Sexual Minority Density and Incidence of Lung, Colorectal, and Female Breast Cancer in California

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Research Article

Sexual Minority Density and Incidence of Lung, Colorectal, and Female Breast Cancer in California

Running title: Sexual Minority Density and Incidence

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ABSTRACT

Objective: Risk factors for breast, colorectal, and lung cancer are known to be more common among lesbian, gay, and bisexual (LGB) individuals, suggesting they may more likely develop these cancers. Our objective was to determine differences in cancer incidence by sexual orientation, using aggregate sexual orientation data.

Methods: Data on cancer incidence were obtained from the California Cancer Registry and data on sexual orientation were obtained from the California Health Interview Survey, from which a measure of age-specific LGB density by county was calculated. Using multivariable Poisson regression models the association between the age-race-stratified count of incident breast, lung, and colorectal cancer cases in each county and LGB density was examined, with race, age group, and poverty as covariates.

Results: Among males, bisexual density was associated with lower incidence of lung cancer and with higher incidence of colorectal cancer. Among females, lesbian density was associated with lower incidence of lung and colorectal cancer, and with higher incidence of breast cancer; bisexual density was associated with higher incidence of lung and colorectal cancer, and with lower incidence of breast cancer.

Conclusions: These study findings clearly document links between county-level LGB density measures and cancer incidence, illuminating an important public health disparity.

Keywords: Homosexuality, cancer incidence, breast cancer, colorectal cancer, lung cancer, disparities, sex differences

ARTICLE SUMMARY

Strengths and limitations of this study

- Variation in cancer incidence due to sexual orientation aggregated at the county-level point to differences by sexual orientation group.
- These county-level differences in cancer incidence provide information for public health planning, previously unavailable.
- Determining whether disparities exist in cancer incidence due to sexual orientation is not possible otherwise, because cancer registries do not document sexual orientation.
- Study findings have the inherent limitations of the ecologic study design.
- Because data are at the county level, it is not possible to link sexual minority status to cancer risk at the level of the individual.

INTRODUCTION

Lung, colorectal, and female breast cancer are three of the most commonly diagnosed cancers in the United States, with incidence rates of 79.5, 51.6, and 121.9 per 100,000, respectively, in 2008. [1] Smoking and alcohol use are well-known risk factors for all three of these cancers; overweight and/or obesity has been linked to risk of female breast cancer and colorectal cancer. [2] In addition, nulliparity is associated with increased risk of female breast cancer.

Research also indicates that the prevalence of these well-known risk factors is generally higher among sexual minority individuals—that is, lesbian, gay, and bisexual individuals. Smoking is more common among sexual minorities, both men and women, than among their heterosexual counterparts.[3-8] Further, in 2007 the President's Cancer Panel found that sexual minority youths smoke at rates as high as those of adults, and tend to start smoking at a younger age than heterosexual youths.[6] Sexual minority women are more likely than heterosexual women to drink alcohol [5, 8-12] and to be overweight or obese.[10, 13-16] In contrast, gay men's alcohol use has not been shown to differ from that of heterosexual men,[12] and gay men are less likely than heterosexual men to be overweight or obese. [17] Finally, sexual minority women have higher rates of nulliparity than heterosexual women. [10, 13, 14, 18-20]

Because cancer registries do not collect information on the sexual orientation of individuals diagnosed with cancer, it cannot be readily determined from SEER or state registry data whether cancer is more prevalent among individuals with a sexual minority orientation. To overcome this lack of data on cancer disparities by sexual orientation, three previous studies used county-level ecologic analyses to relate breast, lung, and colorectal cancer incidence to greater density of sexual minority individuals [21-23]. Using SEER registry data and US Census data on the prevalence of same-sex partnered households as the proxy measure for sexual minority orientation, these ecological studies concluded that greater female sexual minority density (SMD) in a county is associated with greater incidence of breast and colorectal cancer [21, 22], while there was a negative relationship between female sexual minority density and lung cancer incidence [23]. Greater density of sexual minority men was associated with higher incidence of lung and colorectal cancer [22, 23].

While US census data are a well-established proxy for sexual orientation, these data also have known limitations. From available Census data, we can enumerate households led by same-sex adults, but this surely represents an undercount since we capture only sexual minority individuals who live with a same-sex partner, thereby excluding sexual minority individuals who are living alone or with non-partners. Further, we do not know how many members of a same-sex partnered household identify as lesbian, gay, or bisexual. In particular, it is impossible to assess lesbians separately from bisexual women or to assess gay men separately from bisexual men. This is an important limitation, because studies that analyzed lesbian women separately from bisexual women concluded bisexuals fare worse on some health indicators than both heterosexual and lesbian women [24-27].

To address the limitations of US Census data, the present study traded a national scope for an improved measure of sexual minority density. We used statewide population-based data on sexual minority identity (gay, lesbian, or bisexual) to estimate its relationship to colorectal cancer, lung cancer, and female breast cancer incidence.

MATERIALS AND METHODS

The Institutional Review Board deemed this study exempt from protocol review. Data for this research project were taken from the California Health Interview Survey (CHIS), the largest state health survey conducted in the US. The CHIS employs a two-stage geographically stratified random-digit-dial (RDD) sample of households, surveying one randomly selected adult from each sampled household. The survey is administered in multiple languages, resulting in a large multiethnic/multiracial sample that accurately represents the California population living in households. The CHIS response rate shows no significant nonresponse bias by demographic characteristics such as age, sex, income, education, or employment status [28]; however, due to the absence of a sampling frame, nonresponse by sexual orientation has not been evaluated. More detailed information about the survey methodology can be obtained from the website: http://www.chis.ucla.edu/. The CHIS collects information biennually, including data on sexual orientation. To ascertain sexual orientation, respondents were asked about their sexual identity, with response choices of heterosexual, lesbian, gay, or bisexual along with celibate or other, while recording refusals and don't know responses. We combined four years of data, using the adult CHIS surveys from 2001, 2003, 2005, and 2007 to increase the numbers of individuals who report a sexual minority orientation, defined as gay, lesbian, or bisexual.

Data on cancer incidence were taken from the California Cancer Registry, which records all cancer cases to monitor the occurrence of cancer among Californians. We chose the cancer data for the years 2001-2008 because these years cover the same timeframe as the CHIS sexual minority data. We further restricted our data to men and women aged 18 to 84, because we focused on adult cancers and also because this is the age range for which the CHIS had sexual orientation data available. In 2001-2008, among women aged 18-84 in the 58 counties of California, 206,012 were newly diagnosed with breast, 59,182 with lung, and 50,123 with colorectal cancer. Over the same number of years, among men aged 18-84, there were 62,673 new diagnoses of lung cancer and 55,624 of colorectal cancer.

Because there are differences in cancer incidence by age and race, we used the population data from Census 2000 since it has age- and race- specific population data available for all the 58 counties in California. From the Census we also obtained county-level data on poverty, another important confounder of cancer incidence.

Measures

Counts of breast, lung, and colorectal cancer incidence were classified into one of 11 age categories and four race/ethnicity groups. The 11 age categories were 18-24, 25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-59, 60-64, 65-69 and 70-84, while race and ethnicity consisted of (1) Non-Hispanic White, (2) Hispanic, (3) Asian/Pacific Islander, and (4) other race/ethnicity. The group of other race/ethnicity combines non-Hispanic Blacks (6.79% of cancers), other/unknown race/ethnicity (0.73% of cancers) and non-Hispanic American-Indian (0. % of cancers). We calculated each cancer incidence rate using the total female and male population between age 18 and 84 in each county using the Census data.

Our main independent variable is derived from CHIS data on participants' sexual orientation. We are using these data aggregated at the county-level and call this aggregate variable 'sexual minority density' (SMD) because it expresses the variation in the density with which residents of a county report as sexual minorities. To make these data age-specific, we obtained the distribution of sexual minorities, defined as lesbians, gays, or bisexuals, across different age groups, and combined this information with the county-level SMD. Specifically, we obtained the weighted percentage of gay men in a specific age group (denoted as ageweight_gay), using the age information on all gay men in the 58 California counties. Then, we obtained the weighted percentage of all men in the specific age group (denoted as ageweight_all), using the age information on all subjects in the 58 California counties. Finally, we obtained the count of all adult gay men (Ngay) and the count of all adult men (Nall) in the specific age group, and computed the age-specific gay density as:

$$\text{Age-specific gay density} = \frac{N_{gay} * ageweight\_gay}{N_{all} * ageweight\_all}$$

The age-specific lesbian and bisexual density was computed in a similar way, and we considered bisexual men and women as distinct categories for analyses.

We adjusted for poverty level in our analyses, with poverty level being defined as the percentage of the population living under the Federal poverty level, which has been found to be the most consistent, easily interpretable variable which accurately measures socioeconomic disparities in health outcomes [29, 30].

Statistical Analysis

Descriptive statistics summarized variation in adult cancer incidence by gender and race. We assessed county-level association between lesbian/gay/bisexual density (LGBD) and cancer incidence rates using multivariable Poisson regression models with the age-race-stratified count of incident cases in each county as the dependent variable, and the LGBD, race, age group and US Census percent in poverty as covariates. Because the correlation between lesbian/gay density and bisexual density was low—0.36 ($p<0.0001$) for women and 0.15 ($p<0.0001$) for men—we fitted models that considered L/G and B together. The model selection was based on the goodness-of-fit of the models assessed by the Akaike Information Criterion (AIC) and residual diagnostics plots. SAS PROC GENMOD was used to fit the models, with the offset term as the logarithm of the US Census age-race-stratified total adult population in the county. The incidence rate ratio (IRR) was presented as the measure of the effect of each predictor, along with its 95% confidence interval and p-value. The validity of the assumptions and the goodness-of-fit of the assumed models were assessed by residual diagnostic plots and goodness-of-fit statistics such as the Deviance statistic. All analyses were done in SAS 9.2 (SAS Institute Inc, Cary NC, USA).

Regression diagnostics indicated that the Los Angeles County, white male, age 70-84, data point was a potentially influential point. We refit all regression models excluding this data point.

RESULTS

We describe age-adjusted regression results for measures of sexual minority density, race/ethnicity, and poverty as predictors of cancer incidence.

Sexual orientation, demographics, and cancer incidence among males

Controlling for race/ethnicity and poverty, gay density was not associated with county-level lung cancer incidence among males (Table 1), although bisexual density was associated with an 8.4 percent decrease in lung cancer incidence (IRR=0.916, $p<0.0001$). There were expected significant associations between self-reported race/ethnic category and incidence, and a positive association between poverty and lung cancer incidence was weaker but still statistically significant. After excluding the Los Angeles County outlier from the regression model for male lung cancer, the associations were unchanged in strength and significance between gay/ bisexual density and lung cancer.

Controlling for race/ethnicity and poverty, gay density was not significantly associated with colorectal cancer incidence (Table 2), but bisexual density among males was associated with a 2.7% increase in incidence of colorectal cancer (IRR=1.027, $p=0.02$).

Sexual orientation, demographics, and cancer incidence among females

Controlling for race/ethnicity and poverty, each one-percentage-point increase in lesbian density was associated with a 5.1% decrease in incidence of lung cancer (IRR=0.949, p<0.0001; Table 3), whereas each one- unit increase in bisexual density was associated with an 11.3% increase (IRR=1.113, p<0.0001). There were significant negative association between female lung cancer incidence and Hispanic, Asian/Pacific Islander and Other race. There was no significant association between female lung cancer incidence and poverty.

Controlling for race/ethnicity and poverty, each one- unit increase in lesbian density was associated with a 2.9% decrease in the incidence of colorectal cancer among women (IRR=0.971, p=0.0095; Table 4); bisexual density was not associated with incidence of colorectal cancer among women. Hispanic ethnicity had a significant negative association, Asian/Pacific Islander and Other race had a significant positive association with incidence of colorectal cancer among women. Poverty was not significantly associated with incidence of colorectal cancer in females.

Controlling for race/ethnicity and poverty, each one-unit increase in lesbian density was significantly associated with a 2.3% increase, and bisexual density with a 3.2 % decrease, in incidence of female breast cancer (lesbian: IRR=1.023, p<0.0001; bisexual: IRR=0.968, p<0.0001; Table 5). Hispanic, Asian/Pacific Islander, and Other race/ethnicity had significant negative associations with breast cancer incidence. Poverty was modestly but significantly associated with decreased breast cancer incidence.

Excluding Los Angeles County from the regression model resulted in little change to the results for female breast cancer, female lung cancer, and female colorectal cancer.

DISCUSSION

This study's findings document disparities in the age-adjusted incidence of three cancers across the counties of California: disparities that are associated with the density of sexual minorities, controlling for race/ethnicity and the prevalence of poverty. Our outcome measure provides effect estimates in the form of the percentage change in cancer incidence per one unit increase in sexual minority density, and thus an IRR that is only modestly different from 1.0 may represent a substantial difference in real-world terms, given the variation in gay and lesbian densities across counties.

Among males, bisexual density (but not gay density) was significantly associated with cancer incidence. Specifically, bisexual density was associated with lower incidence of lung cancer and, less strongly, with higher incidence of colorectal cancer. Among females, both lesbian and bisexual density were significantly associated with cancer incidence. However, across all three cancers, these two associations were opposite in direction: lesbian density was associated with lower incidence of lung and colorectal cancer, and with higher incidence of breast cancer; bisexual density was associated with higher incidence of lung and colorectal cancer, and with lower incidence of breast cancer. The strongest associations between sexual orientation and cancer incidence, and thus the greatest gap between findings by sexual orientation, were for lung cancer: lesbian density is associated with a 5.1% decrease, and bisexual density with an 11.3% increase, in lung cancer incidence per one-unit increase in sexual minority density.

These differences between results for lesbian/gay density and bisexual density are consistent with an increasing understanding among sexual orientation researchers that—after years of combining lesbian/gay and bisexual individuals into one group due to small sample sizes—differences between these groups come to the forefront once they are separated [8, 31-34]. These findings reflect methodological improvements on our previous studies of sexual minority density and cancer incidence [21-23]: those analyses used U.S. Census data on whether a respondent lived in a same-sex partnered household, whereas data for the current analysis rest on self-reported sexual identity from the California Health Interview Survey, as described above, and distinguish between gay/lesbian and bisexual respondents. A comparison of findings from our other analyses to those of this study shows a mix of consistencies and inconsistencies, partly attributable to this improvement in the ascertainment of sexual minority orientation, the ability to distinguish lesbian/gay density from bisexual density.

Using SEER data, colorectal cancer incidence was significantly and positively associated with both sexual minority men density and sexual minority women density [22]; that finding aligns with this study's finding for male and female bisexual density and colorectal cancer, but is inconsistent with the present findings for gay and lesbian density. In the present study, we identified among males no association between gay density and lung cancer, and a negative association between bisexual density and lung cancer; this conflicts with our finding of a positive association for sexual minority men density and lung cancer using a different dataset [23]. For female lung cancer, our current findings for lesbian women are consistent with our previous finding of a significant negative association between lung cancer and sexual minority women density [23], although the present study also found a positive association with bisexual density specifically. Finally, findings for breast cancer show some consistency: in the present study, lesbian density has a significant positive association with breast cancer incidence, confirming our earlier findings [21], although the present study also identified a negative association with bisexual density.

A number of factors are likely to contribute to differences between results of earlier Census-based analyses, which did not distinguish between gays/lesbians and bisexuals, and those of the present study, which relied on self-reported sexual identity. The Census data on same-sex partnered households are probably better indicators of gay and lesbian than bisexual individuals, given data showing that the majority of partnered gay and lesbian individuals have a same-sex partner, whereas partnered bisexual individuals are more likely to be in heterosexual relationships [34]. Another factor may be the relative size of the subgroups within the LGB adult population: among women, more identify as bisexual than lesbian, whereas among men, more identify as gay [35]. The present study is limited to cancer incidence in California, while the previous SEER-based study was representative of the United States. Given the difference in geographic scope, the earlier studies used a roughly fourfold larger sample (215 counties compared to the present study's 58 counties); thus in the current study we had lower statistical power to detect associations. Both ecological studies failed to achieve a complete ascertainment of sexual minority status, albeit for different reasons; the Census-based studies relied on an enumeration of same-sex partnered individuals, while the present study relied on population estimates of sexual identity. Methodological differences aside, there may be real-world differences between California and the country as a whole in connections between sexual minority density and cancer incidence.

This study has the inherent limitations of the ecologic study design. In particular, because data are at the county level, it is not possible to link sexual minority status to cancer risk at the level of the individual. Thus, our study findings clearly describe links between county-level density measures and cancer incidence and should not be interpreted as evidence of an association between individual sexual orientation and cancer incidence. A finer scale—for example, at the level of the census tract—may provide more insight into patterns of sexual minority density and cancer incidence, but it is not yet clear what is the most appropriate geographic scale for such studies.

At present, there is essentially no systematic surveillance of sexual minorities, other than simply reporting differences in the prevalence of health risk factors. The work described here and in our previous analyses [21-23] pinpoints the existence of public health disparities in cancer incidence at the county level. Future studies are needed to identify ecological causes for the disparity in cancer incidence, which are likely complex, possibly examining county-level factors related to sexual minorities' access to the health care system and quality of care delivery. Nevertheless, the consistency with which our ecological analyses identified disparities in cancer incidence, are an opportunity for public health policy interventions, which are larger in scale, considering county-level programs, rather than interventions that focus on individual behavior change.

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Data sharing agreement: There is no additional data available.

Contributor Statement: U Boehmer originated the study and interpreted the findings. X Miao conducted the analyses and helped to interpret the findings. N Maxwell led the writing. A Ozonoff used his statistical expertise to direct the analysis and helped to interpret the findings. All authors contributed in significant ways to the final article by discussing earlier drafts, reviewing, and revising the manuscript.

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Table 1 *Multivariate Poisson Regression Analysis for* ***Male Lung Cancer†***

Predictors	Regression coefficient estimate	IRR	95% CI of IRR		p-value
Gay density	0.0004	1.0004	0.995	1.006	0.88
Bisexual density	-0.0875	0.916	0.897	0.936	<0.0001
Hispanic vs. non-Hispanic white	-0.4243	0.654	0.637	0.672	<0.0001
Asian/PI vs. non-Hispanic white	-0.0674	0.935	0.910	0.960	<0.0001
Other vs. non-Hispanic white	-0.0537	1.055	1.025	1.086	0.0003
Poverty	0.0134	1.014	1.012	1.015	<0.0001

† results also adjusted for age

Table 2 *Multivariate Poisson Regression Analysis for* ***Male Colorectal Cancer†***

Predictors	Regression coefficient estimate	IRR	95% CI of IRR		p-value
Gay density	-0.0020	0.998	0.993	1.003	0.45
Bisexual density	0.0262	1.027	1.004	1.050	0.02
Hispanic vs. non-Hispanic white	0.0411	1.042	1.018	1.067	0.0006
Asian/PI vs. non-Hispanic white	0.1056	1.111	1.082	1.142	<0.0001
Other vs. non-Hispanic white	0.0942	1.099	1.065	1.134	<0.0001
Poverty	0.0038	1.004	1.002	1.006	<0.0001

† results also adjusted for age

Table 3 *Multivariate Poisson Regression Analysis for* ***Female Lung Cancer†***

Predictors	Regression coefficient estimate	IRR	95% CI of IRR		p-value
Lesbian density	-0.0521	0.949	0.928	0.971	<0.0001
Bisexual density	0.1067	1.113	1.078	1.149	<0.0001
Hispanic vs. non-Hispanic white	-0.7012	0.496	0.482	0.511	<0.0001
Asian/PI vs. non-Hispanic white	-0.5264	0.591	0.573	0.609	<0.0001
Other vs. non-Hispanic white	-0.1527	0.858	0.832	0.885	<0.0001
Poverty	0.0013	1.001	0.999	1.003	0.18

† results also adjusted for age

Table 4 *Multivariate Poisson Regression Analysis for* ***Female Colorectal Cancer†***

Predictors	Regression coefficient estimate	IRR	95% CI of IRR		p-value
Lesbian density	-0.0290	0.971	0.950	0.993	0.0095
Bisexual density	0.0268	1.027	0.994	1.062	0.11
Hispanic vs. non-Hispanic white	-0.0670	0.932	0.909	0.957	<0.0001
Asian/PI vs. non-Hispanic white	0.1133	1.120	1.090	1.151	<0.0001
Other vs. non-Hispanic white	0.1616	1.175	1.139	1.213	<0.0001
Poverty	0.0020	1.002	1.000	1.004	0.056

† results also adjusted for age

Table 5 *Multivariate Poisson Regression Analysis for* ***Female Breast Cancer†***

Predictors	Regression coefficient estimate	IRR	95% CI of IRR		p-value
Lesbian density	0.0225	1.023	1.014	1.031	<0.0001
Bisexual density	-0.0328	0.968	0.955	0.981	<0.0001
Hispanic vs. non-Hispanic white	-0.2691	0.764	0.755	0.774	<0.0001
Asian/PI vs. non-Hispanic white	-0.1790	0.836	0.824	0.848	<0.0001
Other vs. non-Hispanic white	-0.2533	0.776	0.763	0.790	<0.0001
Poverty	-0.0106	0.990	0.989	0.991	<0.0001

† results also adjusted for age

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Sexual Minority Population Density and Incidence of Lung, Colorectal, and Female Breast Cancer in California

Running title: Sexual Minority Density and Incidence

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ABSTRACT

Objective: Risk factors for breast, colorectal, and lung cancer are known to be more common among lesbian, gay, and bisexual (LGB) individuals, suggesting they may more likely develop these cancers. Our objective was to determine differences in cancer incidence by sexual orientation, using sexual orientation data aggregated at the county-level.

Methods: Data on cancer incidence were obtained from the California Cancer Registry and data on sexual orientation were obtained from the California Health Interview Survey, from which a measure of age-specific LGB population density by county was calculated. Using multivariable Poisson regression models the association between the age-race-stratified incident rate of breast, lung, and colorectal cancer in each county and LGB population density was examined, with race, age group, and poverty as covariates.

Results: Among males, bisexual population density was associated with lower incidence of lung cancer and with higher incidence of colorectal cancer. Among females, lesbian population density was associated with lower incidence of lung and colorectal cancer, and with higher incidence of breast cancer; bisexual population density was associated with higher incidence of lung and colorectal cancer, and with lower incidence of breast cancer.

Conclusions: These study findings clearly document links between county-level LGB population density and cancer incidence, illuminating an important public health disparity.

Keywords: Homosexuality, cancer incidence, breast cancer, colorectal cancer, lung cancer, disparities, sex differences

ARTICLE SUMMARY

Strengths and limitations of this study

- Using sexual orientation population data aggregated at the county-level findings identify associations between cancer incidence and sexual minority population density.
- These county-level differences in cancer incidence suggest a need for public health planning, previously unavailable.
- Because cancer registries do not document sexual orientation, determining whether disparities exist in cancer incidence due to sexual orientation is not possible otherwise.
- Because data are at the county level, it is not possible to link sexual minority status to cancer risk at the level of the individual.
- Study findings have the inherent limitations of the ecologic study design.

INTRODUCTION

Lung, colorectal, and female breast cancer are three of the most commonly diagnosed cancers in the United States, with incidence rates of 79.5, 51.6, and 121.9 per 100,000, respectively, in 2008. [1] Smoking and alcohol use are well-known risk factors for all three of these cancers; overweight and/or obesity has been linked to risk of female breast cancer and colorectal cancer. [2] In addition, nulliparity is associated with increased risk of female breast cancer.

Research also indicates that the prevalence of these well-known risk factors is generally higher among sexual minority individuals—that is, lesbian, gay, and bisexual individuals. Smoking is more common among sexual minorities, both men and women, than among their heterosexual counterparts.[3-8] Further, in 2007 the President's Cancer Panel found that sexual minority youths smoke at rates as high as those of adults, and tend to start smoking at a younger age than heterosexual youths.[6] Sexual minority women are more likely than heterosexual women to drink alcohol [5, 8-12] and to be overweight or obese.[10, 13-16] In contrast, gay men's alcohol use has not been shown to differ from that of heterosexual men,[12] and gay men are less likely than heterosexual men to be overweight or obese. [17] Finally, sexual minority women have higher rates of nulliparity than heterosexual women. [10, 13, 14, 18-20]

Because cancer registries do not collect information on the sexual orientation of individuals diagnosed with cancer, it cannot be readily determined from SEER or state registry data whether cancer is more prevalent among individuals with a sexual minority orientation. To overcome this lack of data on cancer disparities by sexual orientation, three previous studies used county-level ecologic analyses to relate breast, lung, and colorectal cancer incidence to greater sexual minority population density [21-23]. Previously, we used SEER registry data and US

Census data on individuals living in same-sex partnered households as a proxy measure for sexual minority orientation. These ecological studies concluded that greater female sexual minority density (SMD) in a county is associated with greater incidence of breast and colorectal cancer [21, 22], while there was a negative relationship between female sexual minority population density and lung cancer incidence [23]. Greater density of sexual minority men was associated with higher incidence of lung and colorectal cancer [22, 23].

While US census data on same-sex households are a well-established proxy for sexual orientation, these data also have known limitations. From available Census data, we can enumerate households led by same-sex adults, but this surely represents an undercount since we capture only sexual minority individuals who live with a same-sex partner, thereby excluding sexual minority individuals who are living alone or with non-partners. Further, we do not know how many members of a same-sex partnered household identify as lesbian, gay, or bisexual. In particular, it is impossible to assess lesbians separately from bisexual women or to assess gay men separately from bisexual men. This is an important limitation, because studies that analyzed lesbian women separately from bisexual women concluded bisexuals fare worse on some health indicators than both heterosexual and lesbian women [24-27].

To address the limitations of US Census data, the present study traded a national scope for an improved measure of sexual minority density. We used statewide population-based data on sexual minority identity (gay, lesbian, or bisexual) to estimate its relationship to colorectal cancer, lung cancer, and female breast cancer incidence.

MATERIALS AND METHODS

The Institutional Review Board deemed this study exempt from protocol review. Data for this research project were taken from the California Health Interview Survey (CHIS), the largest state health survey conducted in the US. The CHIS employs a two-stage geographically stratified random-digit-dial (RDD) sample of households, surveying one randomly selected adult from each sampled household. The survey is administered in multiple languages, resulting in a large multiethnic/multiracial sample that accurately represents the California population living in households. The CHIS response rate shows no significant nonresponse bias by demographic characteristics such as age, sex, income, education, or employment status [28]; however, due to the absence of a sampling frame, nonresponse by sexual orientation has not been evaluated. More detailed information about the survey methodology can be obtained from the website: http://www.chis.ucla.edu/. The CHIS collects information biennially, including data on sexual orientation. To ascertain sexual orientation, respondents were asked about their sexual identity, with response choices of heterosexual, lesbian, gay, or bisexual along with celibate or other, while recording refusals and don't know responses. We combined four years of data, using the adult CHIS surveys from 2001, 2003, 2005, and 2007 to increase the numbers of individuals who report a sexual minority orientation, defined as gay, lesbian, or bisexual.

Data on cancer incidence were taken from the California Cancer Registry, which records all cancer cases to monitor the occurrence of cancer among Californians. We chose the cancer data for the years 2001-2008 because these years cover the same timeframe as the CHIS sexual minority data. We further restricted our data to men and women aged 18 to 84, because we focused on adult cancers and also because this is the age range for which the CHIS had sexual orientation data available.

Because there are differences in cancer incidence by age and race, we used the population data from Census 2000 since it has age- and race- specific population data available for all the 58 counties in California. From the Census, we also obtained county-level data on poverty, another important confounder of cancer incidence.

Measures

Counts of breast, lung, and colorectal cancer incidence were classified into one of 11 age categories and four race/ethnicity groups. The 11 age categories were 18-24, 25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-59, 60-64, 65-69 and 70-84, while race and ethnicity consisted of (1) Non-Hispanic White, (2) Hispanic, (3) Asian/Pacific Islander, and (4) other race/ethnicity. The group of other race/ethnicity combines non-Hispanic Blacks (6.79% of cancers), other/unknown race/ethnicity (0.73% of cancers) and non-Hispanic American-Indian (0.14 % of cancers). We calculated each cancer incidence rate using the total female and male population between age 18 and 84 in each county using the Census data.

We adjusted for poverty level in our analyses, with poverty level being defined as the percentage of the population living under the Federal poverty level, which has been found to be the most consistent, easily interpretable variable which accurately measures socioeconomic disparities in health outcomes [29, 30].

Our main independent variable is derived from CHIS data on participants' sexual orientation. We are using these data aggregated at the county-level and call this aggregate variable 'sexual minority density' (SMD) to express variation in the density of sexual minority populations in a county. To make these data age-specific, we obtained the distribution of sexual minorities, defined as lesbians, gays, or bisexuals, across different age groups, and combined this information with the county-level SMD. Specifically, we obtained the weighted percentage of gay men in a specific age group (denoted as ageweight_gay), using the age information on all gay men in the 58 California counties. Then, we obtained the weighted percentage of all men in the specific age group (denoted as ageweight_all), using the age information on all subjects in the 58 California counties. Finally, we obtained the count of all adult gay men (Ngay) and the count of all adult men (Nall) in the specific age group, and computed the age-specific gay density as:

$$\text{Age-specific gay density} = \frac{N_{gay} * ageweight\_gay}{N_{all} * ageweight\_all}$$

The age-specific lesbian and bisexual population density was computed in a similar way, and we considered bisexual men and women as distinct categories for analyses.

Regression diagnostics indicated that the Los Angeles County, white race, age 70-84, data point was a potentially influential point. We refit all regression models excluding this data point to ensure that our findings are not predominantly dependent on a single observation. Model fit did not improve substantially with the exclusion, and more importantly, changes in estimates of associations between the density measures and cancer incidence were small and well within the standard errors. Therefore, we report all regression results with no data exclusions.

Statistical Analysis

We used descriptive statistics to summarize our outcomes, cancer incidence, and our main independent variables, that is, lesbian, gay, or bisexual population density, for all 58 California counties. We assessed county-level association between lesbian/gay/bisexual density (LGBD) and cancer incidence rates using multivariable Poisson regression models with the age-race-stratified count of incident cases in each county as the dependent variable, and the LGBD, race, age group and US Census percent in poverty as covariates. We fitted models that considered L/G and B together because the correlation between lesbian/gay density and bisexual density was low—0.36 (p<0.0001) for women and 0.15 (p<0.0001) for men and because our primary parameter estimates remained essentially unchanged, when we fitted the two density measures separately All model selections were based on the goodness-of-fit of the models assessed by the Akaike Information Criterion (AIC) and residual diagnostics plots. SAS PROC GENMOD was used to fit the models, with the offset term as the logarithm of the US Census age-race-stratified total adult population in the county. The incidence rate ratio (IRR) was presented as the measure of the effect of each predictor, along with its 95% confidence interval and p-value. The validity of the assumptions and the goodness-of-fit of the assumed models were assessed by residual diagnostic plots and goodness-of-fit statistics such as the Deviance statistic. All analyses were done in SAS 9.2 (SAS Institute Inc, Cary NC, USA).

RESULTS

There is considerable variation in the sexual minority density measures by county. Across 58 California counties, the lesbian density measure ranges from 0 to 3.05 (Median=0.49; Mean=0.66; SD=0.78) and the bisexual density measure from 0 to 4.16 (Median=1.24; Mean=1.16; SD=0.97). Gay and bisexual male density measures respectively range from 0 to 16.02 (Median=0.80; Mean=1.10; SD=2.19) and from 0 to 4.07 (Median=0.44; Mean=0.60; SD=0.76).

Sexual orientation, demographics, and cancer incidence among males

Controlling for race/ethnicity and poverty, gay density was not associated with county-level lung cancer incidence among males (Table 1), although bisexual density was associated with an 8.4 percent decrease in lung cancer incidence (IRR=0.916, $p<0.0001$). There were expected significant associations between self-reported race/ethnic category and incidence, and a positive association between poverty and lung cancer incidence.

Controlling for race/ethnicity and poverty, gay density was not significantly associated with colorectal cancer incidence (Table 2), but bisexual density among males was associated with a 2.7% increase in incidence of colorectal cancer (IRR=1.027, p=0.02).

Sexual orientation, demographics, and cancer incidence among females

Controlling for race/ethnicity and poverty, each one-unit increase in lesbian density was associated with a 5.1% decrease in incidence of lung cancer (IRR=0.949, p<0.0001; Table 3), whereas each one- unit increase in bisexual density was associated with an 11.3% increase (IRR=1.113, p<0.0001). There were significant negative association between female lung cancer incidence and Hispanic, Asian/Pacific Islander and Other race. There was no significant association between female lung cancer incidence and poverty.

Controlling for race/ethnicity and poverty, each one- unit increase in lesbian density was associated with a 2.9% decrease in the incidence of colorectal cancer among women (IRR=0.971, p=0.0095; Table 4); bisexual density was not associated with incidence of colorectal cancer among women. Hispanic ethnicity had a significant negative association, Asian/Pacific Islander and Other race had a significant positive association with incidence of colorectal cancer among women. Poverty was not significantly associated with incidence of colorectal cancer in females.

Controlling for race/ethnicity and poverty, each one-unit increase in lesbian density was significantly associated with a 2.3% increase, and bisexual density with a 3.2 % decrease, in incidence of female breast cancer (lesbian: IRR=1.023, p<0.0001; bisexual: IRR=0.968, p<0.0001; Table 5). Hispanic, Asian/Pacific Islander, and Other race/ethnicity had significant negative associations with breast cancer incidence. Poverty was modestly but significantly associated with decreased breast cancer incidence.

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DISCUSSION

This study's findings document disparities in the age-adjusted incidence of three cancers across the counties of California: disparities that are associated with the density of sexual minorities, controlling for race/ethnicity and the prevalence of poverty. Our outcome measure provides effect estimates in the form of the percentage change in cancer incidence per one unit increase in sexual minority population density.

Among males, bisexual density (but not gay density) was significantly associated with cancer incidence. Specifically, bisexual density was associated with lower incidence of lung cancer and, less strongly, with higher incidence of colorectal cancer. Among females, lesbian density (but not bisexual density) was significantly associated with colorectal cancer. Both lesbian and bisexual density were significantly associated with female breast and lung cancer incidence. However, these two associations were opposite in direction: lesbian density was associated with lower incidence of lung and higher incidence of breast cancer; bisexual density was associated with higher incidence of lung and lower incidence of breast cancer. For each cancer outcome we studied, Los Angeles county, white race, and age 70-84 emerged as an influential outlying data point. Because Los Angeles county is also the most populous county in California, we carefully considered issues around the robustness of our results. We conducted a sensitivity analysis, which suggests our findings are not overly dependent on this single data point, lending strength to the overall reliability of our findings.

The differences between results for lesbian/gay density and bisexual density are consistent with an increasing understanding among sexual orientation researchers that—after years of combining lesbian/gay and bisexual individuals into one group due to small sample sizes—differences between these groups come to the forefront once they are separated [8, 31-34]. These findings reflect methodological improvements on our previous studies of sexual minority density and cancer incidence [21-23]: those analyses used U.S. Census data on whether a respondent lived in a same-sex partnered household, whereas data for the current analysis rest on self-reported sexual identity from the California Health Interview Survey, as described above, and distinguish between gay/lesbian and bisexual respondents. A comparison of findings from our other analyses to those of this study shows a mix of consistencies and inconsistencies.

[insert Figure 1]

Using SEER data, colorectal cancer incidence was significantly and positively associated with both sexual minority men density and sexual minority women density [22]; that finding aligns with this study's finding for male and female bisexual density and colorectal cancer, but is inconsistent with the present findings for gay and lesbian density. In the present study, we identified among males no association between gay density and lung cancer, and a negative association between bisexual density and lung cancer; this conflicts with our finding of a positive association for sexual minority men density and lung cancer using a different dataset [23]. For female lung cancer, our current findings for lesbian women are consistent with our previous finding of a significant negative association between lung cancer and sexual minority women density [23], although the present study also found a positive association with bisexual density specifically. Finally, findings for breast cancer show some consistency: in the present study, lesbian density has a significant positive association with breast cancer incidence, confirming our earlier findings [21], although the present study also identified a negative association with bisexual density.

A number of factors are likely to contribute to differences between results of earlier Census-based analyses, which did not distinguish between gays/lesbians and bisexuals, and those of the present study, which relied on self-reported sexual identity. The Census data on same-sex partnered households are probably better indicators of gay and lesbian than bisexual individuals, given data showing that the majority of partnered gay and lesbian individuals have a same-sex partner, whereas partnered bisexual individuals are more likely to be in heterosexual relationships [34]. The present study's ability to distinguish lesbian/gay density from bisexual density, is an improvement in the ascertainment of sexual minority orientation. This likely accounts for identifying effects that are opposite in direction, as for example lesbian density's association with a 5.1% decrease and bisexual density's 11.3% increase in lung cancer incidence. Another factor may be the relative size of the subgroups within the LGB adult population: among women, more identify as bisexual than lesbian, whereas among men, more identify as gay [35]. Differences in the findings of this study compared to the earlier studies are also attributable to the difference in geographic scope. The present study is limited to cancer incidence in California, while the previous SEER-based study was representative of the United States. Moreover, the earlier studies used a roughly fourfold larger sample (215 counties compared to the present study's 58 counties); thus in the current study we had lower statistical power to detect associations. Both ecological studies failed to achieve a complete ascertainment of sexual minority status, albeit for different reasons; the Census-based studies relied on an enumeration of same-sex partnered individuals, while the present study relied on population estimates of sexual identity. Methodological differences aside, there may be real-world differences between

California and the country as a whole in connections between sexual minority density and cancer incidence.

This study has the inherent limitations of the ecologic study design. In particular, because data are at the county level, it is not possible to link sexual minority status to cancer risk at the level of the individual. Thus, our study findings clearly describe links between county-level density measures and cancer incidence and should not be interpreted as evidence of an association between individual sexual orientation and cancer incidence. A finer scale—for example, at the level of the census tract—may provide more insight into patterns of sexual minority density and cancer incidence, but it is not yet clear what is the most appropriate geographic scale for such studies.

Despite these limitations, and some inconsistencies between the work described here and in our previous analyses [21-23], a particular strength is that these ecological analyses identified the existence of sexual orientation disparities in cancer incidence at the county level, while the consideration of gender minority density was outside of the scope of this study. Future studies are needed to identify ecological causes for the disparity in cancer incidence, which are likely complex, possibly examining county-level factors related to sexual minorities' access to the health care system and quality of care delivery. So far, a contextual understanding of sexual minorities' cancer incidence is lacking as well as knowledge about county or neighborhood effects on sexual minority populations' health and health behaviors more broadly. We suggest the consistency with which our ecological analyses identified disparities in cancer incidence, is an opportunity for public health policy interventions, which are larger in scale, considering county-level programs, rather than interventions that focus on individual behavior change. We hope additional research can be performed to identify county-level factors, such as density of health care, the equality of health care for sexual minorities, along with other known cancer prevention behaviors, such as smoking, that may affect cancer incidence.

While there is an increasing attention to the collection of sexual orientation data in the context of state or federal health surveys, from which one can derive differences in the prevalence of health risk factors, at present, there is no systematic surveillance of sexual or gender minorities with respect to cancer. Because of this omission, our goal has been to examine the question about cancer disparities by sexual orientation using ecological analyses. Similarly, motivated by a lack of individual-level data on sexual orientation and cancer, a recent study analyzed data on women in same sex and opposite sex relationships, i.e., a proxy for sexual orientation, concluding that women in same-sex relationships have greater risk for breast cancer related mortality [36]. So far, evidence is accumulating that sexual minorities carry a disproportionate burden of cancer, therefore calls are growing louder that cancer registries and SEER ought to collect sexual orientation data to adequately fulfill their mission of monitoring population health, which has to include sexual minority populations as well.

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Contributor Statement: U Boehmer originated the study and interpreted the findings. X Miao conducted the analyses and helped to interpret the findings. N Maxwell led the writing. A Ozonoff used his statistical expertise to direct the analysis and helped to interpret the findings. All authors contributed in significant ways to the final article by discussing earlier drafts, reviewing, and revising the manuscript.

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Table 1 *Multivariate Poisson Regression Analysis for* ***Male Lung Cancer†***

Predictors	Regression coefficient estimate	IRR	95% CI of IRR		p-value
Gay density	0.0004	1.0004	0.995	1.006	0.88
Bisexual density	-0.0875	0.916	0.897	0.936	<0.0001
Hispanic vs. non-Hispanic white	-0.4243	0.654	0.637	0.672	<0.0001
Asian/PI vs. non-Hispanic white	-0.0674	0.935	0.910	0.960	<0.0001
Other vs. non-Hispanic white	-0.0537	1.055	1.025	1.086	0.0003
Poverty	0.0134	1.014	1.012	1.015	<0.0001

† results also adjusted for age

Table 2 *Multivariate Poisson Regression Analysis for* ***Male Colorectal Cancer†***

Predictors	Regression coefficient estimate	IRR	95% CI of IRR		p-value
Gay density	-0.0020	0.998	0.993	1.003	0.45
Bisexual density	0.0262	1.027	1.004	1.050	0.02
Hispanic vs. non-Hispanic white	0.0411	1.042	1.018	1.067	0.0006
Asian/PI vs. non-Hispanic white	0.1056	1.111	1.082	1.142	<0.0001
Other vs. non-Hispanic white	0.0942	1.099	1.065	1.134	<0.0001
Poverty	0.0038	1.004	1.002	1.006	<0.0001

† results also adjusted for age

Table 3 *Multivariate Poisson Regression Analysis for* ***Female Lung Cancer†***

Predictors	Regression coefficient estimate	IRR	95% CI of IRR		p-value
Lesbian density	-0.0521	0.949	0.928	0.971	<0.0001
Bisexual density	0.1067	1.113	1.078	1.149	<0.0001
Hispanic vs. non-Hispanic white	-0.7012	0.496	0.482	0.511	<0.0001
Asian/PI vs. non-Hispanic white	-0.5264	0.591	0.573	0.609	<0.0001
Other vs. non-Hispanic white	-0.1527	0.858	0.832	0.885	<0.0001
Poverty	0.0013	1.001	0.999	1.003	0.18

† results also adjusted for age

Table 4 *Multivariate Poisson Regression Analysis for* ***Female Colorectal Cancer†***

Predictors	Regression coefficient estimate	IRR	95% CI of IRR		p-value
Lesbian density	-0.0290	0.971	0.950	0.993	0.0095
Bisexual density	0.0268	1.027	0.994	1.062	0.1105
Hispanic vs. non-Hispanic white	-0.0670	0.932	0.909	0.957	<0.0001
Asian/PI vs. non-Hispanic white	0.1133	1.120	1.090	1.151	<0.0001
Other vs. non-Hispanic white	0.1616	1.175	1.139	1.213	<0.0001
Poverty	0.0020	1.002	1.000	1.004	0.056

† results also adjusted for age

Table 5 *Multivariate Poisson Regression Analysis for* ***Female Breast Cancer†***

Predictors	Regression coefficient estimate	IRR	95% CI of IRR		p-value
Lesbian density	0.0225	1.023	1.014	1.031	<0.0001
Bisexual density	-0.0328	0.968	0.955	0.981	<0.0001
Hispanic vs. non-Hispanic white	-0.2691	0.764	0.755	0.774	<0.0001
Asian/PI vs. non-Hispanic white	-0.1790	0.836	0.824	0.848	<0.0001
Other vs. non-Hispanic white	-0.2533	0.776	0.763	0.790	<0.0001
Poverty	-0.0106	0.990	0.989	0.991	<0.0001

† results also adjusted for age

Figure1. Comparing results for different sexual minority density measures

Research Article

Sexual Minority Population Density and Incidence of Lung, Colorectal, and Female Breast Cancer in California

Running title: Sexual Minority Density and Incidence

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ABSTRACT

Objective: Risk factors for breast, colorectal, and lung cancer are known to be more common among lesbian, gay, and bisexual (LGB) individuals, suggesting they may more likely develop these cancers. Our objective was to determine differences in cancer incidence by sexual orientation, using ~~aggregate~~ sexual orientation data aggregated at the county-level.

Methods: Data on cancer incidence were obtained from the California Cancer Registry and data on sexual orientation were obtained from the California Health Interview Survey, from which a measure of age-specific LGB population density by county was calculated. Using multivariable Poisson regression models the association between the age-race-stratified ~~count of~~ incident rate of breast, lung, and colorectal cancer ~~cases~~ in each county and LGB population density was examined, with race, age group, and poverty as covariates.

Results: Among males, bisexual population density was associated with lower incidence of lung cancer and with higher incidence of colorectal cancer. Among females, lesbian population density was associated with lower incidence of lung and colorectal cancer, and with higher incidence of breast cancer; bisexual population density was associated with higher incidence of lung and colorectal cancer, and with lower incidence of breast cancer.

Conclusions: These study findings clearly document links between county-level LGB population density ~~measures~~ and cancer incidence, illuminating an important public health disparity.

Keywords: Homosexuality, cancer incidence, breast cancer, colorectal cancer, lung cancer, disparities, sex differences

ARTICLE SUMMARY

Strengths and limitations of this study

- Variation in cancer incidence due to Using sexual orientation population data aggregated at the county-level findings identify point to associations between cancer incidence and sexual minority population densitydifferences by sexual orientation group.
- These county-level differences in cancer incidence provide information suggest a need for public health planning, previously unavailable.
- Because cancer registries do not document sexual orientation, Ddetermining whether disparities exist in cancer incidence due to sexual orientation is not possible otherwise, because cancer registries do not document sexual orientation.
- Study findings have the inherent limitations of the ecologic study design.
- Because data are at the county level, it is not possible to link sexual minority status to cancer risk at the level of the individual.
- Study findings have the inherent limitations of the ecologic study design.

INTRODUCTION

Lung, colorectal, and female breast cancer are three of the most commonly diagnosed cancers in the United States, with incidence rates of 79.5, 51.6, and 121.9 per 100,000, respectively, in 2008. [1] Smoking and alcohol use are well-known risk factors for all three of these cancers; overweight and/or obesity has been linked to risk of female breast cancer and colorectal cancer. [2] In addition, nulliparity is associated with increased risk of female breast cancer.

Research also indicates that the prevalence of these well-known risk factors is generally higher among sexual minority individuals—that is, lesbian, gay, and bisexual individuals. Smoking is more common among sexual minorities, both men and women, than among their heterosexual counterparts.[3-8] Further, in 2007 the President's Cancer Panel found that sexual minority youths smoke at rates as high as those of adults, and tend to start smoking at a younger age than heterosexual youths.[6] Sexual minority women are more likely than heterosexual women to drink alcohol [5, 8-12] and to be overweight or obese.[10, 13-16] In contrast, gay men's alcohol use has not been shown to differ from that of heterosexual men,[12] and gay men are less likely than heterosexual men to be overweight or obese. [17] Finally, sexual minority women have higher rates of nulliparity than heterosexual women. [10, 13, 14, 18-20]

Because cancer registries do not collect information on the sexual orientation of individuals diagnosed with cancer, it cannot be readily determined from SEER or state registry data whether cancer is more prevalent among individuals with a sexual minority orientation. To overcome this lack of data on cancer disparities by sexual orientation, three previous studies used county-level ecologic analyses to relate breast, lung, and colorectal cancer incidence to greater ~~density of~~ sexual minority ~~individuals~~ population density [21-23]. Previously, we used ~~Using~~

SEER registry data and US Census data on ~~the prevalence of~~ individuals living in same-sex partnered households as ~~the~~ a proxy measure for sexual minority orientation. ~~, t~~These ecological studies concluded that greater female sexual minority density (SMD) in a county is associated with greater incidence of breast and colorectal cancer [21, 22], while there was a negative relationship between female sexual minority population density and lung cancer incidence [23]. Greater density of sexual minority men was associated with higher incidence of lung and colorectal cancer [22, 23].

While US census data on same-sex households are a well-established proxy for sexual orientation, these data also have known limitations. From available Census data, we can enumerate households led by same-sex adults, but this surely represents an undercount since we capture only sexual minority individuals who live with a same-sex partner, thereby excluding sexual minority individuals who are living alone or with non-partners. Further, we do not know how many members of a same-sex partnered household identify as lesbian, gay, or bisexual. In particular, it is impossible to assess lesbians separately from bisexual women or to assess gay men separately from bisexual men. This is an important limitation, because studies that analyzed lesbian women separately from bisexual women concluded bisexuals fare worse on some health indicators than both heterosexual and lesbian women [24-27].

To address the limitations of US Census data, the present study traded a national scope for an improved measure of sexual minority density. We used statewide population-based data on sexual minority identity (gay, lesbian, or bisexual) to estimate its relationship to colorectal cancer, lung cancer, and female breast cancer incidence.

MATERIALS AND METHODS

The Institutional Review Board deemed this study exempt from protocol review. Data for this research project were taken from the California Health Interview Survey (CHIS), the largest state health survey conducted in the US. The CHIS employs a two-stage geographically stratified random-digit-dial (RDD) sample of households, surveying one randomly selected adult from each sampled household. The survey is administered in multiple languages, resulting in a large multiethnic/multiracial sample that accurately represents the California population living in households. The CHIS response rate shows no significant nonresponse bias by demographic characteristics such as age, sex, income, education, or employment status [28]; however, due to the absence of a sampling frame, nonresponse by sexual orientation has not been evaluated. More detailed information about the survey methodology can be obtained from the website: http://www.chis.ucla.edu/. The CHIS collects information ~~biennually~~biennially, including data on sexual orientation. To ascertain sexual orientation, respondents were asked about their sexual identity, with response choices of heterosexual, lesbian, gay, or bisexual along with celibate or other, while recording refusals and don't know responses. We combined four years of data, using the adult CHIS surveys from 2001, 2003, 2005, and 2007 to increase the numbers of individuals who report a sexual minority orientation, defined as gay, lesbian, or bisexual.

Data on cancer incidence were taken from the California Cancer Registry, which records all cancer cases to monitor the occurrence of cancer among Californians. We chose the cancer data for the years 2001-2008 because these years cover the same timeframe as the CHIS sexual minority data. We further restricted our data to men and women aged 18 to 84, because we focused on adult cancers and also because this is the age range for which the CHIS had sexual orientation data available. ~~In 2001-2008, among women aged 18-84 in the 58 counties of~~

California, 206,012 were newly diagnosed with breast, 59,182 with lung, and 50,123 with colorectal cancer. Over the same number of years, among men aged 18-84, there were 62,673 new diagnoses of lung cancer and 55,624 of colorectal cancer.

Because there are differences in cancer incidence by age and race, we used the population data from Census 2000 since it has age- and race- specific population data available for all the 58 counties in California. From the Census, we also obtained county-level data on poverty, another important confounder of cancer incidence.

Measures

Counts of breast, lung, and colorectal cancer incidence were classified into one of 11 age categories and four race/ethnicity groups. The 11 age categories were 18-24, 25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-59, 60-64, 65-69 and 70-84, while race and ethnicity consisted of (1) Non-Hispanic White, (2) Hispanic, (3) Asian/Pacific Islander, and (4) other race/ethnicity. The group of other race/ethnicity combines non-Hispanic Blacks (6.79% of cancers), other/unknown race/ethnicity (0.73% of cancers) and non-Hispanic American-Indian (0.14 % of cancers). We calculated each cancer incidence rate using the total female and male population between age 18 and 84 in each county using the Census data.

We adjusted for poverty level in our analyses, with poverty level being defined as the percentage of the population living under the Federal poverty level, which has been found to be the most consistent, easily interpretable variable which accurately measures socioeconomic disparities in health outcomes [29, 30].

Our main independent variable is derived from CHIS data on participants' sexual orientation. We are using these data aggregated at the county-level and call this aggregate variable 'sexual minority density' (SMD) because it to expresses the variation in the density with

~~which residents of a county report as~~ of sexual minority populations in a county~~ies~~. To make these data age-specific, we obtained the distribution of sexual minorities, defined as lesbians, gays, or bisexuals, across different age groups, and combined this information with the county-level SMD. Specifically, we obtained the weighted percentage of gay men in a specific age group (denoted as ageweight_gay), using the age information on all gay men in the 58 California counties. Then, we obtained the weighted percentage of all men in the specific age group (denoted as ageweight_all), using the age information on all subjects in the 58 California counties. Finally, we obtained the count of all adult gay men (Ngay) and the count of all adult men (Nall) in the specific age group, and computed the age-specific gay density as:

$$\text{Age-specific gay density} = \frac{N_{gay} * \text{ageweight\_gay}}{N_{all} * \text{ageweight\_all}}$$

The age-specific lesbian and bisexual population density was computed in a similar way, and we considered bisexual men and women as distinct categories for analyses.

Regression diagnostics indicated that the Los Angeles County, white race, age 70-84, data point was a potentially influential point. We refit all regression models excluding this data point to ensure that our findings are not predominantly dependent on a single observation. Model fit did not improve substantially with the exclusion, and more importantly, changes in estimates of associations between the density measures and cancer incidence were small and well within the standard errors. Therefore, we report all regression results with no data exclusions. ~~We adjusted for poverty level in our analyses, with poverty level being defined as the percentage of the population living under the Federal poverty level, which has been found to be the most consistent, easily interpretable variable which accurately measures socioeconomic disparities in health outcomes~~ [29, 30]~~.~~

Statistical Analysis

Descriptive statistics summarized variation in adult cancer incidence by gender and race. We used descriptive statistics to summarize our outcomes, cancer incidence, and our main independent variables, that is, lesbian, gay, or bisexual population density, for all 58 California counties. We assessed county-level association between lesbian/gay/bisexual density (LGBD) and cancer incidence rates using multivariable Poisson regression models with the age-race-stratified count of incident cases in each county as the dependent variable, and the LGBD, race, age group and US Census percent in poverty as covariates. We fitted models that considered L/G and B together Bbecause the correlation between lesbian/gay density and bisexual density was low—0.36 (p<0.0001) for women and 0.15 (p<0.0001) for men and because our primary parameter estimates remained essentially unchanged, when we fitted the two density measures separately—we fitted models that considered L/G and B together. The All model selections was were based on the goodness-of-fit of the models assessed by the Akaike Information Criterion (AIC) and residual diagnostics plots. SAS PROC GENMOD was used to fit the models, with the offset term as the logarithm of the US Census age-race-stratified total adult population in the county. The incidence rate ratio (IRR) was presented as the measure of the effect of each predictor, along with its 95% confidence interval and p-value. The validity of the assumptions and the goodness-of-fit of the assumed models were assessed by residual diagnostic plots and goodness-of-fit statistics such as the Deviance statistic. All analyses were done in SAS 9.2 (SAS Institute Inc, Cary NC, USA).

Regression diagnostics indicated that the Los Angeles County, white male, age 70-84, data point was a potentially influential point. We refit all regression models excluding this data pointa single observationModelwith the exclusion, changes in estimates of were small and well within the standard errorsreport all regression results with no data exclusions.

RESULTS

There is considerable variation in the sexual minority density measures by county. Across 58 California counties, the lesbian density measure ranges from 0 to 3.05 (Median=0.49; Mean=0.66; SD=0.78) and the bisexual density measure from 0 to 4.16 (Median=1.24; Mean=1.16; SD=0.97). Gay and bisexual male density measures respectively range from 0 to 16.02 (Median=0.80; Mean=1.10; SD=2.19) and from 0 to 4.07 (Median=0.44; Mean=0.60; SD=0.76).

We describe age-adjusted regression results for measures of sexual minority density, race/ethnicity, and poverty as predictors of cancer incidence.

Sexual orientation, demographics, and cancer incidence among males

Controlling for race/ethnicity and poverty, gay density was not associated with county-level lung cancer incidence among males (Table 1), although bisexual density was associated with an 8.4 percent decrease in lung cancer incidence (IRR=0.916, $p<0.0001$). There were expected significant associations between self-reported race/ethnic category and incidence, and a positive association between poverty and lung cancer incidence was weaker but still statistically significant. After excluding the Los Angeles County outlier from the regression model for male lung cancer, the associations were unchanged in strength and significance between gay/ bisexual density and lung cancer.

Controlling for race/ethnicity and poverty, gay density was not significantly associated with colorectal cancer incidence (Table 2), but bisexual density among males was associated with a 2.7% increase in incidence of colorectal cancer (IRR=1.027, p=0.02).

Sexual orientation, demographics, and cancer incidence among females

Controlling for race/ethnicity and poverty, each one-~~percentage poin~~unit increase in lesbian density was associated with a 5.1% decrease in incidence of lung cancer (IRR=0.949, p<0.0001; Table 3), whereas each one- unit increase in bisexual density was associated with an 11.3% increase (IRR=1.113, p<0.0001). There were significant negative association between female lung cancer incidence and Hispanic, Asian/Pacific Islander and Other race. There was no significant association between female lung cancer incidence and poverty.

Controlling for race/ethnicity and poverty, each one- unit increase in lesbian density was associated with a 2.9% decrease in the incidence of colorectal cancer among women (IRR=0.971, p=0.0095; Table 4); bisexual density was not associated with incidence of colorectal cancer among women. Hispanic ethnicity had a significant negative association, Asian/Pacific Islander and Other race had a significant positive association with incidence of colorectal cancer among women. Poverty was not significantly associated with incidence of colorectal cancer in females.

Controlling for race/ethnicity and poverty, each one-unit increase in lesbian density was significantly associated with a 2.3% increase, and bisexual density with a 3.2 % decrease, in incidence of female breast cancer (lesbian: IRR=1.023, p<0.0001; bisexual: IRR=0.968, p<0.0001; Table 5). Hispanic, Asian/Pacific Islander, and Other race/ethnicity had significant negative associations with breast cancer incidence. Poverty was modestly but significantly associated with decreased breast cancer incidence.

Excluding Los Angeles County from the regression model resulted in little change to the results for female breast cancer, female lung cancer, and female colorectal cancer.

DISCUSSION

This study's findings document disparities in the age-adjusted incidence of three cancers across the counties of California: disparities that are associated with the density of sexual minorities, controlling for race/ethnicity and the prevalence of poverty. Our outcome measure provides effect estimates in the form of the percentage change in cancer incidence per one unit increase in sexual minority population density, and thus an IRR that is only modestly different from 1.0 may represent a substantial difference in real-world terms, given the variation in gay and lesbian densities across counties.

Among males, bisexual density (but not gay density) was significantly associated with cancer incidence. Specifically, bisexual density was associated with lower incidence of lung cancer and, less strongly, with higher incidence of colorectal cancer. Among females, lesbian density (but not bisexual density) was significantly associated with colorectal cancer. Among females, bBoth lesbian and bisexual density were significantly associated with female breast and lung cancer incidence. However, across all three cancers, these two associations were opposite in direction: -lesbian density was associated with lower incidence of lung and colorectal cancer, and with higher incidence of breast cancer; bisexual density was associated with higher incidence of lung and colorectal cancer, and with lower incidence of breast cancer. The strongest associations between sexual orientation and cancer incidence, and thus the greatest gap between findings by sexual orientation, were for lung cancer: lesbian density is associated with a 5.1% decrease, and bisexual density with an 11.3% increase, in lung cancer incidence per one-unit increase in sexual minority density. For each of the cancer outcome we studieds, Los

Angeles county, white race, and age 70-84 emerged as an influential outlying data point. Because Los Angeles county is also the most populous county in California, initially this raised concerns for us aboutwe carefully considered issues around the robustness of our results. However, because our findings barely changed after the removal of this data point, we wereWe conducted a sensitivity analysis, which suggests reassured that our findings are not overly dependent on thethis single data point of Los Angeles county, white race, and age 70-84, speakinglending strength to the overall reliability of our findings.

These dThe differences between results for lesbian/gay density and bisexual density are consistent with an increasing understanding among sexual orientation researchers that—after years of combining lesbian/gay and bisexual individuals into one group due to small sample sizes—differences between these groups come to the forefront once they are separated [8, 31-34]. These findings reflect methodological improvements on our previous studies of sexual minority density and cancer incidence [21-23]: those analyses used U.S. Census data on whether a respondent lived in a same-sex partnered household, whereas data for the current analysis rest on self-reported sexual identity from the California Health Interview Survey, as described above, and distinguish between gay/lesbian and bisexual respondents. A comparison of findings from our other analyses to those of this study shows a mix of consistencies and inconsistencies. , partly attributable to this improvement in the ascertainment of sexual minority orientation, the ability to distinguish lesbian/gay density from bisexual density.

[insert Figure 1]

Using SEER data, colorectal cancer incidence was significantly and positively associated with both sexual minority men density and sexual minority women density [22]; that finding aligns with this study's finding for male and female bisexual density and colorectal cancer, but is inconsistent with the present findings for gay and lesbian density. In the present study, we identified among males no association between gay density and lung cancer, and a negative association between bisexual density and lung cancer; this conflicts with our finding of a positive association for sexual minority men density and lung cancer using a different dataset [23]. For female lung cancer, our current findings for lesbian women are consistent with our previous finding of a significant negative association between lung cancer and sexual minority women density [23], although the present study also found a positive association with bisexual density specifically. Finally, findings for breast cancer show some consistency: in the present study, lesbian density has a significant positive association with breast cancer incidence, confirming our earlier findings [21], although the present study also identified a negative association with bisexual density.

A number of factors are likely to contribute to differences between results of earlier Census-based analyses, which did not distinguish between gays/lesbians and bisexuals, and those of the present study, which relied on self-reported sexual identity. The Census data on same-sex partnered households are probably better indicators of gay and lesbian than bisexual individuals, given data showing that the majority of partnered gay and lesbian individuals have a same-sex partner, whereas partnered bisexual individuals are more likely to be in heterosexual relationships [34]. The present study's ability to distinguish lesbian/gay density from bisexual density, is an improvement in the ascertainment of sexual minority orientation. This likely accounts for identifying effects that are opposite in direction, as for example lesbian density's association with a 5.1% decrease and bisexual density's 11.3% increase in lung cancer incidence. Another factor may be the relative size of the subgroups within the LGB adult population: among women, more identify as bisexual than lesbian, whereas among men, more identify as gay

[35]. Differences in the findings of this study compared to the earlier studies are also attributable to the difference in geographic scope. The present study is limited to cancer incidence in California, while the previous SEER-based study was representative of the United States. Given the difference in geographic scope Moreover, the earlier studies used a roughly fourfold larger sample (215 counties compared to the present study's 58 counties); thus in the current study we had lower statistical power to detect associations. Both ecological studies failed to achieve a complete ascertainment of sexual minority status, albeit for different reasons; the Census-based studies relied on an enumeration of same-sex partnered individuals, while the present study relied on population estimates of sexual identity. Methodological differences aside, there may be real-world differences between California and the country as a whole in connections between sexual minority density and cancer incidence.

This study has the inherent limitations of the ecologic study design. In particular, because data are at the county level, it is not possible to link sexual minority status to cancer risk at the level of the individual. Thus, our study findings clearly describe links between county-level density measures and cancer incidence and should not be interpreted as evidence of an association between individual sexual orientation and cancer incidence. A finer scale—for example, at the level of the census tract—may provide more insight into patterns of sexual minority density and cancer incidence, but it is not yet clear what is the most appropriate geographic scale for such studies.

Despite these limitations, and some inconsistencies between At present, there is essentially no systematic surveillance of sexual minorities, other than simply reporting differences in the prevalence of health risk factors. Tthe work described here and in our previous analyses [21-23], a particular strength is that these ecological analyses pinpoints identified the existence of ~~public health~~ sexual orientation disparities in cancer incidence at the county level, while the consideration of gender minority density was outside of the scope of this study. Future studies are needed to identify ecological causes for the disparity in cancer incidence, which are likely complex, possibly examining county-level factors related to sexual minorities' access to the health care system and quality of care delivery. So far, a contextual understanding of sexual minorities' cancer incidence is lacking as well as knowledge about county or neighborhood effects on sexual minority populations' health and health behaviors more broadly. ~~Nevertheless, the~~ We suggest the consistency with which our ecological analyses identified disparities in cancer incidence, ~~are~~ is an opportunity for public health policy interventions, which are larger in scale, considering county-level programs, rather than interventions that focus on individual behavior change. We hope additional research can be performed to identify county-level factors, such as density of health care, the equality of health care for sexual minorities, along with other known cancer prevention behaviors, such as smoking, that may affect cancer incidence.

While there is an increasing attention to the collection of sexual orientation data in the context of state or federal health surveys, from which one can derive differences in the prevalence of health risk factors, at present, there is no systematic surveillance of sexual or gender minorities with respect to cancer. Because of this omission, our goal has been to examine the question about cancer disparities by sexual orientation using ecological analyses. Similarly, motivated by a lack of individual-level data on sexual orientation and cancer, a recent study analyzed data on women in same sex and opposite sex relationships, i.e., a proxy for sexual orientation, concluding that women in same-sex relationships have greater risk for breast cancer related mortality [36]. So far, evidence is accumulating that sexual minorities carry a disproportionate burden of cancer, therefore calls are growing louder that cancer registries and

SEER ought to collect sexual orientation data to adequately fulfill their mission of monitoring population health, which has to include sexual minority populations as well.

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Contributor Statement: U Boehmer originated the study and interpreted the findings. X Miao conducted the analyses and helped to interpret the findings. N Maxwell led the writing. A Ozonoff used his statistical expertise to direct the analysis and helped to interpret the findings. All authors contributed in significant ways to the final article by discussing earlier drafts, reviewing, and revising the manuscript.

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Table 1 *Multivariate Poisson Regression Analysis for* ***Male Lung Cancer†***

Predictors	Regression coefficient estimate	IRR	95% CI of IRR		p-value
Gay density	0.0004	1.0004	0.995	1.006	0.88
Bisexual density	-0.0875	0.916	0.897	0.936	<0.0001
Hispanic vs. non-Hispanic white	-0.4243	0.654	0.637	0.672	<0.0001
Asian/PI vs. non-Hispanic white	-0.0674	0.935	0.910	0.960	<0.0001
Other vs. non-Hispanic white	-0.0537	1.055	1.025	1.086	0.0003
Poverty	0.0134	1.014	1.012	1.015	<0.0001

† results also adjusted for age

Table 2 *Multivariate Poisson Regression Analysis for* ***Male Colorectal Cancer†***

Predictors	Regression coefficient estimate	IRR	95% CI of IRR		p-value
Gay density	-0.0020	0.998	0.993	1.003	0.45
Bisexual density	0.0262	1.027	1.004	1.050	0.02
Hispanic vs. non-Hispanic white	0.0411	1.042	1.018	1.067	0.0006
Asian/PI vs. non-Hispanic white	0.1056	1.111	1.082	1.142	<0.0001
Other vs. non-Hispanic white	0.0942	1.099	1.065	1.134	<0.0001
Poverty	0.0038	1.004	1.002	1.006	<0.0001

† results also adjusted for age

Table 3 *Multivariate Poisson Regression Analysis for* ***Female Lung Cancer†***

Predictors	Regression coefficient estimate	IRR	95% CI of IRR		p-value
Lesbian density	-0.0521	0.949	0.928	0.971	<0.0001
Bisexual density	0.1067	1.113	1.078	1.149	<0.0001
Hispanic vs. non-Hispanic white	-0.7012	0.496	0.482	0.511	<0.0001
Asian/PI vs. non-Hispanic white	-0.5264	0.591	0.573	0.609	<0.0001
Other vs. non-Hispanic white	-0.1527	0.858	0.832	0.885	<0.0001
Poverty	0.0013	1.001	0.999	1.003	0.18

† results also adjusted for age

Table 4 *Multivariate Poisson Regression Analysis for* ***Female Colorectal Cancer†***

Predictors	Regression coefficient estimate	IRR	95% CI of IRR		p-value
Lesbian density	-0.0290	0.971	0.950	0.993	0.0095
Bisexual density	0.0268	1.027	0.994	1.062	0.1105
Hispanic vs. non-Hispanic white	-0.0670	0.932	0.909	0.957	<0.0001
Asian/PI vs. non-Hispanic white	0.1133	1.120	1.090	1.151	<0.0001
Other vs. non-Hispanic white	0.1616	1.175	1.139	1.213	<0.0001
Poverty	0.0020	1.002	1.000	1.004	0.056

† results also adjusted for age

Table 5 *Multivariate Poisson Regression Analysis for* ***Female Breast Cancer†***

Predictors	Regression coefficient estimate	IRR	95% CI of IRR		p-value
Lesbian density	0.0225	1.023	1.014	1.031	<0.0001
Bisexual density	-0.0328	0.968	0.955	0.981	<0.0001
Hispanic vs. non-Hispanic white	-0.2691	0.764	0.755	0.774	<0.0001
Asian/PI vs. non-Hispanic white	-0.1790	0.836	0.824	0.848	<0.0001
Other vs. non-Hispanic white	-0.2533	0.776	0.763	0.790	<0.0001
Poverty	-0.0106	0.990	0.989	0.991	<0.0001

† results also adjusted for age

Figure1. Comparing results for different sexual minority density measures

	Same-sex Density	Lesbian/Gay Density	Bisexual Density
Lung Cancer Men	↑	not sig	↓
Colorectal Cancer Men	↑	not sig	↑
Lung Cancer Women	↓	↓	↑
Colorectal Cancer Women	↑	↓	not sig
Breast Cancer Women	↑	↑	↓

	Same-sex Density	Lesbian/Gay Density	Bisexual Density
Lung Cancer Men	↑	not sig	↓
Colorectal Cancer Men	↑	not sig	↑
Lung Cancer Women	↓	↓	↑
Colorectal Cancer Women	↑	↓	not sig
Breast Cancer Women	↑	↑	↓

87x38mm (144 x 144 DPI)