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ORIGINAL ARTICLE – GLOBAL HEALTH SERVICES RESEARCH

The Use of Area-Level Socioeconomic Indices in Evaluating Cancer Care Delivery: A Scoping Review

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ABSTRACT

Background. Multiple composite indices of small-area socioeconomic characteristics have been used to examine how neighborhood characteristics influence cancer care, but there is little consensus regarding how to use them. This scoping review aimed to summarize the use of these indices in cancer literature and their association with outcomes.

Methods. A search was conducted to identify studies from 2015 to 2021 that investigated cancer incidence, disease stage at diagnosis, and mortality using area-based indices of deprivation as an independent variable. Studies were screened and assessed for eligibility. Data were extracted regarding the geospatial and statistical use of these indices.

Results. All the inclusion criteria were met by 45 studies. The area level of analysis was at the census tract level in 19 studies (42.3%), the county level in 15 studies (33.3%), the block group level in 6 studies (13.3%), and the ZIP code level in 5 studies (11.1%). Altogether, 18 unique indices were used, with 4 indices used most frequently. Of the studies that used their indices ordinally, 3 defined high and low deprivation dichotomously, 10 used tertiles, 13 used quartiles, and 15 used quintiles. Of the 45 studies, 34 (76%) showed a significant association between area deprivation and cancer-related outcomes.

Conclusions. Neighborhood deprivation indices are most commonly used at the census tract level and ordinally as quintiles. Despite variance in methods, there is a strong indication that deprived areas are at adverse odds with cancer-related outcomes. Further study investigating deprivation in the context of cancer can inform drivers of inequity and identify potential targets for care delivery and policy interventions.

Inequity in cancer care has been well established by patient socioeconomic status, insurance coverage, race, and geography.[1–4] Increasingly, studies have examined area measures of socioeconomic factors that capture the overall resources where patients and providers may reside. Instead of examining single measures as an estimate of local area socioeconomic factors (i.e., median income at the ZIP code level), composite indices are one of these tools used to capture multiple factors more broadly into a single measure.

Consensus is limited regarding how to use neighborhood-level indices.[1] What remains unclear is which geographic levels are used most frequently, which measures are commonly used, and which cancer outcomes are evaluated. Some studies geocode patient cohorts to the county as the geographic level of analysis to establish neighborhood socioeconomic status (SES), whereas other studies use census tracts—subdivisions of a county with an average capita of 4000 ideally homogeneous residents. Research also has analyzed neighborhood SES by census block groups, which are subdivisions of a census tract covering a contiguous area of roughly 1500 residents, also ideally socioeconomically homogeneous.[5]

Variability also exists in the methods used to construct the indices, particularly in the choice of neighborhood characteristics used to define deprivation and the statistical analysis of those characteristics.[2–4,6–12] The variability in methods challenges interpretation of results and cross-comparison between studies using different indices.

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"Poverty" in one index may be defined as the percentage of persons below the federal poverty level, whereas a different index may use the percentage of persons below 200% the poverty level.

This study aimed to summarize which neighborhood-level methods and indices are most used and the criteria used to characterize each method, to determine commonly used geographic area level of analysis, and to characterize how literature is quantitatively defining deprivation or neighborhood SES. We hope to provide researchers with a resource they can reference during their own study design, and to encourage further review of neighborhood deprivation as a tool to incorporate social determinants of health into disease presentation, intervention, and outcome.

METHODS

The authors followed criteria for conducting a scoping review.[13] A scoping review is a literature review method used to synthesize existing literature within a field to clarify working definitions and conceptual boundaries.[14] Scoping reviews may be of particular use when a field of literature has not been thoroughly reviewed or heterogeneity exists in application of a research method.[15]

Relevant studies were identified that investigated incidence, disease stage at diagnosis, and mortality for various cancers based on multivariable area-level indices of deprivation or neighborhood SES as an independent variable.

Searching

A search of PubMed considered studies from 1 January 2015 to 1 June 2021. The search used a query including the following keywords: "socioeconomic deprivation," "socioeconomic status," "social deprivation," "social vulnerability," "small-area deprivation," "area deprivation," or "neighborhood deprivation"–combined with "measurement," "measure," "index," or "deprivation index"–combined with "cancer"–combined with "incidence," "stage," or "mortality."

Inclusion and Exclusion Criteria

Studies were included in the study if they were published in the English language; investigated a population exclusively in the United States; indexed multiple measures of SES defined at the area level; had a small-area level of analysis conducted at the county, ZIP code, census tract, or block group level; and had at least one study objective to investigate cancer incidence, disease stage at diagnosis, or mortality. Studies were excluded if they were published in a language other than English; were a systematic review, scoping review, or clinical trial; or were without a full text available even when a full effort was made to obtain it.

The authors conducted an initial review of the identified studies from the PubMed screening for the inclusion and exclusion criteria. After this review, the full text of the remaining potential studies were reviewed by the authors, and the studies that did not meet the inclusion criteria were excluded.

Extracting and Charting the Results

After all the included articles were reviewed, the details about each study's use of its area-level deprivation measurement were recorded. The authors recorded every cancer-related outcome investigated in each study (e.g., incidence, disease stage at diagnosis, and/or mortality) and the geographic area of the study's population (e.g., nationwide, multi-state, single state, metropolitan area). Data regarding the specific use of the deprivation or neighborhood SES index were extracted including the small-area level of analysis (e.g. county, ZIP code, census tract, block group), whether the index used was custom developed for the study or a priori based on a validated index, whether the study analyzed the index score as a continuous score or as an ordinal variable, and if ordinal, how the study used an ordinal rank (e.g., tertiles, quartiles, quintiles). The authors also recorded whether a statistically significant correlation existed between the study outcome and the index used.

Additionally, the authors extracted data regarding the citing white paper, the socioeconomic dimensions included in the index, and the individual measures used to construct the index. If a specific index was used three or more times, it was noted as "most commonly used."

RESULTS

The PubMed query produced 897 studies. After title and abstract review, 172 studies were selected for full-text review, and 45 of the studies met all the inclusion and exclusion criteria (Supplementary Appendix A). The primary reason for exclusion ($n = 463$) was the study of a non-United States patient population. The study excluded 239 papers because they did not investigate an outcome specific to cancer incidence, disease stage at diagnosis, or mortality; 97 papers because they did not use a multi-variable area-level index of deprivation; 40 papers because they were systematic or scoping reviews; and 13 papers because they were duplicates (Fig. 1).

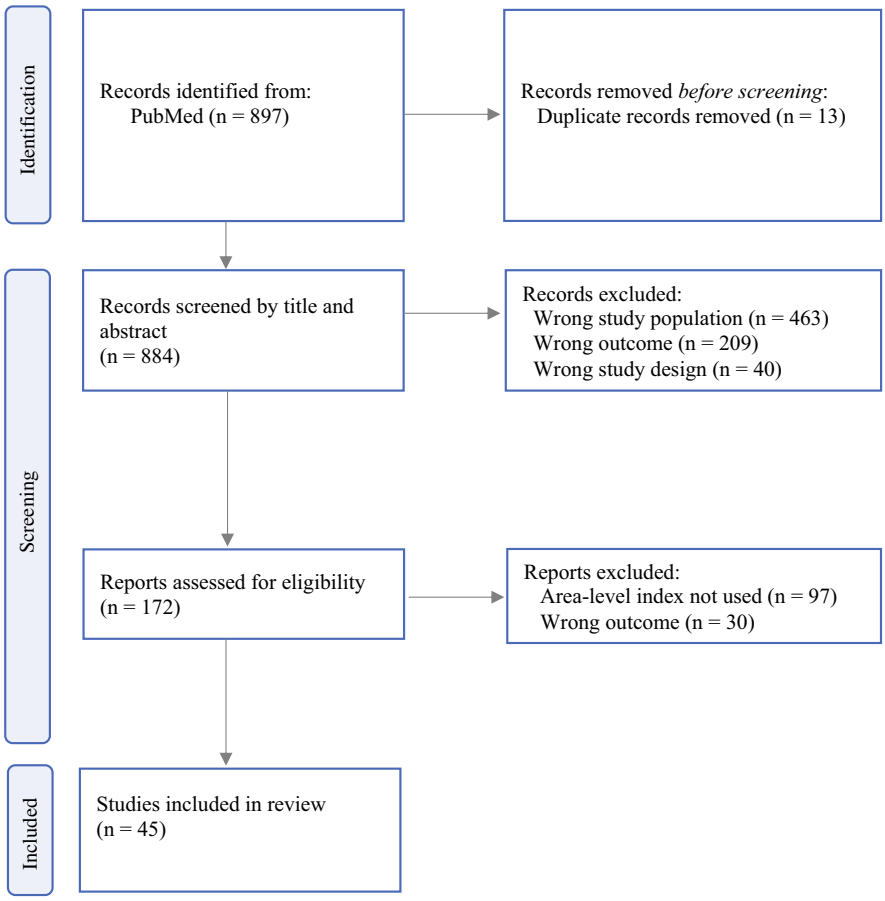

FIG. 1 PRISMA 2020 flow diagram for the included studies

The 45 included studies comprised 17 (33.3%) primary outcomes investigating cancer incidence, 12 (23.5%) investigating disease stage at diagnosis, and 22 (43.2%) investigating mortality (Table 1). Several studies observed more than one of the outcomes of interest, bringing the total outcomes to more than 45.

Of the 45 studies, 10 (22.2%) used a nationwide cohort, 18 (40.0%) used a multi-state area, 12 (26.7%) used a single-state area, and 5 (11.1%) used a metropolitan area. The area level of deprivation was at the county level in 19 (42.3%) studies, the ZIP code level in 5 studies (11.1%), the census tract level in 19 studies (42.3%), and the block group level in 6 studies (13.3%). Of the indices used by the study authors, 39 (86.7%) were a priori methods cited by the authors, and 6 (13.3%) were custom developed. Of the 45 studies, 36 (80.0%) used the indices as ordinal variables, 6 (13.3%) used the indices as a continuous variable, and 3 (6.7%) used the indices as both ordinal and continuous variables (Table 1). Of the studies that used their indices ordinally, 3 defined high and low deprivation dichotomously, 10 used tertiles, 13 used quartiles, and 14 used quintiles. Nine of the studies used their indices as a continuous variable (Fig. 2).

Several of the 18 unique indices across all the studies stood out as the most used (Table 2). The National Cancer Institute (NCI) SES Index was the most frequently used in nine of the studies. It is a census tract-based SES index using United States Census Bureau's American Community Survey (ACS) measures and adopted by the National Cancer Institute (NCI) Surveillance, Epidemiology, and End Results (SEER) as a specialized database.[4,12,16] Additionally, four studies modeled their own indices based on criteria independent of the SEER database. The seven ACS measures comprise percentage of working class persons, percentage of unemployed persons, percentage of persons below 150% of the poverty level, median household income, education index (weighted school years), median house value, and median gross rent (Table 2).

The Neighborhood Deprivation Index (NDI) was used in seven studies.[7] The NDI is validated at the census tract level and uses eight ACS measures comprising the

TABLE 1 Characteristics of 45 studies using deprivation indices

Characteristic	*n* (%)
Cancer-related outcomes[a]	
Mortality	22 (43.2)
Incidence	17 (33.3)
Stage at diagnosis	12 (23.5)
Study area population	
Multi-state	18 (40.0)
Single state	12 (26.7)
Nationwide	10 (22.2)
Multi-county metropolitan area	5 (11.1)
Deprivation index area of analysis	
Census tract	19 (42.3)
County	15 (33.3)
Census block group	6 (13.3)
ZIP code	5 (11.1)
Deprivation index methodology used by authors	
Previously validated in other studies	39 (86.7)
Custom	6 (13.3)
Statistical application of indices	
Ordinal	36 (80.0)
Continuous	6 (13.3)
Ordinal and continuous	3 (6.7)

[a]Sum adds to more than 45 studies because several studies measured more than one outcome.

percentage of individuals below the federal poverty level, the percentage of households with public assistance income, the percentage of patients age 25 years or older with less than a high school diploma, the percentage of unemployed individuals, the percentage of males in management and professional occupations, the percentage of households with more than one person per room (crowding), and the percentage of single-parent households with children younger than 18 years (Table 2).

The Area Deprivation Index (ADI) was used in six studies.[10] Based on 17 ACS measures, the ADI is validated at the block group level.[6] The specific ACS measures include median household income, median house value, percentage of owner-occupied housing units (home ownership rate), median monthly mortgage, median gross rent, percentage of families below the poverty level, percentage of population below the 150% poverty level, income disparity, percentage of population age 25 years or older with less than 9 years of education, percentage of population age 25 years or older with no high school diploma, percentage of unemployed individuals, percentage of employed persons age 16 years or older in white-collar occupations, percentage of households with more than one person per room (crowding), percentage of households without a motor vehicle, percentage of households without a telephone, percentage of occupied housing units without complete plumbing, and percentage of single-parent households with children younger than 18 years (Table 2).

The Social Vulnerability Index (SVI), developed by the CDC, was used in three studies.[11] Based on 15 ACS measures, the SVI is validated at both the census tract and county levels. The specific SVI measures include per capita income, percentage of families below the poverty level, percentage of persons age 25 years or older with no high school diploma, percentage of unemployed persons, percentage of households with more than one person per room (crowding), percentage of households without a motor vehicle, percentage of persons in group quarters, percentage of population housed in structures with ten or more units, percentage of mobile homes, percentage of single-parent households with children younger than 18 years,

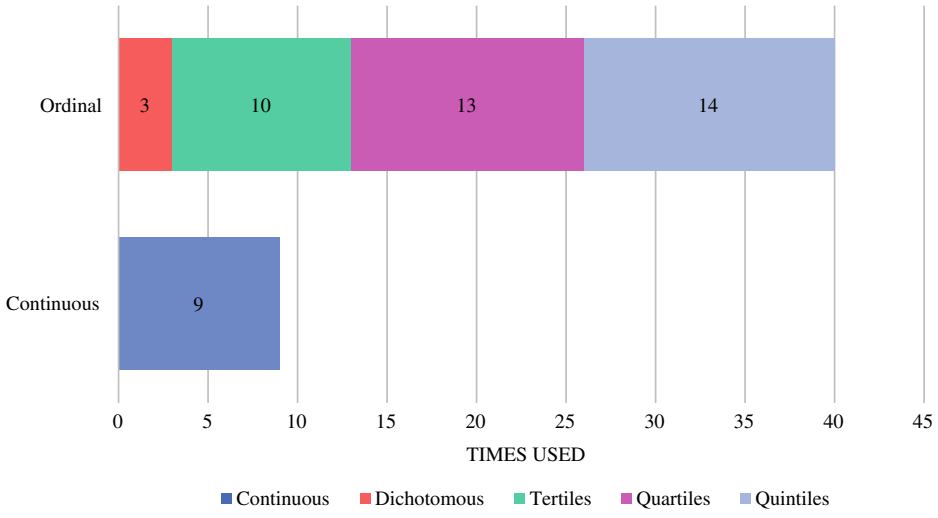

FIG. 2 Statistical application of indices in all the studies

TABLE 2 American Community Survey variables used in commonly used indices

Dimension	Variable	NCI SES Index	NDI	ADI	SVI
Poverty and wealth	Median household income	**X**		**X**	
	Per capita income				**X**
	Median house value	**X**		**X**	
	Percentage of owner-occupied housing units (home ownership rate)			**X**	
	Median monthly mortgage			**X**	
	Median gross rent	**X**		**X**	
	Percentage of families below the poverty level		**X**	**X**	**X**
	Percentage of population below 150% poverty level	**X**		**X**	
	Percentage of households with public assistance income		**X**		
	Income disparity[a]			**X**	
Education	Percentage of patients age ≥ 25 years with <9 years education			**X**	
	Percentage of patients age ≥ 25 years with <high school diploma		**X**	**X**	**X**
	Educational index[b]	**X**			
Employment	Percentage of working-class persons	**X**			
	Percentage of unemployed persons	**X**	**X**	**X**	**X**
	Percentage of males in management and professional occupations		**X**		
	Percentage of employed persons age ≥16 years in white-collar occupations			**X**	
Housing quality	Percentage of households with more than one person per room (crowding)		**X**	**X**	**X**
	Percentage of households without a motor vehicle			**X**	**X**
	Percentage of households without a telephone			**X**	
	Percentage of occupied housing units without complete plumbing			**X**	
	Percentage of persons in group quarters				**X**
	Percentage of housing in structures with 10 or more units				**X**
	Percentage of mobile homes				**X**
Housing composition	Percentage of single-parent households with children age < 18 years		**X**	**X**	**X**
	Percentage of persons age ≥ 65 years				**X**
	Percentage of persons age ≤ 17 years				**X**
	Percentage of non-institutionalized population with a disability				**X**
Minority status and language	Percentage of minority persons (all persons except white, non-Hispanic)				**X**
	Percentage of persons (age 5+ years) who speak English "less than well"				**X**

NCI, National Cancer Institute; SES, socioeconomic status; NDI, Neighborhood Deprivation Index; ADI, Area Deprivation Index; SVI, Social Vulnerability Index

[a]Log of 100 * the ratio of the number of households with < $10,000 in income to the number of households with ≥ $50,000 in income

[b]Percentage of persons with no high school (HS) deploma, with high school only, and more than a high school education calculated as follows: (<HS grad * 9) + (HS only * 12) + (> HS grad * 16)

Bold indicates the Individual American Community Survey variables included to build each index

percentage of persons age 65 years or older, percentage of persons age 17 years or younger, percentage of non-institutionalized persons with a disability, percentage of minority individuals (all persons except white or non-Hispanic), and percentage of persons age 5 years or older who speak English "less than well" (Table 2).

The usage of the NCI SES Index, the NDI, the ADI, and the SVI as well as their distribution among cancer-specific outcomes, study population, area level of analysis, and statistical significance is shown in Fig. 3. Notably, the studies using the NCI SES Index and the NDI more often used census tracts as their level of analysis. Despite validation at the block group and census tract levels, respectively, the ADI was most often used at the ZIP code level, and the SVI was most often used at the county level. The NCI SES Index was primarily used in the study of nationwide, multi-state, and single-state populations. The ADI had equal distribution of use among nationwide, multi-state, and single-state study populations. The NDI was used primarily to study nationwide and multi-state populations, and a large minority of papers. All the studies using the NCI SES Index, the ADI, the NDI, or the SVI

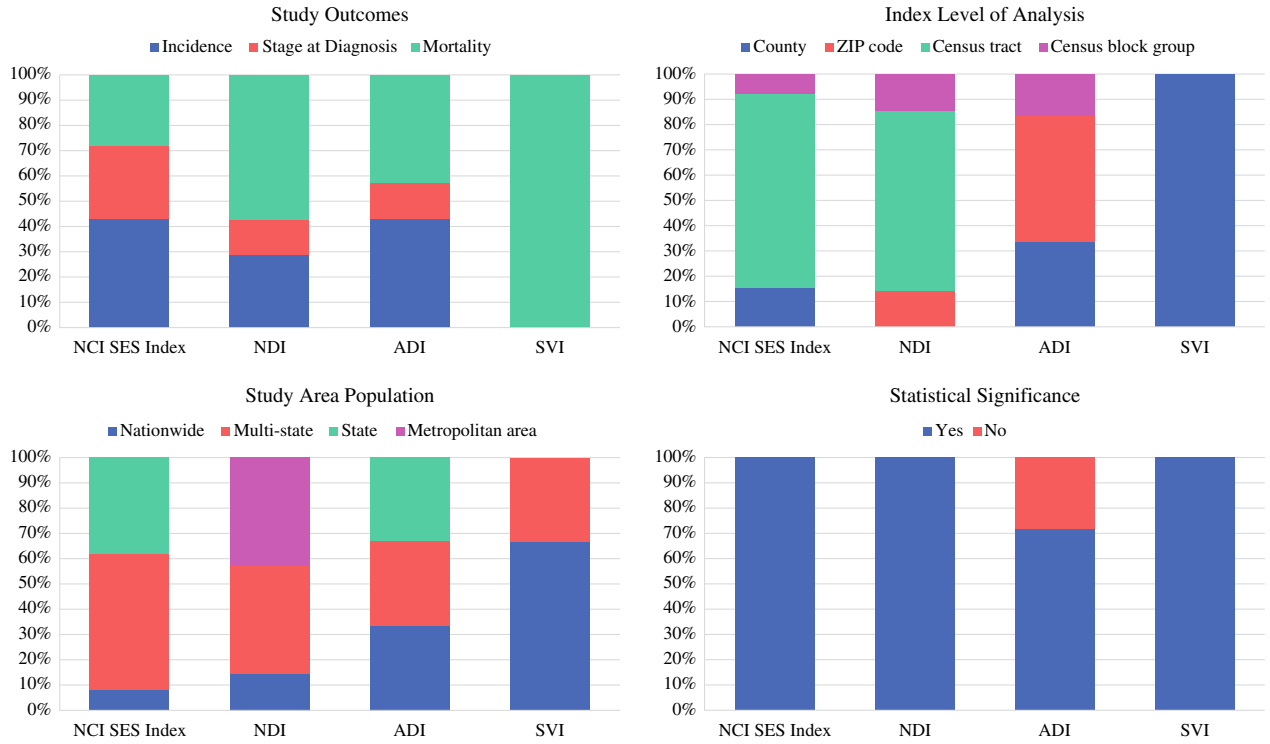

FIG. 3 Distribution of study outcomes, population, levels of analysis, and significance among commonly used indices

found a statistically significant correlation between their outcomes and their indices except for two studies using the ADI (Fig. 3).

DISCUSSION

This review summarizes the recent state of American studies using neighborhood deprivation measures and their effects on cancer and related outcomes. Most of the 45 studies on cancer care defined neighborhood deprivation using ACS measures of poverty and wealth, education, employment, housing quality, housing composition, minority status, and language. The most common geographic level of analysis was the census tract level.

Overall, the review identified 18 unique composite indices measuring deprivation or neighborhood SES. The NCI SES Index, the NDI, the ADI, and the SVI were among the most commonly used indices, and their use varied greatly in terms of study population and geographic level of analysis. Although each method differed slightly in construction and statistical application, a significant association between area-level socioeconomic status and outcomes was demonstrated in in 34 (76%) of the 45 studies.

Socioeconomic indices have demonstrated the ability to reflect a neighborhood's multidimensional SES with robustness, validity, and explanatory power, more than single measures of area-level characteristics. Indices can be useful in documenting the effect of neighborhood characteristics on disease presentation and outcome.[6,7,17] However, the practical definition of a neighborhood varied between the county, ZIP code, census tract, and block group. There are nuanced use cases for differing geographic levels of analysis. Counties tend to remain sociopolitically and geographically stable over time. In contrast, census tracts and block groups are subject to changes at every centennial census.[6,18] When used temporally, counties can provide appropriate social, political, and community context while mitigating the risk of encountering changing smaller geographic levels.[6,19]

Our review found that defining neighborhoods by the census tract is in line with the existing literature, and there are reasons to support this approach. Census tracts are small, relatively homogeneous subdivisions of a county, theoretically composed of people with similar economic statuses and living conditions.[3] They are small enough to offer a more precise definition of a neighborhood, but just large enough to avoid unmasking individuals compared with data at the block group level.[20]

On the other hand, census block groups have been demonstrated to perform just as well at correlating neighborhood SES with cancer-related outcomes and provide a close approximation of SES characteristics measured at the level of the individual.[2–4,21] The extent to which block

groups provide meaningful information that larger geographic scales cannot supply may "differ for different area characteristics or across larger contexts (e.g., cities/metro areas)."[3] If differences exist between populations at a smaller geographic scale, the use of block groups may be more appropriate.

Despite the collective use of census-based geographic areas, our review found a noticeable number of studies defining neighborhoods at the ZIP code level. ZIP codes are used for the efficient delivery of mail, are more conceptual than geographic, and generally do not "respect political or census statistical boundaries."[2] Studies have shown that ZIP code measures deficiently detect cancer mortality and incidence gradients across neighborhood SES.[2,4] Geocoding health data to the tract or block group level may offset the convenience of using potentially less accurate ZIP code data.[4]

The included studies did not discuss the rationale for their use of geographic area. However, most of the studies were confined to the geographic areas provided by specific datasets. The most used dataset was SEER, which provides only data at the ZIP code or census tract level. Other administrative data such as HCUP National Inpatient Sample can provide only ZIP code data, and state cancer registries may provide more granular data, some down to the block group level. The use of smaller areas of analysis can lead to statistical challenges such as the Modifiable Areal Unit Problem, and use of larger areas can result in overlooking significant sociodemographic variation, for instance, with dozens of block groups in a given county.[6,22] It may be advisable for more cancer databases to provide such geographic data, allowing further flexibility among researchers in choosing area levels based on study frameworks while also maintaining protection of patient confidentiality.

Our review demonstrated variation in how indices are evaluated quantitatively. The finding that indices are most commonly defined ordinally as quintile groupings is in line with statistical theory. Studies suggest that neighborhood SES should not be considered a linear scale. A national sample including 5% of all Medicare beneficiaries found that the most deprived neighborhoods made up the top 15% of the distribution.[23] This suggests that deprivation is associated with a "threshold effect," similar in theory to what is considered a "dose response" relation such that at some point residents can no longer compensate, and that this "additional disadvantage leads to increasingly adverse outcomes."[7,23] Quintile grouping appears to be a safe and reliable way to distribute a study cohort and draw meaningful conclusions while avoiding a "dose response." However, tertiles may be more appropriate to use when sample size is limited. Researchers should consider such nuances during the study design phase.[16,18]

Our study showed that 18 unique neighborhood SES indices were used in just 45 studies, each comprising different neighborhood measures and statistical modeling. This variation defines the primary challenge of neighborhood and cancer studies currently—inconsistency. Among the four most commonly used indices (NCI SES Index, NDI, ADI, SVI), 30 different variables are used, ranging from 7 variables in the NCI SES Index to 17 variables in the ADI. Although these studies have consistently confirmed the effects of neighborhood deprivation on cancer-related outcomes, the collective findings can be challenging to compare and interpret due to the variety of methods used to measure neighborhood-level deprivation.

Despite the convergence of the research community to use the four commonly identified indices, they all differ substantially. For example, The NCI SES Index is weighted heavily on the variables included in the poverty/wealth, education, and employment domains while bearing no weight from variables regarding housing, minority status, and language as seen in the SVI. Furthermore, although both indices share inclusion of poverty/wealth variables, the dimensions are defined differently. The NCI SES Index includes median household income, median house value, median gross rent, and percentage of population below 150% poverty level, whereas the SVI consists only of per capita income and percentage of families below the poverty level. The literature demonstrates that these differences matter, and that the selection of variables may depend on the health outcome and population of interest. For example, Yu et al.[16] compared the NCI SES Index with an index developed by Krieger in a SEER registry study. The Krieger Index included variables regarding housing, car ownership, and crowded living quarters, whereas the NCI SES index did not. As a result, the NCI SES index gave lower ranks (less deprivation) than the Krieger Index to rural communities, whose residents were more likely to own a car, live in a house, and live in less crowded spaces. They concluded that although a consensus definition of neighborhood SES does not exist to date, the NCI SES index may provide a simplified definition broadly applicable across geographic areas.[16]

A study included in this review offered a solution to this issue of choice of index selection while studying liver cancer incidence in the Pennsylvania State Cancer Registry.[24] By introducing a Bayesian geo-additive approach, the authors were able to assess visually how neighborhood liver cancer risk changed with the inclusion and exclusion of different neighborhood SES indices, eventually finding a model best fit by combining the NCI SES index criteria with Krieger's Index of the Concentration of Extremes (ICE)–Income model.[25] This combination was able to attenuate relative risk and geographic disparities after neighborhood SES adjustment.[24]

All indices have utility, so researchers may benefit from considering multiple neighborhood SES measures statistically and geospatially to determine which group of measures has an impact on the target study population and provide a rationale for the measure selection.

Most studies did not provide a reason for use of an index versus individual measures. Understanding a study's causal framework can be important in considering the use of indices or individual measures. The use of individual measures may have value in situations that help us understand how certain aspects of SES are associated with outcomes or test a specific hypothesis. For example, individual measures of transportation may be more important to use if the outcome of interest is travel to high-volume hospitals, whereas a measure of food availability may be more appropriate to use in an investigation of surgical outcomes of esophagectomy[26–29] However, use of individual measures risks making inferences based on the inclusion of one variable without concurrently considering the system of factors that contribute to the deprived community, which can produce incomplete conclusions. The use of an index may more accurately reflect the multidimensional nature of a community's SES.[6,30]

Across multiple different methods, there is a strong indication that deprived areas are at adverse odds of cancer-related outcomes. Composite indices can be used for a variety of reasons to target these disparities. Indices can be used to evaluate risk adjustment while controlling confounding factors, identifying and locating areas of geospatial disparity to target for quality assessment at the state or local level, or further investigating the drivers of racial disparities and inequity by controlling for community factors in the context of interpersonal racism.[31–33]

Our study had some important limitations. First, our review aimed to provide an overview of recent use cases of neighborhood deprivation and cancer research. Some cancer-related studies before 2015 used neighborhood deprivation measures not included in our analysis. However, we believe that our review offers a timely glimpse at the current trends of indices and captured sufficient studies for a robust review.

Second, we did not consider analyzing the strength of statistical methods to construct indices. Neighborhood-level indices are often developed using factor analysis, principal component analysis, or *z*-score summation. Although all these methods may produce meaningful indices for specific applications and populations, there are fundamental differences in each approach, and the indices may not maintain validity with other uses. Dissecting this generalizability of indices was not within the scope of this review but warrants additional evaluation.

Finally, we did not have all cancer-related outcomes in our inclusion criteria. Other cancer research may have used additional indices.

Further work in determining a more robust approach to quantifying deprivation in the context of cancer will enhance our understanding of which measures offer the most weight in adverse cancer outcomes and can further inform future health care delivery and policy. The increased use of common deprivation methods may help create a more uniform and refined definition of neighborhood deprivation and direct future studies investigating cancer and area-level socioeconomic characteristics.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1245/s10434-023-13099-x.

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