boundaries are not always congruent; therefore, for neighbourhood analyses, census tracts were associated with the city into which its centroid fell. We used ArcGIS 10.3 (ESRI, Redlands, CA) to calculate and associate centroids with cities. In some cases, portions of census tracts outside of city limits were included in neighbourhood comparisons. This introduces some potential misclassification if the outlying portion of the census tract has different poverty or educational attainment. We also calculated the mean linear distance in miles between the centroids of the census tracts with the highest and lowest poverty and educational outcomes.

Exclusions

The ACS does not publish data for geographic areas with fewer than 50 respondents. Of 1,523 cities the number available for within-city pairwise comparisons varied by race/ethnicity subgroup: 221 cities had data for Black-Asian comparisons, 280 for Asian-White, 245 for Black-White, 364 for Latino-Asian, 252 for Latino-Black, and 611 for Latino-White. We did not have sufficient data to carry out pairwise comparisons that included American Indian/Native Alaskans, Native Hawaiians and Other Pacific Islanders, Multiple races, and Other. Analyses of poverty at the census tract level excluded economically dependent populations in colleges, correctional facilities, and other group quarters and institutions. Two census tracts with a population less than 500 inhabitants were also excluded.

Association between Within-City Geographic Disparities in Educational Attainment and Poverty with Within-City Disparities in Life Expectancy at Birth

To illustrate the association between SDOH and health outcomes within California cities we calculated the correlation coefficient between census tract level life expectancy at birth (LEB) and the two social determinants. The LEB data for California census tracts is publically available through the Health Disadvantage Index Project (http://phasocal.org/ca-hdi/). The census tracts with the highest and lowest educational attainment and those with the highest and lowest poverty rates were matched with their LEB. Within cities, the differences between minimum and maximum (min-max) SDOH and health outcomes, respectively, was calculated. Census tract differences in educational attainment and poverty were scaled so that positive differences indicated greater disparities. Census tract difference in LEB were scaled so that positive differences indicated increases in life expectancy, and conversely, negative differences indicated a lower life expectancy. The correlation coefficient between the differences (min-max) was calculated in R.

RESULTS

Between- and Within-City Racial and Ethnic Disparities and Inequities

The poverty rate of Latinos (18.6%) and Blacks (17.4%) averaged over California cities was nearly twice that of Whites (9.2%) and Asians (9.5%) (Table 1).

Table 1 Between and Within-City Means and Race-Ethnicity Specific Pairwise Differences in Poverty Rate and Educational Attainment, California, 2006-2010

	Percent below the federal poverty level			Percent of adults aged ≥25 years without a high school education		
Between cities	Mean	SD	Median	Mean	SD	Median
White	9.2	6.9	7.5	8.7	7.3	6.7
Black	17.4	12.9	14.6	11.0	8.9	8.8
Asian	9.5	8.7	7.1	12.4	9.8	9.7
Latino	18.6	11.4	16.8	39.6	18.4	39.9

Pairwise differences (p_1-p_2)	Between city		Within city		Between city		Within city	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Black-White	8.2	7.1	8.5	6.2	2.3	2.1	2.0	0.6
Asian-White	0.3	-0.4	1.7	0.9	3.7	3.0	4.4	2.7
Latino-White	9.4	9.3	7.6	7.0	30.9	33.2	26.2	26.6
Black-Asian	7.9	7.5	6.5	4.8	-1.4	-0.9	-3.3	-3.1
Latino-Asian	9.1	9.7	5.1	4.8	27.2	30.2	19.0	19.2
Latino-Black	1.2	2.2	0.3	0.5	28.6	31.1	24.9	25.4

The city average percentage of adults with low educational attainment was 3-4 times higher in Latinos compared to Whites, Asians, or Blacks. The largest mean between-city educational inequity (30.9%) was between Latinos and Whites.

The distribution of within-city differences of race/ethnicity pairs is presented for poverty and low educational attainment (Figure 1). In a large percentage of cities, Asians and Whites had better poverty outcomes than Latinos or Blacks. The largest inequities occurred between Blacks and Whites (8.5% mean difference) and Latinos and Whites (7.6%). In approximately 40% of cities, these differences were statistically significant. Latinos had better poverty outcomes than Asians or Whites in 26% and 18% of cities, respectively. Likewise, Blacks had better outcomes than Asians or Whites in approximately 20% of cities. The average differences in within-city poverty rates between Blacks and Latinos were small (0.3%), but there was considerable variation.

For low educational attainment (Figure 1 b), the largest mean difference was between Latinos and other groups (Latino-Whites, 26.2%; Latino-Blacks, 24.9%; Latino-Asians, 19.0%). Whites tended to have better outcomes than Asians or Blacks. Blacks tended to have better outcomes than Asians. Latinos had poorer outcomes than the other groups in almost all cities (94% or higher). An overwhelming majority of within-city differences between Latinos and other groups were statistically significant.

Supplemental materials include maps of California cities depicting the race/ethnicity with the largest disparity for poverty or educational attainment.

Between- and Within-City Racial and Ethnicity Correlations

Within-city racial/ethnic differences in poverty and overall city poverty rate (Figure 2 a), appear to be correlated for all race/ethnicity combinations with White or Asian referents, but exhibit considerable variability (scatter). Black and Latino inequities (White referents) tended to be larger at higher levels of overall poverty ($r = 0.37$, $P < 0.01$). A

weaker association (r = 0.20, *P* <0.01) was observed for Black or Latinos with Asian referents.

In a large proportion of California cities, Latinos experience both large educational disparities and live in cities with low overall educational attainment. Within-city education differences between Latinos and other groups were strongly associated (r range: 0.48 to 0.60) with overall city low educational attainment (Figure 2 b).

Neighbourhood Disparities

The distribution of within-city differences of poverty and educational attainment between the highest and lowest census tract is presented in Figure 3. The median difference was 14.3% for poverty and 15.7% for educational attainment. Disparities of 25% or greater were observed in 25% of cities for poverty and 33% of cities for educational attainment. In approximately 73% of 500 cities with two or more census tracts, the differences were statistically significant. For the 174 cities with 10 or more census tracts, 99% of differences were statistically significant. The median straight-line distance between the highest and lowest census tracts was 2.6 km (SD, 3.2) for poverty and 2.9 km (SD, 3.04) for educational attainment.

Within-City Associations between Disparities in Life Expectancy at Birth and Disparities in the SDOH

Within cities, increasing disparities in educational attainment between census tracts with the highest and lowest levels were significantly correlated with increasing disparities in which life expectancy decreased (Pearson r=-0.24, p< 0.001). A similar significant correlation was found for poverty disparities and life expectancy (Pearson r=-0.28). In simple linear regression analyses, 0.08 years of life expectancy was lost for each percent of educational disparity and 0.05 years of life expectancy was lost for each percent of poverty disparity.

DISCUSSION

We found widespread racial, ethnic, and geographic differences in educational attainment and poverty within California cities. Comparisons between Whites and Blacks and Whites and Latinos generally conformed to a health inequities model – that historically, socially disadvantaged groups had poorer outcomes than Whites. This was less frequent in comparisons between Asians and Whites. In a small, but not negligible proportion of cities, historically disadvantaged race/ethnicity groups had better SDOH outcomes than Whites. We found a correlation between a city's underlying level of poverty (or educational attainment) and racial/ethnic disparities. Neighbourhood level differences within cities were also ubiquitous. On average, a mere 2.6 km separates a city's census tracts with the highest and lowest poverty rate or educational attainment. An illustrative analysis showed that increases in within-city disparities in poverty and educational attainment are associated with reductions in life expectancy, providing support for the relevance of the identification, targeted intervention, and monitoring of SDOH.

Strengths and Limitations

To our knowledge, this is the first comprehensive tabulation of pairwise within-city SDOH differences between major race/ethnic groups and neighbourhoods across California's cities.

As a univariate analysis, our findings have several limitations. Racial/ethnic differences may be related to other SDOHs which mediate the outcome. For example, recency of immigration profoundly influences poverty and educational attainment,[11] and may explain, in part, the educational inequities we observed in Latinos and Whites. Moreover, SDOH are themselves interrelated. Conducting a multivariate analysis to establish the independence of racial/ethnicity disparities,[4] is not feasible using pre-tabulated ACS tables. Other U.S. Census Bureau products (Public Use Microdata

Sample) and surveys may serve this purpose, but do not provide reliable estimates at small geographies.

For a small percentage of cities, socially disadvantaged groups had significantly better outcomes than Whites. Further research of these cities may reveal whether this finding is associated with community "resiliency", confounded by other sociodemographic factors, or has another explanation.

We acknowledge that the race categories included in the analysis are composed of subpopulations whose poverty and educational attainment are heterogeneous (for instance, differences between Asian ethnic groups). Valuable information may have been lost by aggregation.

Differences in SDOH between geographic units such as census tracts may be disparities or inequities, depending on the history of social disadvantage. Long-standing patterns of racial discrimination and economic segregation within California cities[12] undoubtedly underlie some of the differences that we labeled disparities.

Data suppression in the ACS impacts numerically small, geographically dispersed racial/ethnic populations, creating information bias towards areas with greater racial concentration or segregation. Small rural cities account for a disproportionate number of exclusions in our analysis. Nonetheless, depending on the race/ethnicity comparison, the cities included in our analysis contain between 68% and 88% of the California population.

Cross-sectional data cannot be used to establish causal relationships or directionality. Our finding that a city's poverty rate and its racial/ethnic disparities are interrelated will require longitudinal, confirmatory studies. Studies in the United States and western countries suggest that income inequality inhibits overall economic development and economic mobility.[13]

The time period of this study coincided with high levels of economic instability during the Great Recession, 2007-2009. Cities and regions might have since experienced economic recovery, gentrification, population displacement, and community succession. Due to lags in reporting, ACS data may not reflect current conditions.

What Can Cities Do?

While cities alone cannot be expected to solve economic and educational disparities, they play an important role in shaping the social determinants of health through people- and place-based strategies.[14] In the United States local government plays an active role in recruiting and retaining employers, establishing preferences for minority-owned businesses, adopting local first-hire policies, and legislating minimum wages. School districts and boards exert local control over school policy and funding, whether the bulk of funds are from state or local taxes. Through local zoning, urban revitalization, and the creation of enterprise zones, local government shapes the built environment and the availability of resources for the basics of living (e.g., food outlets, housing, jobs, transportation). Local housing authorities implement federal and state policies that influence the availability and placement of affordable housing. Several health impact assessments and health studies document the likely and actual health promoting impacts of minimum wage ordinances[15, 16] and housing vouchers that relocate renters from neighbourhoods with concentrated poverty to those with low poverty.[17, 18] Many cities are examining their own internal policies and practices with regard to hiring, procurement, and building capacity through authentic deep community engagement.

Local elected officials often comprise the governing bodies of regional associations of government, which make decisions on regional transportation, housing, and economic investments. Economic development strategies forged at a regional level have a wide ranging impact at the local level.[19] There is evidence that some strategies that promote overall regional economic development may exacerbate economic disparities.[20]

What Can Local Health Departments Do?

Data and Surveillance

In general, SDOH indicators have not been institutionalised in public health surveillance at the state and local level in the same manner as mortality surveillance, communicable disease reporting, and behavioral risk factor surveillance. Monitoring SDOH geographic variation, time trends, and population subgroups help assess the magnitude of the problem, identify high risk groups, monitor progress toward meeting goals, set priorities, and target resources for intervention. Several U.S. states have offices of health equity, which issue periodic reports.[21, 22] Due to requirements of the Affordable Care Act (ACA), LHDs in partnership with nonprofit hospitals and community coalitions are producing community health needs assessments and improvement plans [US IRS Code Title IX, §6033(b)], frequently framing health disparities in terms of SDOH.[23, 24] ACA implementation supports the institutionalization of surveillance of the SDOH at geographically resolved areas throughout the United States.

Health departments can also use the distribution of within-city inequities to identify specific cities that share socioeconomic and demographic similarities, but differ on health inequities. Fostering exchanges like learning collaboratives or intervention trials between peer cities may be but one mechanism to engage cities and identify successful strategies to reduce inequities.

Some LHDs are taking systematic approaches to link SDOH surveillance data to action in the form of how-to guides,[25] internal capacity building, and setting explicit goals and activities to reduce disparities.[26]

Internal Capacity Building on Racial and Health Equity

Efforts to examine and counter structural racism in health inequities are being integrated into public health practice by identifying upstream causes,[22, 27] and conducting assessments of organizational behavior in health departments. Educational and action-

oriented workshops, training, and toolkits are increasingly part of public health workforce development, program design, policy development, and evaluation[28, 29] and should touch areas relevant to public health department accreditation.

Health in All Policies

With the ascendance of Health in All Policies (HiAP),[5] public health departments have opportunities to play an active and direct role in educating policy makers on the SDOH and health equity. Because different sectors may frame equity in profoundly different ways,[30] public health practitioners can convene and constructively engage partners, including those central to economic development and education. HiAP-related actions include health impact assessments, advising and participating in cross-sector planning (e.g., land use, transportation, food systems), and developing tools that non-health planners can use to quantify the health benefits or harms of various policies or programs.[28]

Service Environment

Overcoming fragmented social services delivery is highly desirable and underpins comprehensive models of service delivery that may have collective impact and address SDOHs.[31,32] Building on city-level data of poverty and educational inequities, health departments can play a role in monitoring and evaluating the equitable access and distribution of services provided by the health department and other social service agencies.

Conclusions

Racial, ethnic, and geographic disparities in poverty and educational attainment in adults are widespread within and between California cities. Given that public health practice is increasingly addressing root causes of disease, the identification, targeted intervention, and surveillance of the social determinants of health may afford

opportunities for engagement with neighbourhoods, cities, and regional government to be an active partner in strategies that promote health and reduce poverty and low educational attainment.

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CONTRIBUTORS

DB and NM shared responsibilities in the design, analysis, and write up of this research.

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COMPETING INTERESTS

None declared.

PROTECTION OF HUMAN SUBJECTS IN RESEARCH

This study used publicly available data and did not involve human subjects in research.

DATA SHARING STATEMENT

This study used publicly available data. Data sets used in this analysis can be downloaded from:
http://www.cdph.ca.gov/programs/Pages/HealthyCommunityIndicators.aspx.

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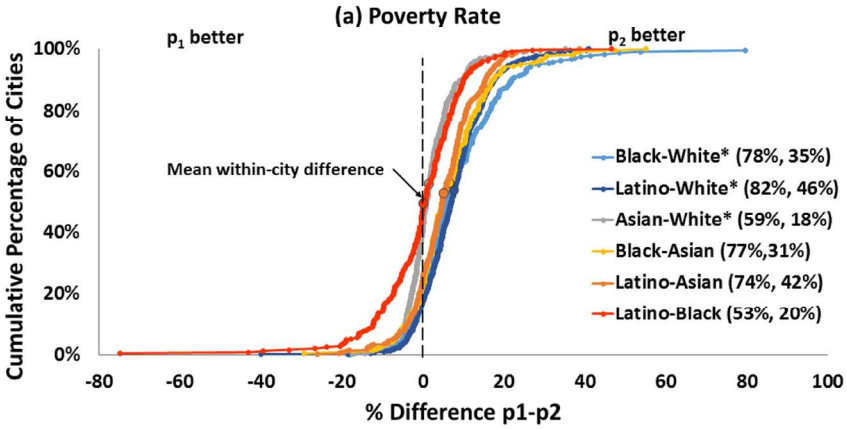
FIGURES LEGENDS

Figure 1. Distribution of Within-City Differences in (a) Poverty Rate and (b) Low Educational Attainment for Pairwise Comparisons of California Whites, Blacks, Latinos, and Asians, 2006-2010. *Considering Whites as a socially advantaged reference group, the differences that favor Whites are considered inequities. The legends show the percent of cities in which the p_2 race/ethnicity group has a better outcome and the percent of cities in which the outcome is statistically significant ($p < 0.1$). For instance, "Black-Asian (77%, 31%)" indicates that 77% of the cities in which the comparison is possible have a better outcome for the Asian group and 31% of those cities have a significantly better outcome.

Figure 2. Within-City Poverty Rate Differences and Overall City Poverty Rate (a) and Low Educational Attainment and Overall City Low Educational Attainment (b), California Cities, 2006-2010. r is the Pearson correlation coefficient between within city differences and the overall city value. *Considering Whites as a socially advantaged reference group, the differences that favor Whites are considered inequities.

Figure 3. Distribution of Within-City Differences in the Highest and Lowest Census Tract Rates for Educational Attainment and Poverty, California, 2006-2010.



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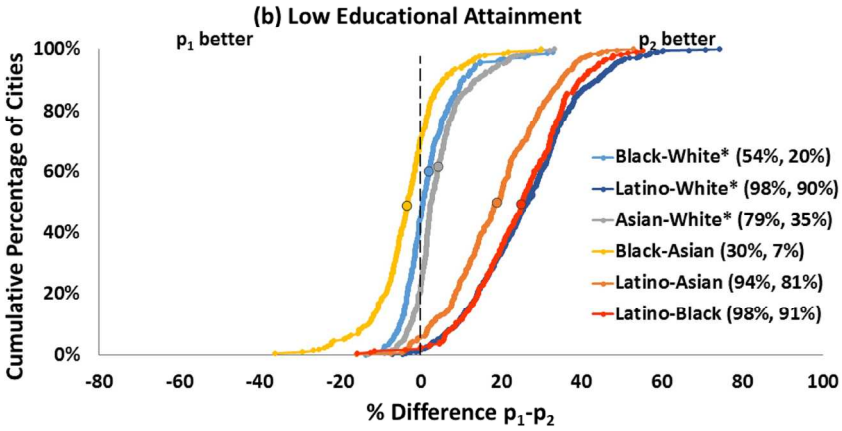

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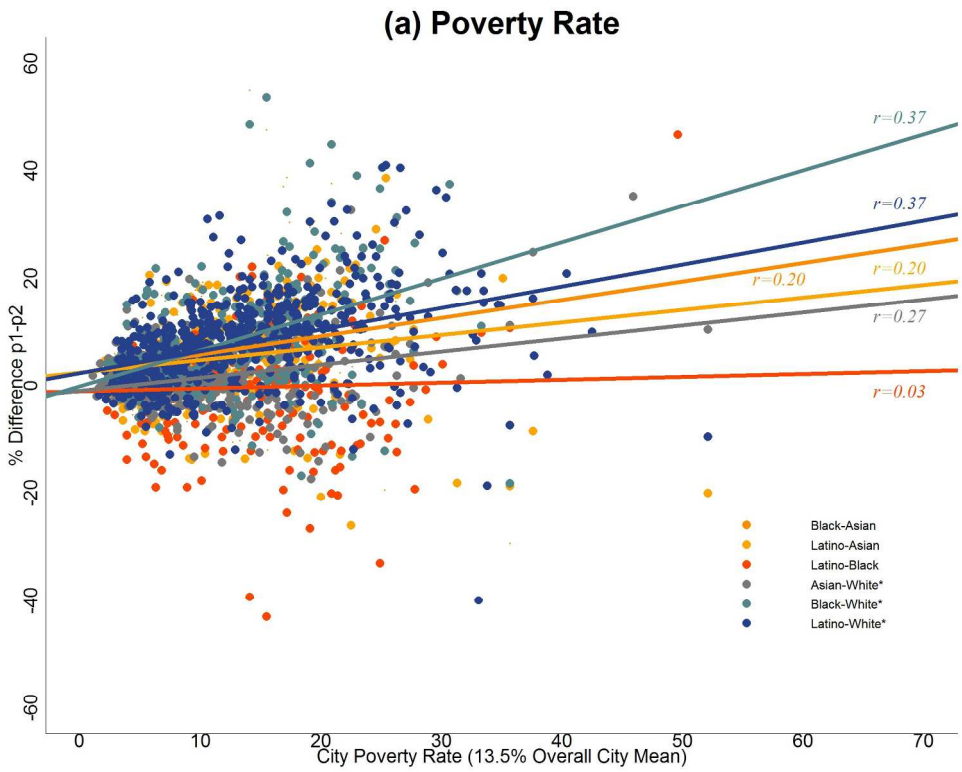

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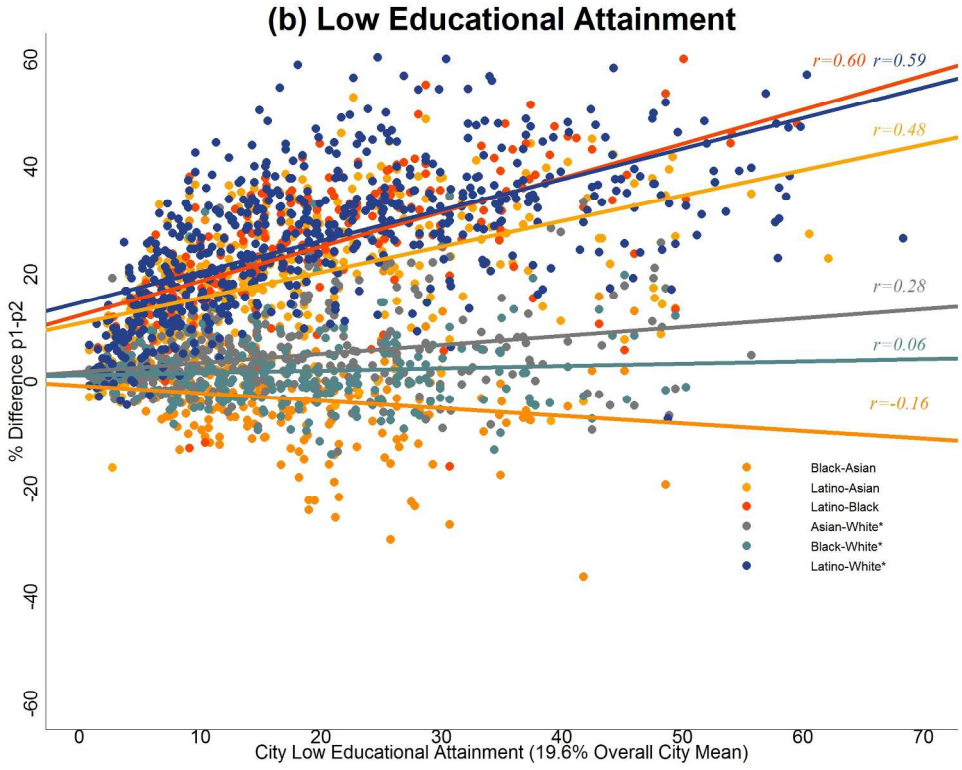

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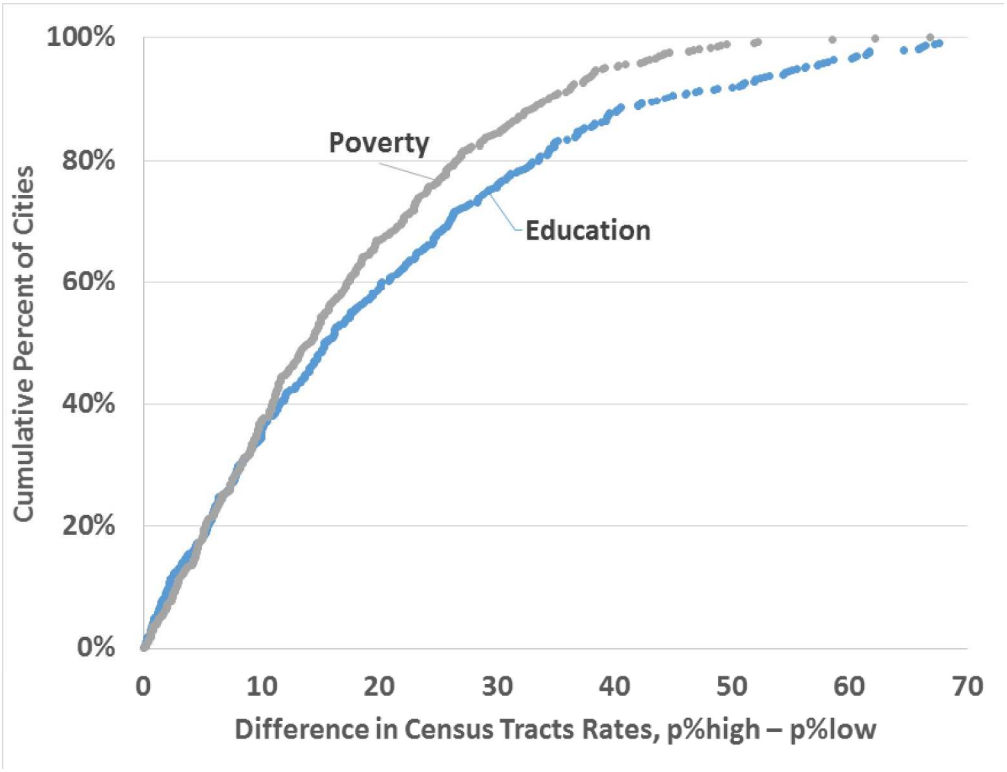

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STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract Page 1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found Pages 2-3
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported Page 5
Objectives	3	State specific objectives, including any prespecified hypotheses Page 5
Methods		
Study design	4	Present key elements of study design early in the paper Pages 7-8, 9
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection Page 6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants Page 6 (cities in California)
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable Pages 7-8, 9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group Sources of data, page 6
Bias	9	Describe any efforts to address potential sources of bias Page 9
Study size	10	Explain how the study size was arrived at Page 6 (data available from U.S. Census)
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why Pages 7-8, 9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
		(*c*) Explain how missing data were addressed
		(*d*) If applicable, describe analytical methods taking account of sampling strategy
		(*e*) Describe any sensitivity analyses Pages 7-8, 9
Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		(b) Give reasons for non-participation at each stage

		(c) Consider use of a flow diagram Page 9
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest
Outcome data	15*	Report numbers of outcome events or summary measures Pages 10-12, Figures 1-3
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period Pages 10-12, Figures 1-3
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses Pages 10-12, Figures 1-3
Discussion		
Key results	18	Summarise key results with reference to study objectives Page 13
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias Pages 13-14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence Page 13
Generalisability	21	Discuss the generalisability (external validity) of the study results Not relevant
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based Page 18

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.