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## The Population Burden of Cancer: Research Driven by the Catchment Area of a Cancer Center

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Cancer centers, particularly those supported by the National Cancer Institute, are charged with reducing the cancer burden in their catchment area. However, methods to define both the catchment area and the cancer burden are diverse and range in complexity often based on data availability, staff resources, or confusion about what is required. This article presents a review of the current literature identifying 4 studies that have defined various aspects of the cancer burden in a defined geographical area and highlights examples of how some cancer centers and other health institutions have defined their catchment area and characterized the cancer burden within it. We then present a detailed case study of an approach applied by the University of California, San Francisco, Helen Diller Family Comprehensive Cancer Center to define its catchment area and its population cancer burden. We cite examples of how the Cancer Center research portfolio addresses the defined cancer burden. Our case study outlines a systematic approach to using publicly available data, such as cancer registry data, that are accessible by all cancer centers. By identifying gaps and formulating future research directions based on the needs of the population within the catchment area, epidemiologic studies and other types of cancer research can be directed to the population served. This review can help guide cancer centers in developing an approach to defining their own catchment area as mandated and applying research findings to this defined population.

cancer; cancer care facilities; catchment area; community health planning; population-based planning; registries

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Abbreviations: CHNA, Community Health Needs Assessment; HDFCCC, Helen Diller Family Comprehensive Cancer Center; NCI, National Cancer Institute; UCSF, University of California, San Francisco.

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### INTRODUCTION

Cancer research is driven by questions at different levels of biological and human organization depending on the disciplinary focus of investigators who generate new knowledge, treatments, and methods of cancer control. Basic research disciplines seek new generalizable truths about genetic, molecular, and cellular processes that can elucidate the many mysteries of carcinogenesis. Clinical research seeks to use basic discoveries to improve the diagnosis, treatment, and care of persons with cancer. Population scientists seek to understand the determinants of cancer incidence, morbidity, and mortality across the continuum and to develop and disseminate effective interventions to reduce them. From the standpoint of a cancer research institution, which might be a health-care system, department of public health, or cancer center, there should be a desire to have an impact on cancer among persons and populations in the particular geographical area surrounding the institution. The

manner in which cancer impacts a particular population is referred to as the cancer burden.

This is now additionally motivated by guidelines from the National Cancer Institute (NCI) requiring that the cancer centers it supports direct research to the populations served in their respective catchment areas (1). The NCI has described each cancer center as a “local, regional, and national resource, directly serving its community,” and therefore it is necessary to define the community that it directly serves or its “catchment area.” The NCI requires that the catchment area “must be defined and justified by the center based on the geographic area it serves. It must be population based, e.g., using census tracts, zip codes, county or state lines, or geographically defined boundaries. It must include the local area surrounding the cancer center” (2).

As such, the nation’s network of 69 NCI-designated cancer centers has a unique role in addressing the cancer burden in their regions through defining their catchment areas and

the needs of the population in those defined areas (3). They are charged with seeking ways to better describe and understand the population characteristics of cancer in their catchment areas and developing, testing, and implementing interventions that are likely to have the most impact on the population served. Centers, therefore, need to have a continuously updated and comprehensive view of the burden of cancer in their geographical regions. Defining a catchment area and the cancer burden of the people who live there can help a center identify population-based problems, critical adverse trends, sources of cancer health inequalities, and health-care resource needs that are most important for that region. Additionally, comprehensive cancer centers strive to ensure that clinical trial accrual is representative of the sex and racial/ethnic distributions in their catchment area populations, which may differ from the center's cancer patient population.

This paper reviews previous literature on assessing aspects of the cancer burden in defined geographical areas and presents an example used by 1 cancer center to define its catchment area and the characteristics of the cancer burden in that area. We illustrate how a description of the cancer burden within a catchment area can help drive the cancer center research agenda. For this analysis, we use a case study of the University of California, San Francisco (UCSF), Helen Diller Family Comprehensive Cancer Center (HDFCCC).

## METHODS

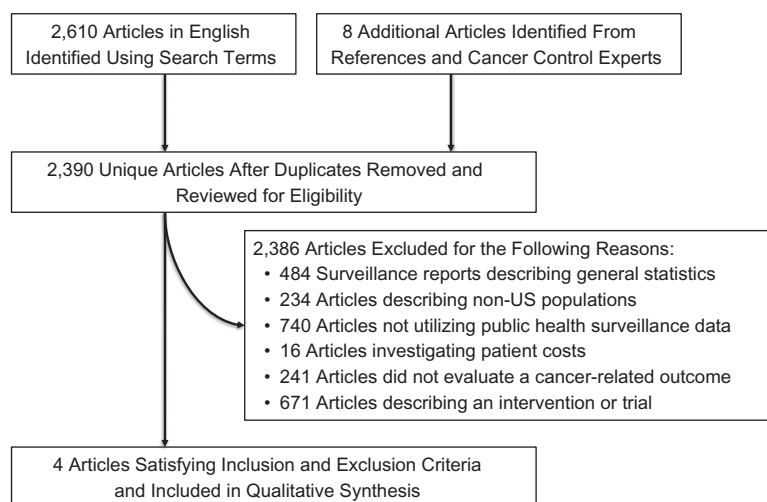
We undertook a review of the literature for studies and reports in the United States that described the use of publicly available data to define a service or catchment area and then guide cancer research or program activities in that area. We conducted a literature review of peer-reviewed journal articles published between January 1973 and February 2016.

Using PubMed and EMBASE, we utilized the following combinations of search terms: “cancer center” AND “catchment area,” “application of cancer registry data” AND “disparities,” “cancer control” AND “disparities,” “cancer control” AND “measuring burden,” “cancer control” AND “spatial analysis” AND “planning,” “cancer control” AND “spatial analysis” AND “disparities,” “population burden of cancer” AND “public health plan,” “cancer control” AND “cancer center” AND “strategic planning,” “cancer control” AND “public health plan” AND “disparities,” and “cancer disease management” AND “public health plan” AND “disparities.” We also identified additional articles from the references of included articles and those suggested to us by experts in the field of cancer control.

Articles identified from this search strategy were screened by using titles and abstracts to determine eligibility for study inclusion; if additional information was needed, the full text was reviewed. Studies were included if they were published in English and used US cancer registry data or other public health surveillance data (e.g., National Center for Health Statistics) to inform local or regional cancer control strategies. Studies were excluded if they were published prior to 1973 or after the cutoff date (February 25, 2016). We also excluded the following: surveillance reports from cancer registries that aim only to present cancer statistics or disparities, articles that described non-US study populations, articles that did not use public health surveillance data, articles of studies that did not evaluate cancer-related outcomes, studies of individual patient cost burden, and studies evaluating cancer treatment or screening test regimen (i.e., radiation therapy regimens, mammography screening trials).

## RESULTS

This search strategy identified 2,610 articles, and an additional 8 articles were identified from review of reference



**Figure 1.** Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) flow diagram describing the identification and selection of articles included in this review.

**Table 1.** Summary of Articles Included in Review

First Author, Year (Reference No.)	Title	Cancer Center	Catchment Area Definition	Catchment Area Size	Use of Catchment Area Characteristics
Wang, 2015 (5)	Catchment area analysis using Bayesian regression modeling	MCC at Virginia Commonwealth University	Used Bayesian hierarchical logistic and Poisson regressions adjusting for demographical variables to identify counties with unusually high probability of patients diagnosed or treated at MCC. These counties encompassed the catchment area.	54-county area based on probability of patients diagnosed at MCC using state cancer registry data from 2009 to 2011 44-county area based on probability of patients diagnosed or treated at MCC using MCC billing data for 2009–2011 (Note: similar data from 2009 to 2012 identified an expanded area of 47 counties.)	Compared patient characteristics (sex, age, race, ethnicity, and insurance type) for patients inside catchment area versus outside catchment area using cancer registry and cancer center data
Hawk, 2014 (7)	Five National Cancer Institute-designated cancer centers' data collection on racial/ethnic minority participation in therapeutic trials	Five centers included in analysis: 1. Sidney Kimmel Comprehensive Cancer Center at Johns Hopkins University 2. University of Alabama, Birmingham, Comprehensive Cancer Center 3. University of California, Davis, Comprehensive Cancer Center 4. Masonic Cancer Center at the University of Minnesota 5. The University of Texas MD Anderson Cancer Center	Centers 1, 3, and 5 used definitions related to the institution's location. Center 4 used a definition based on market share: "counties that contributed to the geographically nearest 75% or highest 75% market share of cases."	Centers 1 and 2 included 2 levels of their catchment area: the entire nation and its home state. Center 3 included 3 levels of its catchment area: the entire nation, its home state, and a 13-county region surrounding the institution. Center 4 market share definition included adjacent counties; number of counties was not described in paper. Center 5 catchment area was its home state.	Centers 1, 2, 3, and 4 compared percentage of race and ethnicity of patients enrolled in therapeutic trials with its catchment area's general population and cancer population, by using US census and state cancer registry data Center 5 compared percentage of race and ethnicity of patients enrolled in therapeutic trials with its catchment area's general population only, using US census data
Su, 2010 (4)	Spatial analyses identify the geographical source of patients at a National Cancer Institute comprehensive cancer center	Sidney Kimmel Comprehensive Cancer Center at Johns Hopkins University	Used statistical software, SaTScan, which uses a Poisson-based model to identify counties that have a high ratio of cancer center cases to all county cancer deaths (Note: county-specific cancer death counts from 1 year of data, 1998, from the National Center for Health Statistics were used to approximate the cancer population.)	58-county area identified by using SaTScan; this area varied slightly when spatial analysis was stratified by sex, cancer site (colon/lung, breast, pancreas, prostate), age (>18 years), and race (white, black).	Developed hypotheses to explain the size of subpopulation-specific catchment areas (i.e., patients with pancreatic cancer or African Americans) based on available literature
Goodman, 2009 (6)	Cancer outcomes research in a rural area: a multi-institution partnership model	Four community cancer centers participated in regional coalition: 1. Phoebe Cancer Center 2. Tift Regional Oncology Center 3. Singletary Oncology Center 4. Pearlman Cancer Center	Counties that participate in the Southwest Georgia Cancer Coalition, a program supported by the Georgia Cancer Coalition	33-county area defined as southwest Georgia	Compared cancer site-specific incidence and mortality rates in the catchment area with those of the state of Georgia using state cancer registry data

Abbreviation: MCC, Massey Cancer Center.

lists or discussion with cancer control experts. After duplicates were removed, 2,390 unique articles remained. The bulk of these articles were excluded after review for a number of reasons as outlined in Figure 1. In the end, only 4 articles were included in our analysis (Figure 1). Their content is summarized in Table 1. We found, not surprisingly, that previous work on assessing the cancer burden has relied heavily on the use of cancer registry data. Two articles used cancer registry data in their approaches to define the catchment area through spatial analyses (4, 5). All articles, except 1, used cancer registry data to characterize the cancer population within a cancer center's defined catchment area (5–7).

Methods to define catchment areas varied from simply using proximity to more complex spatial analyses. Hawk et al. (7) compared 5 NCI comprehensive cancer centers and found that even definitions based solely on proximity could vary because catchment areas can be defined at national, state, or local levels, which may include only counties adjacent to the cancer center. In other words, they found that proximity alone may be insufficient because a center may serve much broader areas, especially if it is a regional referral center. One center chose to use market share, the proportion of the total cancer cases in a region that sought care at the cancer center, but this definition still included location as a criterion (7).

Spatial analyses have also been used to identify clusters of populations of interest to the center regardless of state or local boundaries. Su et al. (4) utilized a statistical software tool, SaTScan, to identify a 58-county catchment area for the Sidney Kimmel Comprehensive Cancer Center at Johns Hopkins that extended across 7 states. This method was based on a Poisson model that estimated whether the cancer cases in a county had a higher relative risk of being patients at the cancer center than cancer cases in other nearby counties. A limitation in their analysis was that they used county-specific death counts from a single year of data, 1998, from the National Center for Health Statistics as a surrogate measure for the cancer population in each county rather than an average case count from multiyear state cancer registry data.

Another approach described by Wang and Wheeler (5) using Bayesian hierarchical Poisson regression aimed to accomplish the same goal, to identify counties in which a cancer case was more likely to be a cancer center patient, but this method also adjusted for demographical county-level covariates such as sex, age, and race. Using Virginia state cancer registry data and their own cancer center patient data, they modeled the proportion of cancer patients in a county that were diagnosed at the Massey Cancer Center. Similarly, using cancer center billing data, they modeled the proportion of cancer patients in a county that were diagnosed or sought treatment at Massey Cancer Center. This defined a 44-county region for diagnosis or treatment and a 54-county region for diagnosis only for the time period, 2009–2011.

In the article by Goodman et al. (6), the catchment area was defined by an existing collaboration of 33 counties in the state of Georgia, the Southwest Georgia Cancer Coalition. Four cancer centers within southwest Georgia provide care to the majority of cancer cases in this region. Although these centers did not individually identify southwest Georgia

as their catchment area, the impact of their research efforts can be measured by changes in cancer-related outcomes in this region. It is unclear how much patient overlap exists among the 4 cancer centers, but because these centers collaborate as part of the coalition and serve as sites of recruitment for the same studies, one can justify the region of interest as the coalition's catchment area.

Cancer centers commonly use cancer surveillance data to evaluate whether their clinical trial patient populations are representative of the cancer population in their catchment areas (7). For Goodman et al., site-specific cancer incidence and mortality rates within the catchment area were compared with those of the entire state of Georgia. Wang et al. compared general characteristics such as age, race, sex, ethnicity, and insurance type for cancer cases within the catchment area versus outside the catchment area. Su et al. did not evaluate the characteristics of cancer cases in their catchment area but drew hypotheses based on the published literature to explain why their site-specific or race-specific catchment areas varied in size. However, our review came across additional studies from the same cancer center reported by Su et al. that evaluated disparities in clinical trial participation and survival rates using the same previously defined catchment area (8, 9). We did not include them as part of our review, because these articles used only cancer center data and did not utilize public surveillance data.

## A CASE STUDY

To provide more detailed information on how 1 NCI-designated cancer center defined its catchment area and the burden in that area, we present a case study of the process used by HDFCCC.

### Defining the catchment area

In this example, a “case density” approach was taken, which is calculated by dividing the number of cancer cases presenting to the cancer center from each county by the total number of cancer cases in that county per year obtained from cancer registry data. Any differential effect of age distribution by county (e.g., many young immigrants in 1 county vs. an older established population in another) is mitigated by comparing only the cancer cases from an area rather than the total population in that area. A center's cancer case density can highlight areas (e.g., counties) where the ratio is highest of cancer patients that have presented to the center relative to all cancer patients from that area. Cutpoints can then be assigned to create hierarchical categories representing levels of cancer care service. A cutpoint can be selected to represent a level of service that is then used to determine the catchment area. These data can be visualized by using a heat map to draw the catchment area based on a gradation of county case densities (refer to Web Figure 1 available at <http://aje.oxfordjournals.org/>).

### Defining the cancer burden

We defined cancer burden by using 5 criteria measured by public health surveillance data: 1) the absolute number of

incident and fatal cancer cases that highlight the most common cancers; 2) trends that identify cancers with recent increased rates of incidence and mortality; 3) medical costs that highlight cancers with the greatest financial burden; 4) changes in modifiable cancer risk factors that point to cancers with possible prevention strategies; and 5) differences in the above measures by race/ethnicity, sex, and other demographical features that highlight disparities or inequities. In this article, we used each of these criteria to identify cancer sites of concern to the UCSF HDFCCC. We chose county-level metrics because they could be determined from data that any cancer center should have access to through publicly available cancer registry databases. Other patient-level metrics could also be explored, such as stage at presentation, place of residence, prevalence of comorbidities at diagnosis, quality of life after treatment, and cancers that may not be common but are particular to the catchment area. Counts and rates were stratified by race/ethnicity: non-Hispanic white, non-Hispanic black, Hispanic, and non-Hispanic Asian or Pacific Islander, hereafter referred to as white, black, Latino, and Asian. Those classified as 2 or more races, other, or unknown were excluded from these analyses.

#### Data sources

We used data from the HDFCCC cancer registry to ascertain the county of residence of persons with cancer. US census data were used to determine the number of persons residing in each county. California Cancer Registry data on cancer incidence by county were used to calculate the proportion of HDFCCC cancer cases among all cases in each county of the HDFCCC catchment area. Using SEER\*Stat (National Cancer Institute, Bethesda, Maryland), we obtained California Cancer Registry data (10) on yearly cancer incidence for the defined catchment area, while information on cancer mortality (11) was obtained through the Cancer Prevention Institute of California, because SEER\*Stat does not provide yearly mortality data. Cancer risk factor data were obtained from the California Health Interview Survey via the AskCHIS portal (12).

Health-care costs were calculated for the 48 counties in the Northern California Region. First, we obtained mean hospital discharge charges for each of the leading causes of cancer incidence for men and women for year 2009 from the California Office of Statewide Health Planning and Development Hospital Discharge Data. We inflated these charges to year 2015 charges by using the gross domestic product deflator and then converted them to costs using the cost-to-charge ratio provided by the Office of Statewide Health Planning and Development. Next, we multiplied the per discharge costs by the annual incidence for each disease to obtain total hospital costs for the catchment area's incident cases. Finally, we multiplied total hospital costs by the ratio of total health-care expenditures (inpatient hospitalizations, outpatient visits, emergency department visits, medications, and home health care) to inpatient hospitalizations. Ratios were derived from the 2013 Medical Expenditures Panel Survey. For each data component, we used the most recent data available to us.

To evaluate whether research projects conducted at HDFCCC aligned with cancer burden in the catchment area, we referred to summary data tables that listed all current active research projects being conducted by HDFCCC investigators as of July 1, 2016. These tables are included in annual cancer center reports required for NCI-designated cancer centers. The tables list the principal investigator, project title, funding source, project or grant number, project start and end dates, and project costs. Research project titles included both the cancer site and the purpose of the project from which we could infer its nature, whether it was at the basic, clinical, or population level.

#### UCSF Helen Diller Family Comprehensive Cancer Center catchment area

The large majority of the cases identified by the California Cancer Registry that sought care at UCSF HDFCCC resided in the 48 counties north of the east-west county boundary San Luis Obispo. The case density in this area was at least 2% and varied up to 28%. The highest case density counties were those in the San Francisco Bay Area, along the northern coast, and the central valley directly east of San Francisco. This is depicted in Web Figure 1, which shows the average yearly case density for each county during 2010–2014. When the yearly case density is plotted, this area is largely unchanged from previous years starting in 2008 (Web Figure 2). Using these metrics, we defined the UCSF HDFCCC catchment area as these 48 counties.

We found that 98% of all cases (25,580/26,080 total HDFCCC cases) served by HDFCCC in 2010–2014 resided in the above-defined catchment area. Within this area, we identified 2 nested subregions with higher case densities that could be a focus for more intense evaluation and intervention. Approximately 65% resided in the 9 Bay Area counties (Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano, and Sonoma), and 21% resided in the city and county of San Francisco itself.

Overall, HDFCCC cared for 8% of all cancer cases in northern California during the period 2010–2014. Other major health-care institutions in the same area that care for the remainder of cancer patients include the University of California, Davis, in Sacramento, the Sutter Health System in the Bay Area generally, Stanford Health Care, Dignity Health in San Francisco, and Kaiser Permanente throughout northern California. That the UCSF catchment area is thus shared does not diminish the value of characterizing the overall cancer burden in this area for the purposes of directing impactful research.

#### Cancer burden criterion 1: number of cancer cases and deaths

We ranked the top 10 cancers in our catchment area by absolute case count, among a population of 36,683,244 men and 37,067,750 women, aggregated for the time period 2009–2013. The top 10 newly diagnosed cancers for white males in order of descending incidence count were as follows: prostate, lung, melanoma, colorectal, bladder, non-Hodgkin lymphoma, kidney, oral, pancreatic, and liver cancer

(Figure 2A). For white females, they were breast, lung, colorectal, corpus uterus, melanoma, non-Hodgkin lymphoma, thyroid, ovarian, pancreatic, and bladder cancer (Figure 2B). When we stratified by race/ethnicity, there were noticeable differences. The above list generally reflects the frequencies of cancer types for whites, but for blacks, myeloma rises into the top 10 cancers for both men and women (Web Tables 1 and 2). Additionally, the burden of liver cancer is much higher for Asian, black, and Latino men, ranking in the top 5. The incidence burden of melanoma affects mostly whites because it does not appear in the top 10 for the other race/ethnicities.

For cancer deaths, the top 10 cancer deaths for white males in order of descending cancer deaths for 2009–2013 were as follows: lung, prostate, colorectal, pancreatic, liver, leukemia, lymphoma, bladder, esophageal, and brain cancer (Figure 3A). For white females, the top 10 cancer deaths were lung, breast, colorectal, pancreatic, ovarian, leukemia, lymphoma, brain, liver cancer, and myeloma (Figure 3B). However, liver cancer rises to be the second most deadly cancer for Latino and Asian men (Web Tables 3 and 4). Stomach cancer also appears in the top 10 for black, Latino, and Asian men, while it is ranked 17th for white men. Breast cancer accounts for the most cancer deaths among Latino women but remains second to lung cancer for the other race/ethnicities.

#### Cancer burden criterion 2: cancer trends 2000–2013

Cancer-screening recommendations have greatly affected US cancer incidence and perhaps mortality rates over the past several decades with mammography in the 1980s (13), Papanicolaou tests at least since the 1970s (14), fecal occult blood tests and sigmoidoscopy/colonoscopy in the 1980s (15), and prostate-specific antigen screening in the 1990s (16). From 2000 to 2013, breast cancer incidence rates have remained reasonably stable, while mortality rates have decreased (Figures 4A and 5A), cervical cancer incidence has decreased (Figure 4B), colorectal cancer incidence and mortality rates have both decreased (Figures 4C and 5C), and prostate cancer incidence and mortality have both decreased (Figures 4D and 5B). Implementation of widespread screening and improved therapies may explain these trends. However, cancer at certain sites has been increasing for unknown reasons: Pancreatic cancer incidence has been increasing steadily among Latinos and Asians (Web Figure 3), while liver cancer incidence and mortality have increased for whites, blacks, and Latinos (Web Figure 4). In the past, Asians have had the highest liver cancer rates, but their rates may be beginning to decrease. Thyroid cancer, although relatively rare, has one of the more rapidly increasing incidence rates (Web Figure 5).

#### Cancer burden criterion 3: cancer costs

For the HDFCCC catchment area, health-care costs in 2015 were highest for prostate and lung cancer among men and breast cancer among women, accounting for nearly \$2.5 billion, \$930 million, and \$940 million, respectively (Tables 2 and 3). Although there were similar numbers of incident lung cancer among men and women, health-care costs for lung

cancer are much higher for men. In general, for the same cancer, men contributed more to the total health-care costs than women. Prostate cancer, especially, stands out because of the high ratio of total to hospital expenditures, indicating that much of the cost burden may be related to care received outside the hospital. Notably, regardless of sex, colorectal cancer, despite being relatively common, contributes much less to cancer costs compared with prostate, breast, or lung cancer.

#### Cancer burden criterion 4: risk factors

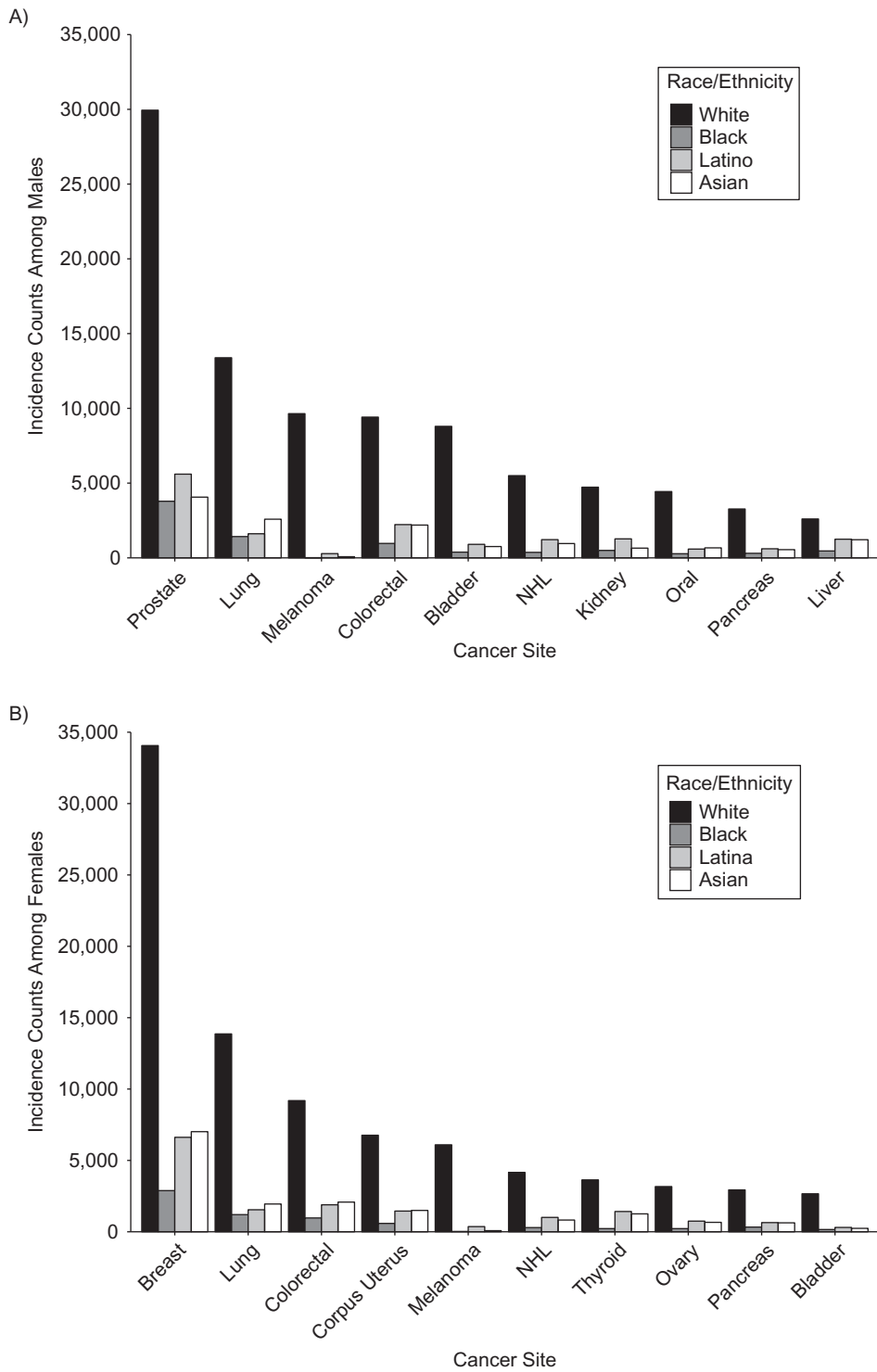
Several environmental exposures are known to cause specific cancers, such as sun exposure for melanoma and tobacco use for lung, oral cavity, bladder, esophageal, and stomach cancer (17). Other cancer sites, such as cervical and probably breast cancer, are also associated with tobacco exposure even though these tissues are not directly exposed. Decreases in prevalence of current cigarette smoking during 2000–2013 (Figure 6), particularly among females and Asian males, occurred alongside rapid decreases in lung cancer incidence and mortality during a similar time period, 2003–2014 (Figure 5D and Web Figure 6). Stomach cancer incidence and mortality follow a more gradual decrease over time (Web Figure 7). As mentioned earlier, melanoma incidence rates are increasing, particularly among white males (Web Figure 8). California Health Interview Survey data indicated that extreme sun exposure is more common among white men, who are more likely to report being sunburned at least 4–5 times in the past 12 months (Web Figure 9) than any other demographical group.

#### Cancer burden criterion 5: differences by race/ethnicity and sex

Blacks continue to experience the highest rates of mortality compared with all other race/ethnicities for the most common cancers: breast, prostate, colorectal, and lung cancer (Figure 5). This disparity has remained unchanged since 2000. Breast cancer incidence was typically highest among white females and black females, but trends indicate that although incidence rates are decreasing for whites, incidence rates for blacks, Latinos, and Asians are continuing to rise. Liver cancer incidence and mortality seem to be increasing for all race/ethnicities except for Asians (Web Figure 4). There are also cancers that are more common in whites, such as melanoma and bladder cancer incidence (Web Figures 8 and 10). For lung cancer, black:white disparities are more apparent among males than females. The ratio of incidence rates for black men versus white men is  $82.8$  to  $60.2 = 1.4$ , respectively, for the aggregated years of 2009–2013 compared with 1.1 for women (Web Tables 1 and 2).

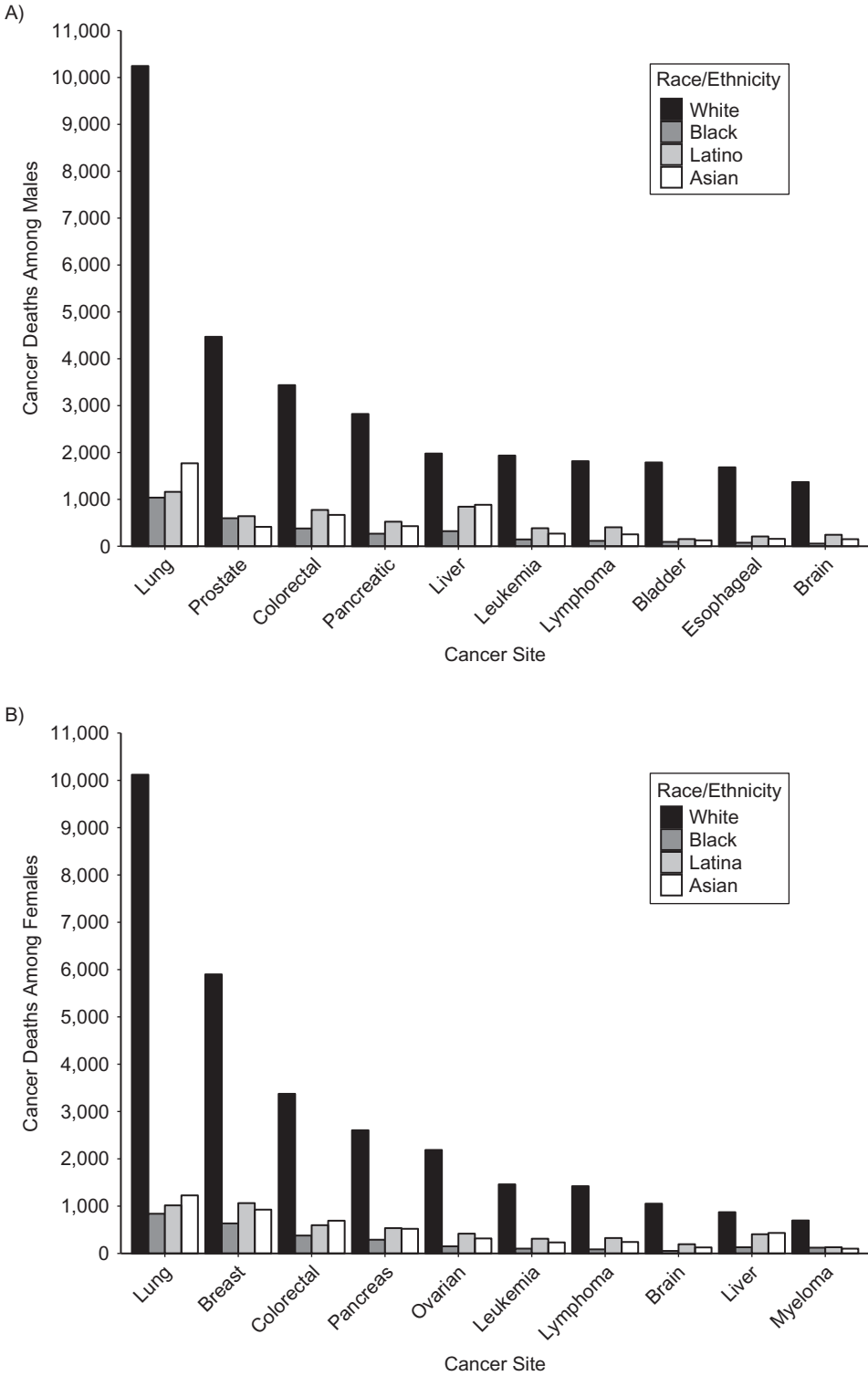
#### Research addressing cancer in the catchment area

We evaluated whether research projects conducted at HDFCCC addressed cancers of interest identified by using the cancer burden criteria described above. As expected, the first criterion, absolute counts, highlighted the most common cancers: breast, prostate, lung, and colorectal

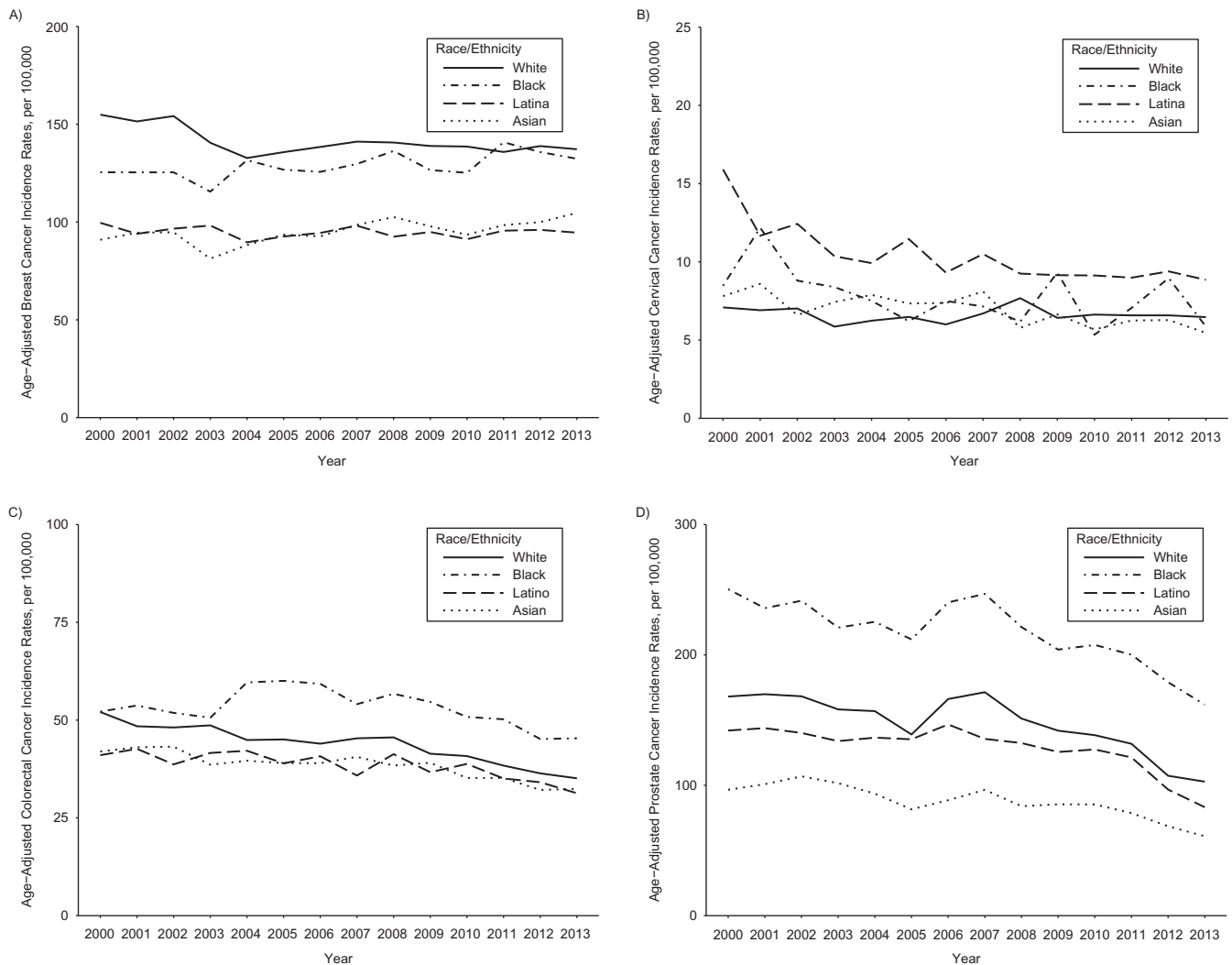


**Figure 2.** Top 10 incident cancers for the 48-county catchment area, 2009–2013. The top 10 incident cancers in the 48-county catchment area for white males (A) and white females (B) are ranked and graphed by number of incident cancer cases, aggregated across years 2009–2013. The numbers of cases for each cancer are also shown by race/ethnicity. Note that the top 10 cancers for whites may not be the top 10 cancers for the other race/ethnicities. NHL, non-Hodgkin lymphoma.





**Figure 3.** Top 10 cancer deaths for the 48-county catchment area, 2009–2013. The top 10 cancer deaths in the 48-county catchment area for white males (A) and white females (B) are ranked and graphed by number of cancer deaths, aggregated across years 2009–2013. The numbers of deaths for each cancer are also shown for the other race/ethnicities. Note that the top 10 cancers for whites may not be the top 10 cancers for the other race/ethnicities.



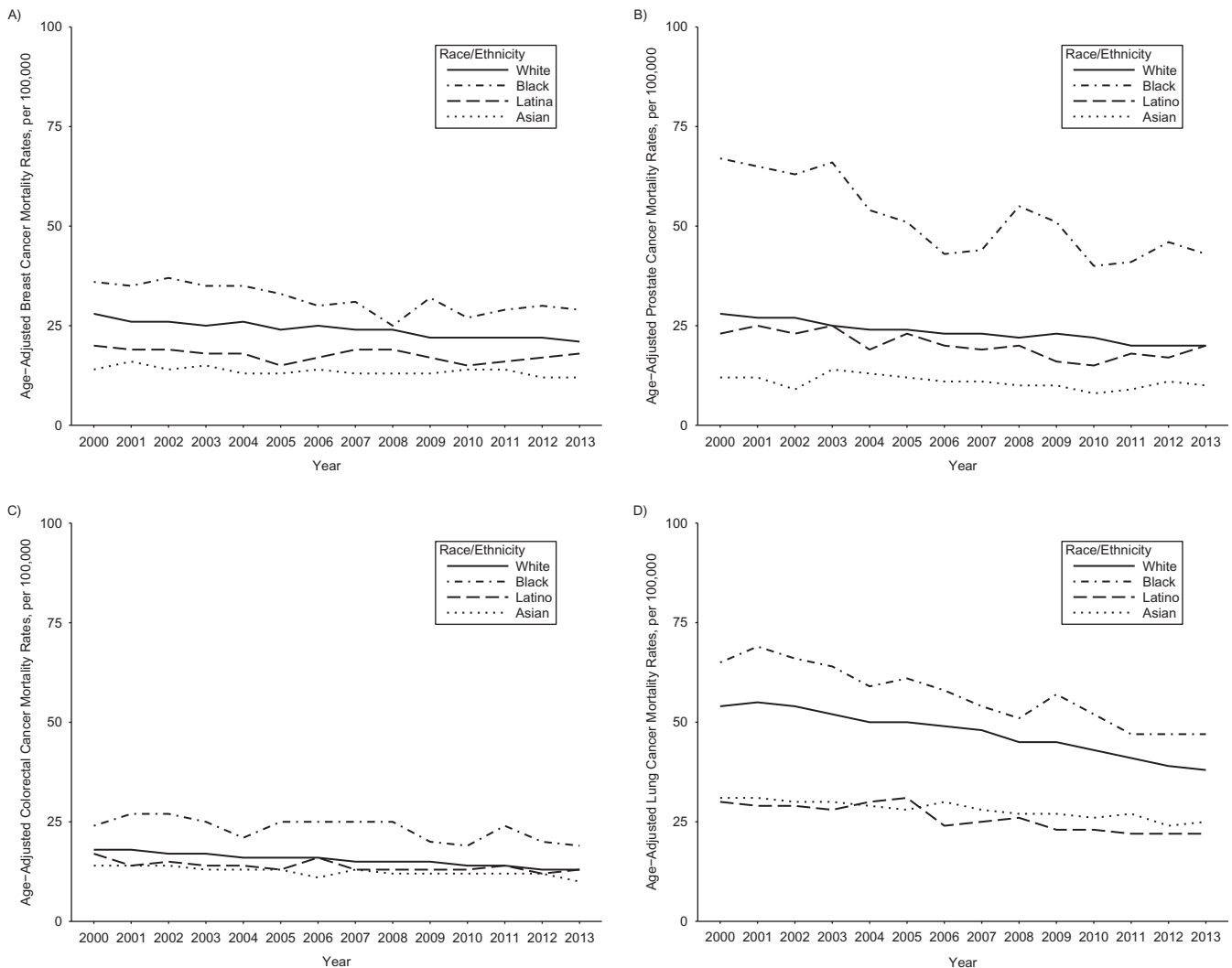
**Figure 4.** Cancer incidence rate trends for cancers with widespread screening tests in the 48-county catchment area, 2000–2013. Cancer incidence rates for 2000–2013 are shown for cancers with widespread screening tests: breast cancer among females only (A), cervical cancer among females only (B), colorectal cancer among males and females combined (C), and prostate cancer among males only (D).

cancers. On the basis of the absolute number of incident cancer cases and cancer deaths, these 4 common cancers should continue to remain a priority in the research portfolio for HDFCCC.

The second criterion, cancer trends, reaffirmed the importance of continued research in prostate, breast, and colorectal cancer as well as the past successes in decreasing lung cancer and cervical cancer rates. HDFCCC currently has site-specific research programs focusing on breast and prostate cancer. Current research projects span the entire cancer-control continuum from discovery to screening, to treatment, and to population-based interventions. These include investigating mammalian target of rapamycin (mTOR) biomarkers for prostate cancer (NCI grant R01CA154916), exploring the myelocytomatosis gene (*myc*)-driven cell cycle progression for aggressive prostate cancer (UCSF project A126205), measuring the effect of aerobic exercise

on genomic signatures of prostate cancer tumors (NCI grant R01CA181802), and evaluating risk-based cancer screening (NCI grant P01CA154292) in community settings.

We also observed adverse trends for liver, pancreatic, and thyroid cancer incidence. The cause for these recent increases is not yet clear and strongly calls for higher prioritization in research for these cancers. HDFCCC has not developed a site-specific research program around these cancers. However, a gastrointestinal site committee coordinates liver and pancreatic cancer research, which includes identifying molecular genetic markers for liver cancer (NCI grant R01CA136606), investigations into epigenetic regulation of pancreatic cancer (NCI grant R01CA172045), and comparisons of different treatments (NCI grant R21CA184429), including several randomized clinical trials (ClinicalTrials.gov identifiers: NCT01844817, NCT02465983, NCT02399137, NCT01764477). HDFCCC researchers can be encouraged to expand their current



**Figure 5.** Cancer mortality rate trends for the 4 most common cancers in the 48-county catchment area, 2000–2013. Cancer mortality rates for 2000–2013 are shown for the 4 most common cancers: breast cancer among females only (A), prostate cancer among males only (B), colorectal cancer among males and females combined (C), and lung cancer among males and females combined (D).

research to include thyroid cancer when exploring biological pathways and their therapeutic products relevant to multiple cancers. Some HDFCCC researchers have already begun exploring the pleiotropic effects of genetic risk factors, such as retrovirus-associated DNA sequence gene (*ras*) mutations in skin and lung cancer (NCI grant R01CA184510).

The third criterion, cancer costs, indicated that prostate, lung, breast, and colorectal cancers account for \$4.6 billion of the \$6.7 billion in health-care costs for the 48-county catchment area (Tables 2 and 3). Screening practices are an important driver of cost. HDFCCC researchers are conducting studies to improve mammography screening and surveillance regimens, comparing personalized versus annual screening for breast cancer (ClinicalTrials.gov identifier NCT02620852) and evaluating different surveillance modalities in breast

cancer survivors (ClinicalTrials.gov identifier NCT02212834). For prostate cancer, researchers are evaluating active surveillance in low-risk patients and identifying inherited genetic variants that predict failure of active surveillance (NCI grant P50CA180995).

The fourth criterion, changes in behavioral and environmental risk factors, showed parallel trends between known cancer-causing exposures and their relevant cancer sites, such as tobacco use and lung cancer. However, it also highlighted subgroups requiring more targeted smoking cessation programs or uptake prevention. Smoking prevalence remains higher among men than women, especially among black males (Figure 6). To further investigate this issue, HDFCCC researchers are evaluating the economic impact of tobacco taxes in African-American populations (UCSF project 22RT-0112) and investigating the disparities in

**Table 2.** Health-Care Costs of Cancer in Males Only for the 48-County Catchment Area in 2015

Cancer	ICD-9 Code	2009 Hospital Discharges, no. <sup>a</sup>	2009 Mean Hospital Charge per Discharge, US\$ <sup>a</sup>	2009 Converted to 2015 Charges, US\$ <sup>b</sup>	2015 Charges Converted to Costs, US\$ <sup>c</sup>	Incidence 2009–2013 <sup>d</sup>	Average Annual Incidence	Total Hospital Costs, US\$	Ratio of Total Health Care to Hospital Expenditures <sup>e</sup>	Total Health-Care Costs for California Incident Cancer Cases, US\$ <sup>f,g</sup>
Prostate	185	2,676	64,150	70,425	19,135	45,525	9,105	174,219,751	14.0	2,439,076,509
Lung	162	1,994	107,193	117,678	31,973	19,221	3,844	122,911,526	7.6	934,127,596
Colorectal	153–154	2,069	123,077	135,116	36,711	15,066	3,013	110,617,688	1.3	143,802,995
Bladder	188	801	83,559	91,732	24,924	11,090	2,218	55,280,752	4.1	226,651,083
Melanoma	172	95	65,426	71,826	19,515	10,824	2,165	42,246,253	5.9	249,252,893
NHL	200, 202	771	145,528	159,763	43,408	8,223	1,645	71,388,175	4.1	292,691,518
Kidney	189	956	103,668	113,809	30,922	7,276	1,455	44,997,548	4.1	184,489,949
Oral	140–149	429	127,051	139,479	37,896	6,084	1,217	46,112,363	4.1	189,060,690
Liver	155	637	97,429	106,960	29,061	5,636	1,127	32,757,464	4.8	157,235,826
Pancreas	157	585	125,396	137,662	37,403	4,774	955	35,712,273	2.3	82,138,228

Abbreviations: ICD-9, *International Classification of Diseases, Ninth Revision*; NHL, non-Hodgkin lymphoma; OSHPD, Office of Statewide Health Planning and Development.

<sup>a</sup> From 2009 OSHPD hospital discharge data.

<sup>b</sup> Using the ratio of the gross domestic product deflator for 2009 and 2015 (100.00 and 109.782); 2015:2009 ratio = 1.09782.

<sup>c</sup> Using the OSHPD 2012 cost:charge ratio = 0.2717.

<sup>d</sup> Data from the California Cancer Registry.

<sup>e</sup> Ratios were derived from the 2013 Medical Expenditures Panel Survey. Separate ratios were calculated for each cancer and by sex. For cancers with no cases, we used the ratios for all cancers combined or the ratios from 2011 if available. Total health-care expenditures include inpatient hospitalizations, office visits, outpatient visits, emergency department visits, medications, and home health care.

<sup>f</sup> Estimated as the California hospital costs × the US total health-care expenditures:US hospital costs ratio.

<sup>g</sup> Total costs = \$4,898,527,285.

**Table 3.** Health-Care Costs of Cancer in Females Only for the 48-County Catchment Area in 2015

Cancer	ICD-9 Code	2009 Hospital Discharges, no. <sup>a</sup>	2009 Mean Hospital Charge per Discharge, US\$ <sup>a</sup>	2009 Converted to 2015 Charges, US\$ <sup>b</sup>	2015 Charges Converted to Costs, US\$ <sup>c</sup>	Incidence 2009–2013 <sup>d</sup>	Average Annual Incidence	Total Hospital Costs, US\$	Ratio of Total Health Care to Hospital Expenditures <sup>e</sup>	Total Health-Care Costs for California Incident Cancer Cases, US\$ <sup>f,g</sup>
Breast	174	2,967	52,816	57,982	15,754	51,285	10,257	161,586,501	5.8	937,201,706
Lung	162	1,937	101,994	111,971	30,423	18,729	3,746	113,956,643	2.2	250,704,614
Colorectal	153–154	2,050	107,264	117,757	31,995	14,363	2,873	91,907,402	1.2	110,288,882
Corpus uterus	179	80	76,381	83,853	22,783	10,455	2,091	47,638,821	2.0	95,277,642
Melanoma	172	70	57,448	63,068	17,136	7,228	1,446	24,771,228	3.6	89,176,420
Thyroid	193	784	45,014	49,417	13,427	6,652	1,330	17,862,785	1.9	33,939,292
NHL	200, 202	572	154,314	169,409	46,029	6,425	1,285	59,146,694	2.8	165,610,742
Ovary	183	827	100,022	109,806	29,834	4,839	968	28,873,574	1.9	54,859,790
Pancreas	157	588	101,595	111,533	30,304	4,568	914	27,685,410	1.3	35,991,033
Kidney	189	589	91,135	100,049	27,183	4,091	818	22,241,453	1.9	42,258,761

Abbreviations: ICD-9, *International Classification of Diseases, Ninth Revision*; NHL, non-Hodgkin lymphoma; OSHPD, Office of Statewide Health Planning and Development.

<sup>a</sup> From 2009 OSHPD hospital discharge data.

<sup>b</sup> Using the ratio of the gross domestic product deflator for 2009 and 2015 (100.00 and 109.782); 2015:2009 ratio = 1.09782.

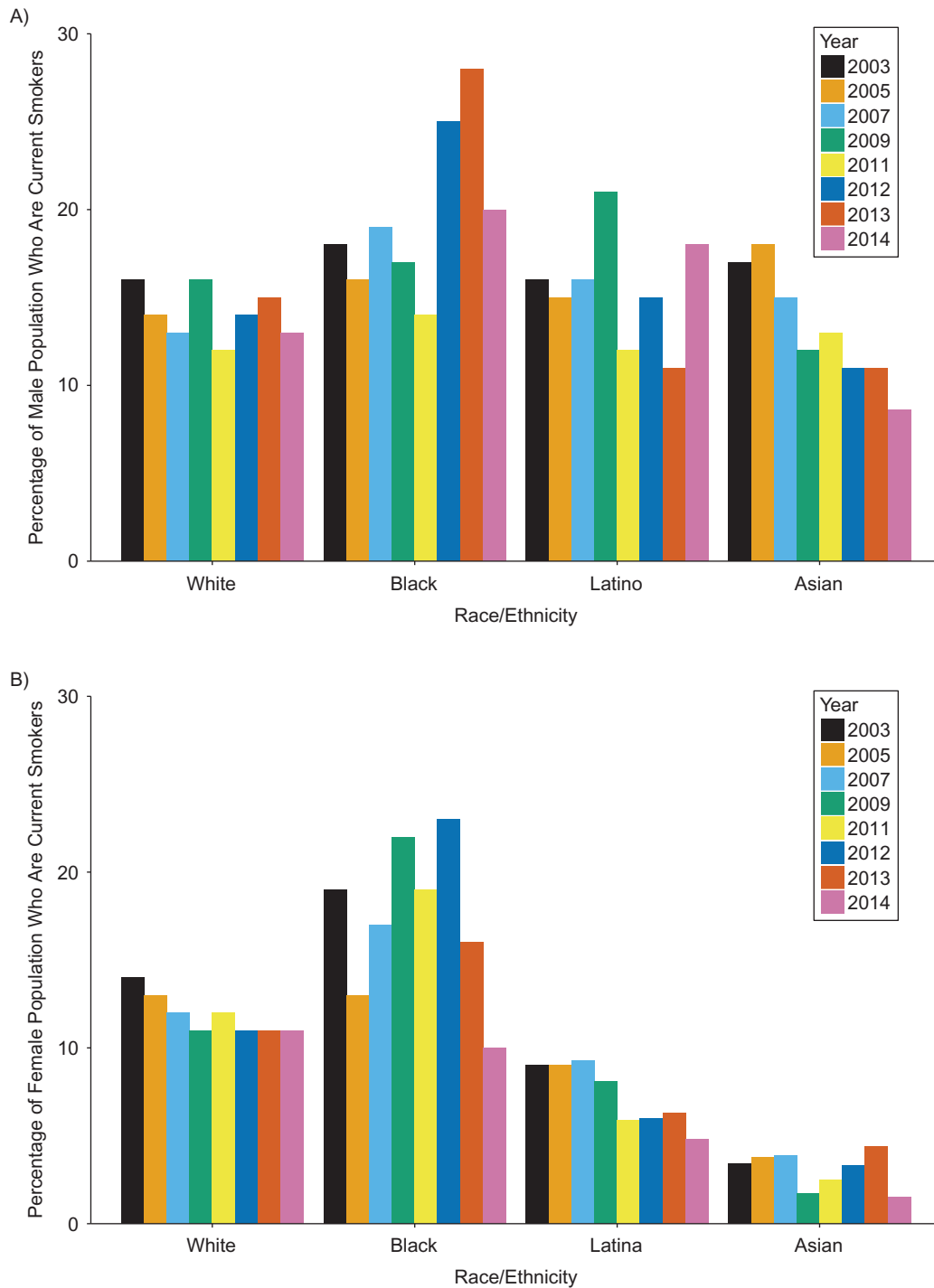
<sup>c</sup> Using the OSHPD 2012 cost:charge ratio = 0.2717.

<sup>d</sup> Data from the California Cancer Registry.

<sup>e</sup> Ratios were derived from the 2013 Medical Expenditures Panel Survey. Separate ratios were calculated for each cancer and by sex. For cancers with no cases, we used the ratios for all cancers combined or the ratios from 2011 if available. Total health-care expenditures include inpatient hospitalizations, office visits, outpatient visits, emergency department visits, medications, and home health care.

<sup>f</sup> Estimated as the California hospital costs × the US total health-care expenditures:US hospital costs ratio.

<sup>g</sup> Total costs = \$1,815,308,882.



**Figure 6.** Tobacco use trends in the 48-county catchment area, 2000–2013. California Health Interview Survey data show the percentage of the population reporting current smoker status separately for males (A) and females (B) during the years, 2003–2014.

quitting rates between blacks and whites (National Institutes of Health grant R01DA031815). Additionally UCSF researchers in the HDFCCC Tobacco Program conduct health policy research on tobacco use and tobacco industry practices (NCI grant R01CA087472).

Finally, the fifth criterion, differences by race/ethnicity and sex, was assessed within the first, second, and fourth criteria. Multiple observations of disparities by race/ethnicity were observed in the catchment area, and this has spurred numerous research questions about the underlying reasons for these

differences, whether they are due to social, cultural, and environmental determinants, health-care access and quality issues, or underlying biological differences. Much of this research is pursued by investigators in cancer control and prevention, who work directly with communities in the catchment area, but clinical research has also been directed to understand differential therapeutic responses, and basic research seeks to understand the mechanisms that may differ by race and ethnicity. Several research projects at HDFCCC focus on understanding the observed high cancer rates among blacks, including the identification of biomarkers for aggressive disease (Department of Defense grant W81XWH-15-1-0395).

Another way that cancer centers provide evidence that they are serving the populations in their catchment area is by evaluating how well clinical trial accrual proportions match the demographics of the catchment area (5). For HDFCCC, with 2013 data, the proportion of patients enrolled in clinical trials closely reflects the demographical makeup of the 48-county catchment area; in therapeutic trials, the percentages for blacks and Asians are 4.2% versus 5.6% and 12.2% versus 12.2%, respectively (Table 4). However, there are an overrepresentation of whites and an underrepresentation of Latinos. Similar patterns were seen for the nontherapeutic intervention trials (Table 4). It is important to note that these percentages are not age adjusted and that the 13.5% Latino population in the catchment area may represent younger Latinos (aged < 65 years) who are not expected to have developed cancer and be eligible for such clinical trials.

In addition to individual investigator projects, the HDFCCC has formed the San Francisco Cancer Initiative, a long-term effort to address the cancer burden in the heart of its catchment area (<http://www.sfcancer.org>). The San Francisco Cancer Initiative is a novel coordinated effort to target breast, colorectal, prostate, and liver cancer, as well as lung and other tobacco-induced cancers across all health-care systems in the city. This effort seeks to make collective impact by building a partnership between the Department of Public Health, HDFCCC, other health-care systems, community clinics, and advocacy groups. For feasibility, this effort will focus on San Francisco County and start with these first 5 programs with the intention to expand to other cancer sites and areas after

proof of concept and impact can be established. The project is a prime example of a data-driven effort to apply effective interventions to implement change in a defined population base.

After a cancer center has conducted its analysis and identified cancer sites of interest or populations to target for further research and interventions, cancer center investigators can be encouraged to pursue these research questions through various incentives. Research projects might aim to either explain adverse trends or to develop interventions to reduce disparities and costs. The approach advanced in this article highlights cancer sites, trends, disparities, behaviors, and costs that are the major contributors to the catchment area cancer burden, but it does not encompass all relevant cancer sites or all research questions with which a cancer center should be concerned. Together, the 5 criteria for the cancer burden provide a detailed picture on the pattern of cancers in the HDFCCC catchment area. However, as mentioned above, additional criteria might be added to provide further insights. For example, 2 areas of interest to HDFCCC not picked up from the data we used were the impact of human immunodeficiency virus-related malignancies and cancers among the large lesbian, gay, bisexual, and transgender (LGBT) community in the San Francisco region.

It is worth mentioning that HDFCCC, similar to other cancer centers, will in some cases serve a much larger and more dispersed population as a quaternary referral center. HDFCCC has served patients from all over the country and internationally in brain cancer treatment for many years. Brain cancer does not represent a cancer with a large burden in the catchment area according to the 5 criteria and is, therefore, an exception to this approach. Nevertheless, in these cases the needs of the larger community can still be identified and addressed in the research agenda to take advantage of the institution's unique expertise.

## DISCUSSION

We have reviewed efforts to use descriptive epidemiologic data to define the cancer burden in a defined geographical area. There are few examples of this kind of analysis in the literature despite an increased emphasis on the relevance of

**Table 4.** UCSF Cancer Cases and Clinical Trial Accruals Compared With Catchment Area Cases by Race/Ethnicity in 2013

Race/Ethnicity	48-County Catchment Area		UCSF Cancer Cases		UCSF Therapeutic Clinical Trial Accruals		UCSF Nontherapeutic Clinical Trial Accruals	
	No. of Cases	% of Total	No. of Cases	% of Total	No. of Cases	% of Total	No. of Cases	% of Total
White	44,033	66.0	4,468	68.5	597	72.9	811	72.7
Latino	8,986	13.5	728	11.2	72	8.8	103	9.2
Black	3,736	5.6	325	5.0	34	4.2	54	4.8
Asian or Pacific Islander	8,122	12.2	844	12.9	100	12.2	124	11.1
Other/not reported	1,862	2.8	160	2.5	16	2.0	23	2.1
Total	66,739	100.1	6,525	100.1	819	100.1	1,115	99.9

Abbreviation: UCSF, University of California, San Francisco.

catchment areas to the cancer research enterprise sponsored by the NCI. We found only 4 studies that fit our search criteria. However, there are examples that exist outside of the peer-reviewed literature, such as Community Health Assessments (CHNAs) that should be discussed to supplement our review. Tax-exempt hospitals, many of which are part of or associated with NCI-designated cancer centers, conduct CHNAs to inform their community service plan, and these documents are often required by state or local health departments or by law.

We highlight 3 CHNAs as supplementary examples. The Dana-Farber Cancer Institute defined the city of Boston, Massachusetts, and select priority neighborhoods as its catchment area. Its catchment area is based on institution location, but its prioritization of certain neighborhoods was based on population size, race/ethnicity, income, education, and crime rates. Dana-Farber described its catchment area by using cancer surveillance metrics, demographics, socioeconomic characteristics, measures of housing and the built environment, and crime rates. This was accomplished with public health surveillance data (e.g., cancer registry, Boston Behavioral Risk Factor Survey, state vital statistics, discharge data, US census). Qualitative data from focus groups and interviews conducted with community members and key informants were also used to characterize perceived needs in this catchment area (18).

The Seattle Cancer Care Alliance defined its catchment area as the 3 counties where most of its patients reside. Exact thresholds were not reported. It then described the demographics, prevalence of risk factors, and site-specific cancer incidence and mortality of these counties by using data from the US census, death certificates, cancer registry, and the Behavioral Risk Factor Surveillance System (19).

Memorial Sloan-Kettering defined a 23-county catchment area that includes all New York City boroughs and sections of New York State, New Jersey, and Connecticut. The rationale for how the catchment area was defined was not provided. Memorial Sloan-Kettering described the cancer burden in this area by using data gathered from an online survey sent to community members and patients that asked questions about respondents' knowledge and perceptions around cancer care and prevention. Cancer statistics were not reported for this catchment area (20).

These select example CHNAs show that catchment areas are often well defined, but the rationale for how they were defined is not always given. Our review revealed that existing spatial analysis methods often used in public health to answer questions about clusters of disease or disparities can be useful for defining a catchment area. However, not all cancer centers have the same resources to use these approaches. Tools such as SaTScan (a trademark by Dr. Martin Kulldorff, Harvard Medical School and Harvard Pilgrim Health Care Institute, Boston, Massachusetts) may allow these methods to be more widely applied, but other approaches based on patients' place of residence, market share, and institutional location continue to exist and are also reasonable methods (4).

Data used to characterize cancer burden include both qualitative and quantitative data, in the form of public health survey data and cancer surveillance data. Metrics describing socioeconomic, structural, and public safety characteristics of the catchment area, such as those used by the Dana-Farber

Cancer Institute, can bring attention to previously unrecognized needs in a cancer center's catchment area. This awareness could motivate researchers to investigate previously unexplored sources of cancer disparities.

In the case study we presented for HDFCCC, we used several publicly available data sources to describe the population burden of cancer. We used a case density approach to define a 48-county catchment area for HDFCCC and systematically defined cancer sites of interest based on 5 burden criteria. The current HDFCCC research portfolio addresses most of these cancers, but emerging trends and persistent disparities will require future research. This example extends the use of epidemiologic surveillance data to determine cancer sites of interest that may be unique to the population served. By clearly establishing a goal to inform the research agenda across basic and clinical research, as well as population-level research beyond community outreach and engagement efforts, this approach expands previous work by cancer centers' CHNAs and community service plans.

In this paper, we have described several approaches taken by a limited number of cancer centers that have been published. However, not all cancer centers are the same, and different methods may be needed depending on the nature of a particular center. Some centers stand alone in a large geographical area; others may be 1 of several in a single urban area. Some may be referral centers and draw patients from a distance; others are more likely to serve a local area only. In most cases, however, a logical means of identifying a geographically bound area from which individuals and patients come to a cancer center can be defined. Likewise, publicly available surveillance and survey data can be used to describe the particular nature of the cancer burden in that area.

There may be limitations to the approach we have presented. We defined our catchment areas on the basis of case density, which can vary over time, and boundaries may need to be redrawn when a cancer center adds new services or medical expertise. Some cancer centers may find that a majority of their patients reside outside their immediate geographical area, state, or defined catchment area. In this case, it may be more effective to identify cancer sites that the center specializes in and for which patients are referred. Such centers may choose to then focus on characterizing the burden for these selected cancer sites. Nevertheless, these limitations do not detract from the basic approach or the fundamental value of using such an approach to define and serve the needs of patients and individuals in the region.

Although all the studies presented in this paper, including our own example, used counties as the smallest unit of observation, other smaller but well-defined areas could also be used, such as zip codes or services areas (21, 22). Because health departments often serve states or counties, data are typically evaluated at the state or county level for public health efforts. However, cancer centers are not often confined by such boundaries. Krieger et al. (23) have shown that socioeconomic metrics can be used to define areas of interest within a geographical area rather than simply using county boundaries.

Future directions can explore socioeconomic differences, quality measures (e.g., time from screening to diagnosis), and other factors to identify new areas of research that can be encouraged through internal cancer center funding mechanisms.

Our example presents an approach that cancer centers can take to align the research they conduct with the needs of the populations they are charged with serving. Health departments may also find these criteria helpful for strategic planning for the cancer preventive services they provide. Through these efforts, we can take a more precise approach to having an impact on the cancer burden and improving both patient and population health.

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