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Article

Disparities in cancer incidence by rurality in California

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Abstract

Background: Cancer rates in rural areas across the United States have different patterns than in urban areas. This study examines associations between rurality and incidence for the top 5 cancers in California and evaluates whether these associations vary jointly by sex, race, and ethnicity.

Methods: We used 2015-2019 California Cancer Registry data to compare incidence rate ratios (IRRs) and trends for breast, prostate, lung, colorectal, and skin (melanoma) cancers. We leveraged census tract aggregation zones and 7 levels of percentage rural population (0%, >0% to <10%, 10% to <20%, 20% to <30%, 30% to <40%, 40% to <50%, and 50+%).

Results: Zones with higher proportions of rural population were significantly associated with lower incidence of female breast cancer and prostate cancer, though the trends were not statistically significant overall. Zones with higher proportions of rural population were significantly associated with higher incidence of lung cancer and melanoma. There were no statistically significant trends for colorectal cancer overall. Comparing areas with 50% and over rural population with areas with 0% rural population, the IRR for lung cancer in Hispanic females was higher (IRR = 1.43, 95% confidence interval [CI] = 1.17 to 1.74) than in Hispanic males (IRR = 0.90, 95% CI = 0.72 to 1.11). Also, in areas with 50% or more rural population, the IRR for melanoma was higher in Hispanic females (IRR = 1.75, 95% CI = 1.23 to 2.45) than non-Hispanic White females (IRR = 0.87, 95% CI = 0.80 to 0.95).

Conclusions: Our findings show that rurality is associated with cancer incidence and underscore the importance of jointly examining rural disparities with sex, race, and ethnicity by cancer site.

Cancer rates in rural areas across the United States have different patterns than in urban areas. Rural areas often report lower incidence rates for breast and prostate cancers and higher rates for lung and colorectal cancers (1-4). Rural disparities in cancer incidence have been attributed to a complex combination of risk factors, including access to health care, screening rates, smoking, obesity, poverty, and neighborhood disinvestment (1,5). However, rural subpopulations may experience risks differently, resulting in variable cancer incidence. These differences confound efforts to interpret findings and generalize about rural cancer disparities (2,6).

Rural cancer research to date has most often defined "rural" in broad terms, using classification schemes based on Rural-Urban Continuum Codes (RUCC) or Rural-Urban Commuting Area (RUCA) codes, both developed by the US Department of Agriculture Economic Research Service (3,4,7-9). In the RUCC scheme, metropolitan counties are coded according to population size, and non-metropolitan counties are coded by population size and adjacency to a metro area. A 9-point coding system comprises the RUCC scheme, with counties often categorized as "urban" (codes 1-3) or "rural" (codes 4-9). The RUCA scheme uses a 10-point system in which census tracts are coded according to population density, urbanization, and daily commuting patterns and then categorized in various ways, such as urban, large rural town, or small rural town (10). Although both the RUCC and RUCA schemes are practical for many research purposes, population size in low-density counties may be too small for the granular statistical analyses necessary to understand cancer disparities within rural populations. Also, collapsing codes into rural vs urban dichotomies masks the considerable variation across levels of rurality.

Recent cancer control studies have begun to examine rurality more as a continuum rather than as a rural–urban dichotomy. Some researchers have used RUCC or RUCA codes to create 4 categories rather than 2 (1,6). Others have explored the use of all 9 RUCC categories, although the use of nominal categories as an ordinal continuum presents limitations in statistical analyses (10,11). Researchers have also explored using an index of rurality with a continuum ranging from 0 to 10 (10). The US Census provides data on proportion of rural residents in a census tract. The US Census defines urban areas as densely developed residential, commercial, and other nonresidential areas; rural areas are defined as all regions not included within an urban area (12,13). However, no consensus has yet emerged about the most feasible and effective way to operationalize a continuum of rurality. In addition, almost no research has

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examined incidence rates by race and ethnicity and sex across a continuum of rurality (14).

We used a novel approach based on census tract aggregation zones, developed through a collaboration with the National Cancer Institute and Westat (15). Census tract aggregation zones were created by combining adjacent census tracts according to demographic and socioeconomic factors (15). Census tract aggregation zones may comprise multiple counties in sparsely populated areas or subcounty units in densely populated areas. This approach allows for reporting results at the subcounty level in more densely populated areas and reduces suppression of results in less densely populated areas. These zones are primarily structured around population and neighborhood attributes rather than relying on geopolitical boundaries, thereby creating geographies that are more homogeneous and potentially more meaningful for assessing cancer risk. Moreover, zones can be characterized based on US Census Bureau data for census tracts that comprise them, including providing a more nuanced measure of rurality.

California has 578 census tract aggregation zones with population sizes ranging from 51 229 to 98 764 and number of census tracts from 5 to 25 (15). We used these zones and California Cancer Registry (CCR) data to examine associations between a 7-level ordinal measure of rurality and incidence rates for the top 5 cancers by sex, race, and ethnicity. California's large, diverse population and varied geography make it possible to investigate nuanced patterns of cancer incidence across rural areas and identify disparities.

Methods

Data source

We used CCR data to estimate 5-year incidence rates (2015-2019) for female breast cancer (International Classification of Diseases [ICD]-O-3 = C50.0-C50.9), colorectal cancer (ICD-O-3 = C18.0, C18.2-C18.9, C19.9, C20.9), lung cancer (ICD-O-3 = C34.1-C34.9), melanoma (ICD-O-3 = C449), and male prostate cancers (ICD-O-3 = C61.9) (16). Analysis was limited to cases reported as male or female sex. This study received University of California San Francisco institutional review board approval as a part of the protocol for the Greater Bay Area Cancer Registry.

Study variables

Rurality was defined as the proportion of residents in rural areas within zones and for the analysis was categorized into 7 levels: 0% (not rural), >0% to <10%, 10% to <20%, 20% to <30%, 30% to <40%, 40% to <50%, and 50+%. We used publicly available census tract–level data on rurality from the US Census, which is defined based on percent of residents who reside in blocks that are designated as rural (12,13). Zone-level rurality was calculated using population-weighted census tract–level data on rurality from Census 2010. Seven levels of rurality were chosen to maximize the granularity of the rural measure while still retaining enough power (ie, cases) to calculate incidence rates.

Zones were generated using a software zone design program called AZTool to create geographically compact areas similar in terms of minority population, poverty, and urban or rural status with a minimum population of 50 000 (17). Counties with larger populations were divided into multiple zones; counties with smaller populations were combined to form zones (18). Cancer incidence rates for the most common invasive cancer sites in California can be viewed by zone at https://www.californiahealthmaps.org/ (15).

Race and ethnicity were defined as non-Hispanic American Indian/Alaska Native, Hispanic, non-Hispanic Asian American/Pacific Islander, non-Hispanic Black, non-Hispanic White, and Other/Unknown. The Hispanic group included people of all races. Other/Unknown includes individuals with other or unknown race and ethnicity. The source of the race and ethnicity data in cancer registry records is taken from patient medical records (which may be self-reported by the patient or noted by the provider or other staff). CCR additionally applies the North American Association of Central Cancer Registries' identification algorithms for Hispanic and non-Hispanic Asian American/Pacific Islander population groups based on ethnicity, ancestry, birthplace, and/or surnames to improve quality of this data (19,20). Sex was defined as male and female and extracted from patient medical records.

Statistical analysis

We computed age-adjusted incidence rates (per 100 000 population) for each of the 7 levels of rurality and incidence rate ratios (IRRs) with reference to 0% (not rural). The 95% confidence intervals (CIs) for age-adjusted incidence rates and IRRs were calculated using the Tiwari et al. (21) modification. Annual population counts for incidence calculations were estimated using linear interpolation and extrapolation of 2017 census tract population estimates produced by Information Management Services with support from the National Cancer Institute (22). We conducted tests for the linear trend of incidence rates across rurality levels by using weighted linear regression, with the inverse of the incidence rate variance as the weight. The analyses were stratified by sex, race and ethnicity, and cancer site combined groups. Data for non-Hispanic American Indian/Alaska Native cases were too sparse to report rates. As population estimates were not available for "Other/Unknown" race and ethnicity, rates were not calculated for this group.

We performed all analyses using SAS software, version 9.4 (SAS institute Inc, Cary, NC, USA). All statistical tests were 2-sided, with $P < .05$ indicating statistical significance.

Results

In California, rural areas are located in the north, Central Coast, Central Valley, and southeastern desert regions, and urban areas are centered around Sacramento, San Francisco, Los Angeles, and San Diego (Figure 1). A total of 450 194 cancer patients diagnosed in California from 2015 to 2019 were included in this analysis. Median age at diagnosis was 67 years (interquartile range = 58-75 years) (Tables 1 and 2).

The study sample included 0.6% non-Hispanic American Indian/Alaska Native cases (n = 2575), 17.7% Hispanic cases (n = 79 716), 11.6% non-Hispanic Asian American/Pacific Islander cases (n = 52 262), 6.4% non-Hispanic Black cases (n = 28 960), 60.4% non-Hispanic White cases (n = 271 740), and 3.9% cases with other or unknown race or ethnicity (n = 14 941). Most cancer cases (53.1%) included in this analysis were located in nonrural zones (0% rural population) (Tables 1 and 2).

Overall, areas with a greater proportion of rural residents had lower rates of female breast cancer, though this trend was only statistically significant for non-Hispanic White females. Non-Hispanic Black females living in areas with 50% or more rural population had statistically significantly lower incidence of breast cancer compared with those in nonrural areas (Figures 2 and 3; Supplementary Tables 1-5, available online).

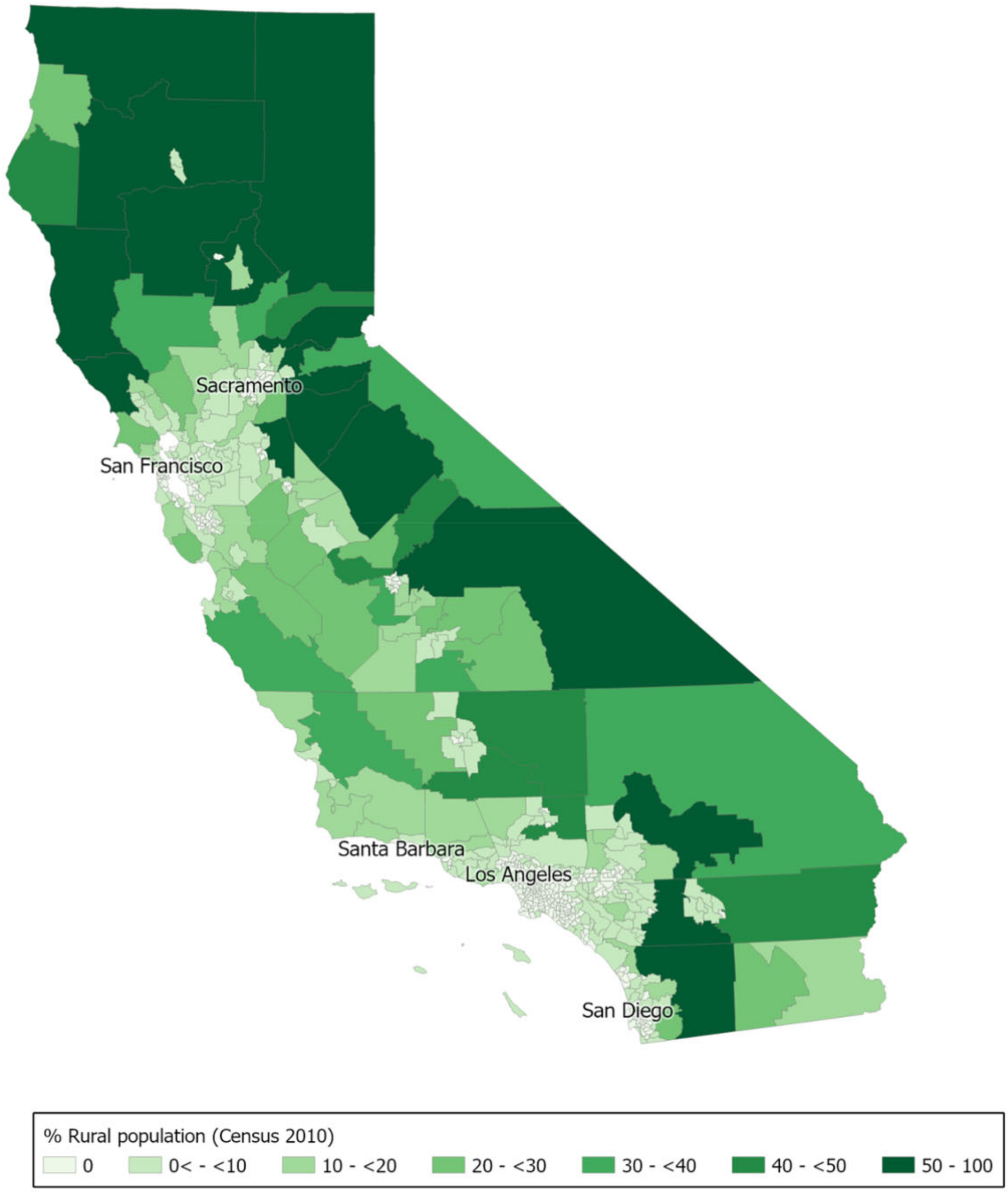

Figure 1. Map of census tract aggregation zones in California by percentage rural population. Rurality was defined as the proportion of residents in rural areas within zones and for the analysis was categorized into 7 levels: 0% (not rural), >0% to <10%, 10% to <20%, 20% to <30%, 30% to <40%, 40% to <50%, and 50+% (12). We used census tract–level data on rurality, which the US Census defines based on percent of residents who reside in blocks that are designated as rural. Zone-level rurality was calculated using population-weighted census tract–level data on rurality from Census 2010.

Areas with a greater proportion of rural residents had lower prostate cancer rates, though this trend was not statistically significant for any groups. However, non-Hispanic Black males living in areas with 50% or more rural population had statistically significantly lower incidence of prostate cancer compared with those living in nonrural areas (Figures 2 and 3; Supplementary Tables 1-5, available online).

Increasing rurality was associated with a statistically significant trend in higher lung cancer incidence overall for both sexes, with variations across racial and ethnic groups. In areas with 50% or more rural population, the IRR for lung cancer in Hispanic females was higher (IRR = 1.43, 95% CI = 1.17 to 1.74) than rates in Hispanic males (IRR = 0.90, 95% CI = 0.72 to 1.11). Increasing rurality was associated with a trend of lower incidence of lung cancer in non-Hispanic Asian American/Pacific Islander males and higher incidence for non-Hispanic White females (Figures 2 and 3; Supplementary Tables 1-5, available online).

There was no association between rurality and colorectal cancer overall. However, increasing rurality was associated with a trend in lower incidence of colorectal cancer for non-Hispanic Black males, and living in areas with 50% or more rural population had particularly low incidence of colorectal cancer (Figures 2 and 3; Supplementary Tables 1-5, available online).

Table 1. Characteristics of female breast, prostate, and lung cancer cases in California (2015-2019)[a]

Characteristic	Female breast No. (%)	Male prostate No. (%)	Male lung No. (%)	Female lung No. (%)
All	139 119 (100.0)	101 161 (100.0)	42 518 (100.0)	42 780 (100.0)
Year of diagnosis				
2015	27 141 (19.5)	18 509 (18.3)	8711 (20.5)	8607 (20.1)
2016	26 911 (19.3)	18 995 (18.8)	8608 (20.2)	8541 (20.0)
2017	27 850 (20.0)	21 047 (20.8)	8454 (19.9)	8712 (20.4)
2018	28 250 (20.3)	20 773 (20.5)	8329 (19.6)	8403 (19.6)
2019	28 967 (20.8)	21 837 (21.6)	8416 (19.8)	8517 (19.9)
Age at diagnosis, y				
0-29	811 (0.6)	7 (0.0)	82 (0.2)	85 (0.2)
30-39	6036 (4.3)	31 (0.0)	196 (0.5)	236 (0.6)
40-49	19 961 (14.3)	1487 (1.5)	798 (1.9)	952 (2.2)
50-59	31 061 (22.3)	17 043 (16.8)	4445 (10.5)	4613 (10.8)
60-69	38 486 (27.7)	42 752 (42.3)	12 164 (28.6)	11 248 (26.3)
70-79	27 861 (20.0)	29 097 (28.8)	14 786 (34.8)	14 632 (34.2)
80+	14 903 (10.7)	10 744 (10.6)	10 047 (23.6)	11 014 (25.7)
Race/ethnicity				
American Indian/Alaska Native	831 (0.6)	465 (0.5)	280 (0.7)	310 (0.7)
Hispanic	29 488 (21.2)	18 766 (18.6)	5558 (13.1)	5346 (12.5)
Non-Hispanic AAPI	20 765 (14.9)	8366 (8.3)	6433 (15.1)	5536 (12.9)
Non-Hispanic Black	8549 (6.1)	9079 (9.0)	3207 (7.5)	3121 (7.3)
Non-Hispanic White	77 529 (55.7)	57 830 (57.2)	26 777 (63.0)	28 243 (66.0)
Other/unknown	1957 (1.4)	6655 (6.6)	263 (0.6)	224 (0.5)
SEER summary stage				
Localized	89 288 (64.2)	38 633 (38.2)	9027 (21.2)	11 504 (26.9)
Regional	37 801 (27.2)	8725 (8.6)	8274 (19.5)	8095 (18.9)
Distant	7689 (5.5)	5342 (5.3)	21 666 (51.0)	19 998 (46.7)
Unknown	4341 (3.1)	48 461 (47.9)	3551 (8.4)	3183 (7.4)
Rural				
0%	76 783 (55.2)	52 270 (51.7)	22 865 (53.8)	22 527 (52.7)
0% to <10%	39 785 (28.6)	29 965 (29.6)	11 403 (26.8)	12 151 (28.4)
10% to <20%	10 386 (7.5)	8122 (8.0)	3278 (7.7)	3315 (7.7)
20% to <30%	3560 (2.6)	2861 (2.8)	1242 (2.9)	1097 (2.6)
30% to <40%	1945 (1.4)	1803 (1.8)	886 (2.1)	854 (2.0)
40% to <50%	1902 (1.4)	1773 (1.8)	705 (1.7)	738 (1.7)
50%+	4758 (3.4)	4367 (4.3)	2139 (5.0)	2098 (4.9)

[a] AAPI = Asian American/Pacific Islander; SEER = Surveillance, Epidemiology, and End Results.

A rural disadvantage for melanoma incidence was found among females and males overall, and there was a statistically significant trend in the association between increasing rurality and higher incidence for melanoma in all females. In areas with 50% or more rural population, the IRR for melanoma was higher in Hispanic females (IRR = 1.75, 95% CI = 1.23 to 2.45) compared with non-Hispanic White females (IRR = 0.87, 95% CI = 0.80 to 0.95) (Figures 2 and 3; Supplementary Tables 1-5, available online).

Discussion

Overall, we found evidence of a rural disadvantage for lung cancer and melanoma incidence. We found more complex patterns in melanoma, breast, lung, and colorectal cancer incidence when race, ethnicity, and sex were considered.

Within rural regions, racial and ethnic minoritized populations often have higher cancer incidence compared with non-Hispanic White populations (14,23). In particular, non-Hispanic Black and non-Hispanic American Indian/Alaska Native populations have notable urban and rural disparities in cancer incidence in the United States (14,23). This disparity is likely due to a combination of factors that rural and minoritized racial and ethnic populations tend to experience, such as poverty and limited access to health care (1,5). Across the United States, of the counties in persistent poverty (sustained level of poverty over 4 decades), 83% were rural (24). Furthermore, the impact of historical and current structural racism on minoritized racial and ethnic populations can also lead to differential access to housing, health care, and socioeconomic opportunities and, ultimately, poorer health outcomes (25-27).

Regional differences are important to consider when evaluating urban and rural disparities. Zahnd et al. (5) analyzed data from the North American Association of Central Cancer Registries public use data set (which represents 93% of the US population and includes data from Center for Disease Control's National Program of Cancer Registries, CCR's Provincial and Territorial Registries, and the National Cancer Institute's Surveillance, Epidemiology, and End Results Registries) and found that incidence of tobacco-associated, human papillomavirus-associated, and lung and bronchus cancers was highest in rural areas, except for the Midwest, where there were no urban and rural differences. Henley et al. (1) looked at cancer incidence data from the National Program of Cancer Registries and the Surveillance, Epidemiology, and End Results Program and found that colorectal cancer incidence rates were higher in rural areas, except in the western United States, where there was no difference. However, Hispanic residents in the rural western United States had a higher rate of colorectal cancer than Hispanic residents in urban areas (1). In California, patterns in cancer incidence rates are different than in other parts of the United States. Cancer incidence rates in California are among the lowest in the nation, in large part due to low smoking rates (6,7). Data on urban

Table 2. Characteristics of CRC and melanoma cases in California (2015-2019)[a]

Characteristic	Male CRC No. (%)	Female CRC No. (%)	Male melanoma No. (%)	Female melanoma No. (%)
All	39 211 (100.0)	35 329 (100.0)	30 144 (100.0)	19 932 (100.0)
Year of diagnosis				
2015	7831 (20.0)	7039 (19.9)	5846 (19.4)	3893 (19.5)
2016	7674 (19.6)	7086 (20.1)	5939 (19.7)	3807 (19.1)
2017	7743 (19.7)	7064 (20.0)	6044 (20.1)	3921 (19.7)
2018	7942 (20.3)	7040 (19.9)	6085 (20.2)	4074 (20.4)
2019	8021 (20.5)	7100 (20.1)	6230 (20.7)	4237 (21.3)
Age at diagnosis, y				
0-29	426 (1.1)	497 (1.4)	387 (1.3)	658 (3.3)
30-39	1167 (3.0)	1115 (3.2)	992 (3.3)	1577 (7.9)
40-49	3424 (8.7)	2956 (8.4)	1842 (6.1)	2181 (10.9)
50-59	8784 (22.4)	6641 (18.8)	4856 (16.1)	3879 (19.5)
60-69	10 600 (27.0)	8055 (22.8)	8155 (27.1)	4963 (24.9)
70-79	8278 (21.1)	7565 (21.4)	8036 (26.7)	3724 (18.7)
80+	6532 (16.7)	8500 (24.1)	5876 (19.5)	2950 (14.8)
Race/ethnicity				
American Indian/Alaska Native	272 (0.7)	262 (0.7)	87 (0.3)	68 (0.3)
Hispanic	9536 (24.3)	8248 (23.3)	1155 (3.8)	1619 (8.1)
Non-Hispanic AAPI	5638 (14.4)	5113 (14.5)	182 (0.6)	229 (1.1)
Non-Hispanic Black	2479 (6.3)	2404 (6.8)	66 (0.2)	55 (0.3)
Non-Hispanic White	20 663 (52.7)	18 739 (53.0)	26 084 (86.5)	15 875 (79.6)
Other/unknown	623 (1.6)	563 (1.6)	2570 (8.5)	2086 (10.5)
SEER summary stage				
Localized	13 857 (35.3)	12 690 (35.9)	21 788 (72.3)	14 943 (75.0)
Regional	13 887 (35.4)	12 489 (35.4)	2679 (8.9)	1437 (7.2)
Distant	8464 (21.6)	7280 (20.6)	1471 (4.9)	649 (3.3)
Unknown	3003 (7.7)	2870 (8.1)	4206 (14.0)	2903 (14.6)
Rural				
0%	21 842 (55.7)	19 787 (56.0)	13 844 (45.9)	9255 (46.4)
0% to <10%	10 465 (26.7)	9687 (27.4)	9926 (32.9)	6444 (32.3)
10% to <20%	2956 (7.5)	2524 (7.1)	2775 (9.2)	1876 (9.4)
20% to <30%	1146 (2.9)	915 (2.6)	918 (3.0)	622 (3.1)
30% to <40%	677 (1.7)	534 (1.5)	518 (1.7)	350 (1.8)
40% to <50%	578 (1.5)	488 (1.4)	564 (1.9)	377 (1.9)
50%+	1547 (3.9)	1394 (3.9%)	1599 (5.3%)	1008 (5.1%)

[a] AAPI = Asian American/Pacific Islander; CRC = colorectal cancer; SEER = Surveillance, Epidemiology, and End Results.

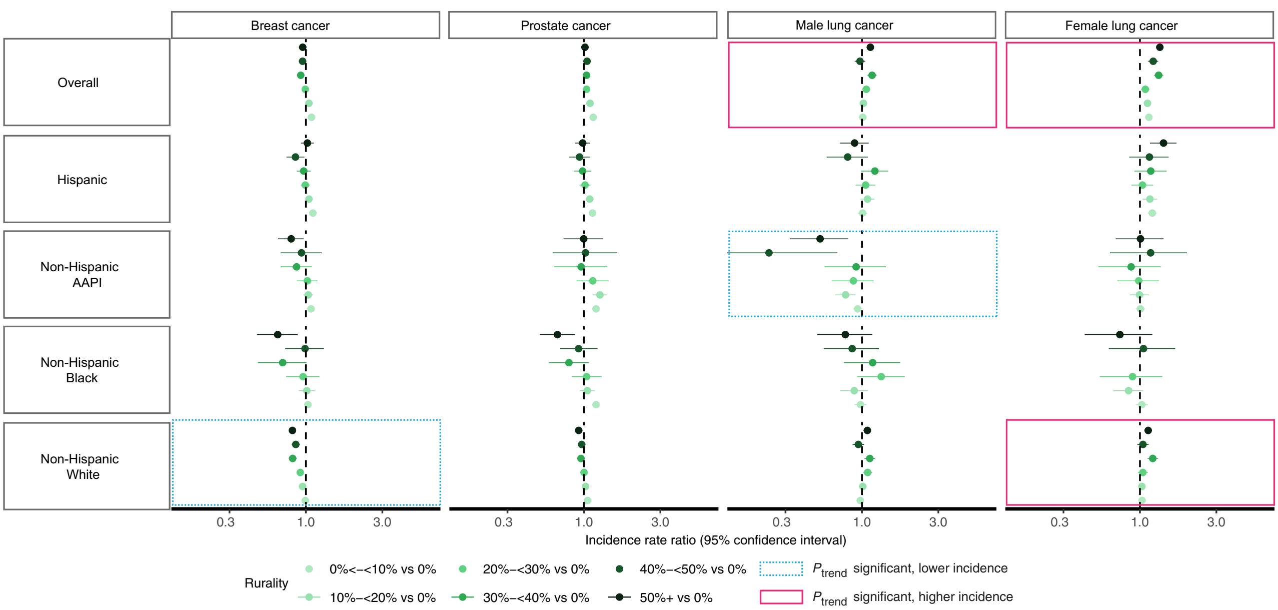

Figure 2. Age-adjusted incidence rate ratios for breast, prostate, and lung cancer by sex, race, and ethnicity in California (2015-2019). The figure is plotted on log scale; however, axis labels for incidence rate ratios are not on log scale for interpretability. Some confidence intervals extend beyond the plot limit. Rurality was defined as the proportion of residents in rural areas within zones and for the analysis was categorized into 7 levels: 0% (not rural), >0% to <10%, 10% to <20%, 20% to <30%, 30% to <40%, 40% to <50%, and 50+% (12). We used census tract–level data on rurality, which the US Census defines based on percent of residents who reside in blocks that are designated as rural. Zone-level rurality was calculated using population-weighted census tract–level data on rurality from Census 2010. AAPI = Asian American/Pacific Islander.

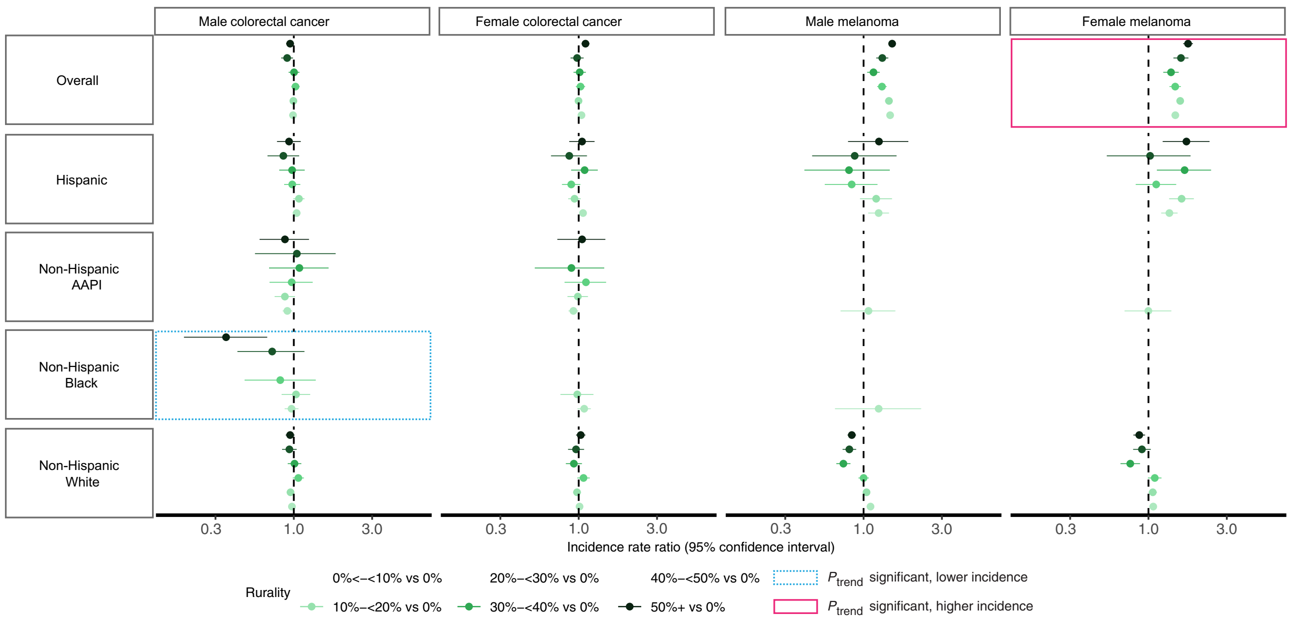

Figure 3. Age-adjusted incidence rate ratios for colorectal cancer and melanoma by sex, race, and ethnicity in California (2015-2019). The figure is plotted on log scale; however, axis labels for incidence rate ratios are not on log scale for interpretability. Some confidence intervals extend beyond the plot limit. Rurality was defined as the proportion of residents in rural areas within zones and for the analysis was categorized into 7 levels: 0% (not rural), >0% to <10%, 10% to <20%, 20% to <30%, 30% to <40%, 40% to <50%, and 50+% (12). We used census tract–level data on rurality, which the US Census defines based on percent of residents who reside in blocks that are designated as rural. Zone-level rurality was calculated using population-weighted census tract–level data on rurality from Census 2010. AAPI = Asian American/Pacific Islander.

and rural cancer disparities in California are relatively sparse; however, Hofer et al. (28) examined rural–urban variations in California cancer cases diagnosed 2006-2015 and found, as we did, incidence of lung cancer and melanoma were significantly higher among residents of rural areas compared with residents of urban areas. In addition, rural males had higher incidence of urinary bladder cancer and rural females had higher incidence of kidney cancer.

Our findings corroborate other breast and prostate cancer incidence studies, which consistently report lower incidence rates in rural areas compared with urban areas (1,5,28-30). This likely reflects the challenges that rural areas face in availability, accessibility, and affordability of health care leading to lower rates for commonly screened cancers (14). Additionally, areas with more urban populations might have higher incidence rates due to overdiagnosis from screening, given higher access to health care in urban areas (1,4,29,31,32). Using national data, Zahnd et al. (4) found that breast and prostate cancer incidence rates were lower in rural settings among non-Hispanic White, non-Hispanic Black, and Hispanic populations. Hofer et al. (28) similarly found lower 10-year incidence of breast and prostate cancers in rural populations across racial and ethnic groups in California.

For lung cancer, a consistent rural disadvantage has been found in numerous studies across the United States, which may be attributed to higher smoking rates in rural populations (1,5,7,11,29,30,33-35). PLACES data show an increasing trend in smoking for more rural areas in California, but these data are not available by race and ethnicity (15,36). We found similar results in the overall population and in non-Hispanic White populations for lung cancer incidence. However, for non-Hispanic Asian American/Pacific Islander males in California, increasing rurality was associated with lower incidence of lung cancer.

Across the United States, a consistent rural disadvantage in colorectal cancer incidence rates has been reported (30). This may be related to higher smoking rates in rural populations or decreased access or acceptance of colorectal cancer screening modalities relative to breast and prostate cancer (1,5,23,29,34,37,38). Rural regions also have higher rates of obesity (39-44), which is associated with increased colorectal cancer incidence (45-47). However, studies have found no urban or rural difference for colorectal cancer incidence in the western United States (1,5). We also found that there is no rural disadvantage for colorectal cancer incidence in California for racial and ethnic groups in our study. This may reflect improved colorectal cancer screening rates or different patterns in obesity in California (39,48-50). Colorectal cancer screening rates in California are among the highest in the nation, and screening rates have improved in recent years (39,51-55). However, it should also be noted that colorectal cancer rates were lower among non-Hispanic Black men in rural areas compared with those in urban areas. This may be driven by differences in lower screening rates due to reduced health-care access or possibly by lifestyle habits such as physical activity or diet (1,4,28).

Two studies on urban and rural differences for melanoma show an urban disadvantage in melanoma incidence rates overall (1,4). Our analysis shows a rural disadvantage for melanoma incidence, especially for Hispanic females living in areas with 50% or more rural population. However, these results are based on relatively small numbers of Hispanic females with melanoma (n = 41) and should be interpreted with caution.

The higher incidence of lung cancer and melanoma in Hispanic females but not males in areas with 50% or more rural population may reflect differences in occupation and access to care. Although Hofer et al. (28) also reported higher lung cancer rates and melanoma in rural Hispanic populations in California, the data were not analyzed by sex. In contrast, Zahnd et al. (5) found that both Hispanic males and females in rural counties had higher rates of lung cancer and melanoma nationwide as well as in the western United States. However, because this study used a dichotomous measure for rurality, gradient in incidence rates across levels of rurality may have been masked (5).

By examining multiple levels of rurality, we were able to identify lower rates for breast cancer in non-Hispanic Black females and lower rates of prostate and colorectal cancer in non-Hispanic Black males living in areas with 50% or more rural population. Additionally, by looking at effects by sex, race, and ethnicity, we were able to identify a higher incidence of lung cancer and melanoma in Hispanic females living in areas with 50% or more rural population, which may have been masked by looking at Hispanic males and females combined.

Limitations of our study include focusing on only the most common cancer sites and relatively low numbers of cases for some groups. Assessing rates of other cancers such as cervical cancer could further lend insight into how screening affects cancer incidence in rural California. However, lower cases for rarer cancers would lead to suppression of data because California Department of Public Health guidelines restrict reporting of cancer incidence rates if based on less than 15 cancer cases and/or a population of less than 10 000 to ensure confidentiality and stable statistical rates. Although we could not present results for granular age categories due to suppression, we conducted a sensitivity analysis on our age-adjusted results by comparing results for those younger than 65 years with those 65 years and older and found generally similar patterns. However, decreasing trends for non-Hispanic Black females with breast cancer, increasing trends in non-Hispanic White females with lung cancer, and increasing trends for Hispanic females with melanoma were limited to those younger than 65 years old (data not shown). Another limitation is that we did not look at regional differences likely masking some of the heterogeneity across these communities, which ranges from predominantly non-Hispanic White mountain communities to predominantly Hispanic agricultural regions.

Our study uncovered previously masked patterns, raising new questions about factors contributing to rural advantage or disadvantage. Although some differences are likely due to variation in health behaviors and access to health care, there is still much to be learned about pathways through which rurality differently influences cancer incidence by site, sex, and racial and ethnic group as well how these pathways manifest in other parts of the country. A more granular understanding of rurality and cancer incidence is needed to effectively direct cancer control efforts to rural areas and subpopulations where they are most needed.

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Data availability

California Cancer Registry data is available by request at: ccrcal.org.

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