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The Impact of Neighborhood Social and Built Environment Factors across the Cancer Continuum: Current Research, Methodologic Considerations, and Future Directions

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Abstract

Neighborhood social and built environments have been recognized as important contexts in which health is shaped. We review the extent to which these neighborhood factors have been addressed in population-level cancer research, with a scan of the literature for research that focuses on specific social and/or built environment characteristics and association with outcomes across the cancer continuum, including incidence, diagnosis, treatment, survivorship, and survival. We discuss commonalities and differences in methodologies across studies, current challenges in research methodology, and future directions in this research area. The assessment of social and built environment factors in relation to cancer is a relatively new field, with 82% of 34 reviewed papers published since 2010. Across the wide range of social and built environment exposures and cancer outcomes considered by the studies, numerous associations were reported. However, the directions and magnitudes of association varied, due in large part to the variation in cancer sites and outcomes being studied, but also likely due to differences in study populations, geographical region, and, importantly, choice of neighborhood measure and geographic scale. We recommend that future studies consider the life course implications of cancer incidence and survival, integrate secondary and self-report data, consider work neighborhood environments, and further develop analytical and statistical approaches appropriate to the geospatial and multilevel nature of the data. Incorporating social and built environment factors into research on cancer etiology and outcomes can provide insights into disease processes, identify vulnerable populations, and generate results with translational impact of relevance for interventionists and policy makers.

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Introduction

Neighborhoods are key determinants of health. Among the first studies to demonstrate an independent effect of neighborhood factors on health, the work of Yen et al. showed that aspects of the neighborhood environment contributed independently to overall mortality (1-3). Subsequent research has shown that social and built neighborhood characteristics shape opportunities for and barriers to health promotion (4-7). The social environment is the socioeconomic composition of the resident population and social aspects of neighborhoods, such as crime, community support, collective efficacy (i.e., social cohesion and willingness to collaborate to intervene for community benefit), social capital (i.e., collective value gained from social networks), and disorder (e.g., presence of trash, graffiti, disorderly groups and/or activity)(2). The built environment comprises the man-made, physical attributes of our surroundings, including structural conditions affecting walkability and recreation, and availability of health-promoting resources (e.g., some grocery stores and playgrounds) and undesirable amenities (e.g., fast food restaurants, liquor stores) that influence individual health behaviors (e.g., physical activity, diet). Evidence is compelling that the social and built environmental conditions facing residents affect health as much as do the individual characteristics of residents themselves (8).

An appreciation for the relationship of neighborhoods and health outcomes is illustrated in several conceptual frameworks. The Centers for Population Health and Health Disparities' “cells-to-society” model (9, 10) focuses on identifying and evaluating multilevel factors that contribute to health disparities so as to inform multilevel interventions. The social ecologic or bioecologic model (11), and the World Health Organization's social determinants of health model, acknowledge the importance of neighborhood social and built environment factors as providing the context within which health is determined. For cancer etiology in particular, the Multilevel Biologic and Social Integrative Construct, proposed by Lynch and Rebbeck (12), defines three primary hierarchical levels – macroenvironment, individual, and biologic factors – that interact in their effects. A commonality across these conceptual models is the featuring of a person's development within environmental systems, including windows of vulnerability, and concurrent exposure to environmental and psychosocial factors.

Among health burdens, cancer is a major contributor, with a current lifetime risk of nearly 50 percent (13). Given that neighborhoods can influence general health outcomes through material deprivation, psychosocial mechanisms, health behaviors, and access to resources, it is likely that they also influence cancer across the continuum, cancer risk, diagnosis, treatment, survivorship, and mortality. Yet, despite the conceptual acknowledgement of the importance of neighborhoods for cancer (12), neighborhood social and built environment factors have not often been considered in cancer research. Although documented associations between neighborhood social and built environments and health behaviors (e.g., physical activity and diet) are of relevance to cancer etiology and outcomes, other aspects of carcinogenesis and cancer survivorship warrant a dedicated review and discussion of the ways in which they are affected by neighborhood environments (10, 12, 14, 15). In light of the public health importance of malignancies and the interventions possible through modification of neighborhood social and built environments, it is opportune to review the extent to which these factors are being addressed in cancer research. To consider a broad range of social and built environment factors and outcomes across the entire cancer continuum, we focus less on the specific study findings, and more on the commonalities and differences in methodologies and results across studies, discussing challenges in research methodology and suggesting future directions in this area of research. As cancer risks attributable to environmental exposures (i.e., environmental contaminants) are well-known, we focus only on the social and built environment, and thus, we hope, contribute to the understanding of the effects of the broader environment on the cancer continuum, a promising area of research.

Review and Summary of the Literature

Methods

We undertook a literature review process to assess the extent of research on social and built environment factors and cancer. For this process, we used the advanced search tool within the National Library of Medicine's PubMed search engine to create a library of primary research articles that reported on studies of cancer outcomes (risk/incidence, tumor and diagnostic characteristics (e.g., stage), treatment, survivorship (including disease progression, quality of life, behavioral factors after diagnosis), and survival/mortality) in relation to exposures to the social and/or built environment. We excluded three types of studies: 1) those based only on neighborhood socioeconomic status (SES), as most employed area-based socioeconomic measures as a proxy for individual-level SES; 2) those examining only cancer risk factors (with exception of studies of cancer survivors), such as physical activity or body mass index (BMI); and 3) those addressing only the effects of pollution and environmental contaminants, or medical care and geographic access. Our search included all relevant articles published through August 2014. We used the boolean operator ‘AND’ to specify combinations or groups of words and quotation marks to delinate the latter. We searched publication titles and abstracts for the terms “cancer” and “contextual,” “neighborhood,” or “social environment.” We also searched all article fields for the terms “cancer” and “food environment,” “built environment,” “neighborhood environment,” “macroenvironment,” “obesogenic environment,” “walkability,” and “food desert.” Among 1,265 articles identified with this search, further review of abstracts and full texts resulted in 34 selected articles. The primary reasons for the exclusion of articles were that they were in fact not focused on neighborhood social and built environment factors (e.g., studies of tumor microenvironment) or were focused solely on neighborhood SES.

Terms “neighborhoods” and “communities,” while sometimes used interchangeably, may refer to different constructs. Neighborhoods are based on place of residence and have both physical and social characteristics that are important for understanding health (16). Communities define population subgroups and may or may not be contained within specific geographic locations or neighborhoods. In this review, we focus on neighborhoods because of our interest in how place, and its social and built environments, contributes to cancer outcomes.

Results

Table 1 presents the 34 papers and selected characteristics, including the cancer site and outcome, the study location, the social and/or built environment factor(s), and the geographic scale being studied; the statistical analysis used; and a summary of main findings pertaining to the social and built environment factors.

Cancer incidence/risk—Among the 11 papers on cancer incidence or risk (Table 1), nine (all using population-based cancer registry data) focused on the ethnic composition of neighborhoods. One study examined incidence rates of breast, colorectal, lung, prostate, and cervical cancer by the percentage of Hispanics within census tracts across nine Surveillance, Epidemiology and End Results (SEER) registries, and found variable associations across these cancer sites (17). Another paper examined thyroid cancer rates in New York neighborhoods of highly observant Jews identified based on census data and website mentions of synagogues, thus using neighborhood-level variables as proxies for individual-level indicators of Jewish ancestry (18). Seven papers used a dataset developed to examine California cancer incidence rates by an established census tract-level SES index (19) and ethnic enclave (a measure of acculturation)structured by principal components analysis of census indicators of ethnic population composition, percentage of recent immigrants, and language use (20-23). Most of these seven studies found differences in cancer incidence by intensity of ethnic enclave, with directions of associations varying by cancer site. Two papers used population cohort data and found associations with other social and built environment characteristics - immigration concentration, crime, and racial residential segregation (i.e., spatial separation or clustering of two groups in a geographic area) in relation to overall cancer risk in one study (24), and light at night (using data from the National Oceanic and Atmospheric Administration (NOAA)) in relation to breast cancer risk in the second study (25).

Tumor characteristics at diagnosis—Eight papers examined associations between social and built environment factors and characteristics at diagnosis of cancers identified through cancer registries. Seven of these papers focused on stage at diagnosis (for breast, prostate, and colorectal cancers) and one on cancer molecular subtypes (for breast cancer) (26-32). Four papers focused on ethnic density or composition, while four focused on other social and built environment factors. All eight studies reported significant associations between social environment characteristics and stage at diagnosis, or breast cancer subtypes. These studies identified environmental characteristics using census administrative data (for measures of ethnic density, ethnic enclave, segregation), California Health Interview Survey data (for a measure of population-level mammography screening), and information from NOAA (for a measure of weather severity). As these studies did not require population denominators, they were able to evaluate patient-level data along with neighborhood-level data, including assessment of interactions between individual- and neighborhood-level measures, and among multiple neighborhood measures (e.g., an examination of block-group racial composition with metropolitan statistical area (MSA)-level segregation measures (29)).

Cancer treatment—Only one paper addressed treatment as an outcome, specifically examining patient, institution, and neighborhood factors in association with receipt of non-guideline treatment (lumpectomy without radiation) or mastectomy for early stage breast cancer among Asian American women. The authors found that women living in low SES and more ethnic neighborhoods were more likely than those in high SES and less ethnic neighborhoods to have non-guideline treatment and mastectomy (33).

Cancer survivorship—Among the seven papers examining cancer survivorship outcomes (including disease progression, quality of life, behavioral factors after diagnosis), two investigated self-rated health (34, 35), three investigated behavioral factors (physical activity (36, 37), alcohol consumption (38)), one investigated disease progression (biochemical failure among prostate cancer patients (39)), and one looked at physical functioning (40). As each paper focused on several social and built environment factors, we did not group these papers according to specific social and built environment factors. Four papers based on a Missouri breast cancer patient cohort (34, 35, 38, 40) and one examining an Australian colorectal cancer patient cohort (36) included patient assessments of perceived neighborhood conditions (including social disorder, physical disorder/decay, and collective efficacy (34, 35, 38, 40)) and administrative data; all five papers reported significant associations of measures of social and built environment factors with self-rated health and behavioral factors among breast cancer survivors. A study of biochemical failure after prostatectomy among prostate cancer patients found joint effects of risk genotypes identified through genome-wide association studies and social isolation (measured with proportion of older residents, vacant housing, older head of household in the neighborhood (a measure of social isolation)) (39).

Cancer survival/mortality—Twelve papers examined social and/or built environment factors and survival after cancer. Ten of these papers evaluated associations between cancer survival and ethnic density or ethnic enclave, together with neighborhood SES (32, 41-44, 47, 49); of these, three examined associations of racial residential segregation and Black ethnic density with survival after breast cancer (29, 45, 46). Some of this research reported associations of cancer survival with neighborhood ethnic density and/or segregation beyond neighborhood SES, and some reported associations with neighborhood ethnic density or enclave moderated by neighborhood SES. The directions of associations of ethnic density or enclave varied across the studies. One study showed higher cancer mortality among Hispanic residents in high relative to low Hispanic density neighborhoods (49), while others showed lower mortality (43, 44). One study showed lower mortality among Blacks in high relative to low Black density neighborhoods (29), while two other studies found the opposite association (45, 46). The differences may reflect regional variations in the impact of these social environment factors (45, 46).

Summary of neighborhood factors included in studies

Most of the 34 reviewed papers used census data to measure ethnic density, ethnic enclave, and/or racial residential segregation in addition to SES. A few studies characterized the built environment using additional census measures, including population density, housing, and commuting characteristics (37), social isolation (39), and residential stability (24). Some studies leveraged other sources of geospatial data, including foreclosure data (35); NOAA data on light at night (25); weather severity measures (30, 31); business data to characterize the food environment (availability of healthy vs. unhealthy food sources and outlets), recreational physical activity environment (37), and alcohol outlet availability (38); and street network data to calculate street connectivity (37). Several studies collected perceived neighborhood measures from respondents (34-36, 38, 40, 48, 50). In addition, the geographic definitions of neighborhood varied across these studies. All cancer-registry-based incidence studies were conducted at the tract level, due to population denominator availability, while other studies were based on patient-level data varying from patient-defined geographies (34, 35, 38, 40) to buffers (37, 38), block groups (25, 29, 32, 33, 37, 41-44), tracts (27, 34, 35, 38-40, 45, 46, 49, 51), clusters of tracts (48), zip codes (47), towns/places/MSA (29-31, 45, 46), and counties (26). The analytical approaches also varied, with most studies treating the neighborhood variables as independent covariates, a few adjusting variance estimates for clustering at the neighborhood level, and a few using multilevel analyses. Only one paper mentioned evaluating spatial autocorrelation (37). Only the papers based on one breast cancer study (34, 35, 38, 40) included propensity analysis to evaluate the extent to which observed associations might be due to residents' self-selection into neighborhoods.

Discussion

Relationship of social and built environments to cancer

The assessment of social and built environment factors in relation to cancer is a new area of research, with 82% of the reviewed papers published since 2010. Nevertheless, despite covering a wide range of social and built environment exposures and cancer outcomes, most of the studies reported an association between a social or built environment measure and a cancer outcomes across the continuum. Thus, they provide evidence that social and built environment attributes exert independent influences beyond SES on cancer incidence, tumor characteristics, treatment, survivorship, and survival/mortality. The directions and magnitudes of associations varied across studies, due in large part to the differing roles of social and built environment influences on the biology and etiology of cancer, its detection, treatment, quality of life of survivors, and mortality (e.g., the associations of Hispanic ethnic density would be expected to differ for incidence of cancers linked to increasing acculturation and those linked to decreasing acculturation). However, as shown here, the variation in findings also is likely to be influenced by differences in study populations (e.g., race/ethnicity), geographical region, and, importantly, choice of neighborhood measure and geographic scale, as discussed above.

Of the social and built environment factors addressed in these studies, ethnic density or enclave was the most frequently studied. All of the studies of cancer incidence reported expected associations given known or suspected risk factor distributions among racial/ethnic or immigrant groups and their neighborhoods. Additional studies incorporating risk factor data are needed to determine if these associations are due distributions of to established risk factors among individuals or if they provide clues to novel risk factors among individual residents or neighborhoods, such as a study of non-Hodgkin lymphoma subtypes (22). For Hispanics with cancer, residence in Hispanic enclaves was consistently associated with higher likelihood of late stage at diagnosis. These associations persist despite adjustment for individual and/or neighborhood SES, and, in some cases, measures of individual-level immigration factors and insurance status, suggesting that there may be additional cultural, language, and/or health care access factors preventing Hispanics from fully engaging in cancer screening and early detection. Most, but not all, of the studies of cancer survivorship demonstrated an association between some social and/or built environment factor and quality of life, disease progression, or health behaviors among cancer survivors. By utilizing patient survey data, many of these studies were able to account for a number of individual-level factors that thus could confound these associations. Given the rapidly increasing population of cancer survivors, this growing body of evidence lends support for further focus on the relevance of neighborhoods in promoting wellness among survivors. Among the studies of cancer survival/mortality, most, but not all, demonstrated associations of worse survival among Hispanics residing in ethnic enclaves; however, among those that considered interactions with individual-level factors (43, 44), this association seemed to be more pronounced for the foreign-born. Residents of ethnic enclaves are more likely to be of lower SES; therefore, a focus on the protective effects of these neighborhoods (e.g., collective efficacy, access to healthy ethnic foods, more walkability, etc.) may identify modifiable neighborhood features for improving survival in spite of economic adversity.

Methodologic considerations, challenges, and opportunities

The reviewed literature points to several methodologic considerations and new opportunities that should facilitate better understanding of how neighborhoods may influence cancer outcomes (see Table 2).

Expansion of neighborhood factors and interactions—While much of the research on neighborhoods and cancer has focused on neighborhood SES, racial/ethnic composition, and ethnic enclave and segregation, future research also should assess additional neighborhood social and built environment features. Better approaches also are needed for understanding how the multidimensional features of our neighborhoods influence cancer outcomes, such as the study examining multiple dimensions of elderly isolation (39), and research examining both racial residential segregation and ethnic density (29, 45, 46). Despite the conceptual frameworks that describe the complex ways multilevel factors influence health, and the examples reviewed here of studies of cross-level interactions, few studies have examined these interactions empirically.

Longitudinal data and implications for temporality—To date, most studies have used cross-sectional data, which limits the potential for detecting causal inferences regarding neighborhood factors and cancer outcomes, and increases the possibility of misclassifying neighborhoods regarding the timing of influence vis-à-vis the critical exposure window for the relevant outcome. Only one paper in our review (27) used two time points to capture the effects of change in neighborhood features. More use of longitudinal data on neighborhood factors would be valuable, as this information can provide insight into how neighborhood changes contribute to cancer risk, and the critical and relevant windows of these exposures. For survivorship and survival outcomes, longitudinal data on neighborhood factors can elucidate pathways through which these factors influence outcomes and identify opportunities for intervention to improve outcomes.

Definition of neighborhood and scale—Another important methodological consideration for this research is the definition of neighborhoods. In most cancer studies, neighborhoods have been defined by administrative boundaries drawn to create meaningful small, homogenous areal units (e.g., zip codes, census tracts or block groups) (52). In population-based studies, this is an efficient approach for characterizing neighborhoods systematically, for accessing population-based secondary data resources, and linking to other administrative data (for example, a measure of connectivity that counts street segments and intersections (24), or counts of types of businesses or amenities and resources within a defined buffer (37)). However, residents may not perceive their neighborhood boundaries according to census designations (53), may not access resources or undertake regular activities (e.g. food shopping, physical activity) within those boundaries, or may be more engaged in another neighborhood. An alternative definition of neighborhoods and their attributes can be based on resident perception and use, although this approach requires more resources (e.g., surveys, audits) to systematically characterize social and built environment features.

Statistical considerations—Studies of neighborhood and cancer are subject to important and unique statistical considerations. First, most studies on neighborhood factors and cancer have used standard regression modeling, which is limited in handling the complex processes and systems that likely lead social and built environments to impact cancer etiology or outcomes (54). Accounting for the hierarchical structure of the data (i.e., individuals nested within neighborhoods) is critical so that correlations within neighborhoods are appropriately modeled and significant neighborhood associations are assessed conservatively. A few of the reviewed studies (27, 34, 35, 38, 40, 45-47) used multi-level modeling, a more sophisticated approach that accounts for hierarchical structure and within neighborhood correlations, and allows for a decomposition of the variance in study outcomes between and within neighborhoods (56). However, issues of inadequate sample sizes, both in the number of neighborhoods included in the study and the number of study participants within neighborhoods, may compromise the ability of these models to be informative. An additional limitation of the multi-level model is its assumptions, such as normality of the error distributions, which that cannot be verified (55). Alternative models have been proposed such as population average models, which use generalized estimating equations and involve fewer assumptions (57). Another statistical consideration is dealing with the non-hierarchical contexts in which individuals exist. As an example, cancer outcomes may influenced by both work and residential environments. Work environments are comprised of individuals from multiple neighborhoods, and individuals within the same neighborhood may be employed in different work environments creating overlapping contexts. Cross-classified models (56) may better account for overlap of contexts; however, a lack of simultaneous information and measurement of work and residential environments creates challenges in using these methods. A final consideration is the need to incorporate concepts of space such as proximity and contagion, in investigations of neighborhood health effects. Spatial analytic methods are also important for assessing neighborhood exposures and for accounting for spatial autocorrelation (propensity for in neighboring areas to be similar, thus affecting assumptions about the independence of residuals (58)). Recent work has introduced spatial multi-level modeling approaches to allow for both space and membership in geographically defined places (59).

Future directions

The reviewed literature points to several areas for future research that should facilitate better understanding of how neighborhoods may influence cancer outcomes (see Table 3).

A life-course perspective—In epidemiology and public health, a life-course approach assumes that patterns in the timing and presentation of health and well-being are due to a dynamic interplay of biological, behavioral, social, and environmental factors that intersect in the lives of individuals and populations (60-62). The timing and severity of disease, for example, is affected by exposures and behaviors occurring at different points in the life course, reflecting specific age-related and developmental combinations of vulnerability and resiliency. For example, a critical exposure window for breast cancer development is early adolescence; accordingly, some current studies are focused on the influence of the social and built environment on the onset of puberty (63-65). After cancer diagnosis, the built and social characteristics of neighborhoods can influence subsequent well-being and health outcomes through access to resources, psychosocial mechanisms, and health behaviors, factors that can affect both the quality and duration of survival. Therefore, we recommend that studies of social and built environments and cancer incidence and outcomes capture the neighborhood environment factors during the relevant time period, as well as account for changes in neighborhood characteristics.

Integration of secondary (objective) and self-report (perception) data—We propose that future studies consider incorporating both secondary and self-reported social and built environment data. Neighborhood characteristics can be ascertained using administrative/secondary data, in-person and virtual audits (66), and self-reported perceptions of neighborhood attributes. Secondary data can provide robust information on neighborhood composition and density, including population, housing and amenities (67). However, information on the perceived quality and use of these features by residents, which is lacking in these data sources, may be better obtained from residents and neighborhood audits (35). In particular, given the replacement of the U.S. Census long form survey with the American Community Survey, and the known limitations of census boundaries to define the neighborhood, future research to characterize neighborhoods will benefit from use of survey data and/or geospatial data together with geographically meaningful neighborhood boundaries (53).

Neighborhood environments at work—Given the considerable time people spend outside of their residential environments, there is a need to understand how occupational, education and recreation environments might affect cancer outcomes across the disease continuum. In particular, we recommend that studies also include assessments of social and built environments of neighborhood at work. U.S. working adults spend 7.6 hours per day at work on average (68), and home and work neighborhood environments may vary substantially in relation to their built and social characteristics (69, 70). To date, no studies have examined social and built environments around the neighborhood at work in relation to cancer outcomes, although a few studies have examined work environments in relation to health behaviors and factors associated with cancer. Several studies have shown that favorable safety and food neighborhood environments around work were associated with individuals' BMI (69, 71, 72). Investigators are now able to use GPS devices to continuously track individuals throughout their daily activities and to create summaries for various buffers surrounding an individual's home, work, or other locations (70). Assessments of such extra-residential neighborhoods will improve design of interventions to make all relevant contexts conducive to healthy life styles.

Development of analytical approaches and tools—Given the unique analytical issues associated with geospatial data, more research is needed on the development and application of analytical approaches and tools. Future research should account for the complex set of social and built environment features, as proposed by Weden and colleagues (73), who acknowledge the multiple dimensions of the neighborhood environment in classifying neighborhoods into several types. Further, more geospatial data are becoming available to assess neighborhood environments, although the majority of these data resources are not developed specifically for assessing social and built environments or linking to health outcomes. Using available data, areas have been characterized with walkability measures (74), food environment measures (75), omni-directional imagery data using Google Street View (66), and other scores/indices developed by private and public entities (35). Using scores can require more sophisticated analytic measures that take into consideration spatial autocorrelation, density or exposures, and changes over time (e.g., stores opening or closing, changes in zoning) (76). Agent-based models that simulate how large-scale (e.g., neighborhood) effects arise from the interactions of individuals or groups ("agents") represent an emerging analytic approach for these types of spatial data (77, 78).

Causal inference—Inferring causality based on evidence drawn from observational studies is always a major challenge, and this is true for neighborhood studies as well (79, 80). Future studies should aim to use causal inference methods, such as marginal structural models, that may allow for estimation of less biased estimates of associations between neighborhood environments and cancer outcomes (81). Such analyses should be informed by a hypothesized causal structure through the use of directed acyclic graphs (82). In addition, these methods are only possible with the use of longitudinal study designs that provide repeated measures of study outcomes, neighborhood exposures, and a comprehensive set of additional study covariates. Longitudinal study designs also are necessary to fully account for selection issues in which individuals are spatially sorted or self-select into certain neighborhoods based on individual characteristics. This problem creates non-exchangeability between individuals exposed vs. unexposed to neighborhood factors also compromising ability to establish causal inferences (83). "Difference in difference models" provide a solution to the self-selection problem by examining changes in neighborhood exposures over time to changes in study outcomes. These models also allow for a better understanding of the dynamic nature of neighborhood environments and capture the ways in which changes in context over time may impact health.

Conclusion

The Healthy People 2020 initiative of the U.S. Department of Health and Human Services emphasizes the importance of creating environments that promote good health for all (84). For cancer, the relevance of context is increasingly recognized and appreciated, as we have shown. However, research in this area is still in its relative infancy, with the majority of studies published after 2010. In the cancer domain, there is much to be learned and leveraged from the rich experiences of neighborhood research in other disease areas and other disciplines. Incorporating social and built environment factors into research of cancer etiology and outcomes can lead to insights into disease processes, identify vulnerable populations, and generate results with translational impact of relevance for interventionists and policy makers.

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Table 1

Articles on social and built environment and cancer

Article # (ref)	First author, year	Outcome examined	Location	Social and built environment measure(beyond socioeconomic measures)	Level of geography	Type of analysis/methods used	Main findings
INCIDENCE/RISK							
Social and/or built environment measure: Ethnic density/concentration, ethnic enclave							
1 (17)	Eschbach 2005	breast, colorectal, lung, prostate, cervical cancer incidence	SEER 9 regions (Connecticut, Iowa, New Mexico, Utah, Hawaii, Detroit, Atlanta, San Francisco-Oakland, Seattle-Puget Sound)	% Hispanic, SES	tract	Poisson regression	negative association between Hispanic density and decreased incidence of lung, prostate, and breast cancer
2 (23)	Keegan 2010	breast cancer incidence	California	Hispanic enclave (composite measure based on Census data), SES	tract	incidence rates	higher enclave associated with lower incidence
3 (21)	Chang 2010	liver cancer incidence	California	Asian & Hispanic enclave, SES	tract	incidence rates	higher enclave and lower SES associated with higher incidence
4 (22)	Clarke 2011	lymphoid malignancies incidence	California	Asian enclave, SES	tract	incidence rates	rates of chronic lymphocytic leukemia/small lymphocytic lymphoma and nodular sclerosis Hodgkin's lymphoma lower among Asian women in ethnic enclaves
5 (18)	Soloway 2011	thyroid cancer incidence	New York	residence in highly observant Jewish neighborhoods, as measured by Census data on percentage of children who speak Yiddish at home and/or presence of Orthodox synagogues; area of high proportion of residents from Russia,	tract	multilevel Poisson model	high Yiddish-speaking census tracts 40% higher risk of thyroid cancer; tracts with synagogues but not a high proportion of Yiddish-speaking children also show

Article # (ref)	First author, year	Outcome examined	Location	Social and built environment measure(beyond socioeconomic measures)	Level of geography	Type of analysis/methods used	Main findings
				Belarus, or Ukraine; poverty rate Belarus, or Ukraine; poverty rate			significantly elevated risk.
7 (20)	Chang 2012	gastric cancer incidence	California	Hispanic enclave, SES	tract	incidence rates	rates higher in higher enclave neighborhoods except cardia subtype in Hispanic men
8 (85)	Froment 2014	cervical cancer incidence	California	Hispanic and Asian enclave, SES	tract	incidence rates	higher incidence of squamous cell and adenocarcinoma cervical cancer in high enclaves
9 (86)	Horn-Ross 2014	thyroid cancer incidence	California	Hispanic and Asian enclave, SES	tract	incidence rates	increase over time in rates of thyroid cancer in all subgroups defined by ethnic enclaves
11 (87)	Ladabaum 2014	colorectal cancer incidence	California	Asian enclave, SES	tract	incidence rates	high SES/low enclave highest incidence and high SES/high enclave lowest incidence
Social and/or built environment measure: Other							
6 (24)	Freedman 2011	incidence of all cancers combined, self-report	US	immigration concentration, crime, segregation, connectivity, population density, air pollution, healthcare delivery environment, economic advantage and disadvantage, residential stability	tract, county	random effects logistic regression with tract cluster adjustment	among men, living in area with higher crime and more segregation associated with higher odds of cancer; among women, living in area with high immigrant concentration associated with lower odds of cancer
10 (25)	Hurley 2014	breast cancer incidence	California	outdoor light at night, urbanization, SES	block group	Cox proportional hazards	increasing levels of outdoor light at night

Article # (ref)	First author, year	Outcome examined	Location	Social and built environment measure(beyond socioeconomic measures)	Level of geography	Type of analysis/methods used	Main findings
							associated with increased br associated with increased br associated with increased br
TUMOR CHARACTERISTICS AT DIAGNOSIS							
Social and/or built environment measure: Ethnic density/concentration, ethnic enclave							
15 (51)	Reyes-Ortiz 2008	breast, cervical, colorectal tumor stage and size	SEER 13 regions (Connecticut, Iowa, New Mexico, Utah, Hawaii, Detroit, Atlanta, San Francisco-Oakland, Seattle-Puget Sound, Alaska, San Jose-Monterey, Los Angeles, rural Georgia)	%Hispanic, income	tract	logistic regression	Hispanics residing in higher % Hispanic neighborhoods have higher odds of diagnosis with later stage breast, cervical, and colorectal cancers
16 (28)	Keegan 2010	breast stage	California	Hispanic enclave, SES	block group	logistic regression	Hispanics in low SES/high enclave neighborhood have higher odds of late stage at diagnosis (compared with high SES/low enclave)
17 (29)	Warner 2010	breast stage	California	% Blacks, racial residential segregation, SES	block group, place	logistic regression	racial composition and metropolitan segregation measures weakly associated with stage
19 (32)	Banegas 2014	breast cancer subtype	California	Hispanic enclave, SES	block group	logistic regression with block group cluster adjustment	greater relative risk of triple negative cancers in high SES areas and greater risk of hormone receptor +/ HER2+ cancers in high ethnic enclaves
Social and/or built environment measure: Other							

Article # (ref)	First author, year	Outcome examined	Location	Social and built environment measure(beyond socioeconomic measures)	Level of geography	Type of analysis/methods used	Main findings
12 (26)	Davidson 2005	stage	California	% in nonurban area, % recent immigrant, % older female, % female-headed households, % race/ ethnicity, % ever had mammogram, % insurance status, healthcare environment, SES	block group, county	logistic regression	greater % female headed household or % recent immigrants associated with later stage at diagnosis; greater % older female associated with earlier stage
13 (31)	Parsons 2007	prostate stage	Maine	% Franco-ancestry, population density, vehicle availability, residential mobility, weather severity, access to care, SES	town	logistic regression	higher Franco ancestry and less snowfall associated with late stage
14 (30)	Parsons 2007	colorectal stage	Maine	Same as #13	town	logistic regression	higher Franco ancestry and distance to primary care associated with late stage
18 (27)	Cho 2011	breast stage	Illinois	change in concentrated immigration (% foreign born, % linguistically isolated) from 1990 to 2000, change in concentrated disadvantage (% families with incomes below the poverty line, % unemployed) from 1990 to 2000	tract	multilevel logistic regression	concentrated immigration in 1990 associated with greater odds of late stage diagnosis; change in concentrated immigration from 1990-2000 associated with greater odds of late stage diagnosis
TREATMENT							
20 (33)	Gomez 2012	breast cancer first-course treatment	California	Asian enclave, SES	block group	logistic regression with block group cluster adjustment, recursive partitioning	low neighborhood SES/high ethnic enclave (relative to high SES/low enclave) associated with higher odds of

Article # (ref)	First author, year	Outcome examined	Location	Social and built environment measure(beyond socioeconomic measures)	Level of geography	Type of analysis/methods used	Main findings
							breast conserving surgery w breast conserving surgery w breast conserving surgery w breast conserving surgery w breast conserving surgery w breast conserving surgery w breast conserving surgery w
SURVIVORSHIP							
21 (36)	Lynch 2009	colorectal cancer, achievement of sufficient levels of physical activity	Australia	self-reported physical environment barriers to physical activity	not specified	logistic regression	perceived physical environment significant predictors of achieving sufficient levels of physical activity at 5-months post-diagnosis, not at 12 months
22 (39)	Rebbeck 2010	prostate cancer, time to biochemical (prostate specific antigen) failure	24 counties in and around Philadelphia, PA	aging and social isolation (% residents age 65+, % households with single resident age 65+) and housing quality (% homes vacant and not for sale, rent or vacation), SES	tract	Cox proportional hazards with tract cluster adjustment	greater % residents age 65+ and greater % vacant housing associated with increased hazard of biochemical failure; joint effects between selected prostate cancer risk genotypes and social isolation (older single head of household)
23 (35)	Schootman 2011	breast cancer, fair/poor self-rated health	Missouri	predicted foreclosure/ abandonment-risk score, perceived neighborhood conditions: social disorder, physical disorder/decay, collective efficacy, neighborhood fear, poverty	tract, self-defined neighborhood unit	multilevel logistic regression	women in higher foreclosure risk areas more likely to report fair/ poor self-rated health but association was explained by household income, physical activity, and perception of

Article # (ref)	First author, year	Outcome examined	Location	Social and built environment measure(beyond socioeconomic measures)	Level of geography	Type of analysis/methods used	Main findings
							more neighborhood physica more neighborhood physica more neighborhood physica more neighborhood physica more neighborhood physica
24 (34)	Schootman 2012	breast cancer, fair/poor self-rated health at 1-year follow-up	Missouri	perceived neighborhood disorder, collective efficacy, neighborliness, neighborhood fear	self-defined neighborhood unit	logistic regression and counterfactual model using g-computation algorithm	perceived neighborhood factors not identified to be associated with self-rated health in multivariable model
25 (40)	Pruitt 2012	breast cancer, physical functioning	Missouri	Same as #24	tract, self-defined neighborhood unit	multilevel path and mediation analysis	lower physical functioning of women in high poverty tracts fully mediated by physical activity and body mass index, perceived neighborhood factors not mediators
25 (38)	Schootman 2013	breast cancer, alcohol consumption	Missouri	alcohol outlet availability, perceived neighborhood disorder, collective efficacy, neighborliness, neighborhood fear, poverty, urbanicity	street network distance to nearest alcohol outlet, tract	multilevel logistic regression	survivors living within 3 miles to nearest alcohol outlet had higher odds having more than 1 drink/day
26 (37)	Keegan 2014	breast cancer, physical activity	San Francisco Bay Area	immigrant population, population density, non-single-family dwellings, recreational facilities, parks, retail food environment, restaurant environment, commuting, traffic density, SES	block group; 1600m network distance; 500m buffer	Logistic regression with block group cluster adjustment	neighborhoods with no fast-food restaurants (vs. fewer fast-food restaurants) to other restaurants, high traffic density, and a high percentage of foreign-born residents less likely to meet physical activity recommendations

Article # (ref)	First author, year	Outcome examined	Location	Social and built environment measure(beyond socioeconomic measures)	Level of geography	Type of analysis/methods used	Main findings
SURVIVAL/MORTALITY							
Social and/or built environment measure: Ethnic density/concentration, ethnic enclave							
28 (49)	Eschbach 2004	7-year mortality from all cancers	5 Southwestern states of Texas, Colorado, Arizona, California, and New Mexico; counties with at least 6.6% Mexican American ethnicity in population	% Mexicans; poverty	tract	Cox proportional hazards with tract cluster adjustment	increased hazard of cancer deaths with increasing % Mexican American of neighborhood
16 (42)	Keegan 2010	breast cancer-specific and overall survival	California	Hispanic enclave, SES	block group	Cox proportional hazards regression	no associations for ethnic enclave and survival
17 (29)	Warner 2010	breast cancer-specific and overall survival	California	% Blacks, racial residential segregation	block group, place	Cox proportional hazards regression	increasing % Blacks associated with improved survival among Black cases, slightly more pronounced in high segregation areas, increasing % Blacks associated with lower survival among Whites regardless of segregation
29 (41)	Gomez 2010	breast cancer-specific and overall survival	California	Asian enclave, SES	block group	Cox proportional hazards regression	lower survival among foreign-born Asians not explained by ethnic enclave or neighborhood SES
30 (47)	Lim 2011	cervical cancer overall survival	Los Angeles County	proportion African-American, Latino, or Asian American households, income	zip code	multilevel Cox proportional hazards regression	among all racial/ethnic groups, higher proportion of African-Americans associated with increased hazards of death; no association for

Article # (ref)	First author, year	Outcome examined	Location	Social and built environment measure(beyond socioeconomic measures)	Level of geography	Type of analysis/methods used	Main findings
							proportion of Latinos and A proportion of Latinos and A proportion of Latinos and A
31 (45)	Russell 2011	breast cancer-specific survival	Georgia	% Black, spatial access to oncologists and academic medical centers, segregation, poverty	census tract, metropolitan statistical area (MSA)	multilevel Cox proportional hazards, mediation analysis	higher proportion of Black residents in census tract associated with increased breast cancer specific deaths
32 (46)	Russell 2012	breast cancer-specific and overall survival	Georgia	% Black residents, racial residential segregation, poverty	census tract, metropolitan statistical area	multilevel Cox proportional hazards (frailty models with robust standard errors)	for breast cancer specific mortality, segregation associations seen only among Black women, and no associations with tract proportion of Black residents; for overall mortality, tract proportion of Black residents associated with higher overall mortality among Whites, no associations with segregation
33 (43)	Patel 2013	lung cancer-specific and overall survival	California	Hispanic enclave, SES	block group	Cox proportional hazards regression with block group cluster adjustment	higher survival among foreign-born Hispanics more pronounced in low SES and high ethnic enclave neighborhoods
34 (44)	Schupp 2014	prostate cancer survival	California	Hispanic enclave, SES	block group	Cox proportional hazards regression with block group cluster adjustment	lower mortality among foreign-born Hispanics more pronounced in low SES and high enclave neighborhoods;

Article # (ref)	First author, year	Outcome examined	Location	Social and built environment measure(beyond socioeconomic measures)	Level of geography	Type of analysis/methods used	Main findings
							low SES neighborhoods ass low SES neighborhoods ass low SES neighborhoods ass low SES neighborhoods ass low SES neighborhoods ass low SES neighborhoods ass low SES neighborhoods ass low SES neighborhoods ass low SES neighborhoods ass low SES neighborhoods ass low SES neighborhoods ass
19 (32)	Banegas 2014	breast cancer survival	California	Hispanic enclave, SES	block group	Cox proportional hazards regression with block group cluster adjustment	no associations of ethnic enclave with survival among all patients or within tumor subtypes
Social and/or built environment measure: Other							
27 (48)	Lochner 2003	premature cancer mortality (death rates among resident age 45-64 years)	Chicago	self-reported social capital: perceptions of neighborhood reciprocity and trust, associational membership	“neighborhood clusters” (~8000 residents in each cluster)	hierarchical generalized linear model, log link function	social capital indicators not associated with cancer death rates, with exceptions of higher levels of trust modestly associated with higher cancer death rates for White men but lower cancer death rates for Black women
26 (37)	Keegan 2014	breast cancer-specific and overall survival	California	See #26 above	block group; 1600m network distance; 500m buffer	Cox proportional hazards regression with block group cluster adjustment	better breast cancer-specific survival associated with a lack of parks, especially among women in high-SES neighborhoods

Table 2

Summary of methodologic considerations, challenges, and opportunities

Methodologic consideration	Challenges	Opportunities
Expansion of neighborhood factors and interactions	• Studies have primarily evaluated only neighborhood SES, ethnic density/enclave	• Expand evaluation to other contextual factors • Consider interactions among contextual factors, and with individual factors
Longitudinal data and implications for temporality	• Studies have generally been cross-sectional, measuring neighborhood factors at one point in time	• Examine how changes in neighborhood composition (e.g., racial/ethnic composition, socioeconomic characteristics) and/or built environment features (e.g., walkability, mixed land use) contribute to cancer risk, and the critical and relevant windows of these exposures. • Conduct longitudinal studies that can inform how neighborhood features shape each other – i.e., do changes in racial/ethnic composition lead to changes in built environment or vice versa?
Definition of neighborhood and scale	• Administratively-defined neighborhood boundaries are convenient to use but may not be meaningful • Geographic scale (e.g., block group, tract, zip code, county) vary across studies	• As resources allow, consider alternative definitions of neighborhoods based on resident perception and use • Choice of geographic scale should consider exposure(s) and relevant policy/intervention contexts
Statistical considerations	• Most studies used standard regression modeling, limited in handling processes linking social and built environments to cancer risk or outcomes	• Explore methods/statistical models that account for hierarchical structure of data, overlapping contexts (e.g., work and home neighborhoods), and concepts of space such as proximity and contagion

Table 3

Summary of future directions

A life-course perspective • Studies of social and built environments and cancer incidence and outcomes should capture the neighborhood environment factors during the relevant time period, as well as account for changes in neighborhood characteristics.
Integration of secondary (objective) and self-report (perception) data • Future studies consider incorporating both secondary and self-reported social and built environment data.
Neighborhood environments at work • Future studies should include assessments of social and built environments of neighborhood at work. Given the considerable time people spend outside of their residential environments, there is a need to understand how occupational, education and recreation environments might affect cancer outcomes across the disease continuum.
Development of analytical approaches and tools • Given the unique analytical issues associated with geospatial data, more research should be conducted on the development and application of analytical approaches and tools.
Causal inference • Future studies should aim to use causal inference methods, such as marginal structural models, that may allow for estimation of less biased estimates of associations between neighborhood environments and cancer outcomes.