Use of the Area Deprivation Index and Rural Applications in the Peer-Reviewed Literature

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Introduction

Key factors such as education levels, poverty, neighborhood, built environment, racism, and structural barriers comprise the social determinants of health (SDOH, increasingly referred to as social drivers of health), which can impact a person's health and quality of life.[1–3] Research has shown a relationship between SDOH and health outcomes, such as health care utilization, hospitalization rates and readmission.[1,2,4–8] Because of the growing evidence of the relationship between SDOH and health outcomes, there is interest in better understanding how these factors differ across the country and how to effectively address these disparities. To assess the impact of social factors, researchers have developed several different tools and indices to capture SDOH at population levels. These tools include the Social Deprivation Index (SDI),[9] Social Vulnerability Index (SVI),[10] Prosperity Index (PI),[11] and the Area Deprivation Index (ADI),[12,13] among others, where each measure captures various components of SDOH at the community level.[14,15] The ADI is a measure of social deprivation originally created by the Health Resources and Services Administration (HRSA) over three decades ago, and the Center for Health Disparities Research at the University of Wisconsin School of Medicine and Public Health has further developed it.[12,13,16,17] The ADI is validated at the Census Block Group level and uses 17 measures across the domains of employment, education, and income.[13,16] The ADI uses 5-year American Community Survey (ACS) data to calculate rankings on both national (1-100) and state levels (1-10).[13,16] Since the creation of the ADI, this measure of neighborhood deprivation has been used commonly for

Key Takeaways

- The Area Deprivation Index (ADI) was developed to capture area-level social deprivation and has since been implemented in policy efforts, especially those related to health equity.
- The ADI has been used widely in the peer-reviewed literature related to health outcomes, particularly in clinical research and studies based at single organizations.
- There is a lack of consensus in how researchers define "deprivation" based on ADI.
- About a third of studies include ADI *and* a measure of rurality, but none consider the relationship *between* ADI level and rurality.
- Future research is needed to understand how applications of the ADI may differentially affect communities and individuals by rurality, race, and ethnicity.

research and policy purpose, including implemented or proposed uses by Centers for Medicare & Medicaid Services (CMS) in the Accountable Care Organization Realizing Equity, Access, and Community Health (ACO REACH) model to increase payments to facilities that have beneficiaries living in high-deprivation and the Medicare Shared Savings Program.[18–21]

The ADI and other similar tools have been used extensively in the peer-reviewed literature recently. For example, studies have found that ADI is correlated with mortality, readmissions, health care costs, health care utilization, surgical, cancer, COVID-19, and diabetes-related outcomes, among others.[22–28] Because of its use in research and as a publicly available, rigorously tested, and frequently updated tool measured at a granular geographic level across the country, the ADI has been viewed as an essential metric for assessing neighborhood-level disadvantage.[14,15] For example, a recent Assistant Secretary for Planning and Evaluation (ASPE) report pointed to the need to "rapidly research the potential consequences of using the available indices" regarding policies, payment structures, and achieving health equity.[15] ASPE additionally recommended the use of the ADI among other indices, such as SVI and SDI, for consideration in short-term policy creation and other uses.[15] There has been further support for the ADI as an indicator for use in payment and reimbursement models for health care services at the federal level. Given the support for the ADI and the inclusion of the ADI in recommendations from ASPE and policy from CMS, it is important to understand how the ADI has been used and how it intersects with rurality in the peer-reviewed literature to date.

The purpose of the current study is to summarize the use of the ADI in the peer-reviewed literature, with a specific focus on applications to rural populations, through a systematic review. We examine the peer-reviewed literature for studies published since 2015 that include the ADI and health-related outcomes such as health care cost, quality, access to care, social determinants of health, health status, or quality of life. Characteristics from studies were extracted and synthesized to describe how the ADI is currently used in research to assess health-related outcomes. The findings of this study will be of interest to researchers, policymakers, and health care organizations participating in federal, state, or organizational programs or efforts that use or recommend including measures of SDOH.

Background of ADI

HRSA initially created the ADI as a population-based measure of disparity. The methodology for the ADI was first detailed by Singh in the 2003 paper *Area Deprivation and Widening Inequalities in US Mortality, 1969-1998*[17] . It was further validated, modified, and made publicly available by Kind and the research team at the Center for Health Disparities Research at the University of Wisconsin School of Medicine and Public Health in 2018 using methodology from Kind et al.'s 2014 paper, *Neighborhood socioeconomic disadvantage and 30-day rehospitalizations: an analysis of Medicare data*.[12,13,16] Singh's original methodology used 17 measures from the 1990 U.S. Census by creating a raw score for each measure and then assigning area deprivation categories in quintiles from least to most deprived for comparison.[17] Kind and team further validated the ADI at the census block group level using American Community Survey (ACS) data with 17 measures across four domains, and importantly converted raw scores into rankings available at the national (1-100) and state levels (1-10), with raw scores no longer publicly available for download to "ensure statistically appropriate interpretation of the metric."[13,16] The ADI is now available

on the Neighborhood Atlas website as a part of the Center for Health Disparities Research, University of Wisconsin School of Medicine and Public Health.

Methods

A systematic review of the peer-reviewed literature was conducted to identify and characterize health-related studies that use the ADI.

Inclusion Criteria

Inclusion criteria included those related to study or publication characteristics as well as criteria related to the use of the ADI in the study. Study characteristics included the following criteria: peer-reviewed, original research, published in English, based in the U.S., published since 2015, and an outcome related to health status, health outcomes, public health, social determinants of health or health care (including cost, quality, and access to care). We used the HHS Healthy People 2030 Framework for social determinants of health,[3] Andersen model for health care utilization,[29] and the Institutes of Medicine's dimensions of quality.[30] In order to be included in the systematic review, studies must have included ADI or Neighborhood Atlas (the online website for the University of Wisconsin ADI database) in the title or abstract. In addition, the study must have included quantitative ADI data in at least one of the following ways: statistical associations between ADI and the outcome of interest, analyses stratified by ADI, or ADI used to define the sampling approach or population included. Given the history of the ADI development and the complexity in calculating standardized meaningful rankings per the recommendation from the Neighborhood Atlas team, we only included studies that use University of Wisconsin national percentile or state decile data and do not calculate their own score or percentiles, or use raw scores.

Search Strategy

The search was conducted in October 2022 in PubMed using the key terms "area deprivation index" or "neighborhood atlas" in the title or abstract.

Review Protocol

A team of five trained reviewers participated in reviewing studies for inclusion. Because of the inclusion of ADI or Neighborhood Atlas in the title or abstract, studies returned by the PubMed search were first reviewed as full texts for inclusion using the criteria above. A random sample of 15 studies was identified for pilot review by all reviewers. These were individually reviewed and then discussed as a group to achieve consensus. A second pilot of an additional 15 studies was conducted to confirm consistency in review. Once consensus was reached, the remaining studies were divided equally among four reviewers with a 15% sample to be double-reviewed by the fifth reviewer.

Data Extraction

Extracted elements included characteristics of the study and how the ADI was operationalized in the study. These elements included ADI level (state, national, both), years of ADI data, ADI measurement (continuous national, continuous state, dichotomous measure, other categorization such as quartiles, quintiles, or threshold cutoffs), inclusion of other area-level measures of deprivation (e.g., Social Vulnerability Index, Distressed Community Index), study scope (single site/facility/health system, sub-

state region, single state, multi-state, national), measures of rurality (none, RUCC, RUCA, population density, etc.), focus area (i.e. surgery, cardiovascular, orthopedics, diabetes, Alzheimer's and dementia, cancer, etc.), focus on a Medicare or Medicaid population, and focus on individuals or facilities. Most elements also included an option for "other" and an option for "study does not specify or unclear." During extraction, a random 5% sample of 14 included studies was assigned for pilot review independently by five reviewers. Once consensus was reached, the remaining studies were divided among pairs of two reviewers for extraction. Extraction for each included study was double-reviewed and consensus was reached.

Analysis

Descriptive analyses of characteristics of included studies were conducted. For many characteristics, categories were not mutually exclusive, therefore counts and percentages may not sum to the total number of studies or 100%.

Limitations

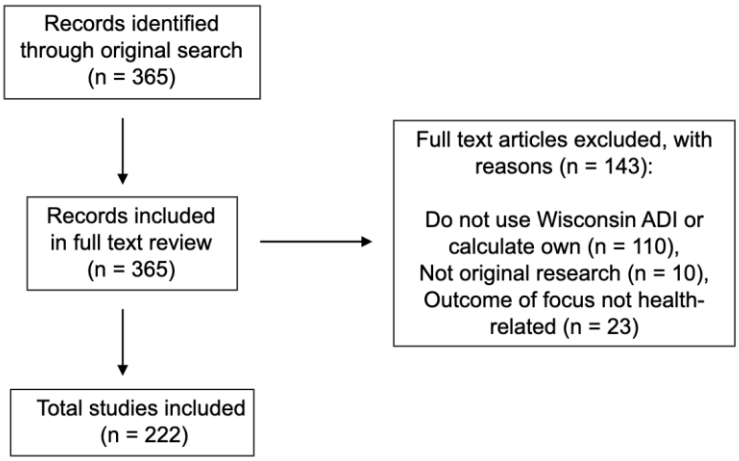
While this study is the first to describe applications of the ADI in the peer-reviewed literature, it is not without limitations. First, the search required ADI to be included in the title or abstract. This likely captured a subset of the full literature using the ADI. Specifically, this strategy likely captured studies focused on social risk or those with significant finding related to ADI which may suggest a potential bias. Second, we only included studies that used ADI from the University of Wisconsin's Neighborhood Atlas or the HIPxChange[31] as the percentile or decile rankings and did not include studies that used raw scores or self-calculated ranks. Many studies also lacked detail on where the ADI was obtained or in what way and were therefore excluded (noted as 'does not specify, unclear, or unable to find'). Third, this study is descriptive in nature and does not capture the findings and significance of the ADI in relation to health-related outcomes. Further research is warranted to characterize the findings of studies.

RESULTS

Literature Review

The original search in PubMed yielded 365 full-text articles which were then included for a full-text review (Figure 1). After full-text review, 143 articles were excluded because University of Wisconsin ADI rankings were not used, the articles were not original research, or the outcome of focus was not health-related. In total, 222 articles met the inclusion criteria and were included in the data extraction.

Figure 1. PRISMA Diagram



Study Characteristics

A detailed table of study characteristics can be found in Appendix 1. The most common focus areas of studies included surgery (n=69, 31.2%), orthopedics (n=43, 19.4%), cardiovascular conditions (n=38, 17.1%), and cancer (n=33, 14.9%). In addition, nearly 10% of studies focused exclusively on a Medicare population (n=21, 9.5%). Most studies did not include a measure of rurality (n=143, 64.4%). For studies that included a measure of rurality, RUCA was the most common measure (n=31, 14.0%). Studies with a measure of rurality generally considered a health-related outcome and included both ADI and rurality as covariates in models. As such, no studies included the association *between* measures of ADI and rurality. Some studies did include other area-level indices, including the Distressed Community Index (n=4, 1.8%) and the Social Vulnerability Index (n=3, 1.4%).

ADI Characteristics and Use

Studies examined the ADI in a variety of ways and often lacked clarity in how ADI was incorporated. A detailed table of ADI characteristics and use can be found in Appendix 2. The majority of studies incorporated national ADI rankings (n=143, 64.4%) followed by state deciles (n=43, 19.4%). Most studies used 2013 (n=23, 10.4%), 2015 (n=53, 123.9%), or 2018 (n=24, 10.8%) ADI. Operationalization of the ADI also varied. Many studies included ADI national rankings of state deciles as continuous or ordinal measures (n=86, 38.7% and n=41, 18.5%, respectively).

More than a fifth of studies dichotomized the ADI into two categories (n=48, 21.6%). Examples of dichotomization using national rankings included dividing the ADI at the mean, median,[32,33] 25th percentile,[34] 33rd percentile,[35] 38th percentile,[36] 44th percentile,[37] 50th percentile,[38–40] 60th percentile,[41] 75th percentile,[42] 80th percentile,[39,41,43,44] 85th percentile,[26,45–48] and 95th percentile.[39,40] While some of these dichotomizations occurred using the national distribution, others relied on the distribution within the sample. Examples of dichotomization using state deciles included deciles 6, 7, 8, or 9 as the threshold for "high" deprivation.[34,49–53]

More than half of studies grouped the ADI into 3 or more categories (n=121, 54.5%), with 4 categories being the most common (n=45, 20.3%). Many studies also utilized tertiles (n=30, 13.5%), quartiles (n=45,

20.3%), or quintiles (n=38, 17.1%), either based on state or national distribution or based on distribution within the study sample.

Discussion

The ADI has been proposed and implemented in policy, practice, and resource allocation applications.[18] This study is the first to take a wide view of the literature and use robust evaluation methods to characterize how the ADI is used. Given the increasing use of the ADI, understanding what is known about it may inform current and future applications.

The ADI has been widely utilized in the peer-reviewed literature, particularly in surgery, orthopedics, cancer, and cardiovascular health. The ADI has been widely adopted and utilized in some fields and areas of research but may be understudied in others.

There is a lack of consistency and clarity in how the ADI is incorporated into studies. The variation in ADI measurement, categorization, and thresholds has implications for what is known about the association between ADI and health-related outcomes. For example, categorizing only the top 5% of block groups as "high deprivation" reflects a potentially very different population and construct as the top 75%. In addition to the lack of agreed upon operationalizations of ADI in the literature, many studies lack key detail on the methods and application of ADI, making it difficult to interpret findings within the context of other studies or applications of ADI in policy and practice.

Many studies incorporate both the ADI and measures of rurality across these areas. Reflective of other literature, there is variation in what measures of rurality are used and how they are measured. The inclusion of rurality in many studies may suggest that rurality is a theoretically distinct contributor to health-related outcomes. However, we found no included studies that considered the direct relationship between rurality and ADI level and this relationship is largely unknown. CMS specifically identifies the unique needs of rural and underserved populations related to the ACO REACH model and Medicare Shared Savings Program, and the ADI is incorporated as part of a health equity adjustment in combination with other measures, but there is no adjustment based on rurality.[20,21,54] There is no current literature that can comment on whether the ADI is a sufficient measure to capture the challenges in rural areas, or whether further adjustment may be needed to address the unique needs in rural communities. In order to understand the implications of such adjustments or future applications of ADI in policy, reimbursement, and resource allocation, more research is needed to understand how ADI varies by rurality and if these efforts may differentially affect a variety of populations, including rural communities, racial and ethnic minority groups, and regions.

Recommendations Future Research

- Future research should be conducted to determine how ADI varies by rurality, race, and ethnicity, and with a health equity lens. Researchers often use ADI and other community-level characteristics such as rurality, race, and ethnicity as covariates modeling a health-related outcome. While important, this overlooks potential relationships that exist between ADI and

these community characteristics. Future research should explore these relationships to inform policy and design of future research studies. Further, it is crucial to the success of applications of ADI to support health equity efforts to understand how ADI differs by these characteristics, and if there are any potential unintended consequences, particularly that may disproportionately affect populations that have been historically disadvantaged.

- Future ADI research should consider including larger populations and other settings. The nature of the ADI being available and validated at the block group level has implications for applications in research. Often health outcomes data are not available at this level of granularity, particularly for rural communities and at large scales. Therefore, many studies are limited to data from a single organization of health system. This may limit generalizability to other populations.

- Researchers should provide details on how ADI was incorporated into their studies. Many studies lack detail on year of the ADI utilized and how the ADI was operationalized in the study. Given changes in the ADI methodology over time and the variation in how the ADI has been implemented across studies, it is important to clearly articulate this information to better understand how ADI relates to important health outcomes of interest. Consistency and clarity in how ADI relates to health outcomes of interest have significant implications for the potential impacts and design of the use of ADI in policy. Lack of clarity around the findings we have to date limit the ability to use the ADI with fidelity. We recommend authors include:
    - Year of the ADI
    - Use of national or state ADI ranks/deciles
    - Use of block group-level or 9-digit ZIP code-level ADI
    - How ADI was operationalized (continuous, categorizations, etc.) including thresholds for dichotomous or categorical measures.

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Appendix 1

Table 1. Study Characteristics

	Count of Studies
	N(%)
Year of Publication	
2017	1
2018	2
2019	3
2020	20
2021	73
2022	123
Study Scope	
Single site/facility/health system	114 (51.4%)
Sub-state region	8 (3.6%)
Single state	25 (11.3%)
Multi-state	8 (3.6%)
National	28 (12.6%)
Other	34 (15.3%)
Does not specify, unclear, or unable to find	5 (2.3%)
Rurality	
No measure of rurality included	143 (64.4%)
RUCA	31 (14.0%)
Other or Unclear	19 (8.6%)
Distance	13 (5.9%)
RUCC	8 (3.6%)
Population Density	6 (2.7%)
Census Urban Areas	3 (1.4%)
Focus Area	
Surgery	69 (31.2%)
Orthopedics	43 (19.4%)

Cardiovascular	38 (17.1%)
Cancer	33 (14.9%)
Trauma/ED/Injury	21 (9.5%)
COVID-19	18 (8.1%)
Primary, preventive, and chronic condition management	15 (6.8%)
Behavioral health (including mental health and substance use)	13 (5.9%)
Pain	9 (4.1%)
Diabetes	8 (3.6%)
HIT/Telehealth	8 (3.6%)
Reproductive Health	7 (3.2%)
Eye Care	5 (2.3%)
Alzheimer's and Dementia	4 (1.8 %)
HIV/AID	3 (1.4%)
Lupus	3 (1.4%)
Financial measures	3 (1.4%)
Other	23 (10.4%)
Other indices	
Distressed Community Index	4 (1.8%)
Social Vulnerability Index	3 (1.4%)
Other Index	14 (%)
Exclusive Focus on Medicare Population	
Yes	21 (9.5%)
No	201 (90.5%

Note: Many study characteristics are not mutually exclusive, therefore counts and percentages may not add up to 222 and 100%, respectively.

Appendix 2

Table 2. ADI Characteristics and Use

	Count of Studies
	N(%)
ADI Level	
National (1-100)	143 (64.4%)
State (1-10)	43 (19.4%)
Both national and state	20 (9.0%)
Does not specify, unclear, or unable to find	16 (7.2%)
Year of ADI Data	
2000	3 (1.4%)
2003	1 (0.5%)
2010	2 (0.9%)
2013	23 (10.4%)
2015	53 (23.9%)
2016	1 (0.5%)
2018	24 (10.8%)
2019	10 (4.5%)
Other	5 (2.3%)
Does not specify, unclear, or unable to find	100 (45%)
ADI Measurement	
Continuous national percentiles	86 (38.7%)
Continuous state deciles	41 (18.5%)
Dichotomized	48 (21.6%)
Categorization	121 (54.5%)
3 Categories	30 (13.5%)
4 Categories	45 (20.3%)
5 Categories	38 (17.1%)
Greater than 5 Categories	10 (4.6%)
Other	4 (2%)
Does not specify, unclear, or unable to find	6 (3%)

Note: Many study characteristics are not mutually exclusive, therefore counts and percentages may not add up to 222 and 100%, respectively.