

Black-White Disparities in Breast Cancer Outcomes in the Surveillance Epidemiology
and End Results (SEER) of the United States and in Michigan: The Role of
Neighborhood and Individual Healthcare Access

by

Omotomilayo F. Akinyemiju

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Dissertation Committee:

Associate Professor Amr S. Soliman, Chair
Professor Sofia D. Merajver
Associate Professor Allison Elizabeth Aiello
Research Professor Mousumi Banerjee
Professor Kendra L. Schwartz, Wayne State University

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DEDICATION

This dissertation is dedicated to my boys. May your lives be an illustration of the transcendence of barriers, filled with health, wealth and happiness.

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List of Abbreviations

SEER	Surveillance Epidemiology and Ends Result
ER	Estrogen Receptor
PR	Progesterone Receptor
SES	Socio-Economic Status
FDA	Food and Drug Administration
BRFSS	Behavioral Risk Factor Surveillance System
MEPS	Medical Expenditure Panel survey
USPSTF	United States Preventive Services Task Force
BC	Breast Cancer
NLMS	National Longitudinal Mortality Study
ARF	Area Resource File
FOI	Freedom of Information
FIPS	Federal Information Processing Standard
PCA	Principal Component Analysis
DO	Osteopathic Doctors
ICE	Index of Concentration in the Extremes
SCBRFS	Special Cancer Behavioral Risk Factor Survey
CBE	Clinical breast examination
MDCH	Michigan Department of Community Health
HCA	Healthcare Access

MCSP	Michigan Cancer Surveillance Program
AAPC	Average Annual Percent Change
APC	Annual Percent Change
NBCCEDP	National Breast and Cervical Cancer Early Detection Program
BCCCP	Michigan Breast and Cervical Cancer Control Program

ABSTRACT

Breast cancer incidence and mortality rates have declined in the US for the past 10-15 years, but the decline has been larger in white women compared with blacks. The causes of racial disparities in breast cancer outcomes have been attributed to biological factors, socio-economic status (SES), and healthcare access (HCA). However, research suggests that when examining social determinants of diseases, it is important to consider both individual and neighborhood level factors. This area of research has received little attention in explaining racial disparities in breast cancer. Therefore, this dissertation aimed to examine the impact of SES and HCA at the individual and neighborhood levels on racial disparities in breast cancer screening, mortality, and survival. First, the impact of SES and HCA at the individual and county levels on breast cancer screening rates among blacks and whites in Michigan was examined using data from the Special Cancer Behavioral Risk Factor Survey. The most important predictors of adequate breast cancer screening were having health insurance and a usual healthcare provider. Second, the impact of individual SES and HCA on breast cancer survival among black and white women was assessed using the linked dataset of U.S. Surveillance, Epidemiology, and End Results (SEER) and National Longitudinal Mortality Study (NLMS). Initial racial differences in survival disappeared after adjusting for socio-demographic and treatment variables. Finally, the annual age-adjusted breast cancer mortality rate and percent late

stage trends in Michigan from 1992-2009 by zip-code SES and HCA was examined using cancer surveillance data from the Michigan Department of Community Health. Black women in Michigan had consistently higher mortality rates and late stage of presentation compared with white women, regardless of neighborhood SES and HCA. White women had increasing rates of late stage presentation, likely due to lower screening rates resulting from lack of health insurance given the high unemployment rates in Michigan. These findings suggest that increasing access to timely screening and treatment among uninsured populations may improve breast cancer outcomes for all population groups regardless of race and socio-economic status.

CHAPTER 1

INTRODUCTION: BACKGROUND AND SPECIFIC AIMS

I. BREAST CANCER EPIDEMIOLOGY

Breast cancer is the most common female cancer in the US. In 2012, an estimated 226,870 new cases were diagnosed in the US, accounting for 29% of all diagnosed cancers in the US (1). The age adjusted incidence rate of breast cancer in the US was 122.9 per 100,000 women between 2003 and 2007, and the age-adjusted mortality rate was 24 per 100,000 in the same time period (2). The median age of diagnosis was 61 years, and about a quarter of all breast cancer cases in the US were diagnosed between the ages of 55 and 64.

Breast cancer incidence and mortality rates have declined steadily in the US for the past 10-15 years. Between 1998 and 2007, breast cancer incidence rates declined by about 1.7% and breast cancer mortality rates declined by 2.2% between 1990 and 2007 (3, 4). The decline in breast cancer incidence rate has been mostly in women younger than age 50, which is unexpected given the increased proportion of older age (35-44 years) at first childbirth, a risk factor for breast cancer. (3). However, research suggests that the risk associated with the increase in age of first birth has been counteracted by the

increasing prevalence of obesity, a possible protective risk factor for breast cancer among pre-menopausal women (4, 5). Obesity is believed to be protective in pre-menopausal women due to lower levels of circulatory steroid hormones (6, 7).

The 5-year relative survival rate for breast cancer between 1999 and 2006 was 89% (8). However, stage at diagnosis is an important predictor of survival. Diagnosis at early stages of the disease with appropriate treatment increases the survival rate. When breast cancer is diagnosed at the localized stage when the disease is confined to the primary site, the 5-year relative survival was 98%; at the regional stage when the disease has spread to regional lymph nodes, the 5-year relative survival was 84%; at the distant stage when the cancer has metastasized, 5-year relative survival is only 23% (2). Fortunately, the majority of breast cancer cases (about 60%) are diagnosed at the localized stage, compared with 33% at the regional stage, and 5% at the distant stage (2).

Breast cancer incidence and mortality rates show marked differences between racial groups in the US as reflected in Figure 1.1 (2). Among white women, the breast cancer incidence rate was 126.5 per 100,000 and the mortality rate was 23.4 per 100,000 between 2003 and 2007(8). For black women, during the same period, the breast cancer incidence rate was 118.3 per 100,000 and the breast cancer mortality was 32.4 per 100,000(8). Since the 1990s, breast cancer mortality has declined, but unevenly by racial group; breast cancer mortality declined by 2.4% annually among white women and by 1.1% per year among black women (4). By 2002, black women had a 37% higher breast cancer mortality rate than whites compared to the rates of 1980s, even though mortality rates were roughly equal in the 1980s.

Receiving timely mammography screening ensures that breast cancer is detected at an early stage where treatment is most effective, and survival rate is highest (9). Studies suggest that mammography utilization rates have been similar between blacks and whites in the past decade (10, 11). However, racial disparities in early detection still exist. Between 1995 and 2001, 43% of black women were diagnosed at regional or distant stage compared with 43% in American Indian/Alaska Natives, 42% in Hispanics, 34% in Asian Americans, and only 33% among white women (4). Between 1999 and 2006, 60% of all breast cancer cases were detected at the localized stage, corresponding to a 5-year survival rate of 98% (2).

Breast cancer survival shows similar disparities between blacks and whites. Between 1995 and 2001, the breast cancer 5-year survival rate among white women was 90%, while for black women 5-year survival was about 77% (4). Survival rate has increased for both white and black women over time; however the increase in black women has been smaller. Survival for patients diagnosed at the localized stage increased from 90% to 98% for whites and from 84% to 92% for blacks. For cases diagnosed at the regional stage, survival increased from 68% to 82% in whites and from 55% to 68% in blacks. Among distant stage diagnoses, survival increased from 18% to 27% in white women, and from 15% to 16% in blacks (4).

Given these stark disparities in breast cancer stage, mortality and survival between black and white women in the US, it is necessary to examine some of the factors that contribute to the worse outcomes among black women. The next section focuses on some of the major research areas that have been explored in the published literature.

II. CAUSES OF RACIAL DISPARITIES IN BREAST CANCER

Significant amounts of research have been devoted to understanding the underlying causes of the observed racial disparities in breast cancer in the US. However, the picture is very complex and multidimensional. Existing studies have identified biological mechanisms such as genetics and tumor biology; social mechanisms such as socio-economic status; and cultural mechanisms such as mistrust of the medical system and fear of the unknown.

Genetics: Research has investigated the role of genetic characteristics as a possible contributor to racial disparities in breast cancer mortality and survival. Mutations in the BRCA1 and BRCA2 genes predispose women to a more aggressive, and fast growing form of breast cancer (31). Furthermore, these BRCA mutations increase lifetime risk of developing cancers. Among carriers of the BRCA1 and BRCA2 genes, the risk of developing breast cancer by the age of 70 is about 54% and 49% respectively (12). However, studies have shown that less than 10% of all breast cancer cases show this genetic characteristic (13), with black women less likely to have the BRCA1 and BRCA2 mutations when compared with white women in the US(14, 15). This distribution implies that genetics probably do not fully explain the black-white disparities in breast cancer outcomes. Despite the low prevalence of BRCA mutations in US women, efforts are being made to encourage women to learn about their family history of breast cancer, and if warranted, undergo genetic counseling and screening. The impact of increased genetic screening and early detection on black-white breast cancer statistics among women with the BRCA gene mutations, if any, remain to be seen.

Tumor Biology: In addition to racial differences in the genetic profile of breast cancer, differences also exist in tumor biology between black and white women (16-18).

Population based studies in the US using data from the Surveillance Epidemiology and End Results (SEER) registry suggests that black women were more likely than whites to be diagnosed with higher grade breast cancer (19), and diagnosis at higher grades is associated with lower survival rates. Furthermore, breast cancer cases that are estrogen receptor (ER)-positive and progesterone receptor (PR) positive have better prognosis compared with cases that are ER and PR negative (20). Black women are more likely to have ER and PR negative breast cancer (20, 21). These tumor characteristics persisted even after adjusting for age of onset and stage at diagnosis. Despite the evidence supporting a more aggressive form of breast cancer in black women, it remains unclear if such differences are the result of an endogenous characteristic, or whether exogenous factors such as social or socio-economic characteristics also play an important role in breast cancer tumor subtypes.

Socio-Economic Status: Other studies have examined the role of socio-economic status (SES) in explaining the black-white disparity in breast cancer outcomes in the US (22-27). Individual level SES is defined using different variables in the literature such as income, education, health insurance status, occupation and social class (25-27). These studies conclude that being poor is a major predictor of late stage of disease at presentation and mortality regardless of race, although blacks are more likely to be poor. However, a major limitation of most research studies assessing the impact of SES on breast cancer mortality differences between blacks and whites is the lack of individual level SES data in most US cancer registries. Neighborhood level SES measures are used

as a proxy for individual SES and after adjusting for other demographic and disease characteristics, it appears that women residing in poor neighborhoods have worse breast cancer outcomes than women residing in non-poor neighborhoods (28, 29).

Multi-level studies assessing both individual and neighborhood level SES measures suggests that poor individual SES due to low education and high poverty as well as poor neighborhood SES due to low community education are associated with increased breast cancer mortality after adjusting for screening and stage of presentation (25). Furthermore, race and poverty appear to be independent significant predictors of higher breast cancer incidence among US women (30). White women residing in affluent areas have higher breast cancer incidence rates compared with those residing in poorer areas, regardless of age (4). Incidence rates are also higher among white women compared with blacks regardless of county poverty level for those ages 50 and older. The lowest incidence of breast cancer is observed among black women residing in poor areas (4). This is likely due to differences in the prevalence of breast cancer risk factors such as age at first birth, hormone replacement therapy and obesity.

Based on these research areas, a clearer picture is emerging about the distribution and determinants of breast cancer incidence and mortality. This picture incorporates the complex social, biological, psychological and genetic differences between ethnic subgroups of patients. Advances in medical care have made breast cancer a disease that is no longer a death sentence if detected early. However, these benefits appear to be restricted to mostly affluent, white women. It is therefore important to continue to focus on understanding the factors that may place specific population groups, such as low-income and black women, at a disadvantage. It is also necessary to explore the role of

race as a proxy for socio-economic and healthcare access factors that influence the seeking and/or receiving of adequate and timely cancer preventive care and treatment among women in the US (31, 32). Understanding the determinants of the black-white disparities in breast cancer outcomes can help in tailoring the best medical care for all breast cancer patients and reducing mortality for all groups, regardless of race or income.

The next section is focused on examining the literature on healthcare access in the US and the evidence for significantly worse outcomes among patients who lack healthcare access. This is an area of study that has not received extensive focus in relation to breast cancer outcomes.

III. HEALTHCARE ACCESS

A close assessment of the breast cancer and SES literature suggests that an intermediary factor between SES and poor breast cancer outcomes that has not received enough attention is healthcare access. Theoretically, low SES may influence breast cancer outcomes through lack of access to care. This is evidenced by low mammography screening rates observed in poor women resulting in later stage at diagnosis (10), or lack of timely and appropriate treatment that may be caused by lack of healthcare insurance or other competing priorities among poor women (27). Lack of timely and adequate access to care may be the missing link between poor SES and higher breast cancer mortality among black women, and exploring this connection will be the major focus area of this dissertation.

Defining Healthcare Access

Since the 1970s, a significant amount of attention has been devoted to developing a comprehensive definition of access to care (33-36). There is consensus that health care access is a very complex, multi-dimensional concept that cannot easily be distilled down to a single measure. Unfortunately, there still is no precise definition of access and different disciplines have evolved with their own perspectives. For instance, sociologists may stress the social aspect of access to care such as language barriers. Political scientists may focus on political factors such as zoning and districting, while medical geographers may focus on the spatial dimensions. Furthermore, healthcare access is often used synonymously with other terms such as accessibility or availability, which are themselves ill-defined and may capture only part of the concept of access to care (37). Nevertheless, several definitions of access to care exist in the literature which may provide a background to help generate a comprehensive list of variables that most closely define the dimensions of healthcare access.

A seminal paper by Andersen (38) described a comprehensive behavioral model of healthcare utilization that associates predisposing, enabling and need factors with level of healthcare use. Predisposing factors include variables such as age, race and gender that may predispose an individual to access the health care system. Enabling factors include variables such as income, health insurance, travel time to facility, waiting time at facility as well as community and social variables. Coughlin et al (39) expanded on Andersen's behavioral model to incorporate variables related to cancer screening. He conceptualized healthcare access with three groups of variables; individual level predisposing factors (age, race/ethnicity, marital status, education, income and household size); individual

level enabling factors (health insurance, routine physical examination in the past year); and neighborhood level enabling factors (number of physicians, number of healthcare centers or clinics, number of mammography centers, designation as a Health Professional Shortage Area).

Parker et al defined access as the ability to reach, obtain or afford entrance to service (33). In a similar vein, Penchansky and Thomas defined access as the degree of fit between a patient and the healthcare system; incorporating dimensions of availability, accessibility, affordability and acceptability (36). These definitions, while useful conceptually, do not address other dimensions such as the socio-cultural and economic barriers that may mediate the effect of their listed dimensions on actual utilization. On the other hand, the US Bureau of Health Planning defined access as the ability to obtain available health services as determined by economic, temporal, spatial, cultural, organizational, and informational factors which may act as barriers or facilitators to obtaining services (37). This definition is more useful as it provides a way to conceptualize potential barriers that have to be overcome to obtain needed healthcare. These barriers to healthcare access may be related to both production and consumption of healthcare services (37). Production related barriers include number of providers, geographic location, specialty type, organization and scope. Consumption related barriers include economic, financial and possibly psychosocial factors (37).

In assessing the impact of health care access on individual health outcomes, Benjamins et al also expanded on the Andersen model of access to care which describes health care access as the combination of enabling or direct factors and predisposing or indirect factors (40). Enabling/direct factors include individual characteristics such as

income, health insurance, race, etc that may affect an individual's ability to access care. The enabling factors also include contextual variables such as the number of hospitals/clinics, number of doctors and nurses in an area. Other enabling factors that influence the acceptability, affordability and proximity to care include public transportation and distance at the contextual level. Furthermore, racial composition in a community affects healthcare utilization because generally, areas with high percentages of racial minorities have less socioeconomic resources leading to lower availability of healthcare facilities and personnel. Predisposing/indirect factors include motivations, perceptions, knowledge about services and individual risk, disease seriousness and likely benefits of service.

Benjamins et al suggests that contextual variables such as racial composition can influence health service utilization rates (e.g. screening) by modifying the predisposing factors (40). An example is the higher rates of mistrust of medical professionals observed among blacks; therefore communities with higher proportion of blacks may be influenced by the more negative attitudes towards healthcare that may negatively impact the utilization of healthcare. Social capital is another possible predisposing/indirect factor that may influence healthcare utilization rates. Social capital refers to the level of trust and networking within communities that often occurs in areas with high concentration of the same ethnic or racial group. These relationships may allow for increased transmission of health related information and increased awareness of preventive services in the community. Compared with racial groups residing in other areas or groups residing in communities with a low concentration of people of the same racial group, increased

social capital/social support may increase individuals' ability to access health care effectively.

Based on prior works, Benjamins suggests that racial/ethnic composition is associated with healthcare utilization rates through three major mechanisms. First, neighborhood racial composition is directly associated with availability of healthcare resources in a community (e.g. number of physicians). Second, neighborhood racial composition is indirectly associated with utilization rates through the values, beliefs and attitudes towards healthcare which modifies the predisposing characteristics of individuals. Third, neighborhood racial composition and racial characteristics is indirectly associated with utilization rates through social capital, making health-related information and services more or less easily accessible and also modifying the predisposing characteristics of individuals.

In general, access to care can only be realized when (1) there is reasonable availability of providers in terms of number, location, distribution and specialty and (2) the individual's health and illness behavior overcomes possible economic, financial and/or psychosocial barriers (37). While very useful, this definition does not distinguish potential and achieved access. Aday and Anderson (1978) on the other hand, define access as dimensions that describe the potential and actual entry of a group of individuals into the healthcare delivery system (34). This approach conceptualizes potential access to care as dependent on first, the characteristics of the health care delivery system (such as the number of distribution of health resources) and second, the population characteristics (such as age, income and insurance) while actualized access to care is dependent on level of use and satisfaction measures.

Given the complex nature and interrelations among dimensions of access to care, it is not surprising that there is currently no single, direct measure. Indirect measures of access are commonly used in research studies, using indices incorporating measures of potential access and/or measures of realized access. These indirect measures have been explored as predictors of health outcomes among individuals. Several studies use individual insurance status or income as a measure of availability of and accessibility to healthcare (41, 42). Other studies use variables such as presence of medical school in a community (43), number of physicians in neighborhood (44), recent physician visit (45), proximity to health clinics (46) and residence in a rural/urban residence (47).

Access to Healthcare and Breast Cancer

More research work is needed to better understand the specific role of healthcare access in breast cancer outcomes generally, and in the sustained racial disparities observed in breast cancer in the US. However, some important research work has been conducted. For instance, research has shown that in the US, women who lack access to care are less likely to have had a routine physical examination in the past year, leading to sustained poor health (39). These women are also less likely to undergo routine mammography screening because as studies show, the physician's office is the main source of screening recommendations (48, 49). Although many states have made significant efforts to reduce the gap in mammography utilization rates for all races in recent years, some states still need more work (50). Lack of adherence to mammography screening guidelines increases the chances of breast cancer diagnosis at advanced stages where treatment options are less effective (23, 51, 52). However, even after adjusting for stage of presentation, studies show persistent disadvantage in breast cancer mortality for

black women compared with whites (52, 53). This is perhaps not surprising given that lack of healthcare access has also been implicated in many other facets of breast cancer, including treatment delays, adequate diagnostic follow up, and type of treatment received (54-57).

Lack of access to care may explain part of the black-white disparity in breast cancer especially if examined from individual and neighborhood levels. Early diagnosis, adequate treatment and receipt of routine health information about the importance of mammography screening are more likely when there is adequate access to healthcare. Health insurance ensures the ability to afford quality healthcare, but black women are more likely to be poor and less likely to have health insurance (26). Moreover, residence in an area that lacks adequate healthcare facilities plays a role, even for women with health insurance. Research has shown that black women are more likely to reside in poor neighborhoods in order to retain their social networks and be near family and friends (58, 59). For this reason, even women who have health insurance and therefore individually have access to care may still have worse breast cancer outcomes because the neighborhood in which they reside is inadequately equipped with healthcare facilities. This implies that individual access to care (through health insurance) may not be enough; women also need to live in neighborhoods with adequate healthcare facilities to meet their needs (60).

This concept was explored in a recent paper by Dai et al. The authors evaluated the impact of black residential segregation and spatial access to care on disparities in late stage breast cancer presentation in Michigan (58). Cancer incidence cases from three counties in Michigan compiled by the Michigan Cancer Surveillance Program were used

for this analysis. Cases were categorized as early stage if presenting at in-situ and localized stages and late stage if presenting at regional and distant stage. Zip codes were classified according to health care access using the number of primary care physicians and mammography facilities. Accessibility of each zip code to each healthcare facility was assessed using estimated travel time. The results revealed that late stage breast cancer rates were much higher in areas with poorer mammography access, low socioeconomic status and socio-cultural barriers such as the presence of racial segregation. Spatial access to primary care physicians was not significantly associated with late stage breast cancer rates, however, the authors suggested that this may be due to the density of primary care physicians in the study area.

Similarly, Tarlov et al examined the impact of spatial accessibility and the characteristics of mammography facility locations in Chicago on stage at diagnosis of cancer (61). The tested hypothesis was that travel distance, public transportation and similarity between clinic location and one's own neighborhood influenced the likelihood of utilizing services, and thus affected breast cancer stage. The authors used three years of breast cancer incidence data from the Illinois cancer registry, combined with mammography facility locations from the FDA and transportation information from the Chicago Area Regional Transportation Authority. Annual violent crime incidents were used as a measure of neighborhood safety, and socioeconomic status and neighborhood similarity were assessed using data from the US Census. The authors found that homicide rate in nearby facility neighborhoods was associated with later stage at diagnosis, suggesting that crime around mammography facilities is a deterrent to utilization. The authors failed to find an association between distance to mammography facilities and

stage of cancer. The authors posit that this may be due to the use of stage of presentation as a measure of utilization instead of actual mammography use rates, or in urban areas where distances are relatively short the cost or travel time to facilities does not vary by much.

To assess the multilevel dimensions of healthcare access, Coughlin et al integrated individual and area level health care access variables to assess mammography use rates among black and white women (39). Mammography and pap screening from BRFSS data was associated with county level health care access variables such as number of mammography facilities, number of primary care physicians, number of health centers/clinics, rural/urban continuum, etc. Individual and county level variables of interest were used to model the receipt of mammography screening among women ages 40 and older. The analysis suggests that significant contextual predictors of screening included non-rural residence, residing outside a health professional shortage area, number of health centers/clinics, number of mammography facilities and proportion of blacks. Furthermore, in counties with a high proportion of blacks residing in them, black women were more likely to have received mammography screening. These results suggest that when area resources are adequate, women have similar screening rates; and blacks residing in counties that have a high proportion of blacks do not necessarily have poor screening rates after adjusting for other individual and neighborhood characteristics. However, blacks residing in counties with a low proportion of blacks may need to be targeted more aggressively.

Using similar predictors of health care access as above, the same authors evaluated the impact of poor health care access on breast cancer diagnosis using newly

diagnosed cases from the SEER registry (62). County level variables included number of mammography facilities, number of primary care physicians, number of health centers/clinics, rural/urban continuum, etc. Individual level variables assessed in the analysis included age, race and ethnicity. The analysis showed that black women were more likely to be diagnosed at distant stages compared with whites; contextual variables associated with distant stage at diagnosis were higher proportion of the population living below poverty level and lower number of physicians per 100,000 females. After adjusting for other variables in the model, significant predictors of late stage at diagnosis were age, race, number of physicians and proportion of people living below the poverty level.

Analysis of Medical Expenditure Panel survey (MEPS) data using county level characteristics derived from the Area Resource File to assess adherence to USPTF screening guidelines shows that both individual and contextual characteristics are important predictors of screening (44). A modifying effect of area racial composition was found; living in a high black area increased the likelihood of mammography screening for Hispanics compared to living in a low black area, the number of physicians per county also increased the likelihood of receiving screening services. Another study using data from MEPS assessed whether individuals had difficulty obtaining care or had financial barriers to obtaining care based on county level racial composition (63). Counties were categorized according to the proportion of blacks and Hispanics present. The analysis revealed that after controlling for individual and other county level variables, blacks living in high black counties had less difficulty obtaining care and had less financial barriers to care. Latinos living in high Latino counties had less difficulty obtaining care, but did not have lower rates of financial barriers to care. Whites living in high Latino

areas were more likely to report difficulty obtaining care and financial barriers to obtaining care. This suggests that disparities in access to care extend beyond individual characteristics, and likely encompasses factors such as community cohesion and socio-cultural identities which require more detailed studies.

Although the majority of studies measure neighborhood level healthcare access at the county level, a major unresolved issue in the literature is a question about the appropriate level at which to measure neighborhood health care access. Different studies have used different scales, dictated mostly by the availability of data, such as community defined neighborhoods, census tracts, zip codes, counties or federal legislative districts. The level at which to measure health care access is not a trivial matter as it may drive some of the observed results. For instance, to assess cancer survival disparities between blacks and whites in Michigan, Meliker et al compared different geographic scales to determine if observed disparities disappeared when smaller geographic levels are used in the analysis (64).

The authors compared federal legislative districts and state house legislative districts. Differences in survival rates between races disappeared at the lower geographic scale (state house district and community defined neighborhoods) for both breast and prostate cancer. At the federal legislative district level (15 in Michigan), 53% of regions had significantly higher breast cancer survival rates for whites compared with blacks; when using state legislative districts (110 in Michigan), only 9% had significantly higher breast cancer survival rates for whites compared with blacks. At the smallest geographic level- community defined neighborhoods- 3% of regions had significantly higher breast cancer survival rates, all of them in Detroit. (Similar trends were observed in prostate

cancer survival rates.) Since the racial disparities decreased at the smaller geographic levels, this suggests that modifiable factors which are not innately part of the individual contribute to the racial disparities. At smaller geographic levels, the population becomes more homogenous in terms of socioeconomic status and access to healthcare- lending credence to the idea that disparities in breast cancer outcomes are driven largely by neighborhood level factors.

In summary, numerous studies have been conducted that show healthcare access at both individual and neighborhood levels significantly influencing health outcomes, including breast cancer. However, more needs to be done to incorporate comprehensive definitions of access to care into explaining black-white disparities in health outcomes, specifically breast cancer which shows a very stark disadvantage in outcomes for blacks.

IV. DISSERTATION PURPOSE AND OUTLINE

While studies show that individual poverty and lack of health insurance adversely affect the trend of breast cancer mortality for a group of individuals, ecological studies assessing the effect of poor neighborhood healthcare on neighborhood mortality rates over time have not been conducted. In addition, there is a need for in-depth analysis of factors that determine breast cancer survival both at the individual level (age, income, education and treatment) as well as at the neighborhood level (socio-economic status and healthcare access). It is important to take into account neighborhood poverty level to assess the unique contribution of healthcare access at the neighborhood level on breast cancer survival, and to test for effect modification e.g. to examine if breast cancer

survival is worse for patients living in neighborhoods that are poor and lack healthcare facilities.

The purpose of this dissertation research is to better understand the relationship between race, socio-economic status and healthcare access in breast cancer screening, mortality and survival disparity. A conceptual framework reflecting the hypothesized relationship between these variables is presented in figure 1.2. This research is important in order to highlight potential areas for interventions aimed at reducing the disproportionate breast cancer mortality burden in the US among blacks. Using unique and rich datasets from population based cancer registries across the US (SEER) and Michigan, this dissertation aims to address some of the gaps in the current breast cancer racial disparity literature. The major contribution of this dissertation to the literature is its focus on individual and neighborhood level healthcare access, simultaneous examination of the impact of SES, and the focus on black-white racial disparities in breast cancer outcomes. For this dissertation, a measure of potential access i.e. availability will be used to develop an index of healthcare access. This index will be used as a predictor of breast cancer screening, breast cancer survival as well as breast cancer mortality trend.

First, healthcare access is conceptualized at the neighborhood level using existing methodology in the published literature and federal government datasets to explore its relationship with individual breast cancer outcomes. Second, the impact of healthcare access on breast cancer mortality rates trend by county over time is assessed using data from a high quality cancer registry. Third, national cancer registry datasets are used to explore the contribution of neighborhood healthcare access and SES on breast cancer survival disparities between racial groups after adjusting for potential confounders.

Fourth, racial disparities in mammography use among women with health insurance is explored by taking advantage of a dataset in Michigan to examine the impact of lack of healthcare access. Figure 1.4 provides a schematic of the major predictive variables and how they relate to the research aims being addressed.

This dissertation will be divided into five chapters. This chapter has provided an introduction with a review of the literature on breast cancer racial disparities and the contribution of SES and access to care. The second chapter will focus on mammography utilization rates in Michigan using a population based survey conducted in 2008 on adult Michigan residents. The third chapter will focus on the role of access to care in breast cancer survival disparities between blacks and whites using a linked data set of national SEER and NLMS data. The fourth chapter will focus on breast cancer mortality trends at the zip-code level in Michigan and the impact of availability of healthcare. The dissertation concludes in the fifth chapter with a summary of the main results and implications for future research.

V. SPECIFIC AIMS

1. To assess the impact of living in a neighborhood with low prevalence healthcare facilities on mammography use and/or adherence among women ages 50-74 in Michigan.
 - Among women ages 50-74 in Michigan, poor county-level healthcare access is significantly associated with lower mammography use/adherence after accounting for individual demographic and healthcare access variables.

2. To assess the contribution of individual level and neighborhood level healthcare access and socio-economic status to black-white disparities in breast cancer survival.
 - Poor county-level healthcare access to care is associated with reduced BC survival rate, and the impact of poor healthcare access on BC survival varies by race.

3. To assess the contribution of zip-code level healthcare access on the trend of percent late stage diagnosis and age-adjusted mortality rate among black and white patients in Michigan between 1992 and 2009
 - Poor zip-code level healthcare access is associated with a slower rate of BC late stage diagnosis, and the impact of healthcare access on percent late stage diagnosis decline varies by race.

- Poor zip-code level healthcare access is associated with a slower rate of BC mortality decline, and the impact of healthcare access on BC mortality decline varies by race.

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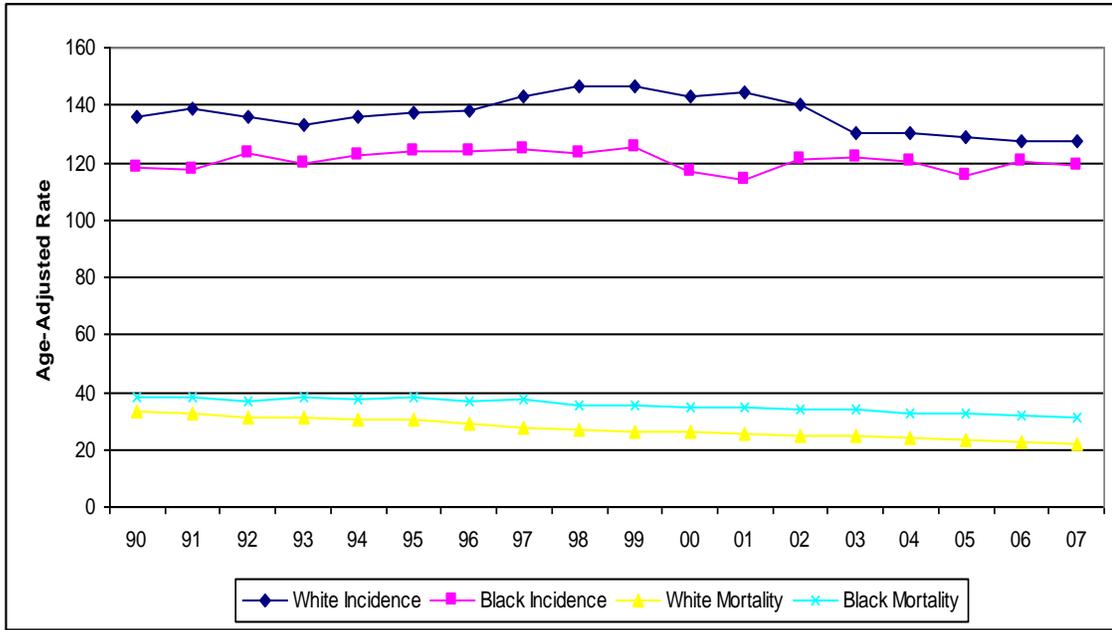


Figure 1.1: Age-Adjusted Breast Cancer Incidence and Mortality Rate, 1990-2007 (Source: SEER Cancer Statistics Review, 1975-2007)

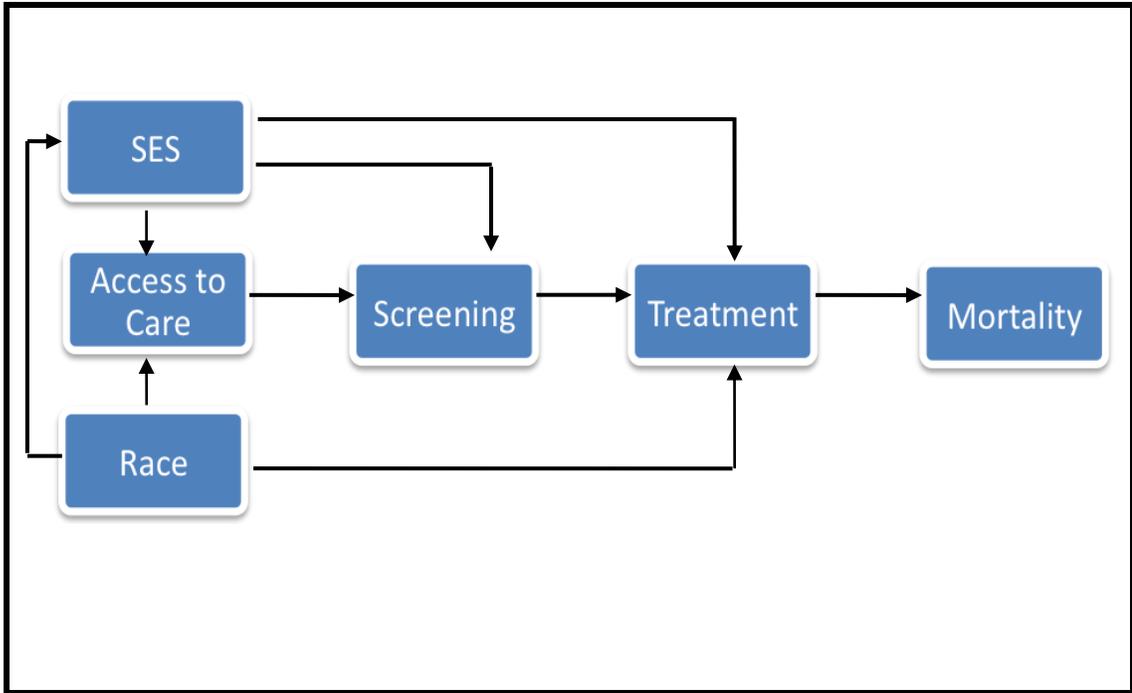


Figure 1.2: Hypothesized Relationship between Socio-economic Status, Healthcare Access and Breast Cancer Outcomes

CHAPTER 2

HEALTHCARE ACCESS AND MAMMOGRAPHY SCREENING IN MICHIGAN: A MULTILEVEL CROSS-SECTIONAL STUDY

I. INTRODUCTION

The breast cancer black-white incidence-mortality disparity has been described as the higher incidence rates observed among white women compared with blacks but disproportionately higher mortality rate among black women compared with whites in the United States [1-6]. Between 2004 and 2008, breast cancer incidence rate was 133 per 100,000 among non-Hispanic whites compared with 120 per 100,000 among black women, while mortality rate was 23 per 100,000 among non-Hispanic whites compared with 32 per 100,000 among black women [7]. Similar trends have also been observed in Michigan [8]. Several studies have suggested that this disparity may be due to biological differences that predispose black women to more aggressive forms of breast cancer [4,9-13], while others attribute the disparity to differences in socio-economic status [5,14-17], access to healthcare [18,19] and mammography use [18,20]. Complete understanding of the incidence-mortality paradox observed in the US is complicated by the presence of racial disparities in these predictors.

In the United States, recent survival studies show that black women are more likely to be diagnosed with breast cancer at advanced stages compared with white women [15,18,19,21], and are less likely to have timely follow-up of abnormal mammography findings [22-24]. This suggests that the observed incidence-mortality paradox may be due to the lack of adequate mammography screening and diagnostic follow-up among black women [21]. Mammography screening remains the most effective method available for early detection and has been shown to increase the likelihood of early diagnosis, optimal treatment, and survival [25,26]. On the other hand, there are associated risks of overdiagnosis and overtreatment to healthy women which have also been discussed [27]. Nevertheless, the United States Preventive Services Task Force (USPSTF) recommends biennial mammography screening for women ages 50–74 years [28]. However, data from hospital records in the US show that mammography screening is underutilized, and racial disparities exist in screening [29]. For instance, the prevalence of mammography screening among women ages 40 years and older across the US in 2006 was 65% among whites, and 59% among blacks [1].

Previous studies have suggested that individual and neighborhood factors such as SES and healthcare access may contribute to underutilization and racial disparities in mammography screening [19,30-34]. For instance, adequate and timely mammography screening are more likely among women who are more educated, have higher incomes and have health insurance [35,36]. Research also suggests that residing in rural areas [30], and neighborhoods with a low supply of primary care physicians and low numbers of health clinics are associated with lower likelihood of cancer screening [20]. In

addition, residing in neighborhoods with low socio-economic status has also been associated with lower mammography screening rates [36,37]. Similarly, lack of adequate healthcare facilities at the neighborhood level may also have significant effects on the likelihood of getting adequate screening and follow-up [24,34]. Unfortunately, few studies in the US have comprehensively assessed the role of individual SES and access to care (such as health insurance and having a usual healthcare provider), while at the same time assessing the impact of neighborhood level SES and access to care on the receipt of adequate breast cancer screening.

The aim of this analysis was to investigate individual (demographics, SES and health care access) and neighborhood (SES and health care access) determinants of mammography screening and clinical breast examination among adult women in Michigan, USA.

II. METHODS

Data sources and analytic samples

The source of data for this analysis was the 2008 Michigan Special Cancer Behavioral Risk Factor Survey [38]. This was a disproportionate stratified telephone survey of non-institutionalized adults 40 years of age or older residing in Michigan. Eligible individuals were identified using random digit dial sampling procedures to ensure that all residents had an equal chance of being included in the study. Within selected households that included at least one eligible adult, one adult was randomly selected to complete the

interview. The aim of the survey was to assess risk factors, family history, screening behaviors and cancer knowledge among adults in Michigan. The survey questions were modeled after those of the Centers for Disease Control and Prevention Behavioral Risk Factor Surveillance System's telephone survey. The survey was designed to over-sample African Americans, Arab/Chaldean Americans, Asian Americans, Native Americans, and Hispanics residing in Michigan, USA in order to facilitate analysis of cancer screening and risk behaviors among these groups, and to ensure enough sample size for meaningful comparisons between these groups and the remaining Michigan population. To account for the varying probabilities of selection, sampling weights were applied to the dataset.

The analytic dataset for this study was restricted to black and white women ages 50–74 who participated in the survey. There were 1163 women residing in 80 out of the 83 counties in Michigan that met this criterion. Michigan had a population of about 10 million in 2008. The average county population size in 2008 was 120,512 [39]. Individual counties were identified using the US Federal Information Processing Standard (FIPS) code [40] to link county variables with individual cases' county of residence at diagnosis as reported in the survey. All analytic variables were based on self-reports from survey respondents. County level variables were obtained from the 2000 US Census. Data regarding the number of certified mammography facilities per county was obtained from the Food and Drug Administration through a Freedom of Information request.

Ethical approval was received from the Michigan Department of Community Health Institutional Review board, and informed consent was obtained from all participants.

Data management

Race was categorized as black (n = 327) and non-Hispanic white (n = 836).

Mammography use was characterized as the amount of time since the most recent mammography. For the analysis, mammography was categorized as received within the past two years (up to 24 months ago) or received more than two years ago. Clinical breast examination (CBE) was characterized as breast examination by a professional (doctor, nurse or other health professional) for lumps or other signs of breast cancer. CBE was categorized as received within the past two years or more than two years ago.

Adjusted Prevalence of Mammography Screening and CBE: estimates of mammography screening and CBE among black and white survey respondents were adjusted for misclassification bias using sensitivity and specificity values obtained from a published meta-analysis of previous studies [1,29]. The meta-analysis was based on 12 published studies that compared self-reported cancer screening such as mammography, CBE and Pap smear against medical and billing records among women ages 40 years and above. To assess for differential misclassification by race, sensitivity and specificity values were calculated separately for blacks and whites when data were available. Specificity was defined as the probability that a negative screening history was reported as negative; sensitivity was defined as the probability that a positive screening history was reported as positive. For mammography screening, sensitivity for both black and white women was 0.97, however, the specificity for black women was 0.49 and for white women was 0.62. For CBE, data were not available by race but overall, sensitivity was 0.94 and specificity

was 0.25. In this study, adjustment for misclassification in mammography and CBE screening prevalence was done using the formula: $(\text{estimated prevalence} - 1 + \text{specificity}) / (\text{sensitivity} + \text{specificity} - 1)$ [41].

Health care access: Individual health care access was assessed by including variables related to health insurance, having a usual source of care such as a particular hospital or clinic, and having a usual healthcare provider such as a personal doctor. We adjusted for differences in population size by dividing the counts per 10,000 people in each county. The derived county level variables were subject to principal component analysis (PCA) on count per 10,000 individuals of number of hospitals, number of medical doctors, number of medical doctors with obstetrics and gynecology specialty, number of DOs, number of DOs with obstetrics and gynecology specialty, number of nurse practitioners, and the number of mammography facilities. SAS Proc Factor was used to generate county-specific scores based on our input variables [42]. The first two components together accounted for 50.5% of the total variance. Based on this finding, MDs per 10,000, MDs in Ob-Gyn per 10,000, nurse practitioners per 10,000, and DOs per 10,000 were loaded on the first component; hereafter named Personnel. Number of hospitals per 10,000 and number of mammography facilities per 10,000 were loaded on the second component; hereafter named Facilities. These scores were categorized into two groups; low and high.

Socio-economic status: County level socio-economic status was defined using PCA to create three composite measures related to affluence, disadvantage and immigration. Concentrated affluence was based on county level proportion of individuals making over \$100,000, proportion over 25 years old with a college degree and the proportion of white collar workers. Concentrated disadvantage was based on county level proportion of persons in poverty, proportion of families with a female-headed household, proportion of households that are food stamp recipients, and proportion of unemployed. Concentrated immigration was based on the proportion of foreign born individuals and the proportion of non-English speaking individuals. The affluence, disadvantage and immigration scores accounted for 84%, 74% and 94% of the total variance respectively, in the county-level dataset. These scores were categorized into two groups; low and high.

Statistical analysis

All statistical analyses were performed using SAS statistical software (SAS, Version 9.2). Sampling weights were applied to the descriptive analysis to facilitate the comparison of blacks and non-Hispanic whites, adjust for non-response and stratifications while taking advantage of the oversampling of black participants. Descriptive statistics were generated using chi-square statistics. Multilevel logistic regression models assessing significant individual and neighborhood predictors of recent mammography screening and recent CBE were created using Proc Glimmix in SAS. This procedure was chosen to account for the correlation of observations within counties. Two models were created; the first model assessed individual level predictors including age, race, income, employment, education,

marital status, health insurance, having a usual source of care and having a usual healthcare provider. The second model included variables related to county level SES, health care access and proportion of blacks.

III. RESULTS

Overall, 90.80% of black and non-Hispanic white women ages 50–74 had received a mammography test in the past 2 years; 90.98% of white women and 90.35% of blacks. After adjusting for misclassification, 85% of black women and 90% of white women had received a mammography test. 88.75% of women overall had received a CBE in the past 2 years; 88.53% of white women, 89.31% of black women. After adjusting for misclassification, 74% of black women and 68% of white women had received a CBE in the past 2 years.

Table 1 presents the distribution of survey respondents according to the SES and healthcare access characteristics of their county of residence. 49% of respondents resided in counties with low healthcare facilities compared with 51% in counties with the high healthcare facilities; 48% of respondents resided in counties with low healthcare personnel compared with 52% in counties with low healthcare personnel. 43% of respondents resided in counties with a low proportion of affluent households, compared with 57% in counties with a high proportion. 61% of respondents resided in counties with a low proportion of socio-economically disadvantaged households compared with 39% in counties with the highest proportion. Furthermore, 70% of survey respondents resided in

counties that were both high in concentrated affluence and concentrated disadvantage (data not shown). 53% of respondents resided in counties with less than 6% of immigrants, compared with 47% in counties with over 6% of immigrants.

The distribution of individual demographics, SES and healthcare access variables, as well as county level SES and healthcare access variables by race are presented in Table 2. In general, blacks were more likely than whites to earn less than \$35,000 per year, were less likely to be employed, and were more likely to be single, divorced or widowed ($p < 0.001$). In addition, blacks were more likely to have a usual source of care (such as a particular hospital or clinic), were more likely to be smokers, and more likely to have had a past diagnosis of breast cancer ($p < 0.05$). At the county level, 80% of blacks resided in counties with low healthcare facilities, although over 95% of blacks resided in counties with high healthcare personnel. This is in contrast with white respondents who were more likely to reside in counties with high level of healthcare facilities (63%), but also in counties with low healthcare personnel (65%). About 44% of white respondents resided in counties with the high concentrated affluence compared with 91% of blacks ($p < 0.001$). However, 83% of black respondents also resided in counties with high concentrated disadvantage compared with only 22% of whites. Blacks were more likely to reside in counties with high concentrated immigration (86%) compared with whites (32%). Over 99% of blacks resided in counties with over 6% of blacks compared with 51% of whites.

The results of the adjusted analyses predicting recent mammography screening and recent clinical breast examination are presented in Tables 3 and 4 respectively. As presented in Table 3, after adjusting for individual demographic variables of age, income, employment, marital status and education, there was no statistically significant difference in mammography screening between black and white women (OR = 0.63, 95% CI = 0.34-1.16). Having no usual source of care reduced the likelihood of mammography screening by 54% (OR = 0.46, 95% CI = 0.21-0.99); having no healthcare provider was associated with 68% lower likelihood of receiving a mammography test in the past two years (OR = 0.32, 95% CI = 0.15-0.69); and having no healthcare insurance was associated with a 73% reduction in the likelihood of receiving a mammography test (OR = 0.27, 95% CI = 0.14-0.54). Adjusting for county level SES and healthcare access covariates tended to attenuate individual level healthcare access variables, although all except having a usual source of care remained statistically significant. Having no usual healthcare provider and no healthcare insurance remained the significant predictors of recent mammography use.

There were no significant racial differences in the model predicting receipt of recent clinical breast examination (OR = 0.68, 95% CI = 0.37-1.26) even after adjustment for demographics, county level SES and healthcare access covariates (Table 4). Covariates that were significantly associated with a recent CBE included lacking a usual healthcare provider (OR = 0.34, 95% CI = 0.17-0.67) and lacking healthcare insurance (OR = 0.40, 95% CI = 0.21-0.75). After adjusting for county level SES and healthcare access, lack of

healthcare insurance was the only statistically significant predictor of recent CBE (OR = 0.37, 95% CI = 0.19-0.71).

IV. DISCUSSION

Potential individual and neighborhood level determinants of adequate breast cancer screening among women residing in Michigan were explored in this analysis. Race was not a statistically significant determinant of cancer screening in adjusted or unadjusted analysis; however, lack of healthcare insurance and lack of a usual healthcare provider reduced the likelihood of getting adequate mammography screening. These variables remained significant even after adjusting for county level SES and healthcare access. Similarly, lacking health insurance was associated with reduced likelihood of receiving a CBE in the past two years.

This study supports previous research that found that individual healthcare access through health insurance and having access to a usual healthcare provider are important determinants of cancer screening [43-47]. We tested the hypothesis that county level SES and healthcare access would also significantly predict cancer screening even after adjusting for individual level predictors. None of our county level predictors were significant, and this may be due to several factors. Firstly, it is possible that by accounting for individual healthcare access, county level SES and healthcare access measures are no longer important. For instance, for someone who has health insurance and a usual healthcare provider, lack of healthcare facilities and high concentrated

disadvantage in their county may no longer be relevant; they already have a relationship with healthcare personnel who may provide recommendations, send reminders and schedule tests. This is in line with another study that reported having a physician recommendation was the single most important predictor of mammography use [48].

Secondly, other county-level covariates that were not assessed in this analysis may be stronger predictors of cancer screening such as community coherence. For instance, despite a lack of hospitals and/or mammography clinics, some communities with high internal coherence may work together to create community centers where cancer screening is offered periodically, or may encourage each other by traveling together to other neighborhoods to get screened. This positive impact of community coherence on health behaviors such as cancer screening has also been described extensively in the literature [46,49-52]. In addition, it is possible that measuring SES and healthcare access at the county level diluted our measures through the aggregation of smaller regions with high and low levels of the covariates. For instance, zip-code or census tract level measures may produce a more homogenous estimate of SES and healthcare access, leading to better estimates of neighborhood level influences. Unfortunately, such data are not readily available and the only neighborhood level identifier in the SCBRFS dataset was the county of residence.

Some studies have suggested that older women with a personal history of breast cancer are less likely to receive surveillance mammography, especially women who had gone

without a visit to a physician in the past year [53-55]. In addition, most of the women in this study did not require follow-up for an abnormal finding. However, among the women that did, the majority received the follow-up within two weeks. Research studies have also suggested that the most important predictors of diagnostic follow-up of an abnormal screening result were fear and anxiety, lack of access care and lack of information from screening staff [56,57]. Although we were unable to assess the impact of breast cancer history and follow-up time on mammography use or CBE due to the low sample size, these studies are in line with our findings that having a usual healthcare provider is a crucial predictor of breast cancer screening.

In examining racial disparities in mammography screening, it is important to include a discussion about the effectiveness of breast cancer screening programs and the impact this might have on screening rates. A recent Cochrane library review advises that women should be informed that, for example, if 2000 women undergo regular screening for 10 years, 1 breast cancer death will be prevented, 10 healthy women will be wrongly diagnosed and treated, and 200 women will receive an initial wrong diagnosis that does not result in treatment [27,58]. Although we found no significant differences in health insurance status and having a usual healthcare provider between blacks and whites in this study population, this may not be true for the general population. The population group with better access to healthcare and a usual healthcare provider may benefit more from screening by having higher participation rates and a better understanding of the potential benefits. Black women, with a historical mistrust of the medical system, perceived racial discrimination or fear of a cancer diagnosis may be disproportionately harmed by the lack

of accurate information on the benefits of screening [59]. The lack of accurate information in some social groups strengthens the argument for the importance of having access to healthcare and a usual healthcare provider. These may be the most important component to consider in eliminating racial disparities in breast cancer screening.

There are several strengths of this study that should be highlighted. First, the data were from a large, probability sample of older non-institutionalized adults residing in Michigan, improving the external validity of the results. Second, the survey was focused on understanding risk factors for cancer and modeled after national cancer risk factor surveys, thereby improving the quality of the questions and its internal validity. Third, the availability of a comprehensive set of individual socio-demographic and healthcare access variables enhanced the ability to control for potential confounders in the analysis. Fourth, the ability to incorporate a comprehensive measure of county healthcare access through several different databases including the FDA to assess mammography facilities improved the quality of the neighborhood covariates used in the analysis.

There are also a couple of limitations of this study. First, the level of misclassification calculated in reports of cancer screening may apply to other questions in the survey, introducing potentially serious misclassification bias in the survey responses. However, such misclassification of socio-demographic and healthcare access variables, if present, is expected to be non-differential with respect to the outcome of cancer screening. In this study, adjusting for misclassification bias had a larger impact on reported clinical breast

examination in the past two years compared with reported mammography use. For instance, adjusted CBE was 15 percentage points lower than reported among blacks, and 20 percentage points lower among whites. Adjusted mammography test prevalence was 5 percentage points lower among blacks, and less than 1 percent lower among whites. The observed misclassification may be due to lack of understanding of what CBE or mammography tests are. Other studies have suggested that when more descriptive or graphic descriptions of procedures are used, false positive rates decline [60]. In addition, misclassification bias has also been described as being related to ‘forward telescoping of dates’ in which events (such as screening) are remembered as occurring more recently than they actually did [29]. Secondly, we included county level healthcare access measures based on the quantity of healthcare facilities and personnel in a county. This county level aggregate analysis may not account for language, cultural or financial barriers to accessing such facilities.

In summary, our research suggests that individual healthcare access is an important determinant of adequate cancer screening among adult women in Michigan. Future studies in the US may focus on adjusting socio-demographic covariates for potential misclassification, as well as measuring neighborhood level effects at smaller geographical scales to further investigate the presence of racial disparities in cancer screening. Globally, more research studies should focus on identifying individual and neighborhood level factors that may influence cancer screening. As breast cancer incidence and mortality rates are projected to increase faster in the coming decades due to westernization of lifestyles and aging populations, early detection will become even more

important. Understanding region-specific barriers to adequate screening will be helpful to design programs aimed at improving screening rates for women regardless of race/ethnicity, socio-economic status or neighborhood of residence.

Table 2.1: Distribution of County Level Socio-Economic Status and Healthcare Access Variables (%) of 2008 SCBRES Participants from 83 Michigan Counties, 2000

	Facilities^a	Personnel^a	Affluence^b	Disadvantage^c	Immigration^d	Percent Black^e
Low	49.35	48.07	42.57	61.04	53.05	35.52
High	50.65	51.93	57.43	38.96	46.97	64.48

^aPersonnel and Facilities, two measures of health care access were defined using principal components analysis on the count per 10,000 population of several variables by county: hospitals, mammography facilities, MDs, DOs and nurse practitioners.

^bConcentrated affluence was based on PCA of county level proportion of individuals making over \$100,000, proportion over 25 years with a college degree and the proportion of white collar workers.

^cConcentrated disadvantage was based on PCA of county level proportion of persons in poverty, proportion of families with a female-headed household, proportion of households that are food stamp recipients, and proportion of unemployed.

^dConcentrated immigration was based on PCA of the proportion of foreign born individuals and the proportion of non-English speaking individuals.

^ePercent black was categorized as low if less than 6% and high if 6% or more

Table 2.2: Characteristics of 2008 SCBRFS Participants

Characteristic	White (N=836)	Black (N=327)	P-Value
Age			
50-60	52.74	55.99	0.32
61-74	47.26	44.01	
Income (\$)			
<35,000	31.86	40.98	<0.001
35,000-74,999	32.37	23.83	
>75,000	17.81	9.53	
Missing	17.98	25.66	
Employment			
Employed	47.38	36.13	<0.001
Unemployed	18.07	15.31	
Retired/Unable	34.55	47.88	
Education			
Less than High School	41.05	40.86	0.48
Some College	34.82	36.28	
College plus	24.01	22.28	
Marital Status			
Single	2.46	13.40	<0.001
Married	77.56	31.16	
Divorced/Separated	11.79	29.00	
Widowed	8.10	25.46	
Usual Source of Care			
Yes	90.28	95.47	0.001
No	9.69	3.99	

Usual Healthcare Provider				
Yes	91.35	91.42	0.24	
No	8.59	8.04		
Family History of Breast Cancer				
Yes	18.68	16.38	0.35	
No	80.96	83.62		
Past Diagnosis of Breast Cancer				
Yes	5.42	10.04	0.02	
No	94.21	89.72		
Health Insurance Status				
Yes	92.85	92.33	0.09	
No	7.15	7.12		
Smoking				
Yes	43.92	56.77	<0.001	
No	56.08	42.77		
Facilities^a				
Low	37.48	79.66	<0.001	
High	62.52	20.34		
Personnel^a				
Low	65.17	4.42	<0.001	
High	34.83	95.58		
Concentrated Affluence^b				
Low	55.85	8.69	<0.001	
High	44.15	91.31		
Concentrated Disadvantage^c				
Low	78.35	16.85	<0.001	
High	21.65	83.15		
Concentrated Immigration^d				

Low	68.21	14.36	<0.001
High	31.79	85.64	
Percent Black			
<6%	49.15	0.73	<0.001
>=6%	50.85	99.27	
Recent Mammography^e			
Yes	87.57	89.14	0.09
No	8.68	9.52	
Missing	3.76	1.34	
Recent CBE^f			
Yes	86.82	86.24	0.29
No	11.25	10.32	
Missing	1.93	3.44	
Follow-up Time^g			
<2 weeks	26.69	25.12	0.01
>=2 weeks	11.16	5.86	
No follow-up required	62.15	69.02	

^aPersonnel and Facilities, two measures of health care access were defined using principal components analysis on the count per 10,000 population of several variables by county: hospitals, mammography facilities, MDs, DOs and nurse practitioners.

^bConcentrated affluence was based on PCA of county level proportion of individuals making over \$100,000, proportion over 25 years with a college degree and the proportion of white collar workers.

^cConcentrated disadvantage was based on PCA of county level proportion of persons in poverty, proportion of families with a female-headed household, proportion of households that are food stamp recipients, and proportion of unemployed.

^dConcentrated immigration was based on PCA of the proportion of foreign born individuals and the proportion of non-English speaking individuals.

^eRecent mammography defined as the receipt of a mammography test in the past 2 years

^fRecent CBE defined as the receipt of a clinical breast examination in the past 2 years

^gFollow-up time defined as the number of days before receipt of final results among women with an abnormal breast exam in the past 10 year

Table 2.3: Multivariate Multilevel Models for Recent Mammography by Individual and County Level Characteristics

Characteristic	Model 1: Demographics^a	Model 2: + County^b
Race		
White	0.63 (0.34-1.16)	0.64 (0.32-1.28)
Black (Ref.)	-	-
Age		
50-60	1.16 (0.71-1.91)	1.12 (0.68-1.85)
61-74 (Ref.)	-	-
Income		
<35,000	0.33 (0.14-0.76)**	0.32 (0.14-0.74)**
35,000-74,999	0.47 (0.21-1.05)	0.46 (0.21-1.03)
>75,000 (Ref.)	-	-
Employment		
Unemployed	0.85 (0.46-1.56)	0.90 (0.48-1.67)
Retired/Unable	1.15 (0.66-2.00)	1.13 (0.65-1.99)
Employed (Ref.)	-	-
Education		
Less than High School	2.19 (1.21-3.96)**	2.05 (1.12-3.75)*
Some College	1.49 (0.85-2.60)	1.45 (0.82-2.56)
College plus	-	-
Marital Status		
Single	0.50 (0.25-1.02)	0.51 (0.25-1.03)
Divorced/Separated	0.74 (0.43-1.27)	0.75 (0.43-1.31)
Widowed	1.24 (0.62-2.48)	1.22 (0.60-2.44)
Married (Ref.)	-	-

Usual Source of Care		
No	0.46 (0.21-0.99)*	0.46 (0.21-1.02)
Yes (Ref.)	-	-
Usual Healthcare Provider		
No	0.32 (0.15-0.69)**	0.33 (0.15-0.71)**
Yes (Ref.)	-	-
Health Insurance Status		
No	0.27 (0.14-0.54)**	0.26 (0.13-0.52)**
Yes (Ref.)	-	-
Facilities^c		
Low		1.55 (0.76-3.14)
High (Ref.)		-
Personnel^c		
Low		1.16 (0.48-2.80)
High (Ref.)		-
Concentrated Affluence^d		
Low		2.23 (0.89-5.56)
High (Ref.)		-
Concentrated Disadvantage^e		
Low		1.26 (0.55-2.87)
High (Ref.)		-
Concentrated Immigration^f		
Low		0.82 (0.32-2.14)
High (Ref.)		-
Percent black^g		
<6%		0.88 (0.37-2.09)
>=6% (Ref.)		-

^aModel adjusting for individual demographic variables only

^bModel adjusting for county level variables including healthcare access and SES in addition to individual demographic variables

^cPersonnel and Facilities, two measures of health care access were defined using principal components analysis on the count per 10,000 population of several variables by county: hospitals, mammography facilities, MDs, DOs and nurse practitioners.

^dConcentrated affluence was based on PCA of county level proportion of individuals making over \$100,000, proportion over 25 years with a college degree and the proportion of white collar workers.

^eConcentrated disadvantage was based on PCA of county level proportion of persons in poverty, proportion of families with a female-headed household, proportion of households that are food stamp recipients, and proportion of unemployed.

^fConcentrated immigration was based on PCA of the proportion of foreign born individuals and the proportion of non-English speaking individuals.

*P<0.05, **p<0.01, ***p<0.001; Ref, reference group

Table 2.4: Multivariate Multilevel Models for Recent CBE by Individual and County Level Characteristics

Characteristic	Model 1: Demographics^a	Model 2: + County^b
Race		
White	0.67 (0.41-1.11)	0.68 (0.37-1.26)
Black (Ref.)	-	-
Age		
50-60	1.30 (0.84-2.01)	1.31 (0.85-2.03)
61-74 (Ref.)	-	-
Income		
<35,000	0.49 (0.24-0.99)*	0.51 (0.25-1.03)
35,000-74,999	0.80 (0.40-1.57)	1.82 (0.41-1.62)
>75,000 (Ref.)	-	-
Employment		
Unemployed	0.69 (0.40-1.18)	0.69 (0.40-1.20)
Retired/Unable	0.91 (0.55-1.49)	0.89 (0.54-1.47)
Employed (Ref.)	-	-
Education		
Less than High School	1.19 (0.69-2.04)	1.25 (0.72-2.16)
Some College	0.91 (0.54-1.53)	0.96 (0.56-1.62)
College plus	-	-
Marital Status		
Single	0.55 (0.29-1.04)	0.54 (0.28-1.04)
Divorced/Separated	0.84 (0.51-1.39)	0.82 (0.49-1.36)
Widowed	1.06 (0.59-1.91)	1.07 (0.60-1.93)
Married (Ref.)	-	-

Usual Source of Care		
No	0.55 (0.26-1.13)	0.53 (0.25-1.09)
Yes (Ref.)	-	-
Usual Healthcare Provider		
No	0.34 (0.17-0.67)**	0.35 (0.18-0.70)**
Yes (Ref.)	-	-
Health Insurance Status		
No	0.40 (0.21-0.75)**	0.37 (0.19-0.71)**
Yes (Ref.)	-	-
Facilities^c		
Low		1.04 (0.65-1.68)
High (Ref.)		-
Personnel^c		
Low		0.65 (0.33-1.29)
High (Ref.)		-
Concentrated Affluence^d		
Low		1.45 (0.70-3.00)
High (Ref.)		-
Concentrated Disadvantage^e		
Low		1.61 (0.93-2.78)
High (Ref.)		-
Concentrated Immigration^f		
Low		0.73 (0.34-1.58)
High (Ref.)		-
Percent black^g		
<6%		0.85 (0.45-1.62)
>=6% (Ref.)		-

^aModel adjusting for individual demographic variables only

^bModel adjusting for county level variables including healthcare access and SES in addition to individual demographic variables

^cPersonnel and Facilities, two measures of health care access were defined using principal components analysis on the count per 10,000 population of several variables by county: hospitals, mammography facilities, MDs, DOs and nurse practitioners.

^dConcentrated affluence was based on PCA of county level proportion of individuals making over \$100,000, proportion over 25 years with a college degree and the proportion of white collar workers.

^eConcentrated disadvantage was based on PCA of county level proportion of persons in poverty, proportion of families with a female-headed household, proportion of households that are food stamp recipients, and proportion of unemployed.

^fConcentrated immigration was based on PCA of the proportion of foreign born individuals and the proportion of non-English speaking individuals.

*P<0.05, **p<0.01, ***p<0.001; Ref, reference group

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CHAPTER 3

INDIVIDUAL AND NEIGHBORHOOD SOCIO-ECONOMIC STATUS AND HEALTHCARE ACCESS IN RELATION TO BLACK-WHITE BREAST CANCER SURVIVAL DISPARITIES

I. INTRODUCTION

Breast cancer incidence and mortality rates have declined steadily in the US for the past 10-15 years [1-7]. The relative 5-year survival rate for breast cancer overall has also increased in the past decade to 89% [8]. Unfortunately, disparities exist in breast cancer outcomes between racial groups in the U.S. Although survival has increased for both white and black women over time, the survival increase in black women has been smaller [2]. Five-year relative survival for breast cancer was 90% for white women and 77% for black women between 2001 and 2007 [8,9]. Several reasons have been suggested for the survival disparity between black and white women, including racial differences in access to and utilization of screening and treatment [10-12], risk factors that are differentially distributed by race [10,13-15] and socioeconomic status (SES) [14,16-20], and biological differences such as tumor aggressiveness [21,22].

The results of research studies assessing the role of SES in racial disparities in breast cancer survival are mixed; some studies reported that racial differences in survival

disappear after adjusting for SES [17,19,20,23,24], while other studies show survival differences persisting after adjustment for SES [13,14,17,20,25-27]. The conflicting results may be due to the lack of SES information in cancer registries in the US, resulting in insufficient characterization of socio-economic levels of patients [11,20,25,28]. In addition to SES, lack of healthcare access at the neighborhood level has also been examined in previous studies as potentially contributing to racial disparities in cancer outcomes [29-36]. However, the same limitations exist as with studies of SES effect on racial disparities in breast cancer survival- lack of consistency in which measure of health care access to use, and questions about which geographic level neighborhood differences are measured. To our knowledge, no other research study has developed a comprehensive definition of neighborhood healthcare access as a predictor of breast cancer survival among blacks and whites in the US, while controlling for individual and neighborhood level SES. The aim of this study was to assess the impact of neighborhood health care access on white-black disparities in breast cancer survival by adjusting for individual and neighborhood SES.

II. METHODS

Data Sources and Analytic Samples

This study utilized the National Cancer Institute's Surveillance Epidemiology and End Results data linked to the US Census Bureau's National Longitudinal Mortality Study database (NLMS). The linked dataset is referred to in this study as SEER-NLMS. Detailed methodology regarding this dataset has been published elsewhere [13,37,38]. In

brief, SEER data on cancer incidence, prevalence and survival from 15 participating registries, covering about 25% of the US population [39] was linked with the NLMS data to capture demographic, socio-economic, and occupation attributes from the Current Population Surveys and the Annual Social and Economic Supplement [38]. A full description of the NLMS is available at the census website (www.census.gov/nlms).

Data on county level SES, health care facilities and health care personnel were obtained from the 2009-2010 Area Resource File [40] which contains over 6,000 variables related to healthcare, socioeconomic and environmental characteristics for each county in the US. Data on the number of certified mammography facilities was obtained through a Freedom of Information (FOI) request to the Food and Drug Administration (FDA), the agency in charge of certifications [41]. Addresses of all mammography facilities certified in the year 2000 was provided by the FDA. The dataset used in the final analysis was restricted to non-Hispanic black and non-Hispanic white first primary breast cancer cases among women ages 40 years and older, diagnosed between 1973 and 2003. A total of 3511 women fulfilled these criteria; 3283 whites and 228 blacks. We focused the main analysis on women residing in counties that contained at least one black and one white breast cancer patient. A total of 1796 women met this criterion; 1580 whites and 216 blacks residing in 60 counties in the US. Counties were identified using the Federal Information Processing Standard (FIPS) code [42] to link county variables with cases' county of residence at diagnosis as recorded in the SEER dataset.

Data Management

Socio-Demographic Variables: Race was categorized as non-Hispanic white and non-Hispanic black. Marital status was categorized as married, widowed, divorced/separated and never married. Employment status was categorized as women in the labor force, and women not in the labor force. Education level was categorized as less than high school (<12 years), high school graduate (12 years) and at least some college (≥ 13 years). Age at diagnosis and income were analyzed as continuous variables; income was analyzed as inflation-adjusted annual household income.

Clinical Variables: Stage at presentation was categorized as in situ/localized, regional and distant/un-staged. Surgical and radiation treatment variables were categorized as surgical treatment received, not received due to medical reasons and not received due to non-medical reasons.

Survival: Survival time was calculated as the number of months between diagnosis and either date of death, date last known to be alive or December 31, 2003. We created two censoring variables based on SEER cause of death variable; one that indicated if a person had died with breast cancer as the underlying cause, and the other that indicated if a person had died of any cause. Patients who died of other causes or were alive at the date of last follow up were censored in the first censoring variable, and patients who were alive at the date of last follow up were censored in the second censoring variable [13].

Health Care Access Variables: Health care access was defined as the linear combination of measures of density of health care resources in the county [32]. We assessed specific variables related to health care resources at the county level and adjusted for differences in population size by dividing the counts per 10,000 people in each county. The derived

variables were subject to principal component analysis (PCA) on count per 10,000 of number of hospitals, number of medical doctors, number of medical doctors with obstetrics and gynecology specialty, number of Osteopathic Doctors (DO), number of DOs with obstetrics and gynecology specialty, number of nurse practitioners, and the number of mammography facilities. SAS Proc Factor was used to generate scores using an eigenequation [43] based on our input variables. The scores were categorized into tertiles; poorest, middle and highest.

Socio-Economic Status Variables: County level SES was defined using the Index of Concentration in the Extremes (ICE). This index was chosen over other approaches (such as the proportion of county residents below poverty level) because it allows for conceptualizing the concentration of affluence and disadvantage as falling along a single continuum. The index theoretically ranges from -1 (where all households are disadvantaged) through 0 (where there is equal proportion of affluent and disadvantaged households) to +1 (where all households are affluent) [44]. Two ICE indices were created; income based and education based.

ICE-Income = [(# Households with Household Income, \$100,000+) - (# Households with Families below Poverty Level)/Total Number of Households]

ICE-Education = [(% Persons 25 years⁺ with 4⁺ Yrs College) - (% Persons 25 years⁺ with <9 Yrs Sch)/100]

For easy interpretation, these measures were also categorized into tertiles. To control for other county level variables that may be associated with income, we included county level proportion of blacks and percent non-English speaking.

County Variables: All county level variables were obtained from the Area Resource File for the year 2000 because it had the most complete year of data and straddled the years included in the SEER dataset. We compared scores for 1990 and 2000 and found them to be highly correlated (ICE-Income Correlation Coefficient=0.90, $p<0.05$ and ICE-Education Correlation Coefficient=0.94, $p<0.05$). There were 3141 counties available for the county level analysis of health care access and SES. The first two components of the PCA had eigenvalues greater than 1, and the scree test also showed a clear break after the second component (figure not shown). Therefore, only the first two components were retained for further analysis. The two components together accounted for 50.5% of the total variance; components that had a factor loading value of greater than 0.4 were said to have loaded on a specific component. Based on this criterion, MDs per 10,000, MDs in Ob-Gyn per 10,000, nurse practitioners per 10,000, and DOs per 10,000 were loaded on the first component; hereafter named Personnel. Number of hospitals per 10,000 and number of mammography facilities per 10,000 were loaded on the second component; hereafter named Facilities. ICE-Income and ICE-Education scores were also calculated per county.

Statistical Analysis

All statistical analyses were performed using SAS statistical software (SAS, Version 9.2). The analysis was weighted according to the US population size during the study period. Descriptive statistics were generated using chi-square statistics and t-tests. Multivariable proportional hazards regression was used to model the hazards of breast

cancer and all-cause mortality in three separate models. The first model adjusted for demographic variables; the second model included clinical variables regarding stage of presentation and treatment, and the third model included county level variables. Robust sandwich estimates for the covariance matrix were used to account for the clustering of cases within counties, and the county FIPS code was specified as the clustering variable.

III. RESULTS

Table 1 provides information on the distribution of county variables relating to healthcare access, socio-economic status and other controls across the US.

Table 2 illustrates the distribution of demographic, clinical, and county level variables. On average, black patients were about 2 years younger compared with white patients, had a lower annual household income (\$25,000 for blacks versus \$44,700 for whites), were more likely to be single (19.1% of blacks versus 7.4% of whites) and divorced (19.7% of blacks versus 9.8% of whites), and were more likely to have less than a high school education (23.6% of blacks versus 9.5% of whites). The distribution of stage at diagnosis was similar between blacks and whites; about 53% of blacks were diagnosed at in situ/localized stage compared with 54.6% of white cases, and 14.2% of blacks were distant/unstaged compared with 13.3% of white cases.

At the county level, black patients were more likely than white patients to live in counties that had a higher proportion of households in poverty (36.9% of blacks versus 16.8% of whites), higher proportion of adults with less than 9 years of education (43.2% of blacks versus 26.9% of whites), and higher proportion of blacks (87.5% of blacks

versus 67.5% of whites). Whites were more likely to reside in counties with the poorest healthcare facilities (38.1% of whites versus 32.7 of blacks) and a higher proportion of non-English speaking residents (77.6% of whites versus 59.7% of blacks). All of these differences were statistically significant at the $p < 0.05$ level.

In unadjusted analysis (table not shown), black women had a 53% higher likelihood of dying of breast cancer ($p = 0.008$) and 32% higher likelihood of dying of any cause ($p = 0.02$) compared with white women. Having less than high school education increased the likelihood of breast cancer mortality by 68%, and all-cause mortality by 95%. Furthermore, being diagnosed at a distant stage and not receiving surgical or radiation treatment was also associated with significantly higher likelihood of death.

Table 3 presents the results of three sequential Cox proportional hazards multivariable models assessing the determinants of breast cancer survival. Model 1 assessed the effect of race on breast cancer mortality after adjusting for demographic variables. Race was no longer a statistically significant predictor of breast cancer death after adjusting for the individual variables (Hazard Ratio, 1.40; 95% CI, 0.99-1.97). Model 2 adjusted additionally for stage at presentation and treatment, and the effect of race remained non-significant. Model 3 presents the effect of county level variables adjusting for individual demographic and clinical variables on breast cancer mortality. Residing in counties with a higher proportion of households in poverty increased the likelihood of breast cancer deaths compared with counties with a higher proportion of affluent households. The hazard ratio of ICE-Income comparing the poorest versus highest group was 1.29 (95% CI, 0.82-2.05), and comparing the middle versus highest group was 1.49 (95% CI, 1.12-1.99). On the other hand, residing in counties with a

higher proportion of residents with less than 9 years of education appeared to reduce the likelihood of breast cancer deaths. The hazard ratio of ICE-Education comparing the poorest versus highest group was 0.55 (95% CI, 0.31-0.98), and comparing the middle versus highest group was 0.65 (95% CI, 0.44-0.96). Furthermore, residing in a county with a higher proportion of black residents ($\geq 6\%$) significantly increased the likelihood of breast cancer death (Hazard Ratio, 1.74; 95% CI, 1.21-2.48). Facilities and Personnel variables did not appear to have an independent significant effect on the likelihood of breast cancer death after adjusting for other variables in the model.

Table 4 presents the results of the Cox Proportional Hazards models assessing the determinants of all-cause mortality. In contrast to the model predicting breast cancer survival (Table 3), race remained a statistically significant predictor of higher mortality among blacks compared to whites even after adjusting for individual demographic and clinical variables. In model 1 which adjusted for demographic variables, being black was associated with a 38% increase in the likelihood of death due to any cause compared with being white (95% CI, 1.08-1.76). In model 2, the hazard ratio associated with being black was 1.33 (95% CI, 1.04-1.70) after adjusting for demographic and clinical variables. After adjusting for county level variables in model 3, the effect of race was attenuated and became non-significant (Hazard Ratio, 1.27; 95% CI, 0.95-1.71). Personnel, Facilities, county proportion of blacks and proportion of non-English speaking residents were not significantly associated with all-cause mortality.

IV. DISCUSSION

In this study of black and white women with breast cancer, the effect of race on breast cancer mortality became non-significant after adjusting for individual demographic variables. For all-cause mortality, race was a significant predictor even after adjusting for demographic and clinical variables such as stage of presentation and treatment. Upon adjusting for county level healthcare access variables, race was no longer significantly associated with all-cause mortality. Facilities and personnel variables did not appear to have a significant independent effect on the likelihood of breast cancer or all-cause mortality after adjusting for other variables in the model. Furthermore, residing in counties with a higher proportion of households in poverty increased the likelihood of breast cancer mortality and all-cause mortality compared with counties with a higher proportion of affluent households.

These findings suggest that neighborhood poverty and lack of access to care might explain part of the black-white disparity in breast cancer survival especially if examined from both individual and neighborhood levels. Many studies have sought to explain the causes of racial disparities in breast cancer survival [10-13,17,23,45-55], with varying results. However, none of these studies assessed the role of neighborhood healthcare access in breast cancer or all-cause survival although other studies have been published about the impact of neighborhood healthcare access on stage at diagnosis [12,33,56]. This study suggests that stage at presentation is an important predictor of breast cancer survival; late stage at diagnosis was associated with a four-fold increase in the hazard of breast cancer mortality after adjusting for other variables. Studies that assessed the role of county level healthcare access on late stage diagnosis of cancer found that women

residing in counties with fewer physicians [33], and poor access to mammography facilities [32] were more likely to have late stage cancer diagnosis. Other studies have suggested that important predictors of mammography use are having a primary care physician, shorter travel times and less public transportation hassles [56-65]. These are all factors which may be compounded if there are inadequate healthcare facilities and personnel within a county.

It was anticipated that these county characteristics, number of physicians and mammography facilities, would also be associated with breast cancer survival through the availability of early diagnosis and adequate treatment. However, the measures of healthcare access used in this study did not independently predict breast cancer survival, even though the initial racial disparity in survival disappeared. This finding is consistent with a recent publication which did not find an association between the availability of medical resources and breast cancer mortality at the county level [66]. Our finding may be due to several factors. First is the geographic level at which the neighborhood attributes are being measured. It is likely that some heterogeneity in exposure (i.e. county SES and healthcare access) is lost by aggregating neighborhood measures to the county level as opposed to the zip-code or census tract level. However, due to patient privacy concerns, the SEER dataset does not routinely disclose patient geographic location at levels smaller than the county. Second, this study accounted for the availability of healthcare resources but not accessibility. However, the concept of healthcare access is very complex and multidimensional, incorporating aspects of availability such as the presence of medical facilities and personnel as well as aspects of accessibility such as distance, affordability and cultural barriers. This study serves as a first step in

understanding the role of one aspect of healthcare access on breast cancer survival, and future studies may build on this research to further improve understanding of other aspects.

Third, other neighborhood level factors such as racial or economic segregation may also be important in understanding racial differences in breast cancer survival and need to be examined. For instance, it was observed that women residing in counties with a higher proportion of blacks had significantly higher hazards of breast cancer mortality. This is especially relevant to this study of racial disparities because studies have shown that due to lower income levels on average, blacks are more likely to reside in poor counties [26,32]. However, due to established social and family networks, even blacks that belong to higher SES groups are more likely to continue to reside in these poor counties. This has implications for the understanding of the impact of SES and breast cancer survival among blacks, because black women earning higher incomes may not benefit as much from their SES as white women earning similar wages but residing in high SES counties.

A significantly increased hazard of breast cancer and all-cause mortality associated with neighborhood income was observed. Women residing in counties with a higher proportion of low income residents compared with high income residents had higher hazards. This is consistent with other studies using other definitions of county SES [20,23,67,68]. However, significant reduction in the hazard of breast cancer and all-cause mortality for counties with a higher proportion of less educated residents was also observed. This observation was unexpected especially since higher individual education level was found to be protective in this study as well as in others [24,37,67,69]. One explanation for this finding may be the small sample size in counties with a higher

proportion of less educated residents. Another potential explanation is the high proportion of immigrants who may be less educated but more likely to have close-knit social networks that has been found to be protective against adverse health outcomes [70].

The major strength of this study was the availability of individual SES information for cancer patients. This allowed for better control of potential confounding of the association between neighborhood characteristics and survival by individual SES. Another strength is the development of a comprehensive definition of neighborhood healthcare access that included a measure of mammography facilities to better capture factors that may affect early detection, which is a major determinant of survival.

There are several limitations of our study. First, there is a possibility of exposure misclassification bias because measures of individual SES (household income, education and employment) were not obtained at the time of diagnosis with cancer. These measures were obtained through surveys which may have been administered before or after cancer diagnosis. However, the analysis was restricted to breast cancer cases ages 40 and older, reducing the likelihood of dramatic changes in SES through the study period. Secondly, the measure of healthcare access at the county level is an indicator of availability, not necessarily accessibility. Several other factors may determine if a person actually benefits from living in a county with good healthcare facilities such as language or cultural barriers, mistrust of the medical system, and lack of health insurance. Thirdly, for analytical reasons, the study sample was restricted to women residing in counties that had at least one black and one white breast cancer patient. This implies that the population may be more urban compared with the rest of the US. However, the results of this

analysis may still be applicable to semi-urban or rural areas where the impact of county SES and healthcare access on breast cancer survival may be even more pronounced.

In summary, this study adds an important component to the existing evidence on survival disparities by conceptualizing healthcare access at the county level as a potential determinant of health outcomes and as a potential modifier of the association between race and mortality. Further studies may focus on defining healthcare access at smaller geographic levels e.g. zip-code or census tracts which may be more homogenous in the distribution of healthcare facilities and personnel. Furthermore, while this study focused on the quantity of healthcare facilities and personnel, other studies may attempt to include a measure of healthcare quality as another indicator of healthcare access and a potential determinant of survival.

Table 3.1: Descriptive Statistics of Healthcare Access and Socio-Economic Characteristics of 3141 US Counties in 2000-2001, Area Resource File 2009-2010

Variable	N	Mean	Std Dev	Minimum	Maximum
<i>County Level Health Care Access</i>					
^a Personnel	3141	-2.05821E-16	1.0000000	-1.5196726	13.7772587
^a Facilities	3141	-1.96852E-16	1.0000000	-2.5652855	10.8010835
<i>County Level Income and Education</i>					
^b Index of Concentration at the Extremes (Income)	3141	-0.0097660	0.0763985	-0.4296578	0.3587847
^b Index of Concentration at the Extremes (Education)	3141	0.0743480	0.1141107	-0.3940000	0.6190000
<i>County Level Controls</i>					
% Non-English Speaking	3141	1.6312809	2.6106646	0	28.7156644
% Black	3141	8.7637377	14.5122176	0	86.5000000

^aPersonnel and Facilities, two measures of health care access were defined using principal components analysis on the count per 10,000 population of county level variables. Facilities: hospitals, mammography facilities; Personnel: MDs, DOs and nurse practitioners.

^bMeasures of SES at the county level are the ICE-Income and ICE-Education variables, defined as:

ICE-Education = (% 25+ years with college degree - % 25+ years with <9yrs education)

ICE-Income = (% with HH income >\$100,000 - % HH in poverty)

Table 3.2: Distribution of Individual and County-Level Characteristics of Breast Cancer Cases by Race

	Black (N=216)	White (N=1796)	P-value
	%	%	
Age at Diagnosis Mean (SD)	61.14 (14.34)	63.51 (13.49)	0.01
Income/\$1000 Mean (SD)	25.03 (24.38)	44.72 (40.40)	<0.001
Marital Status			
Single	19.11	7.36	<0.001
Married	28.60	53.55	
Widowed	30.19	28.04	
Divorced/Separated	19.72	9.84	
Missing	2.39	1.21	
Employment			
In Labor Force	49.91	47.66	0.79
Not in Labor Force	46.10	48.18	
Missing	3.99	4.17	
Education			
< High School	23.57	9.51	<0.001
High School Graduate	29.99	38.76	
College	46.44	51.73	
Rural/Urban			
Rural	6.22	9.15	0.12
Urban	93.78	90.85	
Stage of Diagnosis			
In Situ/Localized	53.01	54.62	0.96
Regional	27.69	27.11	
Distant/Unstaged	14.16	13.25	
Missing	5.14	5.02	

Treatment-Surgery				
Received	91.23	95.07	0.03	
None- Medical Reasons	4.30	2.06		
None- Non Medical Reasons	4.47	2.87		
Treatment-Radiation				
Received	31.17	38.61	0.07	
None- Medical Reasons	62.42	55.68		
None- Non Medical Reasons	6.41	5.70		
Income Disparity				
Poorest	36.94	16.77	<0.001	
Middle	30.79	34.87		
Highest	32.28	48.36		
Education Disparity				
Poorest	43.20	26.90	<0.001	
Middle	24.69	31.43		
Highest	32.11	41.67		
Facilities				
Poorest	32.69	38.10	0.0009	
Middle	50.57	38.46		
Highest	16.74	23.44		
Personnel				
Poorest	13.09	12.10	0.76	
Middle	45.67	44.28		
Highest	41.24	43.62		
Percent Non-English Speaking				
<3%	40.32	22.42	<0.001	
≥3%	59.68	77.58		

Percent Black			
<6%	12.48	32.49	<0.001
≥6%	87.52	67.51	

^aPersonnel and Facilities, two measures of health care access were defined using principal components analysis on the count per 10,000 population of county level variables and then categorized into tertiles. Facilities: hospitals, mammography facilities; Personnel: MDs, DOs and nurse practitioners.

^bMeasures of SES at the county level are the ICE-Income and ICE-Education variables which were calculated and categorized into tertiles, defined as:
 ICE-Education = (% 25+ years with college degree - % 25+ years with <9yrs education)
 ICE-Income = (% with HH income >\$100,000 - % HH in poverty)

Table 3.3: Cox Proportional Hazard Multivariable Analysis of Breast Cancer Mortality, SEER-NLMS, 1973-2003

Characteristic	Hazard Ratio (95% CI) of Breast Cancer Mortality		
	Model 1 <i>Demographics^a</i>	Model 2 <i>+Clinical^b</i>	Model 3 <i>+County^c</i>
Race			
Black	1.40 (0.99-1.97)	1.40 (0.99-1.98)	1.32 (0.73-2.41)
White (ref.)	1.00	1.00	1.00
Age	1.01 (1.00-1.02)	1.01 (0.99-1.02)	1.01 (0.99-1.02)
Income/\$1000	0.99 (0.99-1.00)	0.99 (0.99-1.00)	0.99 (0.99-1.00)
Employed			
Not in Labor Force	1.02 (0.78-1.33)	1.33 (1.01-1.74)*	1.38 (0.89-2.14)
In Labor Force (ref.)	1.00	1.00	1.00
Marital Status			
Single	1.10 (0.72-1.70)	1.21 (0.78-1.87)	1.16 (0.67-2.02)
Divorced/Separated	1.43 (1.01-2.03)*	1.57 (1.09-2.25)*	1.64 (1.09-2.45)*
Widowed	0.95 (0.71-1.28)	1.09 (0.80-1.48)	1.09 (0.72-1.66)
Married (ref.)	1.00	1.00	1.00
Education			
< High School	1.44 (1.00-2.05)*	1.36 (0.95-1.94)	1.35 (0.99-1.85)
High School Grad	1.38 (1.08-1.78)*	1.42 (1.09-1.83)**	1.55 (1.22-1.96)**
College (ref.)	1.00	1.00	1.00
Stage of Presentation			
Regional		3.27 (2.44-4.39)***	3.38 (2.48-4.60)***
Distant/ Unstaged		4.18 (3.03-5.77)***	5.78 (3.06-10.93)***
In Situ/Local (ref.)		1.00	1.00

Surgical Treatment		
None-Medical Reasons	8.55 (5.54-13.21)***	8.15 (3.56-18.68)***
None-Non Medical Reasons		
Received (ref.)	3.72 (2.39-5.84)***	3.23 (1.56-6.68)**
	1.00	1.00
Radiation Treatment		
None-Autopsy Diagnosis	0.87 (0.67-1.41)	0.85 (0.62-1.16)
None-Refused/Unknown	2.10 (1.35-3.28)**	1.91 (0.95-3.86)
Received (ref.)	1.00	1.00
Rural/Urban		
Urban		1.40 (0.84-2.35)*
Rural (ref.)		1.00
^dIncome Disparity		
Poorest		1.29 (0.82-2.05)
Middle		1.49 (1.12-1.99)**
Highest (ref.)		1.00
^dEducation Disparity		
Poorest		0.55 (0.31-0.98)*
Middle		0.65 (0.44-0.96)*
Highest (ref.)		1.00
^eFacilities		
Poorest		1.01 (0.61-1.68)
Middle		1.15 (0.66-1.99)
Highest (ref.)		1.00
^ePersonnel		
Poorest		0.78 (0.40-1.51)
Middle		0.78 (0.49-1.24)
Highest (ref.)		1.00
Proportion Non-English Speaking		
≥3%		0.91 (0.56-1.48)
<3% (ref.)		1.00

Proportion Black

≥6%	1.74 (1.21-2.48)**
<6% (ref.)	1.00

*P<0.05, **p<0.01, ***p<0.001; CI, Confidence Interval; ref, reference group

^aModel adjusting for individual demographic variables only

^bModel adjusting for clinical variables such as stage at presentation and treatment in addition to demographic variables

^cModel adjusting for county level variables including healthcare access and SES in addition to individual demographics and clinical variables

^dMeasures of SES at the county level are the ICE-Income and ICE-Education variables which were calculated and categorized into tertiles, defined as:

ICE-Education = (% 25+ years with college degree - % 25+ years with <9yrs education)

ICE-Income = (% with HH income >\$100,000 - % HH in poverty)

^ePersonnel and Facilities, two measures of health care access were defined using principal components analysis on the count per 10,000 population of county level variables and then categorized into tertiles. Facilities: hospitals, mammography facilities; Personnel: MDs, DOs and nurse practitioners.

Table 3.4: Cox Proportional Hazard Multivariable Analysis of All-Cause Mortality, SEER-NLMS, 1973-2003

Characteristics	Hazard Ratio (95% CI) of All-Cause Mortality		
	Model 1 <i>Demographics^a</i>	Model 2 <i>+Clinical^b</i>	Model 3 <i>+County^c</i>
Race			
Black	1.38 (1.08-1.76)**	1.33 (1.04-1.70)*	1.27 (0.95-1.71)
White (ref.)	1.00	1.00	1.00
Age	1.05 (1.04-1.06)***	1.05 (1.04-1.05)***	1.05 (1.03-1.06)***
Income/\$1000	0.99 (0.99-1.00)	0.99 (0.99-1.00)	0.99 (0.99-1.00)
Employed			
Not in Labor Force	1.0 (0.83-1.21)	1.18 (0.98-1.43)	1.18 (0.92-1.51)
In Labor Force (ref.)	1.00	1.00	1.00
Marital Status			
Single	1.32 (0.97-1.78)	1.44 (1.06-1.95)*	1.40 (0.95-2.06)
Divorced/Separated	1.39 (1.07-1.81)**	1.58 (1.21-2.07)**	1.59 (1.19-2.14)**
Widowed	1.16 (0.96-1.39)	1.29 (1.07-1.57)**	1.36 (1.01-1.83)*
Married (ref.)	1.00	1.00	1.00
Education			
< High School	1.49 (1.19-1.87)**	1.44 (1.14-1.79)**	1.41 (1.05-1.89)*
High School Grad	1.23 (1.04-1.46)*	1.28 (1.08-1.52)**	1.34 (1.10-1.64)**
College (ref.)	1.00	1.00	1.00
Stage of Presentation			
Regional		1.68 (1.40-2.02)***	1.69 (1.41-2.04)***
Distant/ Unstaged		1.87 (1.51-2.30)***	2.16 (1.55-3.02)***
In Situ/Local (ref.)		1.00	1.00

Surgical Treatment		
None-Medical Reasons	7.35 (5.14-10.52)***	6.79 (3.79-12.15)***
None-Non Medical Reasons	2.96 (2.12-4.13)***	2.81 (1.64-4.80)***
Received (ref.)	1.00	1.00
Radiation Treatment		
None-Medical Reasons	0.96 (0.79-1.15)	0.95 (0.77-1.18)
None-Non Medical Reasons	2.23 (1.61-3.09)**	2.10 (1.46-3.03)***
Received (ref.)	1.00	1.00
Rural/Urban		
Urban		1.28 (0.87-1.88)
Rural (ref.)		1.00
^dIncome Disparity		
Poorest		1.37 (1.03-1.82)*
Middle		1.27 (1.03-1.58)*
Highest (ref.)		1.00
^dEducation Disparity		
Poorest		0.61 (0.47-0.81)**
Middle		0.75 (0.60-0.93)**
Highest (ref.)		1.00
^eFacilities		
Poorest		0.98 (0.68-1.41)
Middle		1.13 (0.79-1.64)
Highest (ref.)		1.00
^ePersonnel		
Poorest		0.93 (0.64-1.36)
Middle		0.98 (0.79-1.21)
Highest (ref.)		1.00
Proportion Non-English Speaking		
>3%		0.87 (0.63-1.19)
<3% (ref.)		1.00

Proportion Black

>6%	1.19 (0.97-1.47)
<6% (ref.)	1.00

*P<0.05, **p<0.01, ***p<0.001; CI, Confidence Interval; ref, reference group

^aModel adjusting for individual demographic variables only

^bModel adjusting for clinical variables such as stage at presentation and treatment in addition to demographic variables

^cModel adjusting for county level variables including healthcare access and SES in addition to individual demographics and clinical variables

^dMeasures of SES at the county level are the ICE-Income and ICE-Education variables which were calculated and categorized into tertiles, defined as:
ICE-Education = (% 25+ years with college degree - % 25+ years with <9yrs education)

ICE-Income = (% with HH income >\$100,000 - % HH in poverty)

^ePersonnel and Facilities, two measures of health care access were defined using principal components analysis on the count per 10,000 population of county level variables and then categorized into tertiles. Facilities: hospitals, mammography facilities; Personnel: MDs, DOs and nurse practitioners.

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CHAPTER 4

TRENDS IN BREAST CANCER STAGE AND MORTALITY IN MICHIGAN (1992-2009) BY RACE, SOCIOECONOMIC STATUS AND HEALTHCARE ACCESS

I. INTRODUCTION

Overall age-standardized breast cancer mortality rates have declined significantly over time in the U.S. (1-7) and in Michigan (8). However, widening disparities in breast cancer mortality between black and white patients has been consistently reported across the U.S. and within the state of Michigan (4, 9-12). According to Surveillance Epidemiology and End Results (SEER) data, breast cancer mortality rates declined from 35 per 100,000 to 29 per 100,000 for black women and from 30 per 100,000 to 21 per 100,000 for white women between 1990 and 2000 (4). In Michigan, the breast cancer mortality rate was 23.4 per 100,000 for whites and 33.8 per 100,000 among blacks between 2003 and 2007 (12). In addition, the National Center for Health Statistics reported that between 1999 and 2007, black women were more likely than any other racial group in the US to die of breast cancer (13).

Possible reasons for the observed racial disparity in mortality include differential access to breast cancer screening and timely diagnosis at early stages, as well as adequate treatment (11, 14). Adequate access to screening, diagnosis and treatment were found to be associated with socio-economic status (SES), both at the individual and neighborhood level (15-18). For instance, breast cancer mortality rates in least deprived U.S. counties declined at a higher rate compared with rates in counties that were most deprived (15). Individuals with higher SES have better breast cancer treatment and survival compared with those with lower SES, even though racial disparities were still present (19). In addition, lack of healthcare access (HCA) has been associated with poorer outcomes in many aspects of breast cancer including screening (20), diagnostic follow-up (21, 22), stage of presentation (23, 24), treatment (25, 26) and survival (27). Despite these improvements in our understanding of the contributors to racial disparities in breast cancer mortality, more research is needed to understand long term trends in these factors that influence the racial disparities of breast cancer outcomes. Such research may indicate significant progress or decline in the fight against breast cancer based on seasonal or periodic trends within the state.

Recent studies using national SEER data have reported significant racial and county level socio-economic disparities in breast cancer screening and mortality trends (15, 28, 29).

We sought to assess the presence of racial and socio-economic as well as HCA disparities on breast cancer stage of presentation and mortality in Michigan. To our knowledge, there has been no research study conducted in Michigan to assess the factors that influence the trends in breast cancer stage and mortality and the persistent racial

disparities observed in the state. Understanding the picture in Michigan, a state that has experienced significant economic downturn in recent years, may help with anticipating breast cancer trends in other parts of the country facing similar situations. The aim of this study was to assess the influence of zip-code level HCA and SES on breast cancer stage at diagnosis and mortality trends for white and black patients in Michigan between 1992 and 2009.

II. METHODS

Study Population: Annual breast cancer stage of diagnosis and mortality data were obtained from the Michigan Cancer Surveillance Program (MCSP) at the Michigan Department of Community Health. The MCSP is a member of the North American Association of Central Cancer Registries and is certified for its quality and high level of data completeness. The data included breast cancer deaths for patients ages 20 years and older separately for blacks and whites in each zip-code in Michigan and for every year between 1992 and 2009. Stage of diagnosis data contained the proportion of late stage diagnoses separately for blacks and whites per zip code for each year between 1992 and 2008. Late stage of diagnosis was defined as regional and distant breast cancer according to the 2000 SEER summary stage criteria. Annual age-adjusted mortality rates by race and zip code were calculated using the 2000 U.S standard population.

Study Variables: Since the analytic dataset consisted of data from 1992 to 2009, we chose the year 2000 as a mid-point of the interval for which to define zip-code level SES and HCA.

Socio-Economic Status: We constructed a measure of zip-code level SES by using principal components analysis (PCA) using data obtained from the US Census Bureau (30). Four variables that we believe are most closely related to SES based on previous studies were subject to PCA; a) proportion of adults ages 25 and older with over 4 years of education, b) proportion of residents ages 16 and older in the labor force but unemployed, c) proportion of households in poverty and d) the median household income (31, 32). The first principal component accounted for 62% of the variance in the dataset, and was retained for further analysis as a measure of zip-code level SES. SES was categorized into tertiles corresponding to low, middle and high SES.

Healthcare Access: We sought to define zip code level HCA as the availability of healthcare personnel and facilities in Michigan. However, data on healthcare personnel such as the count of doctors and nurses at the zip-code level for 2000 in Michigan was not available. Therefore, we defined zip-code level HCA as the number of hospitals and mammography facilities available in each Michigan zip-code. A list of names and addresses of all licensed hospitals in Michigan in 1999 were obtained from the Division of Licensing and Certification at the Michigan Bureau of Health Systems. In addition, a list of names and addresses of all licensed mammography facilities operational in Michigan in 2000 were obtained from the Michigan State Radiation Safety Section. For

our final analysis, we defined zip-level HCA as the sum of the number of hospitals and mammography facilities divided by the zip-code population in 2000, multiplied by 10,000. Access was categorized into tertiles; low, middle and high.

Analytic Methods: Age-adjusted breast cancer mortality rate by race was calculated for all zip codes in Michigan annually for 1992-2009, and linked with the dataset containing zip-code level SES and HCA. Annual median age-adjusted breast cancer mortality rates by race, SES and HCA were calculated. Median percent late stage diagnosis per zip code was also calculated by race, SES and HCA. Joinpoint regression with a maximum of three joinpoints was used to compare changes in the median zip-code level mortality rate and percent late stage diagnosis over time by race, SES and HCA. Joinpoints are used to test for significant changes in the slope or trend, and also to assess if two regression functions are coincident or parallel (Joinpoint, Version 3.5.1). Trends in median age-adjusted mortality and percent late stage by race, SES and HCA are defined as increasing or decreasing when the Annual Percent Change is statistically significant ($p < 0.05$), and stable if otherwise. Significant trends throughout the entire years of analysis are also assessed by the Average Annual Percent Change (AAPC). Furthermore Poisson regression was used to model the temporal trend in annual median mortality rate and percent late stage by race adjusting for neighborhood SES and HCA.

III. RESULTS

Percent Late Stage Diagnosis

Between 1992 and 2008, 27% of black patients and 21% of white patients were diagnosed at a late stage (Table 1). Median percent late stage diagnosis declined as zip-code SES increased for both black and white patients. The median percent late stage diagnosis for black patients was 33%, 17% and 11% for low, middle and high SES zip-codes respectively. Among white patients the median proportion of late stage diagnosis was 23%, 21%, 20% for low, middle and high SES zip-codes respectively. Median percent late stage diagnosis for black patients was 29%, 26% and 27% for low, middle and high access zip-codes respectively. Among white patients, the median percent late stage of diagnosis was 20%, 25% and 23% for low, middle and high access zip-codes respectively.

Black patients were consistently diagnosed at a late stage more frequently than white patients over time (Figure 1-1). There was also a statistically significant increase of 4.5% (CI: 0.4, 8.7) in late stage diagnosis among white patients between 2002 and 2006 (Table 2). There were differences in late stage of diagnosis between SES groups (Figure 1-2). Late stage diagnosis among the low SES group remained stable over the study period, but increased in the middle and high SES groups (Table 2). Clear gradients also existed between HCA groups (Figure 1-3). The high access group experienced a statistically significant increase which narrowed the gap between middle and high access groups by

2008 (Table 2). The low access group experienced several statistically significant trends, although remained lower than other groups.

Significant disparities in late stage diagnosis were also observed between blacks and whites when examined within strata of neighborhood SES and HCA (Figure 2). Blacks were more likely to be diagnosed at a late stage in each of the neighborhood types. In most neighborhood types except low SES/high access and mid SES/high access, the percentage of late stage diagnosis among blacks declined over time. In contrast, among white patients the percentage of late stage diagnosis increased over time in most neighborhood types, excluding mid SES/low access, high SES/mid access and high SES/low access. In all neighborhood types, differences in percent late stage between blacks and whites appear to have narrowed over time.

Age-Adjusted Mortality Rates

Between 1992 and 2009, 3,684 black patients and 20,241 white patients died of breast cancer in Michigan (Table 1). Age-adjusted breast cancer mortality rate during this period was 32 per 100,000 among black patients and 29 per 100,000 among white patients. Among black patients, median age-adjusted breast cancer mortality rate increased as zip-code level SES increased. The median age-adjusted mortality rate was 28 per 100,000, 41 per 100,000 and 72 per 100,000 for low, middle and high SES zip-codes respectively. Among white patients, the reverse trend was observed; the median age-adjusted mortality rate was 38 per 100,000, 32 per 100,000 and 25 per 100,000 for

low, middle and high SES zip-codes respectively. As zip-code level HCA increased, median age-adjusted mortality rate remained relatively stable for black patients; 32 per 100,000, 32 per 100,000 and 34 per 100,000 for low, middle and high access zip-codes respectively. Among white patients, the median age-adjusted mortality rate was 34 per 100,000, 22 per 100,000 and 26 per 100,000 for low, middle and high access zip-codes respectively.

Between 1992 and 2009, the age-adjusted breast cancer mortality rate appeared to have declined among whites, but remained statistically unchanged among blacks, resulting in a clear gradient of higher rates among blacks patients compared with whites (Figure 1-4). There were no joinpoints in median mortality rates for blacks, however whites observed a statistically significant change of -1.3% (CI: -1.8,-0.8) during the study period (Table 2). There were initial large differences in rates between SES levels in 1992 with the highest rates among low and middle SES groups but these appeared to have narrowed significantly by 2006 (Figure 1-5). This trend is reflected in the statistically significant joinpoints in median mortality rates for low and middle SES groups (Table 2). There are also clear gradients between the three HCA groups; low access groups had the highest mortality rate, followed by high access and middle access groups (Figure 1-6). All three access groups had statistically significant joinpoints that suggested declining rates over time. Each of the access groups were statistically different from each other (i.e. not coincident), but were parallel to each other.

In all neighborhood types, blacks had higher mortality rates compared with whites, and the disparity between the two racial groups appeared to have increased over time (Figure 3). Among black patients, the age-adjusted mortality rate showed marked increases in all neighborhood types except mid SES/mid access. The largest increase appeared to be in high SES neighborhoods, regardless of access. Among white patients, annual age-adjusted mortality rates declined in all neighborhood types except high SES/high access, high SES/mid access and high SES/low access. In all neighborhood types, differences in age-adjusted breast cancer mortality rates between blacks and whites appear to have increased over time.

IV. DISCUSSION

The purpose of this study was to assess trends in late stage diagnosis and breast cancer mortality rate among black and white women in Michigan between 1992 and 2009, accounting for neighborhood SES and HCA. Our findings suggest that in the past 18 years, black and white breast cancer patients in Michigan have had different experiences with the disease based, in part, on their neighborhood of residence. In the period between 1992 and 2008, when both racial groups are initially examined without accounting for neighborhood type, the proportion of late stage presentation increased annually by 1.0% among white patients, but remained statistically unchanged among black patients. In the same period, the breast cancer mortality rate declined annually by -1.3% among white patients but remained statistically unchanged among black patients.

Further examination of the trends based only on neighborhood SES characteristics suggests that the proportion of late stage presentation narrowed between SES groups by 2008. This narrowing trend was due to the increase in the proportion of late stage presentation among the middle and high SES groups, compared with the statistically unchanged trend among the low SES groups. Similarly, a narrowing of the mortality rate trend occurred between 1992 and 2009; although mortality rates in the high SES group remained statistically unchanged, the low and middle SES groups experienced significant declines in mortality rates irrespective of race. This trend resulted in limited disparity in breast cancer mortality rates between low, middle and high SES groups by 2009, irrespective of race. When outcomes were further examined based only on neighborhood HCA, surprisingly, the proportion of late stage presentation appeared lower among the low HCA group and highest among the middle HCA group. However, by 2008, the low and high HCA groups had experienced significant increases, while the middle HCA remained statistically unchanged. This trend resulted in similarly higher rates for high and middle HCA groups compared with the low access groups at the end of the period. Mortality rates declined for all HCA groups; however, disparities remained between the groups at the end of the study period irrespective of race.

Additionally, examining late stage diagnosis and mortality rate trends between black and white patients from similar neighborhood types suggests that large disparities still remained at the end of the study period. Black patients were consistently diagnosed at a late stage more frequently than whites, although they have experienced a significant reduction in the proportion of late stage diagnosis over time. White patients, on the other

hand, experienced significant increases in the proportion of late stage diagnosis in all neighborhood types. The reverse scenario is observed in age-adjusted mortality rates. Black patients had higher mortality rates than white patients in all neighborhood types, and they have observed a significant increase in mortality rates over time. The largest annual increase appeared to have been among black patients in the high SES/high HCA group; this group had the smallest amount of disparity between black and white patients at the beginning of the study period. White patients in the high SES/high HCA group also experienced a large increase in mortality rate during the study period.

Overall across all the study years, the highest proportion of late stage diagnoses was observed among black patients, patients residing in low SES zip-codes and patients residing in middle access zip-codes. The groups that had the highest breast cancer mortality rates were black patients, patients residing in low SES zip-codes and patients residing in low access zip-codes. These findings are similar to others that have found consistent disparities in cancer outcomes by race, socio-economic status and HCA (28). In addition, other studies have reported the correlation between late stage at diagnosis and high mortality rates, especially among blacks (10, 33). This correlation has been attributed to the lower likelihood of receiving appropriate treatment, and a higher likelihood of co-morbid conditions such as diabetes and hypertension (34-36). Other studies suggest that aggressive, triple-negative breast cancer sub-types may be responsible for the higher mortality rates observed among blacks (37). These cases account for less than 25% of all invasive breast cancer cases, with higher rates observed among blacks compared with whites (38). Therefore, research efforts should be focused

on understanding factors such as SES and HCA that affect the vast majority of breast cancer patients of all races, but may also be related to the development of aggressive breast cancer sub-types (39).

Possible explanations for the high percent late stage diagnosis and age-adjusted mortality rate among black patients even in high SES and HCA zip-codes could be attributed to other dimensions of access to healthcare not captured by availability. This trend of higher mortality rates in higher SES neighborhoods has also been observed at the county level (15). Cultural or language barriers as well as historical mistrust of the medical system could potentially limit the ability of black women to benefit from available healthcare resources. These factors have been consistently associated with reduced contact with healthcare facilities among minority populations in the US (40, 41). In addition, residing in a high SES zip-code may not necessarily mean higher SES individually. Lack of reliable transportation, time off from work or health insurance may be major factors that could preclude routine use of healthcare facilities. Furthermore, research studies have suggested that retaining social and family networks are a major reason why black women reside in low SES neighborhoods (42). Consequently, residing in a high SES neighborhood may result in the loss of established social networks that have also been shown to be important to improved psychosocial wellbeing and health outcomes (41, 43, 44).

More detailed studies focused on assessing care seeking patterns and treatment availability/utilization within neighborhood types will be very helpful to provide concrete explanations for these observed trends. However, it is likely that the decline in late stage diagnosis among black patients may be due to concerted efforts such as the National Breast and Cervical Cancer Early Detection Program (NBCCEDP), which have been helpful in improving screening among low-income, uninsured women who are more likely to be black or of Hispanic descent (45). Unfortunately, the increase in mortality rates among black women may be due to factors such as the receipt of inadequate treatment regimen due to lack of adherence, lack of knowledge about other treatment options or racially based differences in treatment plans (34, 35).

Among white patients in Michigan, the observed increase in the proportion of late stage diagnosis may be due to several reasons. First, Michigan has experienced large declines in employment since 2001, dropping from about 450 jobs per 1,000 residents in 2001 to about 385 jobs per 1,000 in 2009(46). This drop occurred earlier and more deeply than national level employment rates, mainly because of the close ties between the Michigan economy and the auto industry (46). Loss of employment results in loss of insurance coverage for individuals and families, potentially resulting in less access to healthcare and lower cancer screening rates. Data from the Michigan BRFSS shows that in 2000, 68% of white women had received a mammography test in the past year (47). However, the proportion of white women who reported receiving the test in the past year in 2004, 2006, 2008 and 2010 are 63%, 65%, 64% and 61% respectively (48-51). The declining screening rates may be responsible for the increase in late stage presentation observed

among white women in Michigan. In addition, we cannot discount the possibility of an increase in aggressive sub-types of breast cancer among white women which progresses very rapidly and may not always be detected by annual mammography screening.

A major strength of this study is the measure of neighborhood characteristics at the zip-code level, a smaller geographic area than the county which may provide a more homogenous population with respect to SES and HCA. Most research studies use county level characteristics in assessing SES disparities in breast cancer (15, 28, 29, 52-55), and none has assessed zip-code level characteristics in relation to breast cancer in Michigan. In addition, the availability of data on neighborhood SES and HCA improved our ability to parse out differences in late stage and mortality trends between black and white women residing in similar neighborhoods. A limitation of this analysis is that HCA was defined based only on the availability of healthcare facilities at the zip-code level. The availability of healthcare personnel could have improved this measure, but lack of data precluded its inclusion in this analysis. However, facilities and personnel are likely highly correlated at the neighborhood level i.e. the more facilities available, the more personnel will be present. In addition, zip-code level measures of SES and HCA were used in this study as indirect measures; we did not account for the potential porosity of geographic boundaries in which residents of low access zip-codes may have access to and chose to travel to high access zip-codes for healthcare.

In summary, future studies in the US should focus on improving understanding of the factors contributing to the rise and fall of the proportion of late stage at diagnosis and

mortality rate trend over time through detailed analysis of trends in risk factors known to be associated with these outcomes such as mammography screening and improved treatment regimens. In addition, in-depth clinical studies are needed to explore the possibility of rising aggressive sub-types of breast cancer among white women. These aggressive cancers may be partly responsible for rising late stage diagnosis among white women, and understanding this sub-group may help researchers in developing guidelines for more frequent screening in this population. This study and future research will be very helpful in better understanding population sub-groups that are disproportionately experiencing adverse outcomes despite improvements in screening and treatment regimens. Programs such as the NBCCEDP may be extended to other populations or regions where they will be beneficial to patients of low SES and low HCA to help reverse the trend of late stage at presentation and high mortality rates. It will be very helpful to examine trends in other regions of the US that may have experienced significant economic downturn to assess the impact of loss of employment and insurance on breast cancer stage at presentation and mortality. Globally, as breast cancer rates are projected to increase, it will be important to conduct studies like these to identify vulnerable sub-groups that may benefit from concentrated resources aimed at increasing access to timely screening and adequate treatment.

Table 4.1: Distribution of Breast Cancer Mortality and Percent Late Stage by Zip-Code Characteristics

	Frequency % (n)		Median Mortality Rate ^a		% Late Stage ^b	
	Black	White	Black	White	Black	White
Total	13.3 (3,684)	86.7 (20,241)	32.07	28.80	27.27	21.05
SES						
Low	76.1 (2,804)	17.6 (3,572)	27.99	38.35	33.33	23.08
Middle	11.5 (422)	29.9 (6,055)	40.63	31.74	16.67	20.83
High	11.7 (431)	51.3 (10,390)	72.15	25.47	10.79	20.00
Facility						
Low	57.1 (2102)	48.3 (9776)	31.63	34.19	28.57	20.00
Middle	32.6 (1201)	34.9 (7079)	32.23	21.79	26.12	25.00
High	9.6 (355)	15.7 (3171)	33.95	25.89	26.97	23.08

^aMedian of zip-code and year specific mortality rates by race, 1992-2009

^bMedian of zip-code and year specific proportion of late stage by race, 1992-2008

Table 4.2: Trends[†] in Percent Late Stage (1992-2008) and Median Mortality Rate (1992-2009) by Race, SES and Healthcare Access

	Trend 1		Trend 2		Trend 3		Average Annual Percentage Change
	Years	APC (95% CI)	Years	APC (95% CI)	Years	APC (95% CI)	
Percent Late Stage							
Race							
Black	1992-1995	-7.9 (-17.9,3.4)	1995-2002	2.0 (-1.9,6.1)	2002-2008	-2.4 (-6.1,1.5)	-0.5 (-1.9, 0.8)
White	1992-2001	-0.4 (-1.6,0.7)	2001-2006	4.5 (0.4-8.7)*	2006-2008	-5.3 (-16.5,7.4)	1.0 (0.4,1.6)*
SES							
Low	1992-2002	-0.0 (-2.1,2.1)	2002-2006	5.2 (-8.0,20.2)	2006-2008	-10.1 (-31.2,17.4)	0.7 (-0.2,1.7)
Middle	1992-1994	17.2 (-11.6,55.4)	1994-1997	-7.0 (-29.9,23.2)	1997-2008	2.5 (0.5,4.4)*	1.4 (0.2,2.6)*
High	1992-1997	-2.8 (-6.7,1.2)	1997-2008	1.6 (0.4,2.9)*			1.6 (0.4,2.9)*
Access							
Low	1992-1994	18.9 (0.9,40.0)*	1994-1997	-7.7 (-21.6,8.7)*	1997-2008	1.9 (0.8,3.0)*	1.9 (0.8,3.0)*
Middle	1992-1999	-1.6 (-3.2,0.2)	1999-2002	2.7 (-9.8,16.8)	2002-2008	0.2 (-2.0,2.4)	0.1 (-0.5,0.7)
High	1992-1994	-10.3 (-37.5,28.7)	1994-2008	2.0 (0.3,3.7)*			2.0 (0.3,3.7)*
Mortality Rate							
Race							
Black	1992-2000	-0.2 (-2.6,2.3)	2000-2007	1.5 (-2.3,5.5)	2007-2009	-6.0 (-25.1,18.0)	-0.3 (-0.3,1.0)
White	1992-1995	1.4 (-7.4,11.1)	1995-1998	-2.8 (-18.9-16.7)	1998-2009	-1.2 (-2.4,-0.0)*	-1.3 (-1.8,-0.8)*
SES							
Low	1992-2002	-2.6 (-4.6,-0.6)*	2002-2006	-0.7 (-12.9,13.1)	2006-2009	-2.9 (-14.8,10.6)	-2.1 (-2.9,-1.3)*
Middle	1992-2004	-1.4 (-2.5,-0.3)*	2004-2007	1.5 (-15.9,22.5)	2007-2009	-5.7 (-21.9,13.8)	-1.2 (-1.7,-0.7)*
High	1992-1994	3.5 (-8.0,16.3)	1994-2002	-0.0 (-1.6,1.6)	2002-2009	-1.1 (-2.7,0.4)	-0.3 (-0.8,0.3)
Access							
Low	1992-1995	0.5 (-7.7,9.4)	1995-2009	-1.1 (-1.8,-0.3)*			-0.9 (-1.4,-0.4)*
Middle	1992-2001	-2.0 (-3.9,-0.1)*	2001-2007	-0.4 (-5.0,4.5)	2007-2009	-6.8 (-24.7,15.4)	-1.6 (-2.2,-1.0)*
High	1992-2003	-1.9 (-3.6,-0.2)*	2003-2007	3.2 (-9.2,17.1)	2007-2009	-7.3 (-28.1,19.6)	-1.0 (-1.7,-0.2)*

*P<0.05; APC Annual Percent Change; CI Confidence Interval; [†]Trend years may include different time periods based on Joinpoint regression modeling

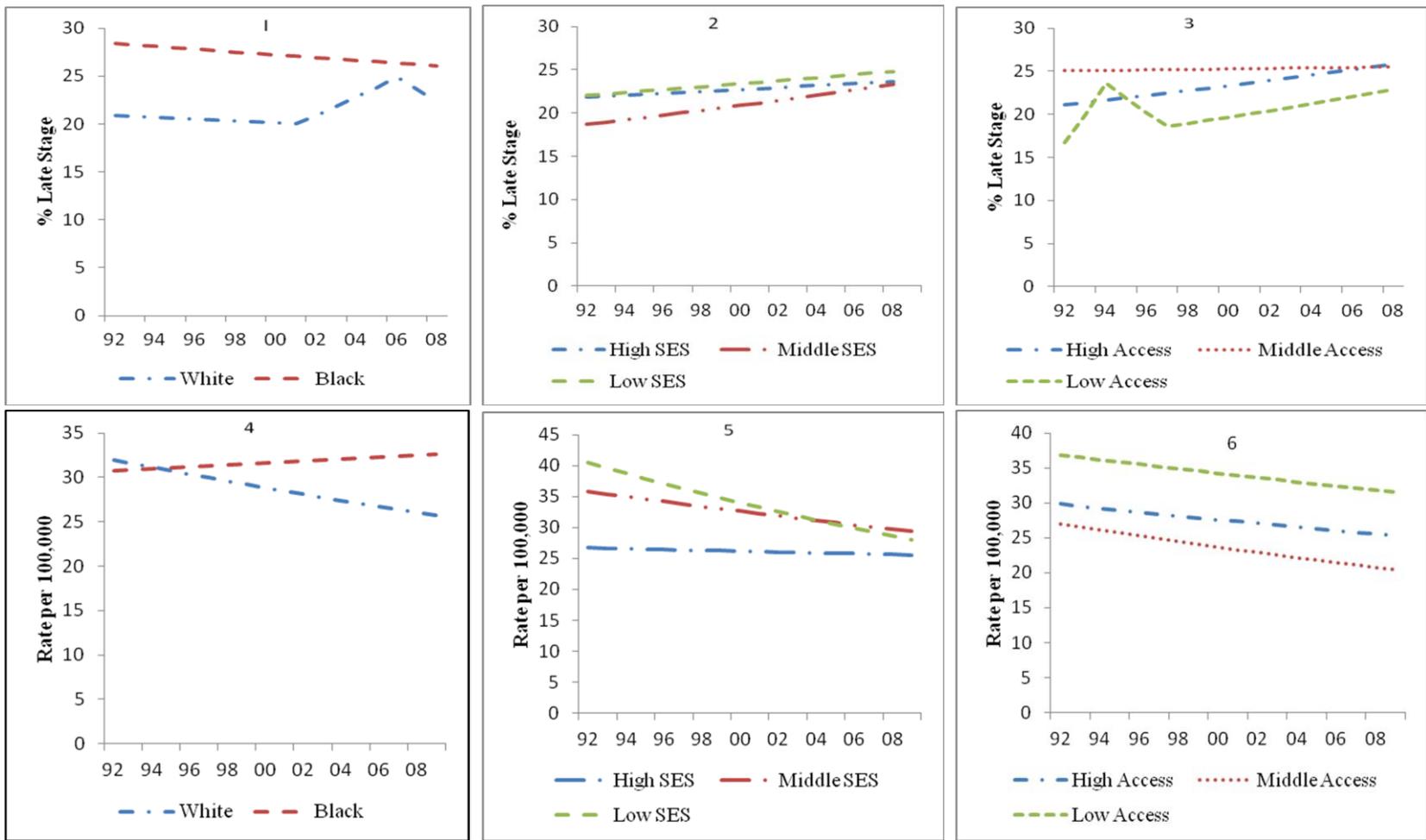


Figure 4.1: Median Predicted Zip-Code Percent Late Stage Diagnosis (1992-2008) and Age-Adjusted Mortality Rate (1992-2009) by Race, SES and HCA (1-3: Percent Late Stage Diagnosis by Race, SES and HCA; 4-6: Age-Adjusted Mortality Rate by Race, SES and HCA)

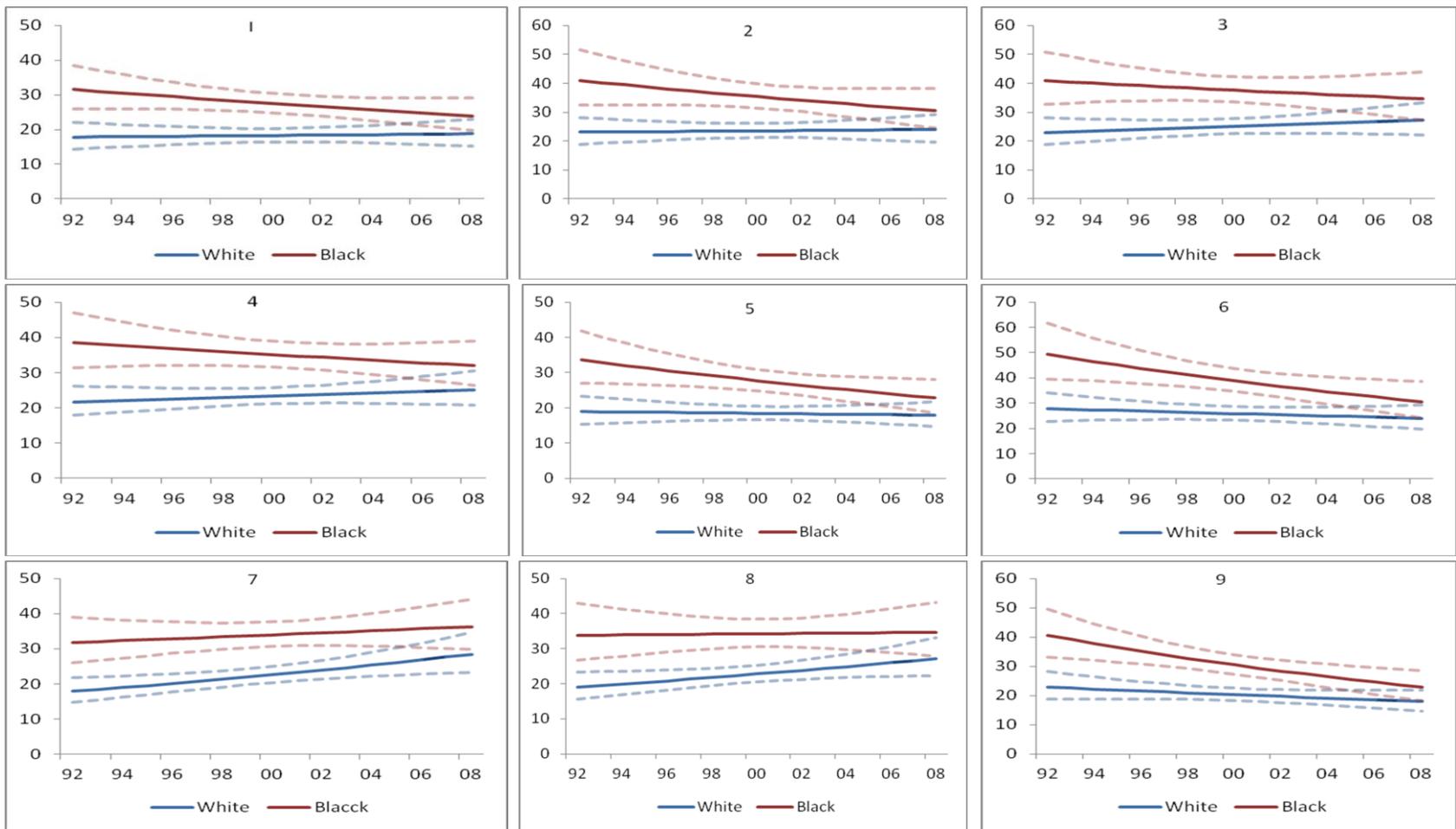


Figure 4.2: Median Predicted Zip-Code Percent Late Stage Diagnosis (1992-2008) by Race and Neighborhood Type
 (1. Low SES/Low Access, 2. Mid SES/Mid Access, 3. High SES/High Access, 4. Low SES/Mid Access, 5. Mid SES/Low Access, 6. High SES/Mid Access, 7. Low SES/High Access, 8. Mid SES/High Access, 9. High SES/Low Access)

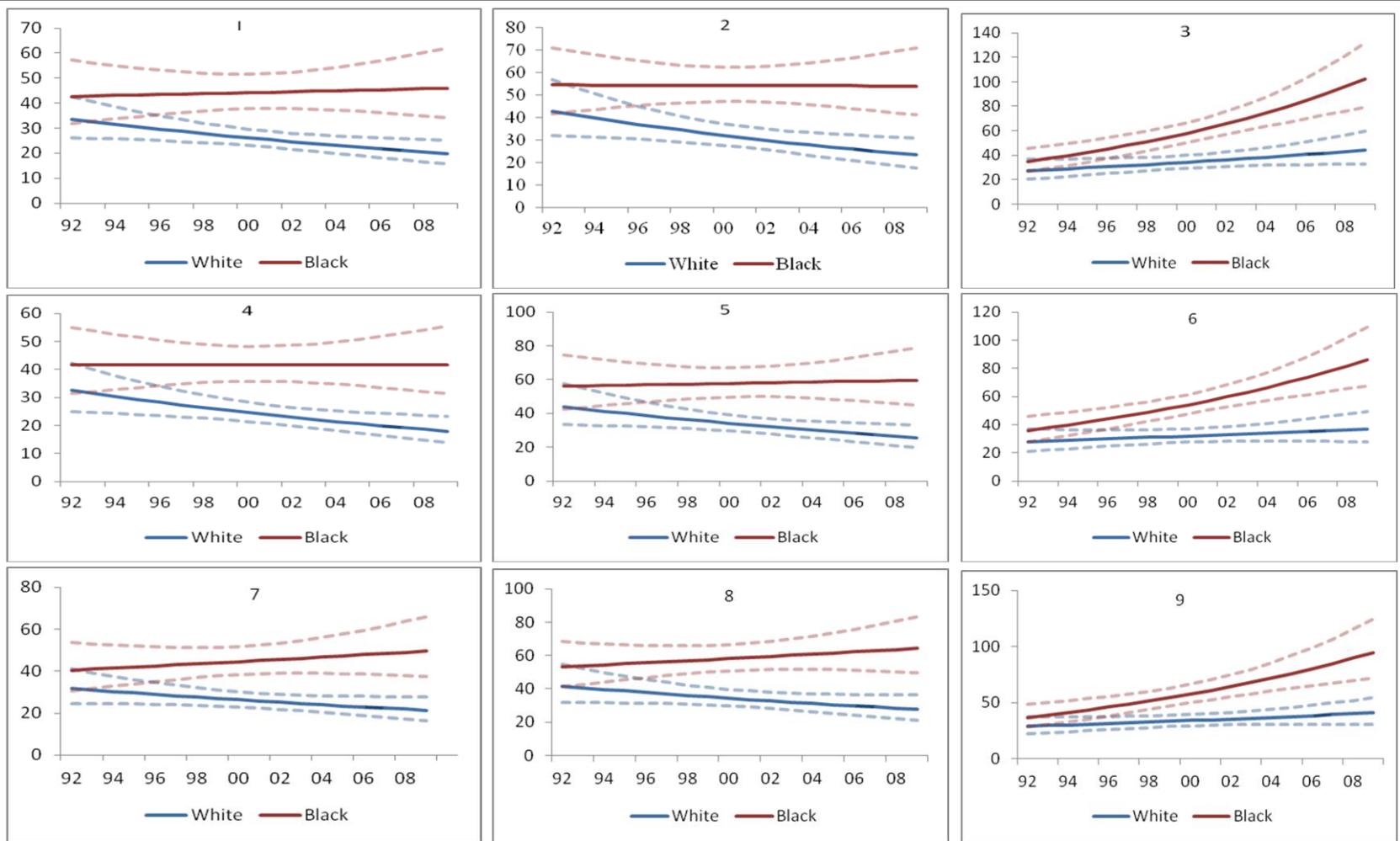


Figure 4.3: Median Predicted Zip-Code Age-Adjusted Mortality Rate (1992-2008) by Race and Neighborhood Type
 (1. Low SES/Low Access, 2. Mid SES/Mid Access, 3. High SES/High Access, 4. Low SES/Mid Access, 5. Mid SES/Low Access, 6. High SES/Mid Access, 7. Low SES/High Access, 8. Mid SES/High Access, 9. High SES/Low Access)

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CHAPTER 5

CONCLUSIONS

Breast cancer is the most common malignancy in females in the US. However, due to significant improvements in understanding the epidemiology, biology, and pathophysiology of the disease, incidence and mortality rates are on the decline. Improved understanding of the epidemiology and pathophysiology has led to better screening programs, leading to the detection of early-stage disease and the development of better therapies and targeted treatments tailored to specific breast cancer sub-types. Despite these overall improvements, some US population sub-groups have not benefited as much as others. Women who are black and/or poor have benefited the least from the scientific advancements. The purpose of this dissertation has been to explore some of the possible variables that contribute to black-white disparities in breast cancer outcomes. The specific variables explored were race, individual socio-economic status, individual healthcare access, as well as neighborhood socio-economic status and healthcare access.

The first paper of this dissertation explores racial disparities in breast cancer by assessing the individual and neighborhood determinants of breast cancer screening in Michigan. This analysis made use of a dataset from a survey of adults in Michigan aimed at examining cancer risk factors and screening among adults. The contribution of individual SES and healthcare access as well as neighborhood level SES and healthcare access on the receipt of a mammography test or clinical breast examination in the past 2 years among women ages 50-74 years was assessed. To my knowledge, this is the first paper to use such a comprehensive set of variables at different levels to assess determinants of breast cancer screening. First, the true screening rate in this population was assessed by adjusting for misclassification error. This revealed the significant disparities that existed in mammography screening rates by race in Michigan. After adjusting for misclassification, significant differences were observed in true screening rates compared with reported screening rates for both black and white women, with the true clinical breast examination rate being 15 percentage point lower among black women and 20 percentage point lower in white women. True mammography screening was 5 percentage points lower among black women and 1 percentage point lower in white women.

In this study, the most important predictors of receiving adequate breast cancer screening in this population were having health insurance and a usual healthcare provider. After adjusting for demographic variables in the model, no racial differences in breast cancer screening were found. However, this study provides evidence that although county level SES and healthcare access may be important, their effects on screening are

primarily driven through more proximal factors related to having a usual healthcare provider and health insurance. This finding is not surprising, but provides further evidence of the importance of programs that make breast cancer screening affordable and accessible. Programs such as the Breast and Cervical Cancer Control Program (BCCCP) in Michigan is an example. These programs have a great potential to improve adequate screening, and by extension, ensure early diagnosis and treatment for all women in Michigan, regardless of race and income.

The second paper focused on black-white disparities in breast cancer and all-cause survival. Its purpose was to take advantage of a high quality cancer data registry available across parts of the country. The SEER registry is unique in its coverage of virtually all cancer cases within its catchment area, using a mixture of active and passive surveillance. It also includes comprehensive treatment variables that allow the assessment of treatment effects on cancer outcomes. No prior research study has assessed neighborhood level SES and healthcare access on breast cancer survival, adjusting for individual level variables. The SEER-NLMS linkage provided the individual level variables which are otherwise not available in SEER. The hypothesis was that after adjusting for demographic variables, poor neighborhood level healthcare access will be associated with lower breast cancer survival, and that this association will vary by race. The results showed that after adjusting for demographic variables, black-white differences in breast cancer survival disappeared. In addition, stage of presentation and treatment were important predictors of survival. County level SES and healthcare access

did not independently predict survival; however, they attenuated some of the individual level effects observed, suggesting the presence of effect measure modification.

This study adds to current knowledge about the determinants of racial disparities in breast cancer survival. It is possible that neighborhood level SES and healthcare access may act through two other individual level variables to influence survival, namely, stage of presentation and treatment. The effect of living in poor neighborhoods that lack adequate healthcare facilities may be reflected through patients presenting at a more advanced stage of presentation and receiving poor treatment. This suggests that programs designed to encourage screening and adequate treatment in poor neighborhoods are likely to significantly improve survival overall, and to reduce racial disparities in survival.

The third and final paper of this dissertation ties together the previous chapters by examining the temporal trend in late stage breast cancer diagnosis and mortality rates among black and white women in Michigan. The analyses of the previous chapters incorporated data in a cross-sectional fashion, looking at outcomes during one time period, while this chapter adds the important component of time trends. It is possible that race, SES and healthcare access impacts screening or survival at one time point; however, it is also important to consider the contribution of these variables over time. This trend analysis allows us to understand, for instance, how economic changes may impact the proportion of late stage presentation, possibly through lower screening rates. It also allows for the observation of changes in mortality rates, and how these may also be

affected by economic changes, perhaps through lower health insurance coverage and hence inadequate treatment.

For this paper, data from the Michigan Department of Community Health Cancer Surveillance Program was used to assess changes in zip-code level proportion of late stage presentation and breast cancer mortality rates for blacks and whites from 1992-2009. Time trends in these outcomes by race, zip-code level SES and zip-code level healthcare access were examined. The results showed that black patients had higher proportions of late stage presentation than white women throughout the time period, although the proportion declined slightly over the period. During the same period, white patients on the other hand experienced an increase in late stage presentation. Black patients also had higher breast cancer mortality rates compared with white women, and the trend appeared to be increasing over time. When black and white patients living in similar neighborhoods were compared, similar trends were observed; blacks had higher late stage presentation and mortality rates than whites, late stage presentation was increasing for whites, and mortality rate was increasing for blacks.

The findings of this paper suggest that race, SES and healthcare access matters in breast cancer outcomes. Programs that serve as a safety-net for the population of women who are poor and lack healthcare insurance are critical to reverse the trend of increasing late stage among whites and increasing mortality rates among blacks.

Overall, this dissertation adds considerably to the literature on racial disparities and breast cancer outcomes in the US, and several strengths of this research should be highlighted. First, this study made use of high-quality datasets at the national and state level, which helped with improving the external validity of the papers. The dataset included all cases within a specified catchment area linked with NLMS (SEER-NLMS), was from a large probability sample of adults (SCBRFS), or was from the state registry which captures all reported cases within the state (MDCH). Secondly, the measures of neighborhood level SES and healthcare access were derived by using high-quality national datasets (US Census Bureau and the Area Resource File) collected in a standardized format, improving the internal validity of the constructs. Thirdly, the access to datasets that included potential confounding variables was a major strength. For instance, access to treatment variables through SEER, individual level healthcare access variables through the SCBRFS, and zip-code level variables related to healthcare access through MDCH all helped significantly with controlling for extraneous factors that might have influenced study results.

There were also some limitations to this study. First, neighborhood healthcare access was defined as the availability of medical personnel and facilities at the county or zip-code level. While healthcare availability is an important component in understanding healthcare access, other dimensions were not captured in the definition. For example, obstacles to accessibility-- such as language or cultural barriers, mistrust of the medical system, and lack of health insurance-- determine whether a person actually benefits from living in a county with good healthcare facilities. Second, in the study of breast cancer

screening in Michigan, significant levels of misclassification error were observed in reported screening rates. This may apply to other questions in the survey, introducing potentially serious misclassification bias in the survey responses. However, such misclassification of socio-demographic and healthcare access variables, if present, is expected to be non-differential with respect to the outcome of cancer screening.

In conclusion, these findings provide evidence of the importance of healthcare access in explaining some of the racial disparities observed in breast cancer screening, mortality and survival rates. Among black and white women, breast cancer outcome experiences differ, and these differences are based on differences in adequate screening, and treatment received. The pathway through which black women compared with white women end up with worse breast cancer outcomes likely involves a combination of lower screening rates due to lack of access to health insurance or a healthcare provider and a higher likelihood of residing in neighborhoods that lack healthcare facilities and/or providers for adequate treatment. However, white women in these situations are also faced with similar prospects of inadequate screening and treatment. The key to ensuring that all population groups receive timely screening and the best treatment is ensuring access to healthcare regardless of race, income or neighborhood.

Future studies of the determinants of racial disparities in breast cancer outcomes are still warranted. First, it is important to study the impact of other dimensions of healthcare access such as affordability on breast cancer outcomes. By better

understanding the impact of all dimensions healthcare access on breast cancer screening and treatment, more knowledge can be gained about how to bridge the gap between healthcare need and the timely delivery of healthcare services. Second, it is important to focus on identifying other individual and neighborhood level factors that may influence cancer screening among different populations in different regions of the world. Due to westernization of lifestyles and aging populations in developing countries, breast cancer incidence and mortality rates are projected to increase in the coming decades, and therefore early detection will become even more important. Understanding region- and population-specific barriers to adequate screening will be helpful in designing programs aimed at improving screening rates for women, regardless of race/ethnicity, socioeconomic status or neighborhood of residence.

APPENDIX

CREATION OF HEALTHCARE ACCESS INDEX USING PRINCIPAL COMPONENTS ANALYSIS (PCA)

SELECTION OF HEALTHCARE ACCESS VARIABLES

Several issues have to be considered when selecting variables to be used to create an index of healthcare access at the county level. First, it is important to identify variables based on epidemiologically sound methods such as conducting a literature review and/or building on past works. That is, it is important to avoid choosing variables on an ‘ad hoc’ basis and to identify a best practice approach. Secondly, PCA works best when selected variables are correlated with each other and also when the distribution of the variable varies across observations (in this case, counties). For instance, a variable which has high values in all counties or low values in all counties would have zero standard deviation and thus would account for no variation between households and would have a weight of zero, contributing nothing or very little to differentiate counties on healthcare access. Thirdly, it is important to avoid issues of ‘clumping’ or ‘truncation’. Clumping occurs when counties group together in a small number of distinct clusters; while truncation

occurs when there is a more even distribution of access, but spread over a very narrow range.

In this analysis, it is anticipated that clumping and truncation may be an issue in rural counties where counties have similar characteristics, but may not be so much of an issue in non-rural counties. This is because rural counties may have identically low measures of healthcare access such as number of hospitals, number of physicians, etc. A potential solution to the issue of clumping and truncation is to have adequate numbers of variables in the dataset. The analysis by Coughlin et al included six variables describing healthcare access at the county level; the variables were included individually in multivariate analysis. Another method is to use a combination of variables related to different aspects of healthcare access such as facilities, personnel and population characteristics. The most important point, however, will be to use a large number of variables that capture inequality between counties.

With these issues in mind, a comprehensive review of the literature as well as detailed review of federal government guidelines on defining healthcare access was conducted in order to generate a list of variables describing healthcare access at the county level.

PRINCIPAL COMPONENTS ANALYSIS

PCA is a variable reduction procedure. It is a multivariate statistical technique that is useful when a dataset contains a number of variables that may be highly correlated or that have some redundancies within them. The correlation may arise because the

variables are measuring the same construct. PCA reduces the variables in the dataset into a smaller number of principal components or dimensions, which are uncorrelated and is a linear weighted combination of the initial variables. This means that from an initial dataset of correlated variables, PCA creates uncorrelated indices or components optimally weighted from the initial dataset.

Using PCA, it is possible to create a score (used as the weight) for each observation in the dataset for each principal component generated from the analysis. This score is given by the eigenvectors of the correlation matrix. SAS Proc Factor is used to generate these weights using a special type of equation called the eigenequation. The weights produced by the eigenequation are optimal since, for a given dataset, no other set of weights could produce a set of components that would account for more variation in the dataset. Then the actual individual values for each variable in the dataset will be weighted using the created score to generate individual values for each component. The general form for the formula used to compute scores on the first principal component (PC_1) extracted in a PCA.

$$PC_{1i} = b_{11}(X_1) + b_{12}(X_2) + \dots + b_{1p}(X_{1p})$$

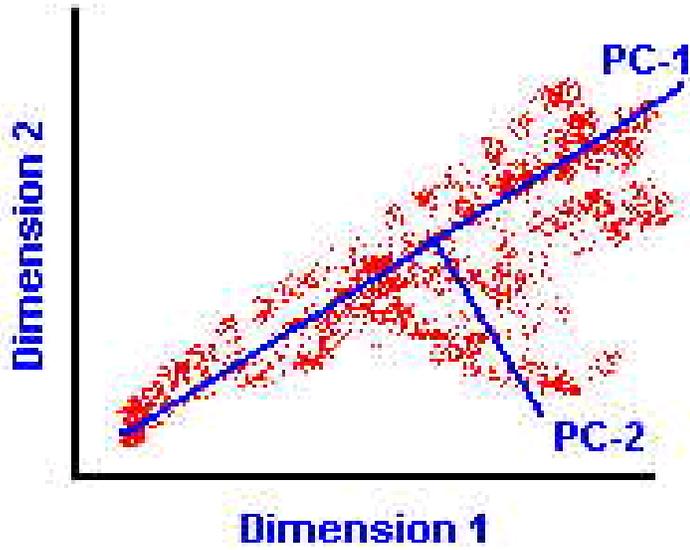
Where, C_{1i} = *individual score on principal component 1 (first principal component extracted)*

b_{1p} = *the weight (or regression coefficient) for observed variable p, as used in creating principal component 1*

X_p = *individual value on observed variable p e.g. individual salary*

Diagrammatically, the concept of PCA is shown in the figure below. The absence of any correlation between the components is highlighted by the fact that the lines are perpendicular, that is, are at right angles to each other. This means that the indices are measuring different dimensions in the data. The higher the degree of correlation among the original variables in the data, the smaller the number of components required to capture the variations present in the dataset.

The components are ordered so that the first component explains the largest amount of variation in the original dataset. The sum of the eigenvalues is the number of variables in the original dataset; therefore the proportion of the total variance in the original dataset accounted for by each principal component is the variance for each principal component divided by the number of variables. The second component is completely uncorrelated with the first component; it explains additional variation in the dataset that was not accounted for by the first, but accounts for less variation in the dataset than the first component. The same principle applies to subsequent components; they are uncorrelated with previous components and account for smaller proportions of the variation in the dataset.



Representation of two sequential components in PCA

Source: Vyas, S and Kumaranayake, L. Constructing socio-economic status indices: how to use principal components analysis. 2006.