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Community-Level Factors Associated with Health-Related Quality of Life Among Older Adults

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COMMUNITY-LEVEL FACTORS ASSOCIATED WITH HEALTH-RELATED QUALITY OF LIFE AMONG OLDER ADULTS

by

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DEDICATION

This work is dedicated in memory of my grandfather, Chun-Mu Lin (林春木).

ACKNOWLEDGEMENTS

To God be the glory, great things He has done.

Thank Drs. Probst, Bennett, Eberth, Qureshi, and Liang, my family, the South Carolina Rural Health Research Center, and friends.

Thank you all for all that you have done for me.

ABSTRACT

Objective: Health-related quality of life (HRQOL) and well-being is a new topic area for Healthy People 2020 in the U.S. In a broad-based literature review, more research explored individual level factors of HRQOL, and few focused on older adults. Multilevel analysis was seldom adopted to investigate the relationship between area-level socioeconomic or social environment factors and HRQOL. In lieu of the traditional Chapter 4 (Results) and Chapter 5 (Conclusion), two manuscripts representing the two specific research aims are included. The main aim of first manuscript was to explore the association between area deprivation, area health resources and older adults' HRQOL. The purpose of this study was to develop county-level estimates of poor HRQOL among older U.S. adults, and to identify spatial clusters of area deprivation and poor HRQOL using a multilevel, post-stratification (MPS) approach.

Method: Cross-sectional study utilizing the 2011 and 2012 Behavioral Risk Factor Surveillance System (BRFSS), merged with data from the 2013-2014 the Area Health Resources File (AHRF), the 2014 Food Environment Atlas Data File, and 2014 County Health Rankings (CHRs) file. The dependent variables were three HRQOL dimensions (general health (GH), physical health (PH), and mental health (MH)). County level analysis utilized Ford and Dzealtowski's area deprivation index, and other health resource factors. Multilevel reweighted modeling techniques examined the county effect on older adults' HRQOL, after accounting for individual-level characteristics.

Subsequently, post-stratification for small area estimation (SAE) was conducted

to generate county-level probabilities of poor HRQOL in older adults in the U.S. Finally, we employed global and local Moran's I (LISA) testing to evaluate the spatial autocorrelation of county-level probabilities of poor HRQOL in older adults and area deprivation.

Results: Area variation was associated with HRQOL, although differences at the area level only contributed modestly to older adult's HRQOL (6.58%, 2.08%, and 1.80% for GH, PH, and MH, respectively). Older adults living in higher area deprivation counties had a higher probability of having fair/poor GH and more physically unhealthy days compared to those living in lower area deprivation counties, but had a lower probability of having mentally unhealthy days, after adjusting for individual and other county characteristics.

The range of county-level probabilities of poor HRQOL in older adults in each state is 0.18-0.35, 0.21-0.32, and 0.14-0.24 for general health, physical health, and mental health, respectively. The spatial autocorrelation tests found that county-level probabilities of poor HRQOL in older adults and area deprivation were spatially dependent.

Conclusion: Despite adjusting for individual level factors, contextual factors continue to exert an important influence on health outcomes, although results were generally smaller than the effects from individual-level factors. Individual-level characteristics had a stronger affect than county-level factors. Furthermore, bivariate choropleth maps and spatial autocorrelations effectively identify vulnerable counties. These results may help to target interventions towards specific counties, based on the results from our SAEs and spatial clustering tests. There are potential implications for the provision of health and social services and more generally for policies affecting community cohesiveness.

Key words: Area deprivation; Behavioral Risk Factor Surveillance System; Health-related quality of life; Multilevel, post-stratification approach; Older adults; Spatial autocorrelation

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ACBS .... Asthma Cell-Back Survey

AHRF .... Area Health Resource File

AL .... Activity Limitation

BRFSS .... Behavioral Risk Factor Surveillance System

CDC .... Centers for Disease Control and Prevention

CHD .... Coronary Heart Disease

CHR .... County Health Rankings

CNI .... Care Need Index

COPD .... Chronic Obstructive Pulmonary Disease

DOE .... Department of the Environment Basic Index

EQ-5D .... EuroQol Five-Dimensional Questionnaire

FIPS .... Federal Information Processing Standards

FIW .... Federal Interagency Workgroup

FPL .... Federal Poverty Level

GH .... General Health

HCAP .... Health Care Access Panel

HIV/AIDS .... Human Immunodeficiency Virus/Acquired Immunodeficiency Syndrome

HRQOL .... Health-Related Quality of life

HUI .... Health Utilities Index

ILD .... Index of Local Deprivation

ILL .... Index of Local Conditions

IMD .... Index of Multiple Deprivation

IMD .... Index of Multiple Deprivation

IOM .... Institute of Medicine

IRSD .... Index of Relative Socio-Economic Disadvantage

LS .... Life Satisfaction

MH .... Mental Health

MLHFQ .... Minnesota Living with Heart Failure Questionnaire

MPS .... Multilevel, Post-Stratification

NHIS .... National Health Interview Survey

NWAHS .... North West Adelaide Health Study

NZDep .... New Zealand Index of Deprivation

OH .... Overall Health

PCSA .... Primary Care Services Areas

PH .... Physical Health

PROMIS .... Patient-Reported Outcomes Measurement Information System

QOL .... Quality of Life

QWB .... Quality of Well-Being

SAE .... Small Area Estimation

SIP .... Sickness Impact Profile

SS .... Social and Emotional Support

TOWNIndex .... Townsend Index of Deprivation

UPA .... Jarman Underprivileged Areas Score

UW-QOL..University of Washington Quality of Life Questionnaire

WEAT ....Web-Enabled Analysis Tool

WHO ICF.............. World Health Organization International Classification of Functioning Disability and Health

WHO .... World Health Organization

WHOQOL.. World Health Organization Quality of Life

ZCTA ....ZIP Code Tabulation Area

CHAPTER ONE

INTRODUCTION

1.1. Background

Owing to major medical and public health advances and greater access to health care, Americans are living longer and better than before. Life expectancy at birth in the U.S. rose from 76.8 years in 2000 to 78.8 years in 2013. This is the longest life expectancy ever recorded. The life expectancy at birth for females stood at 81.2 years, while for men was 76.4 years. The average life expectancy for a person who was 65 years old in 2013 is 19.3 years-20.5 years for women and 17.9 years for men. [1]

As life expectancy continues to rise, how to maintain and improve older adults' quality of life (QOL), especially in later years of life, has become a challenge for public health. Older adults are also seeking ways to maximize their physical, mental, and social well-being to remain independent and active as they age. [2]

1.2. Quality of Life and Health-Related Quality of Life

The World Health Organization (WHO) defines QOL as "individuals' perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns". [3] Similar yet different, health-related quality of life (HRQOL) is defined as "a multi-dimensional concept that includes domains related to physical, mental, emotional, and social functioning. It goes beyond direct measures of population health, life expectancy, and causes of death, and focuses on the impact health status has on quality of life." [4] Some researchers consider HRQOL as general QOL, [5] while others mention that HRQOL is a subset of overall QOL. [6]

Although health is an important domain of overall QOL, there are other domains as well, such as employment, housing, education, neighborhood, and so on. Moreover, QOL is influenced by culture, values, and spirituality, so QOL is difficult to measure. The measurement of HRQOL is clearer than QOL, and it focuses more on physical health and mental health.

HRQOL and well-being is a new topic area for Healthy People 2020 in the U.S. Its goal is to improve HRQOL and well-being for all individuals. The Centers for Disease Control and Prevention (CDC) conducts the Healthy Aging Program to provide comprehensive activities designed to help older adults live longer and have high-quality, productive, and independent lives. [7] HRQOL can be measured by the Medical Outcomes Study Short Forms, including SF-12 and SF-36, the Sickness Impact Profile (SIP), the Quality of Well-Being (QWB), the RAND-36, the EuroQol five-dimensional questionnaire (EQ-5D), the Health Utilities Index (HUI), the Minnesota Living with Heart Failure Questionnaire (MLHFQ), the World Health Organization Quality of Life (WHOQOL), and so on. [3,8–10] HRQOL questions have been added to the Behavioral Risk Factor Surveillance System (BRFSS) since 1993. HRQOL in BRFSS are mainly measured by individuals' self-report general health (GH), and unhealthy days of physical health (PH), mental health (MH), and activity limitation (AL).

In a broad-based literature review, researchers are more interested in exploring the relationship between physical activity and HRQOL in the older population. [11–14] From 1993, HRQOL has been widely applied in BRFSS related studies, either as an explanatory variable or an outcome variable.

As of June 2015, a PubMed search identified 89 articles under the topic heading of "health-related quality of life" and under the title/abstract of "Behavioral Risk Factor Surveillance System". Among those 89 articles, only six articles focused on older population. [15–20] Furthermore, multilevel analysis was seldom adopted to investigate the relationship between area-level socioeconomic or social environment factors and HRQOL. [21,22] A knowledge gap of older adults' HRQOL need to be filled.

1.3. Area Deprivation and Health-Related Quality of Life

Area deprivation is a component index representing the socioeconomic status of areas. Those area socioeconomic measures could be stressors (e.g. poverty, crime, racism, or pollution) or resources (e.g. social support, health care accessibility, or available to residents in an area). [23] Area deprivation indices were widely used in the United Kingdom (U.K.), such as the Townsend Material Deprivation Score, the Carstairs Deprivation Index, the Jarman Index, and the Index of Multiple Deprivation (IMD). [24,25] A component index demonstrated utility across diverse geographic and sociodemographic features, suggesting it has broader geographic generalizability. [25]

Residences in highly socioeconomic disadvantaged environments have been associated with worse health outcomes [25–27] and more negative health behaviors. [25] Previous studies found that the relationship between area-level deprivation and health outcomes vanishes after adjusting for individual characteristics. [28,29] However, recent research supports that area deprivation was significantly associated with both physical and mental health outcome even after adjusting for individual socioeconomic factors. [30] Few studies have been found to explore the relationship between area deprivation and

HRQOL and, unfortunately, most of the previous studies were not conducted in the U.S. [6,28,31–34]

1.4. Research Objective

Until now, little has been known about the association between area deprivation and older adults' HRQOL. The main aim of this study is to explore the association between the area deprivation and older adults' HRQOL using statistical and spatial analyses, including multilevel reweighted regression, multilevel, post-stratification (MPS), and spatial autocorrelation. Multilevel reweighted regression assesses the association between areal factors and older adults' HRQOL after controlling individual factors, the MPS generates county-level probabilities of poor HRQOL in older adults; and spatial autocorrelation examines clustering patterns. Secondly, this study presents the distribution of area deprivation and older adults' HRQOL in U.S. counties.

The specific research objectives are as follows:

1. To examine the associations between individual characteristics and older adults' HRQOL.
2. To examine the associations among area deprivation, health resources, and older adults' HRQOL.
3. To establish county-level probability of older adults having poor HRQOL estimates.
4. To identify spatial clusters in area deprivation and probability of having poor HRQOL for older adults.

1.5. Research Questions and Hypotheses

Based on the research objectives, research questions and hypotheses of this study are as follows:

1. What is the relationship between individual characteristics and the likelihood of older adults having poor HRQOL while controlling for county factors?

   H_0: Individual characteristics do not influence older adults' HRQOL, after controlling the covariates in county factors.

2. What is the relationship between county factors (area deprivation and health resources) and the likelihood of older adults having poor HRQOL while controlling for individual factors?

   H_0: County factors (area deprivation and health resources) do not influence older adults' HRQOL, after controlling the covariates in individual factors.

3. What is the probabilities of older adults having poor HRQOL for each county?

   H_0: The probabilities of older adults having poor HRQOL in each county is the same.

4. Whether the patterns of area deprivation and probabilities of having poor HRQOL for older adults expressed are clustered, dispersed, or random?

   H_0: Area deprivation and older adults' HRQOL are randomly distributed in space.

1.6. Significance of This Study

HRQOL does not only indicate individuals' current health status, but also predict their future health, future medical care, and even health utilization. Though HRQOL has been a subject of inquiry for at least the past two decades, few studies have addressed this topic from area level perspective. Most previous studies have been limited to individual level, which may ignore the important risk factors from area level. There is not a significant amount of studies in the literature as to explore older adults' HRQOL related factors in area level. In this regard, there are limitations in addressing policy issues for older adults.

The study uses BRFSS, which is currently the most robust nationwide survey to measure HRQOL. This study focused on multilevel analysis rather than solely on individual level. Multilevel regression model will be utilized to determine the effect of area deprivation on older adults' HRQOL, after accounting for individual effects. The results enhance the knowledge of older adults' HRQOL and thereby help in shaping the policymakers and health care system planners for older population by bridging the unmet gap.

Furthermore, this study seeks to determine the spatial variation for older adults' HRQOL in the U.S. and clustering patterns. MPS approach was developed to analyze small area estimations (SAEs) for national polling data. Currently studies are applying MPS to generate studies of the prevalence of chronic diseases at county level, e.g. chronic obstructive pulmonary disease (COPD), [35–37] not for HRQOL.

Among the 89 articles, currently, no research examines older adults' HRQOL by spatial analysis. Spatial autocorrelation presents promise for public health research in detecting the cluster patterns of area deprivation and older adults' HRQOL across geographic space.

This original dissertation research is formatted using the manuscript style. In lieu of the traditional Chapter 4 (Results) and Chapter 5 (Conclusion), two manuscripts representing the two specific research aims are included.

CHAPTER 2

LITERATURE REVIEW

2.1. Quality of Life and Health-Related Quality of Life

2.1.1. Definitions and Model of Quality of Life (QOL)

The World Health Organization (WHO) defines QOL as "individuals' perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards, and concerns" [3]. Domains of QOL include marriage, family life, employment, housing, education, neighborhood, health, friendship, public safety, political freedom, and so on. [38–41]

Felce and Perry (1995) mentioned that operational definitions of QOL are "diverse, with variability fueled not only by use of societal or individualistic perspectives but also by the range of applicable theoretical models or academic orientations." [42] They summarized conceptualizations of QOL based on Borthwick-Duffy (1992) model (Figure 2.1). [42]

QOL is an overall well-being which is describing objective life conditions and evaluating subjective feeling of wellbeing from physical, material, social, and emotional well-being together with the extent of personal development and purposeful activity, and weighting by personal values and aspirations. External factors would influence the three elements: objective life conditions, subjective feeling of well-being, and personal values and aspirations. Objective life conditions, subjective feeling of well-being, and personal values and aspirations present a dynamic interaction with each other. When one element changes, the other two would change as well (Figure 2.1). [42]

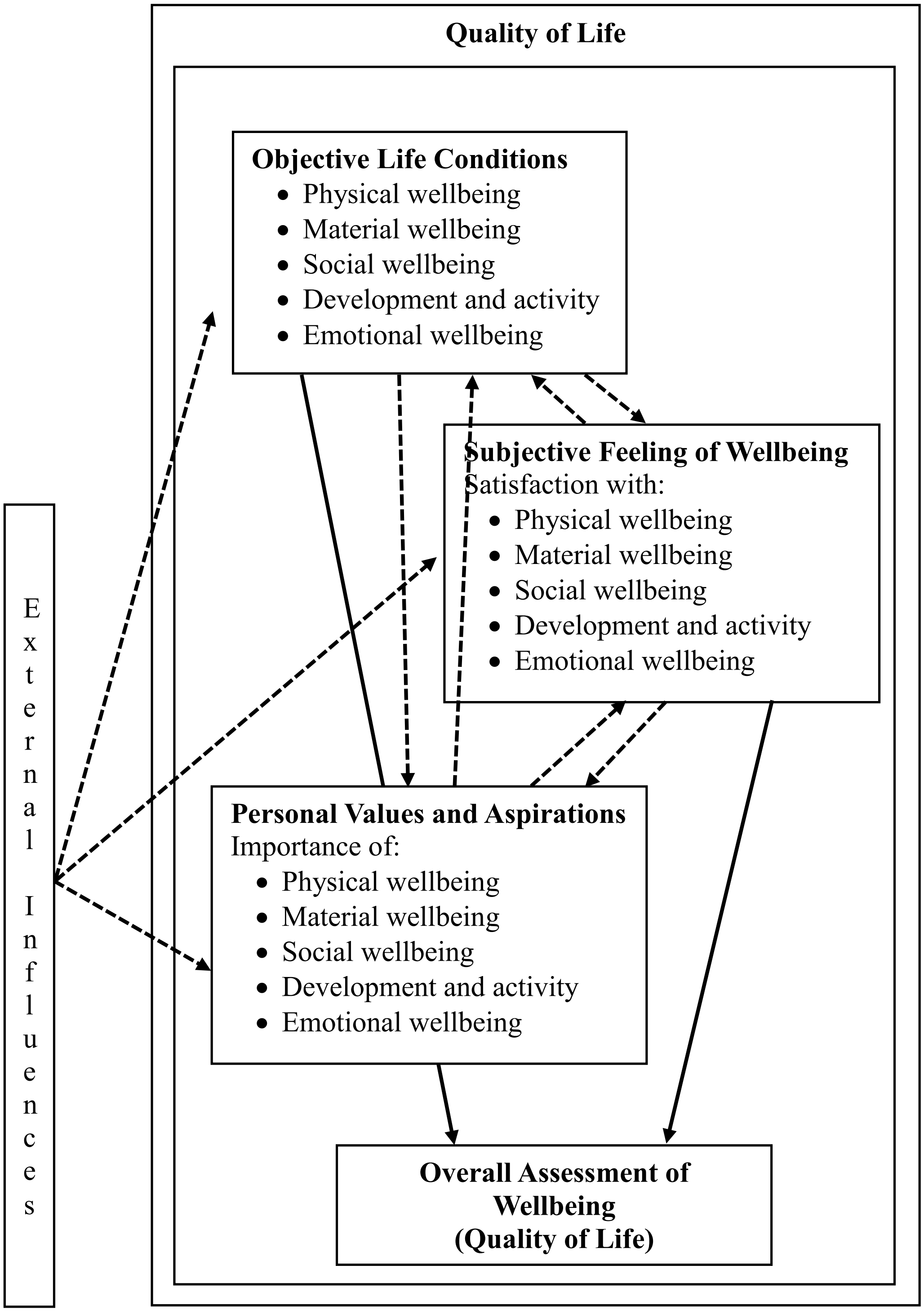


Figure 2.1: Felce and Perry Conceptual Model of Quality of Life

Reference: Felce, D., & Perry, J. (1995). Quality of life: its definition and measurement. *Research in Developmental Disabilities*, *16*(1), 51–74. http://doi.org/10.1016/0891-4222(94)00028-8

2.1.2. Definitions and Model of Health Related Quality of Life (HRQOL)

HRQOL and well-being is a new topic area for Healthy People 2020 in the U.S. Its goal is to improve HRQOL and well-being for all individuals. The Centers for Disease Control and Prevention (CDC) conducts the Healthy Aging Program to provide comprehensive activities designed to help older adults live longer and have high-quality, productive, and independent lives. [7]

Some researchers consider HRQOL as general QOL, [5] while others mention that HRQOL is a subset of overall QOL. [6] Similar yet different, HRQOL is defined as "a multi-dimensional concept that includes domains related to physical, mental, emotional, and social functioning. It goes beyond direct measures of population health, life expectancy, and causes of death, and focuses on the impact health status has on quality of life". [4]

QOL is not only influenced by health, but also culture, values, and spirituality. The measurement of QOL is more difficult than that of HRQOL. On the other hand, the measurement of HRQOL is clearer than QOL, and it focuses more on physical health and mental health.

Bakas et al. (2012) summarized the most frequently applied HRQOL Models as the Wilson and Cleary Model, the Ferrans, Zerwic, Wilbur, and Larson Model, and the World Health Organization International Classification of Functioning Disability and Health (WHO ICF) Model. [10] The Wilson and Cleary Model presents a clearer linkage between the diagnosis and treatment of the HRQOL issue. [41] Ferrans and colleagues revised the Wilson and Cleary Model by adding arrows to identify the relationship between characteristics of both individuals and environments and biological function, removing nonmedical factors, and eliminating the labels on the arrows. [40] The WHO ICF Model describes and organizes information on functioning and disability. The following contexts will introduce the three models in Bakas et al. (2012), [10] as well as Healthy People 2020 Conceptualization of HRQOL.

a. Wilson and Cleary Model

This model includes five levels: biological and physiological variables, symptom status, functioning status, general health perception, and overall QOL. The arrows in the model imply causal associations and potential reciprocal relationships. This model presents a specific causal relationship among those five levels that link traditional clinical variables to measure HRQOL. [41]

Although molecular and genetic factors are considered as the most fundamental determinants of health status, the Wilson and Cleary Model for biological and physiological factors focuses on the function of cells, organs, and organ systems by measuring diagnoses, laboratory values, physiological function examinations, and physical examination findings. Different from the first level, the symptoms are assessed by whole organisms. Symptoms are defined as individuals' perception of an abnormal physical, emotional, or cognitive state. The relationship between biological or physiological variables and symptoms is complex and may be inconsistent, and patient-reported symptoms would determine health utilization and health related costs. [41]

Both symptoms status and functioning status are integrated measurements. Functioning status is influenced by symptoms status, and measured by physical, social, role, and psychological functions. The effect of biological and physiological factors is a mediator of the relationship between symptoms and functioning. If disease-specific measures of symptoms are comprehensive, symptoms would be strong predictors of functioning. [41]

General health perception is considered as medical history, both physical and mental illnesses. After controlling clinical factors, general health perception is a predictor of health utilization and even mortality. Overall QOL focuses on measuring health related satisfaction and circumstantial changes, instead of general subjective well-being. [41]

This model provides a taxonomy for measuring five levels of health outcomes, and points out a causal relationship to measure HRQOL. This model is useful to formulate strategies to improve HRQOL (Figure 2.2).

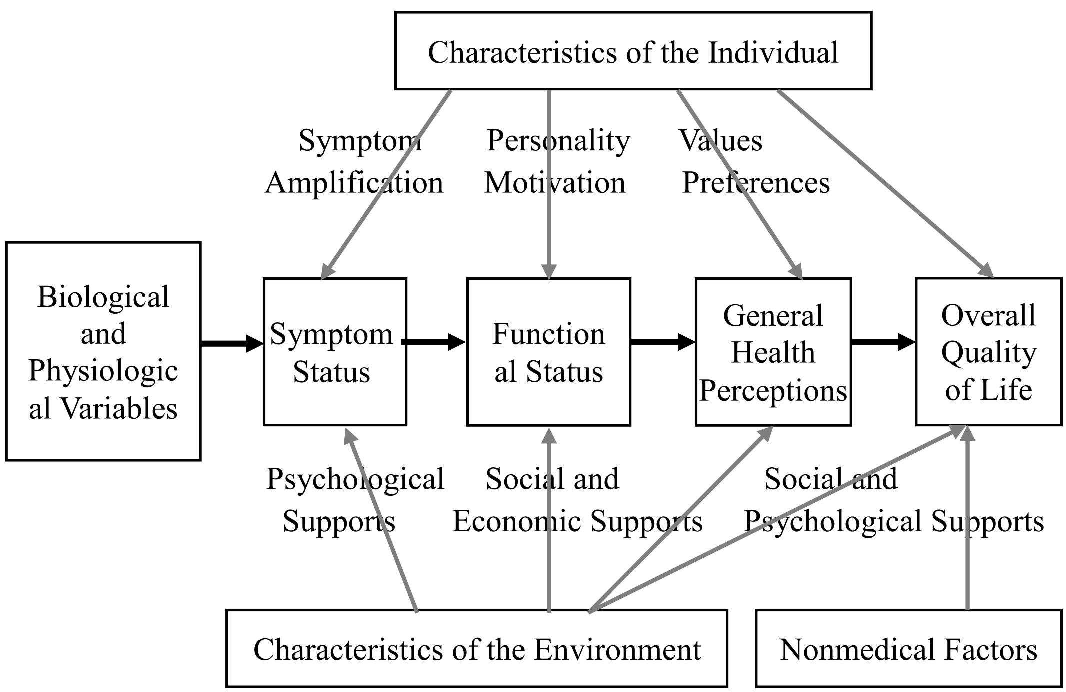


Figure 2.2: Wilson and Cleary Model
Reference: Wilson, I. B., & Cleary, P. D. (1995). Linking clinical variables with health-related quality of life. A conceptual model of patient outcomes. *JAMA*, *273*(1), 59–65.

b. Ferrans, Zerwic, Wilbur, and Larson (2005) Model

Ferrans and colleagues revised the Wilson and Cleary Model. However, characteristics of the environment were based on McLeroy and colleagues' Ecological

Model. [40] The Ecological Model includes five aspects: interpersonal factors, interpersonal processes and primary groups, institutional factors, community factors, and public policy. [43] Interpersonal related factors were considered as individual characteristics; the others were as environmental characteristics. In the revised model, characteristics of the individual categorized as demographic, developmental, psychological, and biological factors, and of the environment, are categorized as social and physical factors. [40]

Ferrans and colleagues revised the original model by three ways. First, they argued that biological and physiological variables are associated with both characteristics of the individual and the environment, so they added arrows to identify the relationships. Second, they pointed out that nonmedical factors already existed in either individual or environmental characteristics; thus, they decided to remove it. Third, they claimed that the labels on the arrows would restrict the comprehensive relationships, and entirely removed labels on the arrows (Figure 2.3). [40]

Ferrans and colleagues maintained the major components of the original model, simplified the structure of the model, and expanded the scopes of application. The revised model contains both theoretical background knowledge and advanced knowledge, so it is more useful to measure HRQOL than the original model, especially in nursing and health care fields.

c. The World Health Organization International Classification of Functioning Disability and Health Model (WHO ICF)

In 2001, the WHO ICF Model changed its focus from consequences of disease to components of health. [10] It presents a conceptual basis for the definition and measurement of health and disability. It integrates various models of disability, and demonstrates an

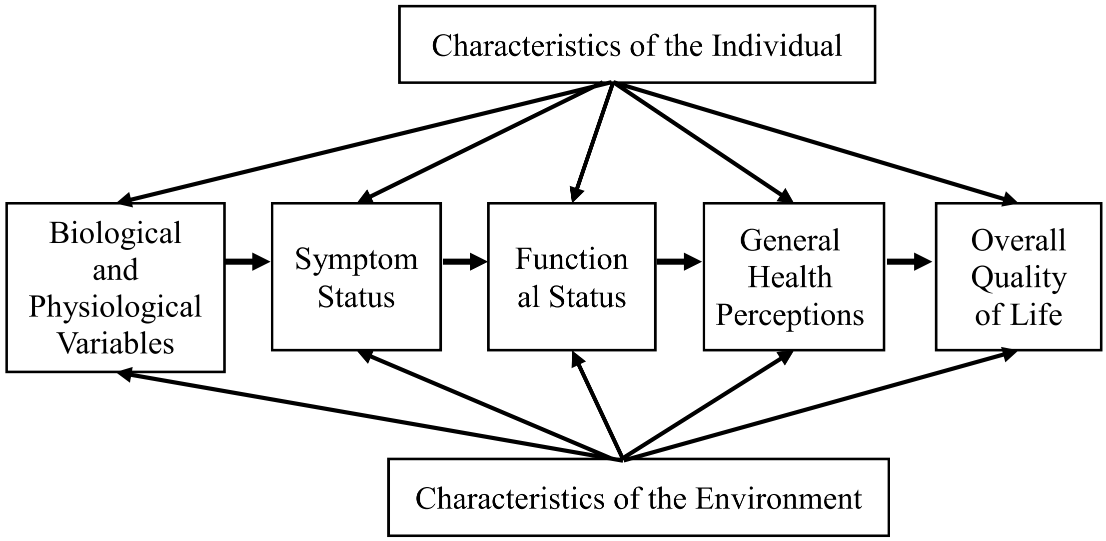


Figure 2.3: Ferrans, Zerwic, Wilbur, and Larson Revised Model
Reference: Ferrans, C. E., Zerwic, J. J., Wilbur, J. E., & Larson, J. L. (2005). Conceptual model of health-related quality of life. *Journal of Nursing Scholarship : An Official Publication of Sigma Theta Tau International Honor Society of Nursing / Sigma Theta Tau*, *37*(4), 336–342. http://doi.org/http://dx.doi.org/10.1111/j.1547-5069.2005.00058.x

interactive and evolutionary process of classification of functioning and disability. [44,45]

The three functioning and disability components—body functions and structures, activities, and participation—present a dynamic interaction between individuals' health conditions, environmental factors, and personal factors. Body functions and structures are functioning at the level of the body to present impairments; activities are at the individual level containing activity limitations they experience; and participation is between individual level and community level. Participation is the functioning of a person as a member of society, and it might be restricted by their experiences. [44,45] The personal and environmental factors address contextual factors. The environmental factors are affected by the above components and these experiences, and may be either facilitators or barriers (Figure 2.4). [10,44,45]

Cieza and Stucki (2008) mentioned that the WHO ICF Model is a basis for the operationalization of HRQOL. [46] Bakas et al. (2012) concluded that the WHO ICF model is a mapping and classification framework in the area of HRQOL, not only a guild for hypothesis generation. [10] Currently, the WHO ICF Model not only applies in assessing individuals' functioning and disability, but also in general health conditions and HRQOL.

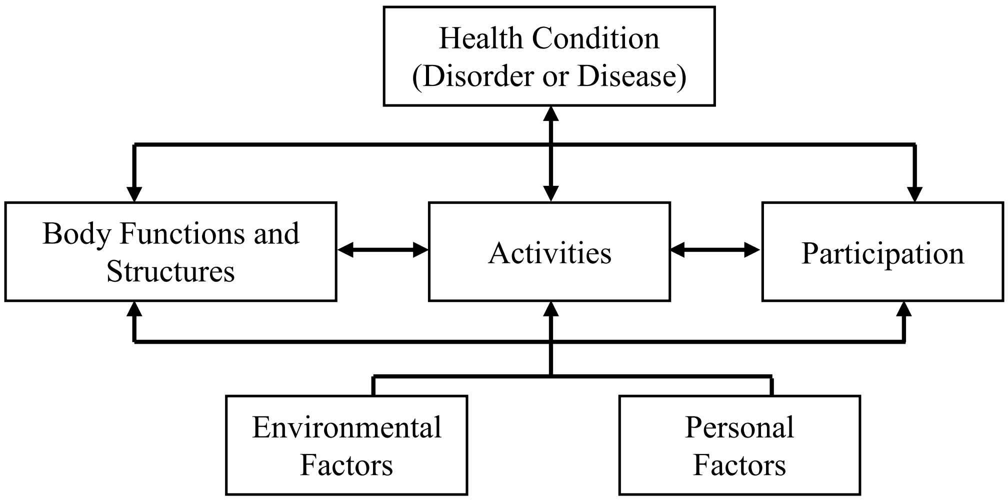


Figure 2.4: The World Health Organization International Classification of Functioning Disability and Health Model
Reference: World Health Organization. (2001). *The International Classification of Functioning, Disability and Health. World Health Organization*.

d. Healthy People 2020 Conceptualization of HRQOL

The four overarching goals of Healthy People 2020 are "eliminating preventable disease, disability, injury, and premature death, achieving healthy equity, eliminate disparities, and improve the health of all groups, creating social and physical environments that promote good health for all, and promoting healthy development and healthy behaviors across every stage of life." [47] There were 15 priority areas with 226 objectives in 1990 Health Objective, and was increased to 42 focus areas with more than 1,200 objectives in Healthy People 2020. 'HRQOL and well-being' is one of the new focus areas for the Healthy People 2020 in the U.S. [47] 'HRQOL and well-being' is mainly to reach the fourth overarching goal, "promoting quality of life, healthy development, and health behaviors across all life stages." [47]

The Federal Interagency Workgroup (FIW) developed a graphic model to visualize the ecological and social determinants approached in the overarching goals of Healthy People 2020 (Figure 2.5). [4] The social determinants contain physical environment, social environment, health services, individual behavior, and biology and genetics. Those social determinants were overlapped with health outcomes. The framework also emphasizes a continued focus on population disparities, including those categorized by race/ethnicity, socioeconomic status, gender, age, disability status, sexual orientation, and geographic location. [4]

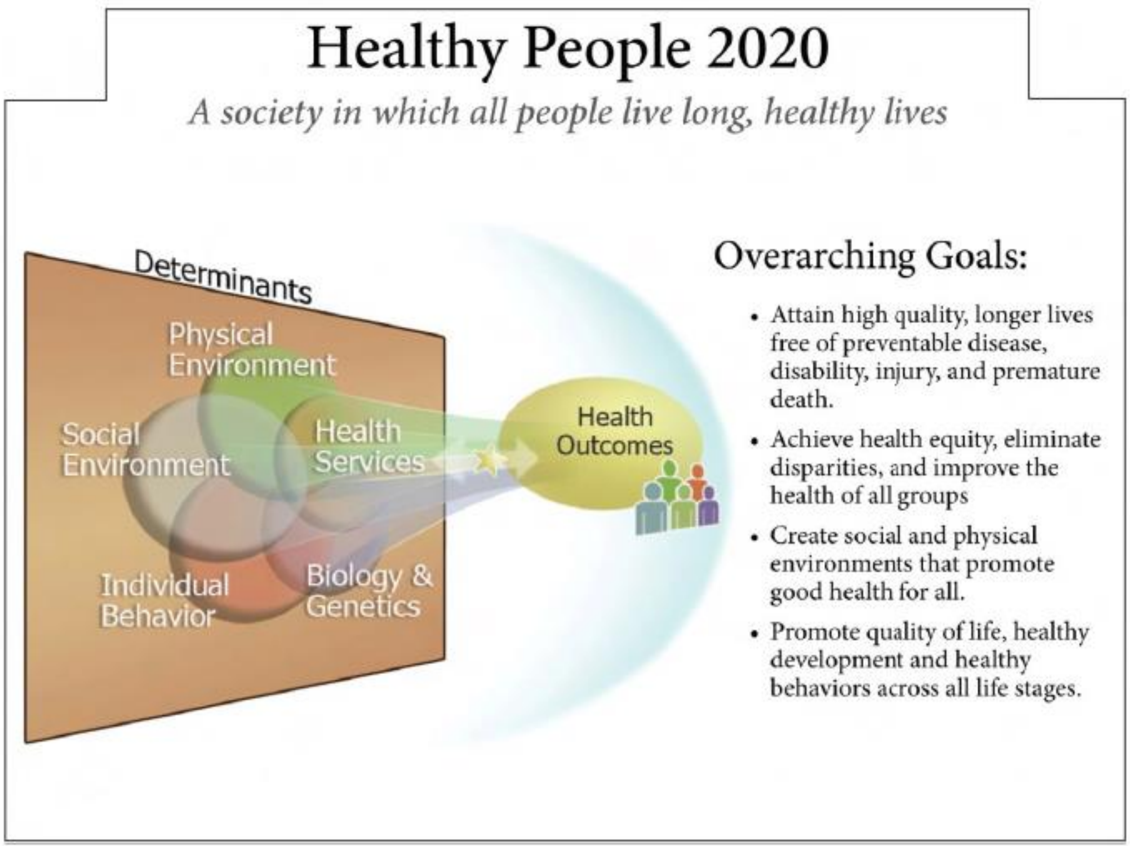


Figure 2.5: Graphic model of Healthy People 2020
Reference: U.S Department of Health and Human Services. (2013). The vision, mission and goals of Healthy People 2020. *Healthy People 2020*, 1–3. Retrieved from www.healthypeople.gov

The Action Model to Achieve Healthy People Goals is adapted from an Institute of Medicine (IOM) model that presents the determinants and ecological nature of health across the life course (Figure 2.6). [47] To achieve the overarching goals, a feedback loop exists among intervention, assessment, and dissemination of evidence. The impacts of interventions (including policies, programs, and information) influence the determinants of health at multiple levels (containing individual—both innate individual and individual behavior— social, family and community networks, living and working conditions, broad social, economic, cultural, health, and environmental conditions and policies at the global, national, state, and local levels) to improve outcomes. The outcomes contain behavioral outcomes, specific risk factors, diseases, conditions, injuries, well-being and HRQOL, and health equity (Figure 2.6). [47]

HRQOL and well-being in Healthy People 2020 is evaluated by three complementary and related domains: self-rated physical and mental health, overall well-being, and participation in society. The patient-reported outcomes measurement information system (PROMIS) measure of global health using 10-item global HRQOL scale measures self-rated physical and mental health. These 10 questions mainly apply on the National Health Interview Survey (NHIS) 2010. Well-being measures physical (e.g. vigor and vitality), mental (e.g. being satisfied with one's life, balancing positive and negative emotions, accepting one's self, finding purpose and meaning in one's life, seeking personal growth, autonomy, and competence, believing one's life and circumstances, and generally experiencing optimism), and social (such as providing and receiving quality support from family, friends, and others) aspects of a person's life. [48] Participation in society is measured by an individuals' current health status and within the individuals' current social and physical environments, including education, employment, civic/social/leisure, and family role participation. [49]

This study is based on WHO ICF Model and Healthy People 2020 Conceptualization Model to explore the relationship between area deprivation and older adults' HRQOL.

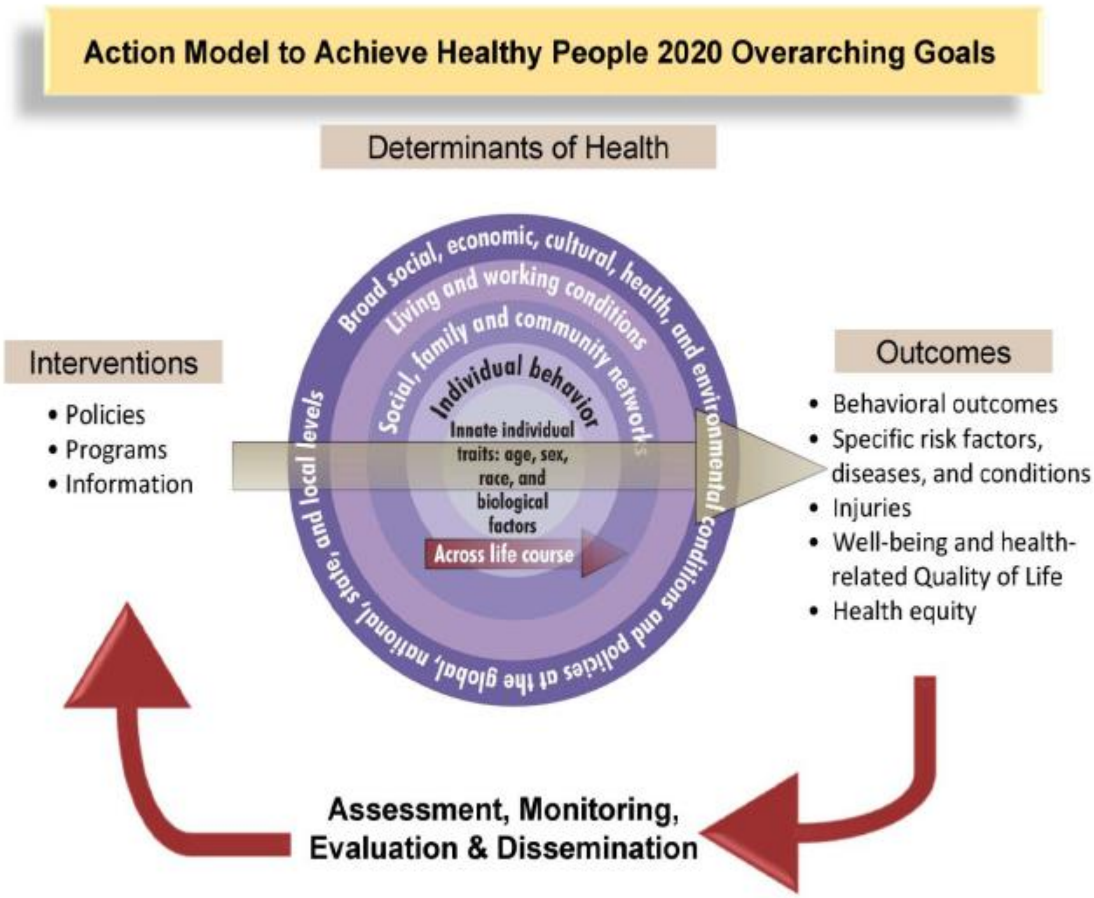


Figure 2.6: The action model to achieve Healthy People goals
Reference: US Department and Human Services. (2008). *The Secretary's Advisory Committee on National Health Promotion and Disease Prevention Objectives for 2020: Recommendations for the Framework and Format of Healthy People 2020*. Retrieved from http://healthypeople.gov/2020/about/advisory/PhaseI.pdf

2.2. Factors of Health-Related Quality of Life

As of June 2015, a PubMed search identified 89 articles under the topic heading of "health-related quality of life" and under the title/abstract of "Behavioral Risk Factor Surveillance System". Among those 89 articles:

(1) 8 articles had not used BRFSS dataset, but BRFSS-HRQOL questions; [18,50–56]

(2) 9 articles conducted structural equation modeling, explored HRQOL correlations, or retested HRQOL validity and reliability; [57–65] and

(3) 1 article was listed twice in PubMed search engine. [66]

2.2.1. HRQOL as an Explanatory Variable

An explanatory variable is an independent variable applied to a dependent variable, and the two terms are often used interchangeably. Among the remaining 71 articles, 7 studies applied HRQOL as an explanatory variable; [67–73] and 4 studies applied HRQOL domains as both explanatory and outcome variables. [74–77]

As an explanatory variable, HRQOL associated with cancer screening (such as mammography use, Pap test, colorectal cancer screening), [67,69] treatment type, [68] less likely to report being prepared for a disaster, [73] life satisfaction, [70] social and emotion support, [71] losing weight, [72] and gender. [72]

2.2.2. HRQOL as an Outcome Variable

Within 60 articles, one article applied HRQOL as an indirect outcome variable to calculate HRQOL, quality-adjusted life years, and quality-adjusted life expectancy. [78] For the other 59 articles, HRQOL is assessed by 4 core dimensions and 8 sub-dimensions, and can be summarized into 13 modules. The core dimensions are general health (GH: self-reported general health), physical health (PH: physically unhealthy days), mental health (MH: mentally unhealthy days), and activity limitation (AL: activity limitation unhealthy days). The four dimensions are integrated as an outcome aspect in the Healthy People 2020 Conceptualization Model.

The 8 sub-dimensions are measured by

(1) life satisfaction (LS: "In general, how satisfied are you with your life?"),

(2) disability ("Are you limited in any way in any activities because of physical, mental, or emotional problems?" and "Do you now have any health problem that requires you to use special equipment, such as a cane, a wheelchair, a special bed, or a special telephone?"),

(3) social and emotional support (SS: "How often do you get the social and emotional support you need?"),

(4) depression ("during the past 30 days, for about how many days have you felt sad, blue, or depressed?"),

(5) anxiety ("during the past 30 days, for about how many days have you felt worried, tense, or anxious?"),

(6) sleep ("during the past 30 days, for about how many days have you felt you did not get enough sleep or rest?"),

(7) energy/vitality ("during the past 30 days, for about how many days have you felt very healthy and full of energy?"), and

(8) pain ("During the past 30 days, for about how many days did pain make it hard for you to do your usual activities, such as self-care, work, or recreation?").

Moreover, some researchers calculated 'overall health' (OH: total unhealthy days, calculated by the sum of physically unhealthy days and mentally unhealthy days, and the maximum is 30 days), and considered it as one dimension. [79–87] The 13 modules are summarized in the following (Table 2.1):

Module 1 (core dimension): GH, PH, MH, MH

Module 2: PH, MH

Module 3: GH, OH

Module 4: GH, PH, MH

Module 5: PH, MH, OH

Module 6: PH, MH, AL, OH

Module 7: GH, PH, MH, AL, OH

Module 8: GH, PH, MH, AL, LS, SS

Module 9: GH, PH, MH, AL, LS, disability

Module 10: GH, PH, MH, AL, depression, anxiety, sleep

Module 11: GH, PH, MH, depression, anxiety, sleep, energy/vitality

Module 12: PH, MH, AL, pain, depression, anxiety, sleep, energy/vitality

Module 13: GH, PH, MH, AL, pain, depression, anxiety, sleep, energy/vitality

Table 2.1: Health-related quality of life module summary

	GH	PH	MH	AL	OH	LS	SS	DIS	DPR	ANX	SLE	EV	Pain
Module 1	●	●	●	●									
Module 2		●	●										
Module 3	●				●								
Module 4	●	●	●										
Module 5		●	●		●								
Module 6		●	●	●	●								
Module 7	●	●	●	●	●								
Module 8	●	●	●	●		●	●						
Module 9	●	●	●	●		●		●					
Module 10	●	●	●	●					●	●	●		
Module 11	●	●	●						●	●	●	●	
Module 12		●	●	●					●	●	●	●	●
Module 13	●	●	●	●					●	●	●	●	●

Note: GH: general health; PH: physical health; MH: mental health; AL: activity limitation; OH: overall health; LS: life satisfaction; SS: social and emotional support; DIS: disability; DPR: depression; ANX: anxiety; SLE: sleep; EV: energy/vitality.

The following sections will discuss related factors for each dimension and sub-dimension. This section focuses on the main predictors (excluding all other covariates) of HRQOL or at least predictors of specific components of HRQOL. Table 2.2 further details comparisons of those 59 studies.

a. General health/Overall health (GH/OH) related factors

GH/OH was declined with age [81,85,88,89]. Males have higher GH/OH than females. [81,85,88,90] Sexual orientation, e.g. bisexual women, associated with poor GH/OH. [91]

Native Americans and non-Hispanic blacks were more likely to have poor GH/OH; [81] however, other studies found that Hispanics were more likely to report poor GH/OH. [88,92] Veterans were more likely to have poor GH/OH. [93]

Individuals with lower education were more likely to have poor GH/OH. [81,89,94] Employment status (e.g. unable to work, disabled, or unemployment) associated with poor GH/OH. [88,90] Individual with lower income were more likely to have poor GH/OH. [81,86,88–90] People with medical financial barriers have more likelihood of poor GH/OH. [95]

Living with an incarcerated household member during childhood associated with higher risk of poor GH/OH. [79] Living areas associated with poor GH/OH, [96] such as mountaintop mining counties, [97] in the county with worse socioeconomic status. [22,98]

People with chronic conditions [50,53,80,99] (such as coronary heart disease (CHD) status, [81,100] cardiovascular conditions, [99,101] chronic obstructive pulmonary disease (COPD) status, [102–104] diabetes, [19,88,90,99,105] and asthma status [65,87,88,90,106]) more likely have poor GH/OH. Obesity associated with poor GH/OH. [65,82,88,91,99,107] People with epilepsy associated with poor GH/OH. [84,108]

People with depression were more likely to have poor GH/OH. [109,110] Anxiety symptoms associated with poor GH/OH. [111] Sleep insufficient associated with poor GH/OH. [112]

People with visual impairment has poor GH/OH. [15,80] Arthritis associated with poor GH/OH. [66,82,113] Physical activity associated with better GH/OH. [90] On the other hand, physical limitation associated with poor GH/OH. [17,114,115]

GH/OH was associated with risky health behaviors. [116] Smoking status and greater nicotine dependence associated with poor GH/OH. [90,117,118] Among binge drinkers, the highest-intensity binge drinkers were more like to report worse GH/OH. [119]

b. Physical health (PH) related factors

Younger adults have lower odds of worse PH. [12,85,88,90] Females were more likely to have worse PH. [85,88,90] Native Americans and non-Hispanic blacks were more likely to have worse PH, [81,92,109] while Asians were less likely to report worse PH. [92]

Employment status (e.g. unable to work, disabled, or unemployment) associated with worse PH. [88,90] Individual with lower income were more likely to have worse PH. [86,88,120] Veterans were more likely to have worse PH than civilians. [93,95,121] People with medical financial barriers have more likelihood of worse PH. [95] Individuals with limited health care access were more likely to have worse PH. [122]

Living with an incarcerated household member during childhood associated with higher risk of worse PH. [79] Living areas associated with poor PH, [96] such as in mountaintop mining counties, [83,97] in the county with worse socioeconomic status. [21,22]

People with chronic conditions [50,80,122] (such as CHD status [81,100], cardiovascular conditions, [99,101] COPD status, [102,104] diabetes, [90,99,105] and asthma status [87,88,90,106]) were more likely to have worse PH. Obesity associated with worse PH. [82,99,107] People with epilepsy associated with worse PH. [84,108]

People with depression were more likely to have worse PH. [109,110] Anxiety symptoms associated with worse PH. [111] Sleep insufficient associated with worse PH. [112]

Individuals with a functional limitation were more likely to have worse PH. [16]

People with visual impairment has worse PH. [15,20,80] Arthritis associated with worse PH. [66,82,113,123]

Physical activity is associated with better PH. [12,90,124,125] On the other hand, physical limitation associated with worse PH. [17,114,115] Individuals who did not adhere to physical activity guidelines were more likely to have worse PH. [17,116,124,126]

PH was associated with risky health behaviors. [116] Smoking status (e.g. current, former, or unsuccessful quitters) and greater nicotine dependence associated with worse PH. [117,118,127,128] Among binge drinkers, the highest-intensity binge drinkers were more like to report worse PH. [129]

c. Mental health (MH) related factors

Younger adults have lower odds of poor MH. [12,85] Females were more likely to have worse MH. [85,88,90] Sexual orientation, e.g. bisexual women, associated with worse MH. [91]

White or Native Americans were more likely to have worse MH, [92,109] while Asians were less likely to report worse MH. [92] Veterans were more likely to have worse MH than civilians. [93,95,121] Married status (not married) associated with worse MH. [120] People with higher education were more likely to have to better MH. [94,120]

Employment status (e.g. unable to work, disabled, or unemployment) associated with worse MH. [88,90] Individual with lower income were more likely to have worse MH. [86,88,120] People with medical financial barriers have more likelihood of worse MH. [95] Individuals with limited health care access were more likely to have worse MH. [120,122]

Living with an incarcerated household member during childhood associated with higher risk of worse MH. [79] Living areas associated with poor MH, [96] such as in mountaintop mining counties, [83,97] in the county with worse socioeconomic status. [21,22]

People with more chronic conditions [50,80,99] (such as CHD status, [81,100] cardiovascular conditions, [99,101] COPD status, [102,104] diabetes, [90,99,105] and asthma status [87,90,106]) were more likely to have worse MH. Obesity associated with worse MH. [82,91,99,107] People with epilepsy associated with worse MH. [84,108]

People with depression were more likely to have worse MH. [109] Anxiety symptoms associated with worse MH. [111] Sleep insufficient associated with worse MH. [112] People with visual impairment has worse MH. [15,20,80] Individuals with a functional limitation were more likely to have worse MH. [16] Individuals who did not adhere to physical activity guidelines were more likely to have worse MH. [17,116,124,126] Arthritis associated with worse MH. [66,82,113,123] Physical activity associated with better MH. [12,124] On the other hand, physical limitation associated with worse MH. [17,115]

People with more risky behaviors were more likely to have worse MH. [116,122] Smoking status (e.g. current, former, or unsuccessful quitters) and greater nicotine dependence associated with worse MH. [90,117,118,120,127,128] Among binge drinkers, the highest-intensity binge drinkers were more like to report worse MH. [119,129]

d. Activity Limitation (AL) Related Factors

Younger adults have lower odds of worse AL. [85] Females were more likely to have worse AL. [85,88] Native Americans and non-Hispanic blacks were more likely to have worse AL, [81,92] while Asians were less likely to report worse AL. [92] Veterans were more likely to have worse AL than civilians. [93,95,121]

Employment status (e.g. unable to work, disabled, or unemployment) associated with worse AL. [88] Individual with lower income were more likely to have worse AL. [86,88]

People with medical financial barriers have more likelihood of worse AL. [95] Living areas associated with worse AL, [96] such as in mountaintop mining counties, [97] in the county with worse socioeconomic status. [21,22]

People with more chronic conditions [53,80,99] (such as CHD status, [81,100] cardiovascular conditions, [99,101] COPD status, [102,104] diabetes, [99,105] and asthma status [87,88,106]) were more likely to have worse AL. Obesity associated with worse AL. [82,99,107] People with epilepsy associated with worse AL. [84,108]

People with depression were more likely to have worse AL. [109,110] Anxiety symptoms associated with worse AL. [111] Sleep insufficient associated with worse AL. [112] People with visual impairment has worse AL. [15] Arthritis associated with worse AL. [66,82,113] Physical activity associated with worse AL. [12,17,124,125] People with more risky behaviors were more likely to have worse AL. [116] Smoking status (e.g. current, former, or unsuccessful quitters) and greater nicotine dependence associated with worse AL. [117,118,128]

e. Life satisfaction (LS) and disability related factors

People with visual impairment or depression were more likely to have worse LS and disability. [15,110,127]

f. Social/Emotion support (SS) related factors

People with depression status were more likely to have worse SS. [110,127]

g. Depression related factors

Females were more likely to have worse depression. [88] Married status (not married) associated with worse depression. [120] People with less education were more likely to have to worse depression. [120] Employment status (e.g. unable to work, disabled, or unemployment) associated with worse depression. [88] Individual with lower income were more likely to have worse depression. [88,120] Individuals with limited health care access were more likely to have worse depression. [120]

Physical limitation associated with worse depression. [115] Sleep insufficient associated with worse depression. [112] Smoking status (e.g. current, former, or unsuccessful quitters) associated with worse depression. [118,120,127]

h. Pain related factors

Younger adults have lower odds of worse pain. [88] Females were more likely to have worse pain [88]. Black, Hispanics, and Asian were less likely to have frequent pain. [92] Veterans were more likely to have worse pain. [93] Employment status (e.g. unable to work, disabled, or unemployment) associated with worse pain. [88] Individual with lower income were more likely to have worse pain. [88]

People with depression status more likely to have worse pain. [110,127] Anxiety symptoms associated with worse pain. [111] Sleep insufficient associated with worse pain. [112]

Physical limitation associated with worse pain. [114] Smoking status (e.g. current, former, or unsuccessful quitters) associated with worse pain. [118,127]

i. Anxiety related factors

Black, Hispanics, Asian, or other race were less likely to have frequent anxiety. [88,92] Females were more likely to have worse anxiety. [88] Married status (not married) associated with worse anxiety. [120] Veterans were more likely to have worse anxiety. [93] People with less education were more likely to have to worse anxiety. [120]

Employment status (e.g. unable to work, disabled, or unemployment) associated with worse anxiety. [88] Individual with lower income were more likely to have worse anxiety. [88,120] Individuals with limited health care access were more likely to have worse anxiety. [120]

Physical limitation associated with worse anxiety. [115] People with depression status more likely to have worse anxiety. [110,127] Sleep insufficient associated with worse anxiety [112]. Smoking status (e.g. current, former, or unsuccessful quitters) associated with worse anxiety. [118,120]

j. Sleep related factors

Black, Hispanics, Asian, or other were less likely to have frequent sleep insufficiency. [88,92] Females were more likely to have worse sleep. [88] Veterans were more likely to have worse sleep. [93] Employment status (e.g. unable to work, disabled, or unemployment) associated with worse sleep. [88]

Physical limitation associated with worse sleep. [114,115] Anxiety symptoms associated with worse sleep. [111] Smoking status (e.g. current, former, or unsuccessful quitters) associated with worse pain. [118]

k. Energy/Vitality related factors

Females were more likely to have worse energy/vitality. [88] 'Other' race group people were more likely to have worse energy/vitality. [88] Veterans were more likely to have worse energy/vitality. [93] Employment status (e.g. unable to work, disabled, or unemployment) associated with worse energy/vitality. [88] Individual with lower income were more likely to have worse energy/vitality. [88]

Physical limitation associated with worse energy/vitality. [115] Anxiety symptoms associated with worse energy/vitality. [111] Smoking status (e.g. current, former, or unsuccessful quitters) associated with worse energy/vitality. [118]

Table 2.2: Comparisons of 59 studies

Authors, year	BRFSS year	Key explanatory variables	Module
Brown, Carroll, Workman, Carlson, & Brown (2014)[12]	2009 BRFSS	Aerobic physical activity	2
Crews, Chou, Zhang, Zack, & Saaddine (2014)[15]	2006-2010 BRFSS	Visual impairment	9
Gjelsvik, Dumont, Nunn, & Rosen (2014)[79]	2009/2010 BRFSS	Living with an incarcerated household member during childhood	2
Joshi, Khanna, & Shah (2014)[109]	2011 BRFSS, arthritis patients	Depression	1
Antwi, Steck, & Heidari (2013)[102]	2011 South Carolina BRFSS	COPD	1
Austin, Qu, & Shewchuk (2012)[126]	2007 BRFSS: individuals with physician-diagnosed arthritis who were over 45 years	Adherence to recommended levels of physical activity	2
Jackson, Suzuki, Coultas, Singh, & Bae (2012)[103]	2009 Texas BRFSS	COPD	GH
Knoeller, Mazurek, & Moorman (2012)[106]	2006-2009 BRFSS, and Asthma Call-back Survey	Work-related asthma	1
Luncheon & Zack (2012)[121]	2007-2009 BRFSS	Veteran status	1
Shen & Sambamoorthi (2012)[95]	2009 BRFSS: women	Medical financial barriers and veterans status	1
Thompson, Zack, Krahn, Andresen, & Barile (2012)[16]	2009 BRFSS	Functional limitations	2
Wen et al. (2012)[129]	2008-2010 BRFSS	Drinking intensity	2
Chen, Baumgardner, & Rice (2011)[99]	2007 BRFSS	8 chronic conditions (asthma, arthritis, heart attack, angina, stroke, diabetes, and hypertension), and obesity	1
Davila et al. (2011)[117]	2007 Florida BRFSS and Florida Tobacco Callback Survey	Nicotine dependence	1

Authors, year	BRFSS year	Key explanatory variables	Module
Furner, Hootman, Helmick, Bolen, & Zack (2011)[82]	2003, 2005, and 2007 BRFSS	Arthritis	7
Hayes et al. (2011)[81]	2007 BRFSS	CHD	7
Jiang & Zack (2011)[122]	2008 Rhode Island BRFSS	Risky behaviors, health conditions, health care access, and use of preventive services	2
Li et al. (2011)[20]	2006 and 2008 BRFSS, aged 65 years and older	Age-related eye diseases (AREDs)	8
Wen & Balluz (2011)[80]	2005 and 2006 BRFSS in Arizona, Connecticut, Maryland, and Texas	Presence of visible in-house mold (PVIM)	5
Zullig & Hendryx (2011)[97]	2006 BRFSS and county-level supplementary file from the Energy Information Administration data	Mining area	1
Brown et al. (2010)[104]	2007 North Carolina BRFSS	COPD	1
Chowdhury, Balluz, & Strine (2010)[92]	2001-2002 BRFSS	Race/ethnicity	13
Fredriksen-Goldsen, Kim, Barkan, Balsam, & Mincer (2010)[91]	2003-2007 Washington State BRFSS, lesbians and bisexual women	Lesbians and bisexual	1
Zullig & Hendryx (2010)[83]	2006 BRFSS, county-level supplementary file (EIA and the Appalachian Regional Commission)	Presence of coal mining, Appalachian region residence	7
Jia, Moriarty, & Kanarek (2009)[22]	Individual level: 1999-2001 BRFSS; county-level: 2000 US Census, AHRF, Mortality File, and other community health datasets	county-level with total 27 variables	1
McClave, Dube, Strine, &	2006 BRFSS in 4	Smoking status	13

Authors, year	BRFSS year	Key explanatory variables	Module
Mokdad (2009)[127]	states (Delaware, Hawaii, Rhode Island, and New York)		
Strine et al. (2009)[127]	2006 BRFSS	Depression (measured by the Patient Health Questionnaire depression scale (PHQ-8)	13
Li et al. (2008) [101]	2003 BRFSS	CVD	1
Ford et al. (2008)[100]	2004 BRFSS	Coronary heart disease	1
Jiang & Hesser (2008)[88]	2004 Rhode Island BRFSS	Demographics, health conditions, and health risk behaviors	13
Richardson, Wingo, Zack, Zahran, & King (2008)[114]	2000-2002 BRFSS	Activity limitation primarily because of their cancer	4
Li, Ford, Mokdad, Jiles, & Giles (2007)[116]	2005 BRFSS	Healthy lifestyle habits	1
Freelove-Charton, Bowles, & Hooker (2007)[17]	2003 BRFSS	Physician-diagnosed arthritis	1
Kim & Kawachi (2007)[21]	2001 BRFSS, and other surveys and administrative sources	State-level: social capital index (14 indicators)	1
Zahran, Zack, Vernon-Smiley, & Hertz (2007)[94]	2003-2005 BRFSS	Student groups (education level)	1
Jiang & Hesser (2006)[88]	2002 Rhode Island BRFSS	Demographic, health conditions, and health risk behaviors	13
Mody & Smith (2006)[128]	2001 BRFSS	Smoking	1
Abell, Hootman, Zack, Moriarty, & Helmick (2005)[123]	2001 BRFSS	Arthritis or chronic joint symptoms (CJS)	2
Strine & Chapman (2005)[112]	2002 BRFSS	Sleep	13
Strine, Chapman, Kobau, & Balluz (2005)[111]	2002 BRFSS	Depressive symptoms	13
Strine, Hootman, Chapman, Okoro, & Balluz (2005)[115]	2002 BRFSS	Pain-related activity difficulty (PRAD)	11
Strine, et al. (2005)[118]	2001-2002 BRFSS	Smoking	13
The Centers for Disease Control and Prevention (2005)[84]	2003-2004 South Carolina BRFSS	Epilepsy	6

Authors, year	BRFSS year	Key explanatory variables	Module
Brown et al. (2004)[105]	1999 and 2001 BRFSS	Diabetes status	1
Okoro et al. (2004)[119]	2001 BRFSS	Drinking status	1
Zack, Moriarty, Stroup, Ford, & Mokdad (2004)[85]	1993-2001 BRFSS	Age and gender	7
Ahluwalia, Holtzman, Mack, & Mokdad (2003)[120]	1998, 2001, and 2001 BRFSS: 18-44 women	Demographic characteristics and health behaviors	10
Barrett, Boehmer, Boothe, Flanders, & Barrett (2003)[93]	2000 BRFSS; active duty personnel, reserves, veterans, and no military services	Veterans status	13
Brown et al. (2003)[124]	2001 BRFSS	Physical activity	1
Ford et al. (2003)[87]	2000 BRFSS	Asthma	7
Mili, Helmick, & Moriarty (2003)[113]	1996-1999 BRFSS: 15 states + Puerto Rico	Arthritis	7
Zabran, Moriarty, Zack, & Kobau (2003)[86]	1995-2001 BRFSS; adults aged 45-64 years	Income	6
Cintron & Kobau (2002)[96]	1996-2000 Puerto Rico BRFSS	Geographic region	7
Greenlund, Giles, Keenan, Croft, & Mensah (2002)[125]	1999 BRFSS; 20 states	Physician advice for diet and exercise	7
Ford, Moriarty, Zack, Mokdad, & Chapman (2001)[107]	1996 BRFSS; excluded pregnant women	BMI	7
Kobau (2001)[108]	1998 Texas BRFSS	Epilepsy	7
Kanarek et al. (2000)[98]	1993-1997 BRFSS	Community health status indicators	OH
Reese et al. (2000)[66]	1996-1998 BRFSS, 11 states	Arthritis	7
Campbell, Crews, Moriarty, Zack, & Blackman (1999)[19]	1993-1997 BRFSS and 1994 National Health Interview Survey Core and 1994 NHIS Second Supplement on Aging	Age, gender, race/ethnicity, education, income, employment, marital status, chronic health conditions, smoking, and BMI	3

Note: COPD: chronic obstructive pulmonary disease; CHD: coronary heart disease; AREDs: age-related eye diseases; PVIM: Presence of visible in-house mold; EIA: The Energy Information Administration; AHRF: area health resource file; PHQ-8: The Eight-Item Personal Health Questionnaire Depression Scale; CVD: cardiovascular disease; CJS: chronic joint symptoms; PRAD: Pain-related activity difficulty; BMI: Body Mass Index.

2.3. Area Deprivation

2.3.1. Definition of Area Deprivation

Deprivation is a concept of broadened poverty. In the past decade, there has been a shift from a physiological model of deprivation to a social model of deprivation. A physiological model of deprivation focuses on the non-fulfilment of basic material or biological needs, while a social model of deprivation focuses on elements lacking of autonomy, powerlessness, self-respect or dignity. [130] Furthermore, deprivation can be categorized as absolute deprivation and relative deprivation. Absolute deprivation is the worst condition in society, such as physical abuse, starvation, and poverty, while relative deprivation is one's condition relative to other members of society. [131,132] Relative deprivation is based on social comparison theory. The majority of area deprivation indices assess relative deprivation among small areas rather than absolute deprivation.

Deprivation could be at the individual level or area level. Anderson and colleagues defined area deprivation as "an area's potential for health risks from ecological concentration of poverty, unemployment, economic disinvestment, and social disorganization." [133] Piro, Næss, and Claussen defined area deprivation as "the clustering of people with limited possibilities for choosing destination of residence." [134] Small area estimation (SAE) analysis is widely applied to measure area deprivation. The unit of small area could be a neighborhood, ZIP Codes (postcode sector), electoral ward or enumeration district (in the U.K.). [135]

Elements of area deprivation frequently include socioeconomic status, such as economic disadvantage, unemployment, education, household characteristics, housing conditions, and so on. [136,137] The indicators of area deprivation in health related research include population density, overcrowded household, unemployment rate, the highest and lowest 5% percentile socioeconomic status ratio, Gini coefficient, car ownership rate, house owner rate, care needs index (CNI), percent of poverty, low/middle income people employed rate, single parent family rate, percent of on public assistance rate, immigrants who immigrated less than 1 year rate, minority percentage, chronic conditions rate, and so on. [138–142] Some indicators present characteristics of an area, and others measure area income inequality.

2.3.2. Indices of Area Deprivation

Deprivation indices are composed by area socioeconomic status indicators and present area deprivation, such as the Department of the Environment basic index (DOE), the Index of Local Conditions (ILC), the Index of Local Deprivation (ILD), the Jarman underprivileged areas score (UPA), the Townsend Index of Deprivation (TOWN index), the Carstairs index, and the New Zealand Index of Deprivation (NZDep). The first three indices are most commonly employed in the U.K., the Carstairs index is in Scotland, and the last is in the New Zealand.

Deprivation indices used in the U.S. are also considered as neighborhood deprivation index, including Estabrooks and colleagues neighborhood socioeconomic status, [143] Ford and Dzewaltowski neighborhood deprivation, [26] Major and colleagues deprivation indices, [144] Messer and colleagues neighborhood deprivation index, [25] Niyonsenga and colleagues socioeconomic status deprivation indices, [145] Pearl and colleagues socioeconomic conditions, [146] Penfold and colleagues deprivation index, [147] Singh area deprivation index, [148] and so on. The U.S. appears to lack a formal or standardized deprivation indices that is in common use. These indices vary in the number of elements included from only 3 through 16. The following paragraphs will discuss the components of each index in the U.S. The summary of the eight area deprivation indices is as Table 2.3.

a. Estabrooks and colleagues neighborhood socioeconomic status

The purpose of Estabrooks and colleagues' study was to determine the association between physical activity resources and neighborhood socioeconomic status. [143] They selected six neighborhood characteristics, including the percentage of unemployment, per capita income, percentages of below poverty threshold, of ethnic composition, of less than high school education, and average tract size; then, the categorized neighborhoods into 3-level socioeconomic status (low, medium, and high) based on the first three variables. [143] Therefore, we may conclude that Estabrooks and colleagues neighborhood socioeconomic status index only include three variables: percentage of unemployment, per capita income, and percentage of below poverty threshold. They found that physical activity resources in low- and medium-socioeconomic status neighborhoods are significantly fewer than in high-socioeconomic status neighborhoods.

b. Ford and Dzewaltowski neighborhood deprivation

The purpose of Ford and Dzewaltowski's study was to determine the association between neighborhood deprivation and BMI. [26] This study applied census tracts as the proxy for neighborhoods. The deprivation variables were composed by eight indicators: percentages of unemployment, of adults over 25 years with less than a high school education, of households under federally designated poverty level, of households with more than one person per room, of female head of households with children, of households with public assistance income, median household income, and percentage of households with no access to a vehicle. The Cronbach's α of this index is 0.85, Eigenvalue is 4.83, and captures a cumulative 60.83% of variance. They found that WIC mothers who lived in higher deprivation tracts more likely increase their BMI, after controlling for individual demographic characteristics. [26]

c. Major and colleagues deprivation index

The purpose of Major and colleagues' study was to examine the association between neighborhood socioeconomic deprivation and the risk of prostate cancer among African American and Caucasian men. [144] Their deprivation index was composed by the percentages of less than high school education, of unemployment, of in managerial jobs, of with public assistance, of households headed by a female, crowding, without a car, had annual income of less than$30,000 or below federal poverty levels (FPL), non-White population percentage, and Gini coefficient. They found that deprivation index and Gini coefficient were associated with an increased risk of prostate cancer among African American and Caucasian men.

d. Messer and colleagues neighborhood deprivation index

The purpose of Messer and colleagues' study was to develop a standardized neighborhood deprivation index and examine selected areas. [25] They selected 20 variables based on 7 domains (poverty, housing, occupation, employment, education, residential stability, and racial composition) to do principal components analysis and factor analysis. Finally, 8 variables retained for the index: percentages of males in management and professional occupations, of crowded housing, of households in poverty, of female headed households with dependents, of households on public assistance, of households earning less than $30,000 per year (estimating poverty), of less than high school education, and of unemployment. The total variance range of the 8 variables is from 51% to 73%, and the total variance is 67% for the combined deprivation index. Due to inherent intertwining for dimensions of disadvantage, indicators are strongly associated in a given area. [25]

e. Niyonsenga and colleagues socioeconomic status deprivation indices

Niyonsenga and colleagues develop socioeconomic status deprivation indices and measure the indices predictive validity for human immunodeficiency virus/acquired immunodeficiency syndrome (HIV/AIDS) incidence relative to individual neighborhood-level indicators. [145] A total 13 variables were employed in the socioeconomic status deprivation indices: no access to a car, crowding, poverty status (below FLP), wealth (percentage of owner-occupied home worth more than $300,000), median income, low income (percentage of households with annual income less than $15,000), high income (percentage of households with annual income more than $150,000), income disparity (ratio of low income to high income), low education (less than 12th grade education), high education (over a graduate or professional degree), renting a house (percentage of households living in a rented house), percentage of unemployment, and high class work (percentage of population aged 16 and over employed in high working class occupations). Income disparity, poverty status, low income, and household median income were categorized as rural ZIP code tabulation area (ZCTA), and the others are urban ZCTA. Cronbach's α is 0.889 for rural ZCTAs and 0.924 for urban ZCTAs. They found that socioeconomic status deprivation indices were associated with HIV/AIDS incidences. [145]

f. Pearl and colleagues socioeconomic conditions

The purpose of Pearl and colleagues' study was to determine the association between neighborhood socioeconomic conditions and birthweight, adjusting individual socioeconomic. [146] They applied three socioeconomic conditions: poverty (percentage of below than FPL), percentage of unemployment, and low education (percentage of less than high school education). After controlling mothers' individuals socioeconomic and other risk factors, they found that mothers living in deprived areas are more likely have lower birthweight babies.

g. Penfold and colleagues deprivation index

Penfold and colleagues examine the association between area deprivation and risk of perforated appendicitis. [147] They created a deprivation index, including percentages of single parent households, of less than high school education, of no vehicle available, of poverty, of unemployment, and median family income. The range of factor loading is -76 to 87, and final communalities is 0.463-0.757. They found that higher rates of perforation in metropolitan urbanized areas remain statistically significant, after adjusting age-sex cohort, comorbid conditions, and insurance type.

h. Singh area deprivation index

Singh examined age-, sex-, and race-specific gradients in U.S. mortality by area deprivation from 1969 to1998. [148] He selected 21 socioeconomic indicators for factor analysis, and retained 17 indicators: percentages of less than 9 years of education, of less than high school education, of employed in white-collar occupations, median family income, income disparity, median home value, median gross rent, median monthly mortgage, percentage of owner-occupied housing unite (home ownership rate), of unemployment, of poverty, of population below 150% FPL, of single parent households, of households without vehicles, of households without a telephone, of occupied housing units without complete plumbing, crowding. He found that area deprivation gradients in U.S. mortality increased substantially during 1969-1998.

Table 2.3: Summary of the U.S. area deprivation indices

	1	2	3	4	5	6	7	8
% unemployment	●	●	●	●	●	●	●	●
Per capita income	●							
Median tract income		●			●		●	●
% below poverty threshold	●	●	●	●	●	●	●	●
% below 150% FPL								●
% of households earning <$30,000				●				
% of households earning <$15,000					●			
% of households earning >$150,000					●			
Income disparity					●			●
% ethnic composition			●					
% education attainment (< high school)		●	●	●	●	●	●	●
% education attainment (< 9 years)								●
High education (> a graduate or professional degree)					●			
Crowding (% >1 person per room)		●	●	●	●			●
Renting a house					●			
% female headed of households with children		●	●	●				
% with public assistance income		●	●	●				
% households with no access to a vehicle		●	●		●		●	●
% managerial jobs			●	●				
High class work					●			●
Gini Coefficient			●					
% of owner-occupied home worth ≥$300,000,					●			
Median home value								●
Home ownership rate								●
% single parent households							●	●
Median gross rent								●
Median monthly mortgage								●
% households without a telephone								●
%occupied housing units without complete plumbing								●

Note: 1: Estabrooks and colleagues neighborhood socioeconomic status; [143] 2: Ford and Dzewaltowski neighborhood deprivation; [26] 3:Major and colleagues deprivation index; [144] 4: Messer and colleagues neighborhood deprivation index; [25] 5: Niyonsenga and colleagues socioeconomic status deprivation indices; [145] 6: Pearl and colleagues socioeconomic conditions; [146] 7: Penfold and colleagues deprivation index; [147] 8: Singh area deprivation index. [148]

2.4. Area Deprivation and Health

2.4.1. Area Deprivation and Health

Inequality and equality are measurable constructs, while inequity and equity are political concepts to express a moral commitment to social justice. [149] WHO defined health inequalities as "differences in health status or in the distribution of health determinants between different population groups." [150] Health inequalities are attributed to biological variations and external environment and conditions, so it tends to be used as a generic term. [149,150] Health inequalities can be assessed by individuals and groups' health status and outcomes, and it might be either unavoidable or avoidable. If the health inequalities are due to biological variations, it may be unavoidable because it may be impossible, ethically or ideologically unacceptable to change. On the other hand, if it is due to external environment and conditions, it is avoidable and presents unfair conditions. Kawachi et al. defined health inequity as "those inequalities in health that are deemed to be unfair or stemming from some form of injustice." [149] It means that health inequity is also resulted from health inequalities. From this aspect, everyone has a fair opportunity to achieve the maximum health status. No one shouldn't be health inequity due do external environment conditions.

The goal of health equality may provide an effective mechanism to maintain societal consensus and focus on the relevant factors of declining health not only on absolute poverty. [151] Individuals' socioeconomic status and area deprivation both influence health and health inequality. For instance, access barriers to health care or services, such as distance of health care facilities, lacking availability and insurance coverage, and high cost, lead to unmet health needs, delay in receiving appropriate care, inability to get preventive services, and hospitalizations that could have been prevented. [152] Those barriers which resulted from individuals' socioeconomic status or area deprivation would result in health equality.

Area deprivation could be linked to negative health outcomes because insufficient resources of individuals or areas would influence accessibility of health services. Some research has pointed out that area deprivation and mortality have a positive association, which is when variation in degree of deprivation increased, the association of area deprivation and mortality is increased. [138,153–158] It may imply that people living in higher deprived areas would present worse health conditions, higher morbidity, and lower health care accessibility. [33,159–162]

Furthermore, residences in highly socioeconomic disadvantaged environments have been associated with worse health outcomes [25–27] and more negative health behaviors. [25] Previous studies found that the relationship between area-level deprivation and health outcomes vanishes after adjusting for individual characteristics. [28,29] However, recent research supports that area deprivation was significantly associated with both physical and mental health outcomes even after adjusting for individual socioeconomic factors. [30]

The following sections summarize selected research that discusses the relationship among area deprivation and health outcomes.

a. Mortality

Li, Sundquist, Zoller, and Sundquist (2015) employed several national Swedish datasets to examine the relationship of area deprivation and incident and mortality rates of lung cancer from 2000 to 2010. [163] They controlled individual-level sociodemographic characteristics, such as age, gender, marital status, family income, educational attainment, immigration status, urban/rural status, mobility, and comorbidities (including COPD, tobacco abuse, and alcoholism), in the multilevel logistic regression models. They found that there were significant differences in incident and mortality rates of lung cancer between areas, after adjusting individual-level sociodemographic characteristics. The results would explain 58% variance for incident and 66% for mortality after inclusion of both area deprivation and individual-level variables, while the explained variances are only 25 % for incident and 33% for mortality if only including area deprivation. It indicates that both area deprivation and individual-level variables influenced incident and mortality rates of lung cancer. [163]

Li, Sundquist, and Sundquist (2012) employed the MigMed 2 database to examine the relationship between area deprivation and prostate cancer mortality in Sweden. [164] The MigMed 2 database is maintained by the Center for Primary Health Care Research at Lund University, Sweden. They also controlled individual-level variables in the multilevel logistic regression models, including age, marital status, family income, educational attainment, immigrant status, urban/rural status, morbidity, and comorbidities (COPD only). The explained variance is 13% in only area deprivation model and jumped to 54% after controlled individual-level variables. They concluded that area deprivation is a predictor for mortality in men with prostate cancer. [164]

Jaffe, Eisenbach, Neumark, and Manor (2005) used the Israel Longitudinal Mortality Study to investigate the effects of neighborhood socioeconomic status on mortality by gender and age. [165] This study considered a multilevel analysis. The level 1, individual variables (including age, marital status, origin, educational attainment, crowding, and household amenities score), was nested within level 2, area-level socioeconomic status index (considered as area deprivation index). In addition, they derived a relative household socioeconomic status score, which presented the individual's household socioeconomic status relative to the person's statistical area of residence. They found that people living in deprived areas are associated with increased risk of mortality regardless of age or gender, after controlling individual socioeconomic status variables. [165]

Singh (2003) examined age-, sex-, and race-specific gradients in U.S. mortality by area deprivation from 1969 to1998. [148] He selected 21 socioeconomic indicators for factor analysis and retained 17 indicators. He employed log linear model to examine annual exponential rate of declines in mortality rate. He found although the mortality rate declined from 1969 to 1998, the most deprived areas maintained the highest mortality rate regardless of gender or race. He concluded that area deprivation gradients in U.S. mortality increased substantially during 1969-1998. [148]

b. Morbidity

Siegel, Mielck, and Maier (2014) used 2002-2006 German cross-sectional survey data, the Taylor Nelson Sophres Health Care Access Panel (HCAP), to measure the relationship between socioeconomic deprivation and health inequalities at the individual and the small area level. [166] They found that socioeconomic in both individual level and small area deprivation present inequalities in obesity, hypertension, and diabetes. [166]

Zhang, Cook, Lisboa, Jarman, and Bellis (2013) examined the effects of area deprivation and self-reported morbidity in England by linear regression model. [167] They aggregated individuals' self-reported morbidity to small areas and applied logtransformed to correct for skewed distributions. They found that compared to the lower deprived areas, people living in higher deprived areas present worse self-report morbidity outcomes. Moreover, people living in an area, which is surrounded by greater affluence areas, has a negative impact on health. [167]

Griffiths, Gately, Marchant, and Cooke (2013) examined the relationship between area deprivation and adiposity in children aged 11-12 years by a multilevel logistic regression model. [168] The level 1 children variables were nested within level 2 small areas. They found that when children were nested within small areas, area deprivation is not statistically significant for any of measures of obesity and not linear. It may indicate that this study refuses the assumption that area deprivation and obesity have a linear relationship. [168]

Singh, Siahpush, and Kogan (2010) employed the 2007 National Survey of Children's Health to examine the association among neighborhood socioeconomic conditions, built environments, and childhood obesity by logistic regression models. [169] They found children have increased odds of obesity and of being overweight when they live in lower amenities built environment, but the same pattern is not presented in socioeconomic conditions areas, after controlling covariates.

The first set of four mortality-related studies presents consistent results that area deprivation is significantly associated with mortality, even controlling individual-level variables. However, the second set of four morbidity-related studies demonstrates inconsistent results. Thus, the relationship between area deprivation and health outcomes when adjusting individual level characteristics is unclear.

2.4.2. Area Deprivation and Health-Related Quality of Life

Few studies have been found which explore the relationship between area deprivation and HRQOL and, unfortunately, most of the previous studies were not conducted in the U.S. [6,28,31–34].

Breeze et al. (2005) assessed how neighborhood characteristics and personal social circumstances combine to contribute towards HRQOL among people aged 75 years and over in Britain. [33] The HRQOL was measured by the U.K. version of the SIP, and area deprivation is based on Cartairs deprivation index. They also adjusted for both individual and living circumstances. They concluded that poor socioeconomic status of both the area and the individual are associated with worse HRQOL of older people in the community.

Woolley et al. (2006) examined the correlation between indices of deprivation and HRQOL in patients with oral and oropharyngeal squamous cell carcinoma during and after their treatment in the U.K. [6] The HRQOL is measured by the University of Washington quality of life questionnaire (UW-QOL), and the area deprivation indices are compared with TOWN index, Carstairs index, UPA, and the index of multiple deprivation (IMD) 2006. They found that patients living in the least deprived areas reported a better HRQOL.

Adams et al. (2009) employed the North West Adelaide Health Study (NWAHS) to examine the effect of local area socioeconomic disadvantage after accounting for individual socioeconomic status and determined if these differ between various health and risk factor variables (including obesity, smoking, HRQOL, physician activity, hypertension, diabetes, alcohol use, cardiovascular disease risk). [31] HRQOL is measured by SF-36, and area deprivation is based on the Index of Relative Socio-Economic Disadvantage (IRSD). They found that aggregated area-level characteristics make modest, but significant, independent contributions to smoking, obesity, and HRQOL, but not for other health outcomes.

2.5. Restatement of Research Aims

Among the 89 articles discussed in section 2-2, only six articles focused on the older population. [15–20] Limitations for the majority of BRFSS studies included mechanisms of individual- and area-levels variables for assessment of older adults' HRQOL. Studies demonstrate that there are differences related to the area deprivation and health outcomes based on both non-nested multilevel and multilevel analyses and present contradictory findings. Moreover, in the U.S., few studies explore the relationship between area deprivation and older adults' HRQOL using both statistic and spatial analyses. Therefore, this study will enhance the knowledge of older adults' HRQOL and thereby help in shaping the policymakers and health care system planners for the older population by bridging the unmet gap.

Until now, little has been known about the association between area deprivation and older adults' HRQOL. After reviewing the literature the goal of this analysis will attempt to determine individual- and area-level factors associated in HRQOL for the older population. The proposed study aims to explore the following specific research questions. The research aims and analysis hypothesizes are below:

1. What is the relationship between individual characteristics and the likelihood of older adults having poor HRQOL while controlling for county factors?

   H_0: Individual characteristics do not influence older adults' HRQOL, after controlling the covariates in county factors.

2. What is the relationship between county factors (area deprivation and health resources) and the likelihood of older adults having poor HRQOL while controlling for individual factors?

   H_0: County factors (area deprivation and health resources) do not influence older adults' HRQOL, after controlling the covariates in individual factors.

3. What is the probabilities of older adults having poor HRQOL for each county?

   H_0: The probabilities of older adults having poor HRQOL in each county is the same.

4. Whether the patterns of area deprivation and probabilities of having poor HRQOL for older adults expressed are clustered, dispersed, or random?

   H_0: Area deprivation and older adults' HRQOL are randomly distributed in space.

CHAPTER 3

METHODOLOGY

3.1. Research framework

This research framework is as Figure 3.1. It has combined the WHO ICF model and the Healthy People 2020 model. Determinants are divided by environmental factors and personal factors. Environmental factors are county-level variables, including area deprivation and health resources conditions. Personal factors are individual-level variables, including demographic characteristics and health related factors. Health outcomes are older adults' HRQOL, including GH, PH, and MH.

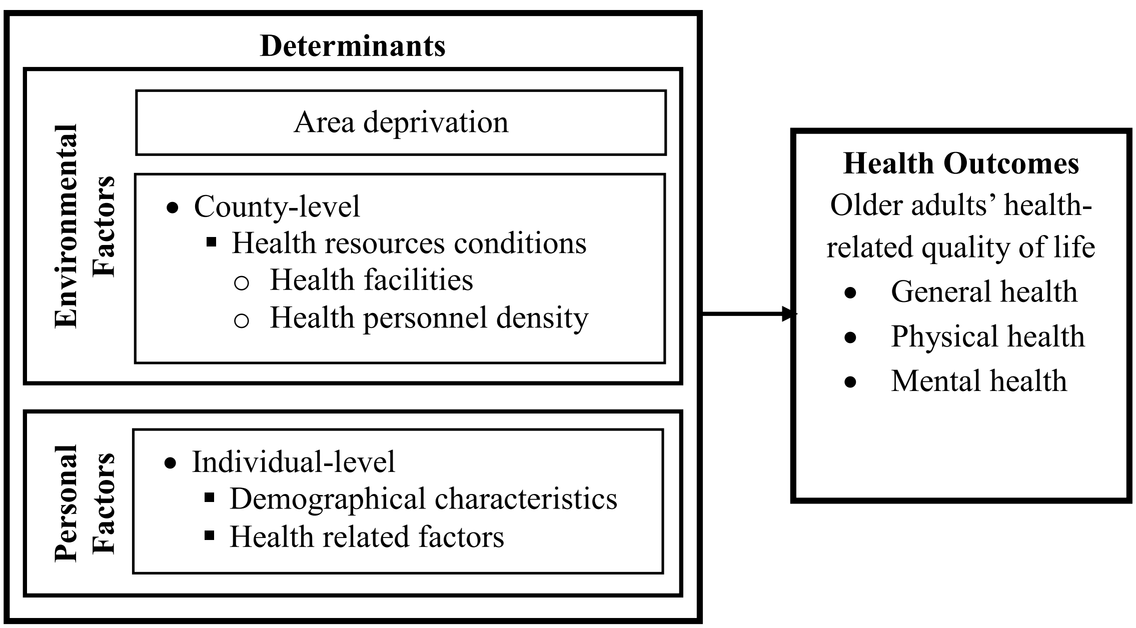


Figure 3.1: Research framework

3.2. Data Sources

This is a cross-sectional study including two levels of analysis: individual-level and county-level. Data for individual-level mainly applied the 2011 and 2012 Behavioral Risk Factor Surveillance System (BRFSS), which has been maintained by the Center for Disease Control and Prevention (CDC). County-level data is retrieved from the 2013-2014 Area Health Resources File (AHRF), the 2014 Food Environment Atlas Data File, and the 2014 County Health Rankings data file (CHR).

3.2.1. Individual-Level Data

BRFSS is an annual survey, and more than 500,000 adults (aged 18 and over) completed interviews each year. Currently, it is one of the largest continuously conducted health survey systems in the world. It was initiated in 1984, at which time only 15 states were enrolled in the surveillance data. Since 2001, all American states and territories (50 states, the District of Columbia, Guam, the U.S. Virgin Islands, and the Commonwealth of Puerto Rico) have participated BRFSS. Before 2011, BRFSS conducted only a landline telephone survey, which was a randomly selected adult in a household. Since 2011, BRFSS uses both landline and cellular telephone lines to conduct the survey. The cellular telephone survey selected adults who participated by using a cellular telephone (Table 3.1). [170,171]

Table 3.1: Timeline history of BRFSS

Year	Events
1981-1983	Feasibility of behavioral surveillance, initial point-in-time state surveys in 29 states
1984	Established the BRFSS, 15 states participated
1988	Developed core questions
1993	Nationwide surveillance system Reached 100,000 interviewers
2001	All states and territories participated
2002	The 1st biannual BRFSS Expert Panel Meeting, following in 2004, 2006,

Year	Events
	and 2009
2005	The Asthma Call-back Survey (ACBS), 3 piloted states
2007	Added a Web-Enabled Analysis Tool (WEAT)
2008	Piloted Cellular Phone Survey
2011	Conducted Cellular Phone Survey Reached 500,000 interviewers New weighted methodology
2013	The 30th year

Reference: National Center for Chronic Disease Prevention and Health Promotion. (2014). About the Behavioral Risk Factor Surveillance System (BRFSS). Retrieved from http://www.cdc.gov/brfss/about/about_brfss.htm

BRFSS mainly contains three parts: core component, optional CDC modules, and State-added questions. The core component is a set of standard questions and applies to all states. It includes queries about current health-related perceptions, conditions, behaviors (such as health status, health care access, alcohol consumption, tobacco use, disability, and HIV/AIDS risks), and demographic questions. Optional CDC modules are sets of questions on specific topics, e.g. excess sun exposure, cancer survivorship, mental illness, and stigma. Some states elect to add their own questionnaires. There are 34 optional modules in 2011 and 27 in 2012, which were supported by the CDC (for more information, see http://www.cdc.gov/brfss/questionnaires/category2011.htm and http://www.cdc.gov/brfss/questionnaires/category2012.htm). State-added questions were developed or acquired by participating states but not edited or evaluated by the CDC. [171,172]

There were 506,467 records for 2011 and 475,687 records for 2012. For the purpose of this study, we restricted the data to older adults who are aged 65 and over. There were 160,529 older adults in 2011 and 152,541 in 2012. After deleting missing values in age, general health, physical health, mental health, state, and county, only 263,914 respondents (weighted N=76,733,680) remained for analysis (Figure 3.2) (Table 3.2).

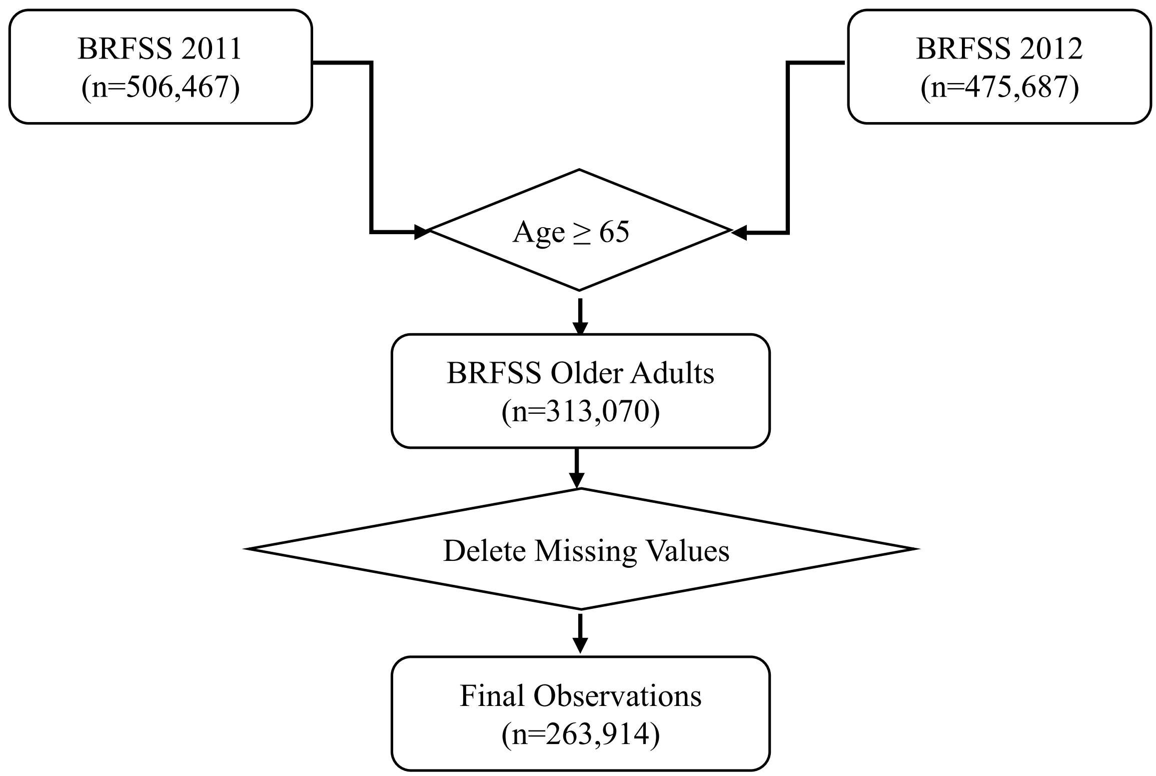


Figure 3.2: Exclusion steps for analysis

Table 3.2: Impacts of removal or exclusion of certain observations

Variable Name	Action Taken	Results
Age	Excluded observation where data were missing Excluded observation where age was less than 65	1 observation with missing age information in BRFSS 2011 2011: 345,938 observations excluded 2012: 323,146 observations excluded
County	Excluded all observation of unknown county and those with missing data	25,792 observations with missing and unknown county information
General health	Excluded all observation of unknown general health and those with missing data	1,451 observations with missing and unknown general health information
Physical health	Excluded all observation of unknown physical health and those with missing data	10,389 observations with missing and unknown physical health information
Mental health	Excluded all observation of unknown mental health and those with missing data	4,727 observations with missing and unknown mental health information

Note: Initial sample size equaled 982,154. After exclusions, total sample size equaled 263,914.

Based on Figure 3-2 and Table 3-2, inclusion observations are 263,914 (weighted: 76,733,680), while exclusion observations are 49,156 (Weighted: 9,501,774). This study conducted Chi-square tests (using PROC SURVERYFREQ procedure with chisq option in SAS software) for testing bias between included and excluded respondents. Age, race, gender, and general health were significant (Table 3.3). There may exist biases between inclusion and exclusion groups. The excluded persons were more likely to fall into the older age, non-White, female, and fair/poor general health groups.

Table 3.3: Chi-square test for inclusion and exclusion groups

Variable	Included in analysis		Excluded in analysis		*p*-value
	%	SE	%	SE	
Age					<0.0001
65-74	56.14	0.18	47.01	0.09	
75-84	34.83	0.17	39.17	0.08	
85+	9.03	0.09	13.81	0.04	
Race (6 groups)					<0.0001
White, non-Hispanic	79.99	0.18	73.18	0.08	
Black, non-Hispanic	7.74	0.10	10.04	0.04	
Asian, non-Hispanic	2.46	0.11	1.72	0.02	
American Indian/Alaskan Native, non-Hispanic	0.76	0.03	1.24	0.01	
Hispanic	7.50	0.12	11.90	0.07	
Other race, non-Hispanic	1.55	0.04	1.91	0.02	
Race (4 groups)					<0.0001
White	79.99	0.18	73.18	0.08	
Non-White	10.04	0.10	10.04	0.04	
Hispanic	11.90	0.12	11.90	0.07	
Others	4.87	0.12	4.87	0.04	
Gender					<0.0001
Male	43.39	0.18	39.98	0.09	
Female	56.61	0.18	60.02	0.09	
General Health (5 groups)					<0.0001
Excellent	12.24	0.11	7.11	0.03	
Very good	2.81	0.15	17.28	0.04	
Good	33.73	0.17	32.45	0.08	
Fair	18.17	0.14	26.08	0.06	

Variable	Included in analysis		Excluded in analysis		*p*-value
	%	SE	%	SE	
Poor	7.72	0.09	12.15	0.04	
General Health (2 groups)					<0.0001
Excellent/very good/good	74.11	0.17	56.84	0.09	
Fair/poor	25.89	0.16	38.23	0.08	

3.2.2. County-Level Data

Counties were identified using federal information processing standards (FIPS) codes and county data was retrieved from the 2013-2014 AHRF, which was developed by the Health Resources and Services Administration, United State Department of Health and Human Services; the 2014 Food Environment Atlas Data File, which was released from Economic Research Service, the United States Department of Agriculture; and the 2014 CHR, which were developed based on variables collected from multiple sources.

This study focused on the county-level areal unit rather than a smaller areal unit, such as primary care services areas (PCSAs) or ZIP codes, because variables of interest in both individual- and county-level datasets were not available at smaller geographic levels.

There were 3,141 counties included in the 2014 AHRF. After merging with the 2014 Food Environment Atlas Data File and 2014 County Health Rankings data file and excluding missing data, the total county observations were 3,101 counties. After merging data from the other sources, and excluding the U.S. territories, Alaska, and Hawaii, out total sample size included 263,914 respondents in 2,238 counties within 48 states and the District of Columbia (Figure 3.3). We examined inclusion and exclusion counties to ensure whether inclusion counties can be represented exclusion counties via independent t test and Chi-square test.

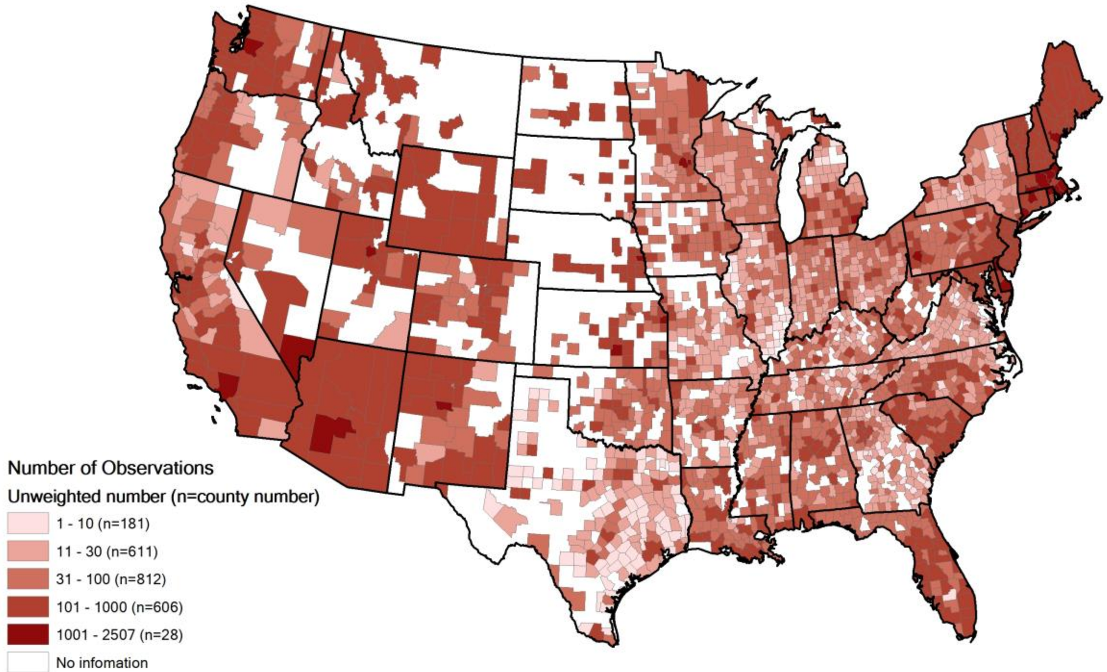


Figure 3.3: The BRFSS included counties (n=2,238)

3.3. Variables

3.3.1. Dependent Variables

The BRFSS contains four HRQOL questions, including general health (GH), physical health (PH), mental health (MH), and activity limitations (AL). This study will analyze each indicator independently.

GH was measured by self-report general health status: "would you say that in general your health is?" PH was measured by "Now thinking about your physical health, which includes physical illness and injury, for how many days during the past 30 days was your physical health not good?" MH was measured by "Now thinking about your mental health, which includes stress, depression, and problems with emotions, for how many days during the past 30 days was your mental health not good?" AL was measured by "During the past 30 days, for about how many days did poor physical or mental health keep you from doing your usual activities, such as self-care, work, or recreation?" The validity and reliability for public health surveillance for the four HRQOL questions in BRFSS were examined [61,64]. Since a large proportion of AL responses were missing (51.82%), this study did not examine AL. Thus, only the first three indicators, GH, PH and MH, were included.

According to previous research suggestions, GH was divided into two groups: excellent/very good/good and fair/poor. [50,53,65,85,88,115] Although previous research suggested that PH and MH can be dichotomized into infrequent (0-14 days) and frequent (15-30 days) number of unhealthy days, [50,65,80,88,117] most BRFSS respondents included in the sample reported no physically (61.42%) or mentally (78.37%) unhealthy days in the past 30 days, skewing the distributions. Thus, PH and MH were categorized into two groups: low unhealthy days (first to third quartiles, 0-4 days (0-74.3%) for PH and 0 days (0-79.4%) for MH) versus high unhealthy days (fourth quartile, 5-30 days (74.3-100%) for PH and 1-30 days (79.4-100%) for MH) (Table 3.4).

Then, HRQOL scores will be aggregated to county-level data based on individual FIPS codes and be used for multilevel modeling. This study applied MPS approach to generate county-level probabilities of having fair/poor GH and high physically/mentally unhealthy days.

Table 3.4: Older adults' physical health, mental health, and activity limitation distributions before exclusions

	Physically unhealthy days		Mentally unhealthy days		Activity limitation days	
	Unweighted	Weighted	Unweighted	Weighted	Unweighted	Weighted
0	59.87%	58.60%	77.37%	76.10%	1.21%	1.17%
1	2.49%	2.48%	1.95%	2.10%	1.86%	1.90%
2	4.26%	4.44%	3.28%	3.32%	1.28%	1.34%
3	2.73%	2.93%	1.84%	1.93%	0.80%	0.84%
4	1.62%	1.71%	0.96%	0.97%	1.59%	1.69%

	Physically unhealthy days		Mentally unhealthy days		Activity limitation days	
	Unweighted	Weighted	Unweighted	Weighted	Unweighted	Weighted
5	2.94%	3.16%	2.08%	2.22%	0.32%	0.31%
6	0.60%	0.65%	0.33%	0.37%	0.79%	0.79%
7	1.72%	1.75%	0.71%	0.76%	0.21%	0.25%
8	0.34%	0.40%	0.20%	0.23%	0.04%	0.04%
9	0.08%	0.09%	0.03%	0.03%	1.46%	1.56%
10	2.45%	2.60%	1.64%	1.76%	0.02%	0.02%
11	0.03%	0.03%	0.01%	0.01%	0.14%	0.17%
12	0.21%	0.26%	0.10%	0.13%	0.01%	0.02%
13	0.02%	0.04%	0.01%	0.01%	0.50%	0.46%
14	1.07%	0.99%	0.29%	0.27%	1.58%	1.69%
15	2.41%	2.64%	1.52%	1.57%	0.03%	0.03%
16	0.05%	0.07%	0.02%	0.02%	0.02%	0.02%
17	0.03%	0.03%	0.01%	0.01%	0.03%	0.03%
18	0.05%	0.05%	0.02%	0.03%	0.01%	0.01%
19	0.01%	0.01%	0.00%	0.01%	0.93%	1.05%
20	1.33%	1.46%	0.79%	0.96%	0.16%	0.16%
21	0.30%	0.30%	0.06%	0.06%	0.02%	0.03%
22	0.03%	0.03%	0.01%	0.01%	0.01%	0.01%
23	0.02%	0.02%	0.01%	0.01%	0.02%	0.02%
24	0.04%	0.03%	0.01%	0.00%	0.43%	0.52%
25	0.62%	0.67%	0.30%	0.38%	0.01%	0.02%
26	0.02%	0.02%	0.01%	0.01%	0.02%	0.02%
27	0.04%	0.04%	0.01%	0.01%	0.09%	0.11%
28	0.18%	0.21%	0.07%	0.09%	0.04%	0.03%
29	0.11%	0.12%	0.05%	0.05%	5.12%	5.20%
30	10.43%	10.20%	3.68%	3.81%	1.62%	1.51%
Don't know/ not sure	3.17%	2.91%	2.01%	1.88%	27.42%	27.76%
Refused	0.76%	1.07%	0.62%	0.87%	0.39%	0.61%
Missing	0%	0%	0%	0%	51.82%	50.61%

Note: Total unweighted observations before excluded: 313,070; weighted observations before excluded: 86,235,454.

3.3.2. Key Explanatory Variables

Area deprivation index. This study applied Ford and Dzealtowski's area deprivation index. [26] We chose this particular index because all elements required to calculate the index were available at the county-level. The index is composed of eight indicators (data year from resources): percent of adults unemployed (2011), percent of adults over 25 years with less than a high school education (2008-2012), percent of households under the federally-designated poverty level (2008-2012), percent of households with more than one person per room (2008-2012), percent of female head of household with children (2010), percent of households with public assistance income (2008-2012), median household income (2011), and percent of households with no access to a vehicle (2010). [26] The data for percent of households with no access to a vehicle was obtained from the 2014 Food Environment Atlas Data File, and other data elements from the 2013-2014 AHRF.

We transposed the median household income. Then, each indicator was calculated as a standardized z-score ($z = \frac{x-\mu}{\sigma}$). Each indicator presents a standard normal distribution with a mean of 0 and a standard deviation of 1. Then, all indicators are summed into an area deprivation index score, with higher score indicating the area is more deprived. The area deprivation score was divided into two groups based on mean score: low (affluent) versus high (deprived).

3.3.3. Covariates

Covariates contain individual- and county-level characteristics. Individual-level characteristics includes sociodemographic characteristics and health related factors. County-level characteristics were represented by health care resources.

a. Individual-level characteristics

(i) Sociodemographic characteristics

Gender sets female as reference group. *Age* was divided into three categories: 65-74 years old (reference category), 75-84 years old, or 85 years old and above.

Race/Ethnicity was collapsed into four categories: White (reference category), Black/African American, Hispanic/Latino, or others groups. Others includes Asian, Native Hawaiian/other Pacific Islander, American Indian/Alaska Native, and others.

Educational attainment was divided into two groups: less than high school (<grade 12, reference category) or college and above.

Marital status were also divided into two categories: married and living with spouse and living alone, regardless of marital status (reference category). The second category consisted primarily of divorced, widowed, separated, and never married (single).

Employment status was categorized as three categories: employed, unemployed, or retired (reference category). Employed includes employed for wages, self-employed, and homemakers. Unemployed contains out of work, students, and unable to work.

Annual household income was collapsed into two categories: less than $20,000 (reference category), $20,000 and above, or non-response/missing group.

(ii) Health related factors

Body mass index (BMI) was calculated by weight in kilograms divided by the square of the height in meters (kg/m^2) or by weight in pounds divided by the square of the height in inches and multiply a conversion factor of 703 (lb/in^2). BMI was divided into three categories: optimal weight (18.5-25, reference category), underweight (<18.5), or overweight/obese (>25.0).

Disability was accorded to the question "Are you limited in any way in any activities because of physical, mental, or emotional problems?", and divided into yes or no (reference category).

Smoking was defined as current smoking ("Do you now smoke cigarettes every day, some days or not at all”), dividing into non-smokers (reference category) or smokers. Current smoking was defined as smoking cigarette every day or some days.

Alcohol consumption was accorded the question “During the past 30 days, how many days per week or per month did you have at least one drink of any alcoholic beverage such as beer, wine, a malt beverage or liquor?” and categorize as non-drinkers (0 days, reference category) or drinkers (at least one day).

Number of chronic conditions were summed up whether they reported having a chronic disease diagnosis, including myocardial infarction, angina or coronary heart disease, stroke, asthma (current having asthma), any type of cancer, chronic obstructive pulmonary disease (COPD)/emphysema/chronic bronchitis, arthritis, depressive disorder, kidney diseases, and diabetes. Those 10 chronic conditions were categorized as 4 groups: 0 (no chronic condition, reference category), 1 (having only 1 chronic conditions), 2 (having any 2 chronic conditions), or 3 and more (having 3 and more chronic conditions).

b. County-level characteristics: health care resources

Health care resources were categorized as health facilities and health personnel density. Health facilities factors contain general hospital, county health related centers (including community health center, community mental health center, federal qualified health center, and rural health clinic), and long-term care facility (including long term hospital, skilled nursing facility, and nursing facility). Health personnel density factors contain all primary care providers (including primary care physicians and other primary care providers), and dentists. The data of whole primary care providers gains from the 2014 CHRs, and others are from the 2013-2014 AHRF.

County-level characteristics were adjusted by population size, calculating by the number of each variable divided by total population in the area and multiply 10,000, and presented health resources to population ratios or health personnel densities as the following equation. Then, all county-level factors were divided by mean scores into low (less than mean) or high (larger than mean) groups.

$$\text{Health care resource to population ratio/health personnel densities} = \frac{Number\ of\ each\ health\ care\ resource}{Total\ population} * 10{,}000$$

Table 3.5: The operational definition of variables

Study variables	Operational Definition	Attributes
Key explanatory variables		
Area deprivation index	In multilevel analysis: 1=low (deprived) 2=high (affluent)	Categorical; Numerical (in spatial analysis)
Covariates		
Individual-level		
Sociodemographic characteristics		
Gender	1=Male 2=Female (reference category)	Categorical
Age	1=65-74 years (reference category) 2=75-84 years 3=85 years and over	Categorical
Race/Ethnicity	1=White (reference category) 2=Black/African American 3=Hispanic/Latino 4=Others, including Asian/Native Hawaiian or other Pacific Islander, American Indian/Alaska Native, and others	Categorical
Educational attainment	0=Less than high school (<grade 12) (reference category) 1=College and above	Categorical
Marital status	1=Married/A member of an unmarried (reference category) 2=Divorced/Widowed/Separated/Never married	Categorical
Employment status	1=Employed 2=Unemployed 3=Retired (reference category)	Categorical
Annual household	1=Less than $20,000 (reference category)	Categorical

Study variables	Operational Definition	Attributes
income	2=$20,000 and above 3=Non-response, don't know/not sure, or missing	
Health related factors		
Body Mass Index	1=Optimal weight (reference category) 2=Underweight 3=Overweight/obese	Categorical
Disability	0=No (reference category) 1=Yes	Categorical
Smoking	0=Non-smoking (reference category) 1=Current smoking (every day or some days)	Categorical
Alcohol consumption	0=No drinking (reference category) 1=Drinking	Categorical
Number of chronic conditions	Summed up whether they reported having a chronic disease diagnosis: myocardial infarction, angina or coronary heart disease, stroke, asthma (current having asthma), any type of cancer, chronic obstructive pulmonary disease (COPD)/emphysema/chronic bronchitis, arthritis, depressive disorder, kidney diseases, and diabetes. Grouping up: 0=0 chronic condition (reference category) 1=1 chronic condition 2=2 chronic condition 3=≥3 chronic condition	Categorical
Community-level		
Health facilities factors	Including: 1. General hospital to population ratio 2. County health related centers a. Community health center b. Community mental health center c. Federal qualified health center d. Rural health clinic 3. Long-term care facility to population ratio a. Long term hospital b. Skilled nursing facility c. Nursing facility Dividing by mean scores: 1=low (< mean) 2=high (≥ mean)	Categorical
Health personnel density factors	Including: 1. All primary care providers density a. Primary care physicians b. Other primary care providers 2. Dentists density	Categorical

Study variables	Operational Definition	Attributes
	Dividing by mean scores: 1=low (< mean) 2=high (≥ mean)	
Dependent Variables		
General health	In multilevel analysis: 0=excellent/very good/good 1=fair/poor In spatial analysis: calculating by MPS approach	Categorical; Numerical
Physical health	In multilevel analysis: 0=low unhealthy days (first to third quartiles) 1=high unhealthy days (fourth quartiles) In spatial analysis: calculating by MPS approach	Categorical; Numerical
Mental health	In multilevel analysis: 0=low unhealthy days (first to third quartiles) 1=high unhealthy days (fourth quartiles) In spatial analysis: calculating by MPS approach	Categorical; Numerical

3.4. Statistical Analysis

This study applied both non-spatial statistical analysis and spatial statistical analysis. Non-spatial statistics was used for descriptive data analysis, bivariate analysis, and multilevel regression modeling.

3.4.1. Statistical Analysis

Descriptive data analysis was generated for two level characteristics. This study then applied Chi-square test to examine the bivariate correlations between each characteristics and older adults' HRQOL. Data analyzed had a hierarchical structure where individual data (level 1) were nested in county (level 2). Multilevel analysis was used to observe the county effect on older adults' HRQOL, a random intercept multilevel model was preferred to other statistical approaches because it manages more levels simultaneously and returns separate residual variance components for between and within-group variability. Regression coefficients and variance components at county and individual levels were estimated for older adults' HRQOL.

Four models were fitted. The first model is an empty model and includes no independent variables. The empty model is used to determine whether the overall difference between county and individuals in terms of HRQOL will be significant. Model 2 includes the individual-level variables, model 3 includes the county-level, and model 4 includes both individual-level and county-level variables. The fixed effects were presented as odds ratios (ORs). This study used multilevel logistic regression to estimate ORs with 95% confidence intervals (CIs) and *p*-values. The dependent variables for the multilevel logistic regression models are a dichotomous variable. Older adults with fair/poor GH and low physically/mentally unhealthy days were coded as 1, and those with excellent/very good/good GH and higher physically/mentally unhealthy days were coded as 0. The equation for multilevel logistic model can be written as:

$$\text{logit}(\pi_{ijk}) = \alpha + u_i + v_{ij} + \beta^T X_{ijk} + \epsilon_{ij}$$

where u_is are independent identically distributed (i.i.d) with $\text{N}(0, \sigma_u^2)$, v_{ij}s i.i.d. $\text{N}(0, \sigma_{uj}^2)$, and ϵ_{ij}s i.i.d. $\text{N}(0, \sigma_\epsilon^2)$ as an error term. Note that u_is are state-level random effects and v_{ij}s are county-level random effects which were nested within state-level. Also, *j* represents county-level characteristics and *k* represents individual-level characteristics. α and β are fixed effects, while α represents the intercept and β is a vector of regression coefficients.

Furthermore, intra-class correlation coefficients (ICCs) were calculated to observe the variance at the county-level to the total variance. For multilevel linear models, the ICC was calculated based on the following formula:

$$\text{ICC} = \frac{\sigma_n^2}{\sigma_i^2 + \sigma_n^2}$$

where σ_n^2=county-level variance, and σ_n^2=individual-level variance. Because the variance of a logistic distribution with scale factor 1 is $\pi^2/3$ (nearly 3.29) in a hierarchical logistic regression model, this formula, thus, can be reformulated as [173]:

$$\text{ICC} = \frac{\sigma_n^2}{\sigma_i^2 + (\frac{\pi^2}{3})}$$

a. Multilevel reweighted model

Because BRFSS uses a complex survey design, we applied multilevel reweighted regression model through the GLIMMIX procedure with the 2010 and 2011 BRFSS data. The original BRFSS weight by design weight (W_{state}) multiple percentage of population by an age-by-race-by-sex category (C_{state}):

$$\text{BRFSS Weight} = W_{state} * C_{state}$$

C_{state} is the number of people in an age-by-race-by-sex category in the population of the state divided by the sum of the product of the preceding weights for the respondents in that same age-by-race-by-sex category. W_{state} is the following design weight:

$$W_{state} = S * \frac{1}{P} * A$$

where *S* is for differences in the probability of the respondent's telephone number selection, *P* is the number of residential telephone numbers in the respondent's household, and *A* is the number of adults in the respondent's household. [174] D'Agostino and Goodman modified weighted system for analyzing county-level data. [174] Using W_{county} and C_{county} replace the original model ($\text{BRFSS Weight} = W_{state} * C_{state}$) is defined as the equation:

$$W_{county} = W_j = \sum_k (S * \frac{1}{P} * A)_{jk}$$

, and C_{county} is defined as the equation:

$$C_{county} = C_j = \frac{n_{jk}}{W_j}$$

where n_{jk} is the number of people in county j that belong to demographic group (age-by-race-by-sex category) k at the county level. S is for differences in the probability of the respondent's telephone number selection, P is the number of residential telephone numbers in the respondent's household, and A is the number of adults in the respondent's household. [174]

A rule of thumb for applying multilevel model sample size by Kreft & de Leeuw 1998) is 30/30 rule, which means for designing a multilevel model researchers should strive for a sample of at least 30 groups with at least 30 individuals per group. However, Hox (1998) mentioned the rule of thumb could be wisely modify as 50/20 rule and even 100/10 rule. [176] The 50/20 rule is more interesting in cross-level interaction, while the 100/10 rule is more in the random part. Thus the rule of thrum could be accepted if the number of groups is increased, the number of individuals per group decreases. [176] For this study scenario, since we applied multilevel reweighted regression, and have large county-level sample size, we did not exclude any observation.

b. Multilevel, post-stratification (MPS)

We applied the MPS approach to estimate the probability of three HRQOL indicators for all 2,208 counties in the U.S. We followed four steps of MSP for generating our county-level estimates. [35,36] First, we ran a multilevel (3 level: individual county, state), logistic regression analysis on our weighted sample. We included age, gender, and race/ethnicity at the individual level, area deprivation at the county level, and county and state level random intercepts.

Individual-level characteristics only adjusted age (aged 65-74, aged 75-84, or aged over 85), gender (male or female), and race/ethnicity (Non-Hispanic White, Africa American, Hispanic, or others), resulting in 24 demographic categories (3*2*4).

The multilevel prediction models for all three HRQOL indicators followed the same format as the multilevel models. The formula for multilevel logistic model is as:

$$\text{logit}(\pi_{ijk}) = \alpha + u_i + v_{ij} + \beta^T X_{ijk} + \epsilon_{ij}$$

where u_is are independent identically distributed (i.i.d) with $\text{N}(0, \sigma_u^2)$, v_{ij}s i.i.d. $\text{N}(0, \sigma_{uj}^2)$, and ϵ_{ij}s i.i.d. $\text{N}(0, \sigma_\epsilon^2)$ as an error term. Note that u_is are states-level random effects and v_{ij}s are county-level random effects which were nested within states. Also, j represents county-level characteristics (i.e., area deprivation) and *k* represents individual-level characteristics (i.e., age, sex, and race/ethnicity). α and β are fixed effects, while α represents the intercept and β is a vector of regression coefficients.

In our second step, we applied model prediction of county level subpopulations by age, gender, and race/ethnicity to the census population estimates. County area deprivation was used in the prediction model to further adjust for the local socioeconomic status influence on older populations' HRQOL. The expected probability of HRQOL in older adults were obtained for all demographic groups in a counties, while non-sampled county random effects were obtained by applying spatial smoothing on its adjacent counties with random effect. [35,36]

Finally, we generated model-based small area estimations (SAEs) via post-stratification. The probability of HRQOL in older adults in county j is the population weighted estimate of the predicted probability of three HRQOL indicators in older adults for all 24 subpopulation groups within a county.

$$P_{ijk} = \frac{\sum_k P_{ijk} * Pop_{ijk}}{\sum_k Pop_{ijk}}$$

where *j* indicates county-level, and *i* is state-level. P_{ijk} is the predicted probability for an individual belonging to a particular demographic group (age-by-sex-by-race/ethnicity category) k in county *j* within state *i*. Pop represents the population number for each demographic subgroup.

Step four was internal validation. After generating model-based SAEs, we compared them with BRFSS direct estimates for all 48 states and DC and for counties with at least 50 respondents. For BRFSS county-level direct estimates, we calculated the percent of adults reporting poor HRQOL, dividing the number of older adults reporting poor HRQOL by the total number of older adults. For comparing the distributions of our model-based SAEs and BRFSS direct estimates and internal consistency, we conducted basic summary statistics and Pearson correlation coefficients, respectively.

The modified weight was calculated by SAS and applied in PROC GLIMMIX weight statement. Statistical significant was determined for differences where two-sided $p<0.05$. All statistical analyses were performed with SAS version 9.4 (SAS Institute, Inc., Cary, NC).

<u>3.4.2. Spatial Analysis</u>

Before doing spatial analysis, we applied MPS approach to generate county-level probabilities of older adults having fair/poor GH and high physically/mentally unhealthy days. Distribution and bivariate choropleth maps employed for visualization geographic conditions. The nearness of geographic units must be quantified when applying spatial analysis [177]. This study employed global and local Moran's I tests, applying inverse distance methods with row standardization, for evaluating the spatial autocorrelation of older adults' HRQOL and area deprivation. A higher positive Moran's I indicates that values in the neighboring areas tend to cluster, while a lower negative Moran's I implies that higher and lower values are dispersed. [178]

Data was exported for spatial analysis and mapping using Microsoft Excel (Microsoft Corporation). Spatial analysis and maps were performed using ArcGIS (Environmental System Research Institute, CA).

CHAPTER FOUR

MANUSCRIPT ONE

AREA DEPRIVATION, AREA HEALTH RESOURCES, AND OLDER ADULTS' HEALTH-RELATED QUALITY OF LIFE: A MULTILEVEL ANALYSIS [i]

[i] Lin, Y-H, Probst, J.C., Bennett, K.J., Eberth, J.M., Qureshi, Z. To be summited to *The Journal of Rural Health*.

4.1 Abstract

Objective: Health-related quality of life (HRQOL) and well-being is a new topic area for Healthy People 2020 in the U.S. In a broad-based literature review, more research explored individual level factors of HRQOL, and few focused on older adults. Multilevel analysis was seldom adopted to investigate the relationship between area-level socioeconomic or social environment factors and HRQOL. The primary aim of this study was to explore the association between area deprivation, area health resources and older adults' HRQOL.

Method: Cross-sectional study utilizing the 2011 and 2012 Behavioral Risk Factor Surveillance System (BRFSS), merged with data from the 2013-2014 the Area Health Resources File (AHRF), the 2014 Food Environment Atlas Data File, and 2014 County Health Rankings (CHRs) file. The dependent variables were three HRQOL dimensions (general health (GH), physical health (PH), and mental health (MH)). County level analysis utilized Ford and Dzealtowski's area deprivation index, and other health resource factors. Multilevel reweighted modeling techniques examined the county effect on older adults' HRQOL, after accounting for individual-level characteristics.

Results: Area variation was associated with HRQOL, although differences at the area level only contributed modestly to older adult's HRQOL (6.58%, 2.08%, and 1.80% for GH, PH, and MH, respectively). Older adults living in higher area deprivation counties had a higher probability of having fair/poor GH and more physically unhealthy days compared to those living in lower area deprivation counties, but had a lower probability of having mentally unhealthy days, after adjusting for individual and other county characteristics.

Conclusion: Despite adjusting for individual level factors, contextual factors continue to exert an important influence on health outcomes, although results were generally smaller than the effects from individual-level factors. Individual-level characteristics had a stronger affect than county-level factors. There are potential implications for the provision of health and social services and more generally for policies affecting community cohesiveness.

4.2 Introduction

The World Health Organization (WHO) defines quality of life (QOL) as "individuals' perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns". [3] Relatedly, health-related quality of life (HRQOL) is defined as "a multi-dimensional concept that includes domains related to physical, mental, emotional, and social functioning. It goes beyond direct measures of population health, life expectancy, and causes of death, and focuses on the impact health status has on quality of life."[4]Some researchers consider HRQOL as general QOL, [5] while others mention that HRQOL is a subset of overall QOL. [6]

'HRQOL and well-being' is a new topic area for Healthy People 2020 in the U.S. Healthy People 2020 is "a national health agenda that communicates a vision and a strategy for improving the health of the Nation's population and achieving health equity" and it [47] The goal of 'HRQOL and well-being' in Healthy People 2020 is to improve HRQOL and well-being for all individuals. There were 15 priority areas on disease prevalence in 1990 Health Objective, which increased to 42 focus areas more focused on a broader view of health in Healthy People 2020.

The objective of 'HRQOL and well-being' in Healthy People 2020 is to "increase the proportion of adults who self-report good or better health," including physical health and mental health. It is evaluated across three conceptual areas: self-rated physical and mental health, overall well-being, and participation in society. The patient-reported outcomes measurement information system (PROMIS) measure of global health using 10-item global HRQOL scale measures self-rated physical and mental health. These 10 questions mainly apply on the National Health Interview Survey (NHIS) 2010. [49] However, 'HRQOL and well-being' in Healthy People 2020 focuses on general adult population rather than on specific age groups, but other programs did. For example, the Centers for Disease Control and Prevention (CDC) conducts the Healthy Aging Program to provide comprehensive activities designed to help older adults live longer and have high-quality, productive, and independent lives. [4]

Since 1993, HRQOL has been widely studied using the Behavioral Risk Factor Surveillance System (BRFSS), either as an explanatory variable or an outcome variable. As of June 2015, a PubMed search identified 89 articles under the topic heading of "health-related quality of life" and under the title/abstract of "Behavioral Risk Factor Surveillance System". Among those 89 articles, only six articles focused on the older population (aged 65 and over). [15–20] Furthermore, few researchers used multilevel analysis to investigate the relationship between area-level socioeconomic or social environment factors and HRQOL. [21,22]

Residence in highly socioeconomically disadvantaged environments is associated with more negative health behaviors [25] and worse health outcomes [25–27] . Previous studies found that the relationship between area-level deprivation and health outcomes is not significant after adjusting for individual characteristics. [28,29] However, recent research supports the idea that associations exist between area deprivation and physical/mental health outcomes, even after adjusting for individual socioeconomic factors. [30] We found few studies that explored the relationship between area deprivation and HRQOL and most were not conducted in the U.S. [6,28,31–34]

HRQOL does not only indicate individual's current health status, but also predicts their future health, future medical care, and health utilization. Most previous studies have been limited to individual level, which may ignore the important risk factors. The primary aim of this study was to explore the association between area deprivation, area health resources, and older adults' HRQOL.

4.3 Method

4.3.1. Data Sources

This cross-sectional study includes two levels of analysis: individual-level and county-level. Data for the individual-level analysis was obtained from the 2011 and 2012 BRFSS, which is a nationwide survey by telephone and has been maintained by CDC. County-level data was retrieved from the 2013-2014 Area Health Resources File (AHRF), the 2014 Food Environment Atlas Data File, and the 2014 County Health Rankings. [171,179–181]

For the purpose of this study, data was restricted to older adults who were aged 65 and over. There were 160,529 older adults in 2011 and 152,541 in 2012. After deleting observations with missing values for age, general health, physical health, mental health, state, and county, 263,914 respondents (weighted N=76,733,680) remained for analysis. After merging data from the other sources, and excluding the U.S. territories, Alaska, and

Hawaii, out total sample size included 263,914 respondents in 2,238 counties within 48 states and the District of Columbia (Figure 4.1). We examined inclusion and exclusion counties to ensure whether inclusion counties can be represented exclusion counties via independent t test and Chi-square test.

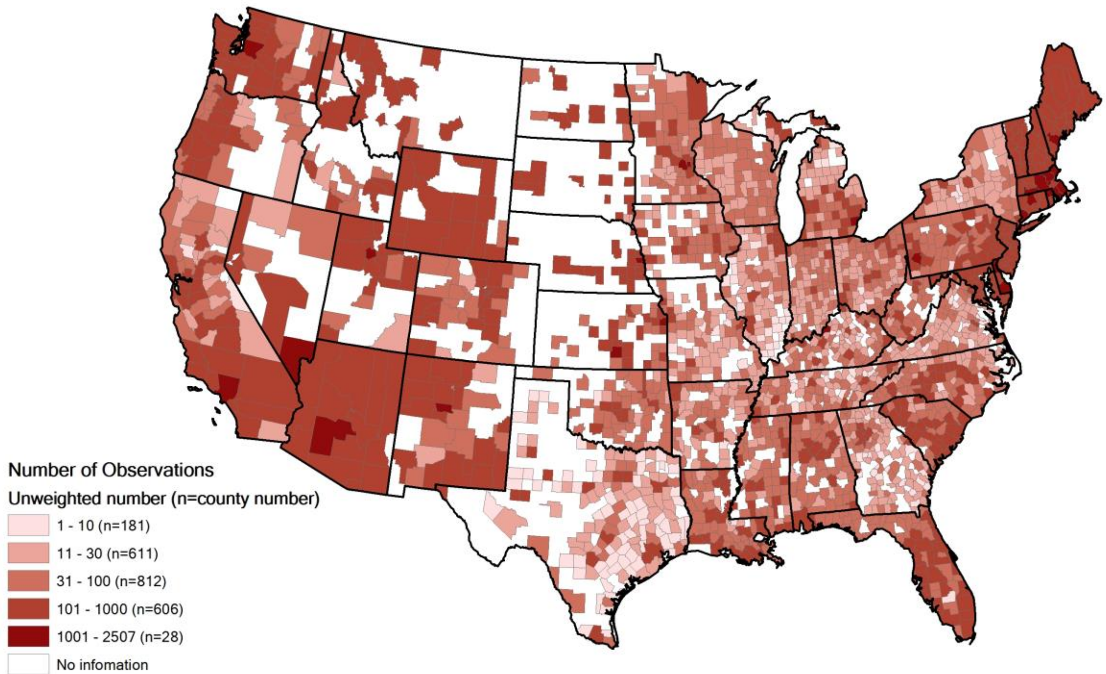


Figure 4.1: Counties included in the 2011-2012 BRFSS

4.3.2. Variables

a. Dependent variables

The BRFSS contains four HRQOL questions related to general health (GH), physical health (PH), mental health (MH), and activity limitations (AL). Since a large proportion of AL responses were missing (51.82%), this study did not examine AL. Thus, only the first three indicators, GH, PH and MH, were included.

According to previous research suggestions, GH was divided into two groups: excellent/very good/good and fair/poor. [50,53,65,85,88,115] Although previous research suggested that PH and MH can be dichotomized into infrequent (0-14 days) and frequent

(15-30 days) number of unhealthy days, [50,65,80,88,117] most BRFSS respondents included in the sample reported no physically (61.42%) or mentally (78.37%) unhealthy days in the past 30 days, skewing the distributions. Thus, PH and MH were categorized into two groups: low unhealthy days (first to third quartiles, 0-4 days (0-74.3%) for PH and 0 days (0-79.4%) for MH) versus high unhealthy days (fourth quartile, 5-30 days (74.3-100%) for PH and 1-30 days (79.4-100%) for MH).

b. Key explanatory variables

Area deprivation index. This study utilized Ford and Dzealtowski's area deprivation index. The reason for choosing it because all indicators are available in county-level data sets. This index was composed of eight indicators: percent of adults unemployed, percent of adults over 25 years with less than a high school education, percent of households under the Federally designated poverty level, percent of households with more than one person per room, percent of female head of household with children, percent of households with public assistance income, median household income, and percent of households with no access to a vehicle. [26] The data of percent of households with no access to a vehicle gains from the 2014 Food Environment Atlas Data File, and others are from the 2013-2014 AHRF.

We transposed the median household income. Then, each indicator was calculated as a standardized z-score ($z = \frac{x-\mu}{\sigma}$). Each indicator presents a standard normal distribution with a mean of 0 and a standard deviation of 1. Then, all indicators are summed into an area deprivation index score, with higher score indicating the area is more deprived.

c. Covariates

Covariates potentially associated with HRQOL included individual and county-level characteristics. Individual-level characteristics included sociodemographic characteristics and health related factors. Sociodemographic characteristics included gender, race/ethnicity (White, Black, Hispanic, or others), educational attainment (less than high school or college and above), marital status (non-single or single), employment status (employed, unemployed, or retired), and annual household income (less than $20,000, $20,000 and above, or non-response/missing value). Health related factors included body mass index (BMI), disability (optimal weight, underweight, or overweight/obese), current smoking status (non-smokers or smokers), alcohol consumption (according to the question "During the past 30 days, how many days per week or per month did you have at least one drink of any alcoholic beverage such as beer, wine, a malt beverage or liquor?" and categorize as non- drinkers (0 days) or drinkers (at least one day)), and number of chronic conditions (summed up to 10 chronic conditions, and grouped up into 4 categories: 0, 1, 2, or over 3 chronic conditions).

County-level characteristics were represented by health care resources and health personnel density. Health care resource factors included the number of general hospitals, county health related centers (including community health centers, community mental health centers, federal qualified health centers, and rural health clinics), and long-term care facilities (including long term hospitals, skilled nursing facilities, and nursing facilities). Health personnel density factors included the number of whole primary care providers (including primary care physicians and other primary care providers), and dentists.

The data on number of whole primary care providers comes from the 2014 CHRs, and others are from the 2013-2014 AHRF. County-level characteristics were adjusted by population size, calculating by the number of each variable divided by total population in the area and multiplied by 10,000, and presented health resources to population ratios or health personnel densities.

4.3.3 Statistical Analysis

Descriptive data analysis was generated for individual level and county level characteristics. Chi-square tests were used to examine the bivariate correlations between each characteristics and older adults' HRQOL. The Data had a hierarchical structure, in which individual data (level 1) was nested within counties (level 2). Multilevel analysis was used to control for the county effect on older adults' HRQOL. A random intercept multilevel model was preferred to other statistical approaches because it tests whether the association of area deprivation with HRQOL among older adults varied across counties. Regression coefficients and variance components at county and individual-levels were estimated for older adults' HRQOL.

Four models were fitted. The first model was an empty model and includes no independent variables. The empty model was used to determine whether the overall difference between county and individuals in terms of HRQOL would be significant. The second model included only the individual-level variables; the third model included only the county-level variables; and the fourth model included both individual-level and county-level variables. This study used multilevel reweighted regression to estimate the adjusted odds ratios (ORs) with 95% confidence intervals (CIs) and *p*-values. The dependent variables for the multilevel logistic regression models were dichotomous variables; older adults with fair/poor general health and low physically/mentally unhealthy days were coded as 1, and those with excellent/very good/good general health and high physically/mentally unhealthy days were coded as 0. The equation for multilevel logistic model was as follows:

$$\text{logit}(\pi_{ij}) = \alpha + u_j + \beta^{\tau} X_{ij}$$

where $u_j \sim \text{N}(0, \sigma_u^2)$, u_j is the random effect, *j* represents county-level characteristics. α and β are fixed effects, α represents the intercept and *i* represents individual-level characteristics.

Furthermore, intra-class correlation coefficients (ICCs) were calculated to observe the variance at the county-level to the total variance. For multilevel linear models, the ICC was calculated based on the following formula:

$$\text{ICC} = \frac{\sigma_n^2}{\sigma_i^2 + \sigma_n^2}$$

where σ_n^2=county-level variance, and σ_n^2=individual-level variance. Because the variance of a logistic distribution with scale factor 1 is $\pi^2/3$ (nearly 3.29) in a hierarchical logistic regression model, this formula, thus, can be reformulated as [173]:

$$\text{ICC} = \frac{\sigma_n^2}{\sigma_i^2 + (\frac{\pi^2}{3})}$$

Because BRFSS uses a complex survey design, the analysis applied multilevel reweighted regression model through the GLIMMIX procedure. Because BRFSS design weight focuses on state-level, D'Agostino and Goodman modified the weight system for analyzing county-level data, using W_{county} and C_{county} to replace W_{state} and C_{state}. [174] W_{county} is defined as the equation:

$$W_{county} = \sum_j (S * \frac{1}{P} * A)_{ij}$$

, and C_{county} is defined as the equation:

$$C_{county} = \frac{n_{ij}}{W_{county}}$$

where n_{ij} is the number of people in county i that belong to demographic group (age-by-race-by-sex category) j at the county level. S is for differences in the probability of the respondent's telephone number selection, P is the number of residential telephone numbers in the respondent's household, and A is the number of adults in the respondent's household[174].

The modified weight was calculated by SAS and applied in PROC GLIMMIX weight statement. All statistical analyses were performed with SAS version 9.4 (SAS Institute, Inc., Cary, NC). Statistical significance was determined for differences where two-sided $p<0.05$.

4.4. Results

4.4.1. Factors Associated with Health-Related Quality of Life

a. Description of the study population

Among the 263,914 older adults (weighted=76,733,680), nearly three—fourths of older adults reported excellent/very good/good general health (74.1%), 73.6% reported low physically unhealthy days, and 78.4% had low mentally unhealthy days. Respondents had a mean of 5.30 (*SD*=0.04) physically unhealthy days, and 2.39 (*SD*=0.03) mentally unhealthy days. The average age was 74.16 years old (*SD*=0.03), and average number of chronic conditions was 1.69 (*SD*=0.01). Table 4.1 shows the sociodemographic characteristics and health related factors of the sample in more detail.

Table 4.1 also lists the estimates of the bivariate analyses used to examine group differences across categorical variables. All health outcomes varied significantly with sociodemographic characteristics and health related factors. For example, HRQOL significantly differed by sex; male gender had a higher percentage of fair/poor GH, but lower percentage of being high physically and mentally unhealthy days. As expected, more people with worse health related factors, such as obesity, disability, smoking status, and more chronic conditions in unhealthy groups.

b. Description of Study Counties

Table 4.2 presents county-level factors for study counties and, for comparison, all excluded counties. The area deprivation index, rurality, and most of the area health resources factors were significantly different by groups. Within the area deprivation indicators, independent t test for education attainment, poverty, crowding, and households with public assistance income were not differ significantly. On the other hand, unemployment rate, female head of household with children, median household income, and car access were significantly different. Furthermore, study counties have significantly higher average area deprivation index than all other counties (Table 4.2).

While about 45% of the study counties are urban, a majority of excluded counties are located in rural areas (91.5%). For area health resources, the hospitals to population ratio, long-term care facilities to population ratio, county health centers to population ratio, and dentist density were significantly differ by two groups, while whole primary care providers density not differ from 10.7 to 11.3 (t=-1.10, p=0.2693) (Table 4.2). In general, our study counties may be not represent to excluded counties.

Table 4.1: Individual characteristics associated with HRQOL, BRFSS, 2011-2012

	General health %		Physically unhealthy days[d] %		Mentally unhealthy days[e] %		Total
	Excellent/ very good/ good	Fair/ poor	Low unhealthy days	High unhealthy days	Low unhealthy days	High unhealthy days	
Observations	198,894 (75.4)	65,020 (24.6)	196,046 (74.3)	67,868 (25.7)	209,468 (79.4)	544,46 (20.6)	263,914 (100)
Sociodemographic characteristics							
Gender[a,b,c]							
Male	43.0	44.4	44.6	39.9	45.8	34.6	43.4
Female	57.0	55.6	55.4	60.1	54.2	65.4	56.6
Age[a,b,c] (*M*±*SD*)	73.9±0.03	74.9±0.05	74.0±0.03	74.7±0.05	74.3±0.03	73.6±0.06	74.2±0.03
65-74	57.7	51.7	57.4	52.7	55.3	59.4	56.1
75-84	34.0	37.2	34.1	36.9	35.4	32.7	34.8
85+	8.3	11.1	8.6	10.4	9.3	8.0	9.0
Race/Ethnicity[a,b,c]							
White	83.3	70.6	81.1	76.8	80.9	76.6	80.0
Black	6.7	10.8	7.3	9.0	7.5	8.6	7.7
Hispanic	5.4	13.4	6.8	9.6	6.9	9.8	7.5
Others	4.7	5.1	4.8	4.6	4.7	5.0	4.8
Education attainment[a,b,c]							
Less than high school	45.2	65.6	47.7	58.2	49.3	54.8	50.5
College and above	54.5	34.0	52.0	41.5	50.4	44.9	49.2
Marital status[a,b,c]							
Non-single	58.2	48.9	57.6	50.8	57.4	50.0	55.8
Single	41.5	50.9	42.1	49.0	42.3	49.8	43.9
Employment							

	General health %		Physically unhealthy days[d] %		Mentally unhealthy days[e] %		Total
	Excellent/ very good/ good	Fair/ poor	Low unhealthy days	High unhealthy days	Low unhealthy days	High unhealthy days	
status[a,b,c]							
Employed	23.7	15.2	23.5	16.1	21.9	20.1	21.5
Unemployed	3.5	14.1	3.8	13.0	4.6	11.9	6.2
Retired	72.6	70.4	72.5	70.7	73.2	67.8	72.0
Annual household income[a,b,c]							
Less than $20,000	14.6	32.8	16.3	27.9	17.4	26.2	19.3
$20,000 and above	67.8	49.2	66.0	54.4	64.4	57.8	62.9
Non-response/Missing value	17.6	18.0	17.7	17.7	18.2	16.0	17.7
Health related factors							
Body mass index[a,b,c]							
Optimal weight	34.2	26.6	33.7	27.9	32.7	30.5	32.2
Underweight	1.5	2.2	1.4	2.3	1.5	2.0	1.7
Overweight/obese	61.5	67.8	61.8	66.7	62.8	64.4	63.1
Disability[a,b,c]							
No	74.3	39.4	74.8	38.7	43.6	42.5	65.2
Yes	21.8	55.7	21.2	56.7	8.0	10.9	30.6
Smoking[a,b,c]							
Non-smokers	91.2	87.5	90.8	88.8	90.9	88.0	90.3
Smokers	7.7	11.2	8.1	10.0	8.0	11.9	8.6
Alcohol consumption[a,b,c]							
Non-drinkers	49.7	68.7	51.1	64.4	53.7	57.7	54.6

	General health %		Physically unhealthy days[d] %		Mentally unhealthy days[e] %		Total
	Excellent/ very good/ good	Fair/ poor	Low unhealthy days	High unhealthy days	Low unhealthy days	High unhealthy days	
Drinkers	45.3	25.4	43.8	30.1	40.9	37.4	40.2
Number of chronic conditions[a,b,c] (*M*±*SD*)	1.4± 0.01	2.6± 0.01	1.4± 0.01	2.5± 0.01	1.5± 0.01	2.3± 0.01	1.7± 0.01
0	25.2	6.5	25.0	7.5	23.0	10.8	20.3
1	35.3	20.1	34.4	22.8	33.2	24.8	31.4
2	23.7	26.3	23.7	26.4	23.9	26.4	24.4
3+	15.8	47.1	16.9	43.3	20.0	38.0	23.9

Note: *p*-value in significant level of Chi-square test in [a]general health, [b]physically unhealthy days, and [c]mentally unhealthy days. [d]Lov physically unhealthy days is 0-4 days (first to third quartiles, 0-74.3%), and high is ≥5 days (fourth quartiles, 74.3%-100%). [e]Low mentally unhealthy days is 0 days (first to third quartiles, 0-79.4%), and high is ≥1 day (fourth quartiles, 79.4%-100%).

Table 4.2: County-level factors descriptive analysis

Variables	All other counties (n=863) Mean±SD/n(%)	Study counties (n=2,238) Mean±SD/n(%)	*P* value
Area deprivation components			
Unemployment rate (%; 2011)	7.41±3.50	9.00±2.62	**<.0001[a]**
Persons 25+ years without high school diploma (%; 2008-2012)	16.21±7.80	15.79±6.73	0.1296[a]
Households under poverty level (%; 2008-2012)	12.02±6.62	11.95±5.04	0.5962[a]
Housing units with > 1 person per room (%; 2008-2012)	2.17±2.13	2.27±1.66	0.2754[a]
Female head of household with children (%; 2010)	14.20±7.32	17.68±5.54	**<.0001[a]**
Households with public assistance income (%; 2008-2012)	2.12±2.01	2.27±1.17	**0.0431[a]**
Median household income ($; 2011)	40556.0±8817.7	44957.1±11541.2	**<.0001[a]**
Households with no car and low access to store (%; 2010)	3.30±2.74	2.93±1.92	**0.0003[a]**
Area deprivation index (mean)	-0.63±5.53	0.20±3.75	**<.0001[a]**
Low (< -0.03)	294(34.07)	1046(46.74)	**<.0001[b]**
High	569(65.93)	1192(53.26)	
Rurality			**<.0001[b]**
Urban	73(8.46)	1006(44.95)	**<.0001[b]**
All rural	790(91.54)	1232(55.05)	
Micro	70(8.46)	598(26.72)	
Small adjacent	250(28.97)	411(18.36)	
Remote rural	470(54.46)	223(9.96)	
Area health resources (mean)			
Hospitals to population ratio	1.17±1.43	0.33±0.27	**<.0001[a]**
Low (<0.56)	509(58.98)	387(17.29)	**<.0001[b]**
High	354(41.02)	1851(82.71)	
Long-term care facilities to population ratio	2.08±1.90	0.81±0.54	**<.0001[a]**
Low (<1.16)	557(64.54)	468(20.91)	**<.0001[b]**

Variables	All other counties (n=863)	Study counties (n=2,238)	*P* value
	Mean±SD/n(%)	Mean±SD/n(%)	
High	306(35.46)	1770(79.09)	
County health centers to population ratio	3.68±4.12	1.06±1.29	**<.0001[a]**
Low (<1.79)	553(64.08)	445(19.88)	**0.0004**
High	310(35.92)	1793(80.12)	
Whole primary care providers density	10.71±6.57	11.03±6.75	0.2693
Low (<10.95)	229(39.81)	941(42.24)	0.2443
High	452(60.19)	1287(57.76)	
Dentists density	2.93±2.77	4.22±2.38	**<.0001[a]**
Low (<3.87)	246(29.67)	1098(49.08)	**<.0001[b]**
High	583(70.33)	1139(50.92)	

Note: [a]Independent t test; [b]Chi-square test. Low: lower than mean; and high: higher than mean.

4.4.2. Multilevel Assessment of Factors Associated with Health-Related Quality of Life

a. General health

The following are the results of the multilevel models using general health as the dependent variable. From the first model, approximately 6.53% of the variability in the rate of having fair/poor general health is accounted for at the county level, leaving 93.47% of the variability to be accounted for by the individual or other unknown factors. These results also indicate that there is a statistically significant amount of variability in the log odds of having fair/poor GH between the counties in the sample (τ_{00}=0.2297; z=22.23, p<0.0001). In the unconditional model (model 1), the probability of having fair/poor GH at a typical county was 0.26; however, the probability of having fair/poor GH varied considerably across counties (Table 4.3).

The estimated variance at model 2 was 2.57% and at model 3 was 2.75%, as compared to 1.75% at model 4. ICC of Model 4 show that 1.75% of the variance can be attributed to the county-level. The ICC in model 4 reduced the percentage of variance associated with nesting by county by 47% in model 2 and by 9% in model 3 (Table 4.3).

At the individual level, male gender (b=0.26, p<0.0001), older age (b=0.16, p<0.0001 and b=0.31, p<0.0001 for aged 75-84 years and over aged 85 years, respectively), non-White (b=0.56, p<0.0001, b=0.89, p<0.0001, b=0.25, p<0.0001 for Black, Hispanic, and other races, respectively), unemployed (b=0.77, p<0.0001), being underweight (b=0.55, p<0.0001), being overweight/obese (b=0.05, p=0.0001), disability (b=1.32, p<0.0001), being smokers (b=0.36, p<0.0001), having at least one chronic condition (b=0.68, p<0.0001, b=1.24, p<0.0001, and b=2.05, p<0.0001 for having 1, 2 and more than 3 chronic conditions, respectively), and area deprivation (b=0.18, p<0.0001) were associated with a higher probability of having fair/poor general health (Table 4.3).

Higher educational attainment (b=-0.60, p<0.0001), being employed (b=-0.22, p<0.0001), higher household annual income (b=-0.51, p<0.0001), being drinkers (b=-0.52, p<0.0001), and dentists density (b=-0.08, p=0.007) were associated with a lower probability of having fair/poor general health (Table 4.3).

After taking county-level factors into account, older adults living in higher area deprivation counties had an adjusted odds of 1.19 of having fair/poor GH when compared to those who living in lower area deprivation counties (Table 4.3).

Table 4.3: Multilevel reweighted regression models for probability of having fair/poor general health, BRFSS, 2011-2012

	Model 1 Empty model	Model 2 individual-level	Model 3 county-level	Model 4 both individual- and county-level
	Estimate(SE)	Estimate(SE)	Estimate(SE)	Estimate(SE)
Intercept	**-1.02(0.01)*****	**-2.36(0.03)*****	**-1.13(0.02)*****	**-2.42(0.04)*****
Individual-level				
Sociodemographic characteristics				
Gender				
Female(ref)				

	Model 1 Empty model	Model 2 individual-level	Model 3 county-level	Model 4 both individual- and county-level
	Estimate(SE)	Estimate(SE)	Estimate(SE)	Estimate(SE)
Male		**0.24(0.01)***		**0.26(0.01)***
Age				
65-74(ref)				
75-84		**0.16(0.01)***		**0.16(0.01)***
85+		**0.31(0.02)***		**0.31(0.02)***
Race/Ethnicity				
White(ref)				
Black		**0.58(0.02)***		**0.56(0.02)***
Hispanic		**1.10(0.29)***		**0.89(0.03)***
Others		**0.29(0.03)***		**0.25(0.03)***
Education attainment				
Less than high school(ref)				
College and above		**-0.60(0.01)***		**-0.60(0.01)***
Marital status				
Non-single(ref)				
Single		-0.001(0.01)		0.01(0.01)
Employment status				
Retired(ref)				
Employed		**-0.19(0.02)***		**-0.22(0.02)***
Unemployed		**0.76(0.02)***		**0.77(0.02)***
Annual household income				
Less than $20,000(ref)				
$20,000 and above		**-0.53(0.02)***		**-0.51(0.02)***
Non-response/Missing value		**-0.27(0.02)***		**-0.26(0.02)***
Health related factors				
Body mass index				
Optimal weight(ref)				
Underweight		**0.55(0.04)***		**0.55(0.04)***
Overweight/obese		**0.05(0.01)**		**0.05(0.01)**
Disability				
No(ref)				
Yes		**1.30(0.01)***		**1.32(0.01)***

	Model 1 Empty model	Model 2 individual-level	Model 3 county-level	Model 4 both individual- and county-level
	Estimate(SE)	Estimate(SE)	Estimate(SE)	Estimate(SE)
Smoking				
Non-smokers(ref)				
Smokers		**0.35(0.02)*****		**0.36(0.02)*****
Alcohol consumption				
Non-drinkers(ref)				
Drinkers		**-0.53(0.01)*****		**-0.52(0.01)*****
Number of chronic conditions				
0 chronic condition(ref)				
1 chronic condition		**0.70(0.02)*****		**0.68(0.02)*****
2 chronic condition		**1.27(0.02)*****		**1.24(0.02)*****
3 chronic condition and more		**2.07(0.02)*****		**2.05(0.02)*****
County-level				
Area deprivation index				
Low(ref)				
High			**0.37(0.02)*****	**0.18(0.02)*****
Area health resources				
Hospitals to population ratio				
Low(ref)				
High			0.03(0.03)	0.04(0.03)
Long-term care facilities to population ratio				
Low(ref)				
High			0.01(0.03)	0.01(0.03)
County health centers to population ratio				
Low(ref)				
High			**0.06(0.03)***	0.03(0.03)
Whole primary care providers density				
Low(ref)				
High			**-0.05(0.02)***	-0.02(0.02)

	Model 1 Empty model	Model 2 individual-level	Model 3 county-level	Model 4 both individual- and county-level
	Estimate(SE)	Estimate(SE)	Estimate(SE)	Estimate(SE)
Dentists density				
Low(ref)				
High			**-0.18(0.02)*****	**-0.08(0.02)****
Rurality				
Urban(ref)				
All rural			0.01(0.02)	-0.01(0.02)
Variance (s.e.)	0.2297 (0.0103)	0.0869 (0.0064)	0.0929 (0.0055)	0.0585 (0.0050)
z value for covariance parameter estimates	**22.23*****	**13.61*****	**16.84*****	**11.68*****
ICC%	6.53%	2.57%	2.75%	1.75%
-2 Log Likelihood	288132.8	199250.4	274760.8	189557.3
AIC	288136.8	199294.4	274778.8	189615.3
AICc	288136.8	199294.4	274778.8	189615.3
BIC	288148.3	199421.5	274830.1	189780.6
Pearson Chi-Square	259440.5	222709.6	250161.3	213400.9
Pearson Chi-Square/DF	0.98	0.93	0.99	0.93

Note: *$p<0.05$, **$p<0.01$, ***$p<0.001$. Values based on SAS PROC GLIMMIX. Entries show parameter estimates with standard errors in parentheses; Estimation Method: Laplace. Model 4 is a better fitting model. Ref: reference group. Observation numbers: 263,911 for model 1; 239,836 for model 2; 253,416 for model 3; and 230,056 for model 4.

b. Physical health

From model one, approximately 1.39% of the variability in the rate of being in the high physically unhealthy days group is accounted for by county-level factors in our study, leaving 98.61% of the variability to be accounted for by individual-level or other unknown factors. This result also indicates that there is a statistically significant amount of variability in the log odds of having high physically unhealthy days between the counties in our sample (τ_{00}=0.0700; z=14.87, p<0.0001). The unconditional model (model 1) results revealed that the probability of having high physically unhealthy days at a typical county is 0.26. However, the probability of having high physically unhealthy days varies considerably across counties (Table 4.4).

For the fourth model, the estimated variance at model 2 was 1.19% and at model 3 was 1.56%, as compared to 1.14% at model 4. ICC of Model 4 show that 1.14% of the variance can be attributed to the county-level. The ICC in model 4 reduced the percentage of variance associated with nesting in county by about 4% in model 2 and by 37% in model 3 (Table 4.4).

Factors such as older age (b=0.05, $p<0.0001$ and b=0.08, $p<0.0001$ for aged 65-74 and aged over 85, respectively), non-White (b=0.07, $p=0.0017$, b=0.28, $p<0.0001$, and b=0.08, $p=0.0088$ for Black, Hispanic, and other race, respectively), unemployed (b=0.74, $p<0.0001$), being underweight (b=0.45, $p<0.0001$), being overweight/obese (b=0.04, $p=0.0006$), disability (b=1.29, $p<0.0001$), being smokers (b=0.13, $p<0.0001$), and having at least one chronic conditions (b=0.57, $p<0.0001$, b=0.91, $p<0.0001$, and b=1.52, $p<0.0001$ for having 1, 2 and more than 3 chronic conditions, respectively), and area deprivation (b=0.06, $p=0.0008$) had a positive statistical significance associated with probability of having high physically unhealthy days (Table 4.4).

Older adults living in higher area deprivation counties had an odds of 1.06 of high physically unhealthy days when compared to those who living in lower area deprivation counties, after adjusting for individual and other county characteristics (Table 4.4). Factors associated with being in the low physically unhealthy days group included male gender (b=-0.14, $p<0.0001$), higher educational attainment (b=-0.21, $p<0.0001$), being single (b=-0.08, $p<0.0001$), being employed (b=-0.20, $p<0.0001$), higher household annul income (b=-0.30, $p<0.0001$), and being drinkers (b=-0.32, $p<0.0001$) (Table 4.4).

Table 4.4: Multilevel reweighted regression models for probability of having high physically unhealthy days, BRFSS, 2011-2012

	Model 1 Empty model	Model 2 individual-level	Model 3 county-level	Model 4 both individual- and county-level
	Estimate(SE)	Estimate(SE)	Estimate(SE)	Estimate(SE)
Intercept	**-1.03(0.01)*****	**-2.04(0.03)*****	**-1.06(0.02)*****	**-2.04(0.03)*****
Individual-level				
Sociodemographic characteristics				
Gender				
Female(ref)				
Male		**-0.15(0.01)*****		**-0.14(0.01)*****
Age				
65-74(ref)				
75-84		**0.05(0.01)*****		**0.05(0.01)*****
85+		**0.08(0.02)*****		**0.08(0.02)*****
Race/Ethnicity				
White(ref)				
Black		**0.08(0.02)*****		**0.07(0.02)****
Hispanic		**0.29(0.03)*****		**0.34(0.03)*****
Others		**0.07(0.03)*****		**0.08(0.03)****
Education attainment				
Less than high school(ref)				
College and above		**-0.21(0.01)*****		**-0.21(0.01)*****
Marital status				
Non-single(ref)				
Single		**-0.07(0.01)*****		**-0.08(0.01)*****
Employment status				
Retired(ref)				
Employed		**-0.19(0.01)*****		**-0.20(0.01)*****
Unemployed		**0.73(0.02)*****		**0.74(0.02)*****
Annual household income				
Less than $20,000(ref)				
$20,000 and above		**-0.29(0.01)*****		**-0.30(0.02)*****
Non-response/Missing value		**-0.21(0.02)*****		**-0.21(0.02)*****
Health related factors				

	Model 1 Empty model	Model 2 individual-level	Model 3 county-level	Model 4 both individual- and county-level
	Estimate(SE)	Estimate(SE)	Estimate(SE)	Estimate(SE)
Body mass index				
Optimal weight(ref)				
Underweight		**0.43(0.04)*****		**0.45(0.04)*****
Overweight/obese		**0.04(0.01)****		**0.04(0.01)****
Disability				
No(ref)				
Yes		**1.29(0.01)*****		**1.29(0.01)*****
Smoking				
Non-smokers(ref)				
Smokers		**0.13(0.02)*****		**0.13(0.01)*****
Alcohol consumption				
Non-drinkers(ref)				
Drinkers		**-0.33(0.01)*****		**-0.32(0.01)*****
Number of chronic conditions				
0 chronic condition(ref)				
1 chronic condition		**0.58(0.02)*****		**0.57(0.02)*****
2 chronic condition		**0.92(0.02)*****		**0.91(0.02)*****
3 chronic condition and more		**1.53(0.02)*****		**1.52(0.02)*****
County-level				
Area deprivation index				
Low(ref)				
High			**0.20(0.02)*****	**0.06(0.02)****
Area health resources				
Hospitals to population ratio				
Low(ref)				
High			-0.01(0.03)	-0.01(0.03)
Long-term care facilities to population ratio				
Low(ref)				
High			-0.01(0.02)	-0.01(0.03)
County health centers to				

	Model 1 Empty model	Model 2 individual-level	Model 3 county-level	Model 4 both individual- and county-level
	Estimate(SE)	Estimate(SE)	Estimate(SE)	Estimate(SE)
population ratio				
Low(ref)				
High			0.05(0.02)	0.02(0.02)
Whole primary care providers density				
Low(ref)				
High			-0.01(0.02)	0.001(0.02)
Dentists density				
Low(ref)				
High			**-0.09(0.02)******	0.01(0.02)
Rurality				
Urban(ref)				
All rural			0.00(0.02)	-0.03(0.02)
Variance (s.e.)	0.06997 (0.0047)	0.0397 (0.0039)	0.0521 (0.0040)	0.0380 (0.0039)
z value for covariance parameter estimates	**14.87******	**10.25******	**12.99******	**9.80******
ICC%	2.08%	1.19%	1.56%	1.14%
-2 Log Likelihood	2299406.0	226363.7	287535.6	216997.9
AIC	229410.0	226407.7	287554	217055.9
AICc	229410.0	226407.7	287554	217055.9
BIC	229421.6	226534.8	287605	217221.2
Pearson Chi-Square	261023.3	237207.9	251028	227540.2
Pearson Chi-Square/DF	0.99	0.99	0.99	0.99

Note: **p*<0.05, ***p*<0.01, ****p*<0.001. Values based on SAS PROC GLIMMIX. Entries show parameter estimates with standard errors in parentheses; Estimation Method: Laplace. Model 4 is a better fitting model. Ref: reference group. Observation numbers: 263,911 for model 1; 239,836 for model 2; 253,416 for model 3; and 230,056 for model 4.

c. Mental health

From model one, approximately 1.80% of the variability in the rate of having high mentally unhealthy days is accounted for by the county-level factors in our study, leaving 98.20% of the variability to be accounted for by the individual-level or other unknown factors. This result also indicates that there is a statistically significant amount of variability in the log odds of having high mentally unhealthy days between the counties in out sample (τ_{00}=0.0602; z=13.41, p<0.0001). The unconditional model (model 1) results indicated that the probability of having high mentally unhealthy days at a typical county is 0.20; however, the probability of having high mentally unhealthy days varies considerably across counties (Table 4.5).

In the fourth and final model, the estimated variance at model 2 was 2.01% and at model 3was 1.61%, as compared to 1.75% at model 4. ICC of Model 4 show that 1.75% of the variance can be attributed to the county-level. The ICC in model 4 reduced the percentage of variance associated with nesting in county by about 15% in model 2, but increased by 9% in model 3 (Table 4.5).

Other factors associated with being in the high mentally unhealthy days group included being Hispanic (b=0.24, p<0.0001)/other race (b=0.09, p=0.0044), being single (b=0.08, p<0.0001), non-retired (b=0.07, p<0.0001 and b=0.59, p<0.0001 for employed and unemployed, respectively), being underweight (b=0.09, p=0.0144), disability (b=0.56, p<0.0001), being smokers (b=0.22, p<0.0001), being drinkers (b=0.06, p<0.0001), and having at least one chronic conditions (b=0.32, p<0.0001, b=0.70, p<0.0001, and b=1.16, p<0.0001 for having 1, 2 and more than 3 chronic conditions, respectively)(Table 4.5).

Male gender (b=-0.54, p<0.0001), older (b=-0.29, p<0.0001, and b=-0.51, p<0.0001 for aged 75-85 years and over 85, respectively), higher education attainment (b=-0.07, p<0.0001), higher household annul income (b=-0.18, p<0.0001), being overweight/obese (b=-0.08, p<0.0001), area deprivation (b=-0.06, p=0.0038), hospital to population ratio (b=-0.06, p=0.0356), long-term care facilities to population ratio (b=-

0.06, *p*=0.0394), and all rural counties (b=-0.05, *p*=0.0225) were negative statistically significant with probability of having high mentally unhealthy days (Table 4.5).

Older adults living in higher area deprivation counties had an odds of 0.95 to have lower mentally unhealthy days when compared to those who living in lower area deprivation counties, after adjusting for individual and other county characteristics (Table 4.5).

Table 4.5: Multilevel reweighted regression models for probability of having high mentally unhealthy days, BRFSS, 2011-2012

	Model 1 Empty model	Model 2 individual-level	Model 3 county-level	Model 4 both individual- and county-level
	Estimate(SE)	Estimate(SE)	Estimate(SE)	Estimate(SE)
Intercept	**-1.38(0.01)*****	**-1.81(0.02)*****	**-1.33(0.02)*****	**-1.73(0.03)*****
Individual-level				
Sociodemographic characteristics				
Gender				
Female(ref)				
Male		**-0.54(0.01)*****		**-0.54(0.01)*****
Age				
65-74(ref)				
75-84		**-0.29(0.01)*****		**-0.29(0.01)*****
85+		**-0.52(0.02)*****		**-0.51(0.02)*****
Race/Ethnicity				
White(ref)				
Black		-0.02(0.02)		-0.02(0.02)
Hispanic		**0.11(0.03)****		**0.24(0.03)*****
Others		**0.07(0.03)***		**0.09(0.03)****
Education attainment				
Less than high school(ref)				
College and above		**-0.07(0.01)*****		**-0.07(0.01)*****
Marital status				
Non-single(ref)				
Single		**0.08(0.01)*****		**0.08(0.01)*****
Employment status				
Retired(ref)				

	Model 1 Empty model	Model 2 individual-level	Model 3 county-level	Model 4 both individual- and county-level
	Estimate(SE)	Estimate(SE)	Estimate(SE)	Estimate(SE)
Employed		**0.06(0.01)*****		**0.07(0.01)*****
Unemployed		**0.59(0.02)*****		**0.59(0.02)*****
Annual household income				
Less than $20,000(ref)				
$20,000 and above		**-0.16(0.01)*****		**-0.18(0.02)*****
Non-response/Missing value		**-0.26(0.02)*****		**-0.27(0.02)*****
Health related factors				
Body mass index				
Optimal weight(ref)				
Underweight		**0.09(0.04)***		**0.09(0.04)***
Overweight/obese		**-0.08(0.01)*****		**-0.08(0.01)*****
Disability				
No(ref)				
Yes		**0.57(0.01)*****		**0.56(0.01)*****
Smoking				
Non-smokers(ref)				
Smokers		**0.22(0.02)*****		**0.22(0.02)*****
Alcohol consumption				
Non-drinkers(ref)				
Drinkers		**0.07(0.01)*****		**0.06(0.01)*****
Number of chronic conditions				
0 chronic condition(ref)				
1 chronic condition		**0.33(0.02)*****		**0.32(0.02)*****
2 chronic condition		**0.71(0.02)*****		**0.70(0.02)*****
3 chronic condition and more		**1.17(0.02)*****		**1.16(0.02)*****
County-level				
Area deprivation index				
Low(ref)				
High			**0.05(0.02)****	**-0.06(0.02)****
Area health				

	Model 1 Empty model	Model 2 individual-level	Model 3 county-level	Model 4 both individual- and county-level
	Estimate(SE)	Estimate(SE)	Estimate(SE)	Estimate(SE)
resources				
Hospitals to population ratio				
Low(ref)				
High			-0.05(0.03)	**-0.06(0.03)***
Long-term care facilities to population ratio				
Low(ref)				
High			**-0.08(0.03)****	**-0.06(0.03)***
County health centers to population ratio				
Low(ref)				
High			0.03(0.03)	0.00(0.03)
Whole primary care providers density				
Low(ref)				
High			**-0.04(0.02)***	-0.03(0.02)
Dentists density				
Low(ref)				
High			-0.01(0.02)	0.04(0.02)
Rurality				
Urban(ref)				
All rural			**-0.04(0.02)***	**-0.05(0.02)***
Variance (s.e.)	0.0602 (0.0045)	0.0675 (0.0052)	0.0537 (0.0043)	0.0586 (0.0049)
z value for covariance parameter estimates	**13.41*****	**12.96*****	**12.49*****	**12.03*****
ICC%	1.80%	2.01%	1.61%	1.75%
-2 Log Likelihood	267985.9	225534.9	258497.7	217419.6
AIC	267989.9	225578.9	258516	217477.6
AICc	267989.9	225579.0	258516	217477.6
BIC	268001.5	225706.0	258567	217642.9
Pearson Chi-Square	260835.0	236762.1	250652.0	227288.1
Pearson Chi-Square/DF	0.99	0.99	0.99	0.99

Note: **p*<0.05, ***p*<0.01, ****p*<0.001. Values based on SAS PROC GLIMMIX. Entries show parameter estimates with standard errors in parentheses; Estimation Method: Laplace. Model 4 is a better fitting model. Ref: reference group. Observation numbers: 263,911 for model 1; 239,836 for model 2; 253,416 for model 3; and 230,056 for model 4.

4.5. Discussion

This study indicates that there is an association between area deprivation and older adults' HRQOL. We treated hierarchically in a model of the probability of individual health effect in our multilevel reweighted regression. Cross-level interactions allow for analyses of effects for population subgroups. In this study, we found that area deprivation was associated with HRQOL, although differences at the area level only contributed modestly to older adult's HRQOL (6.58%, 2.08%, and 1.80% for GH, PH, and MH, respectively). In general, after adding county-level factors, the coefficients of individual characteristics presented slightly changed (range: 0-0.25).

4.5.1. Individual-Level Effects

Comparing model 2 and model 4 for each outcome variable, we chose model 4 based on the likelihood ratio test and smaller AIC values. Overall, our results agreed with previous studies that older age, non-White race/ethnicity, lower education, unemployment, lower income, disability, being smokers, and the presence of chronic diseases were associated with being fair/poor GH. [17,50,53,81,85,88,117] Similarly, older age, female gender, non-White race/ethnicity, low education, unemployment, low income, disability, being smokers, and with chronic disease were associated with reporting a higher number of physically unhealthy days. [17,80,81,85,88,117] Finally, older age, female gender, non-White race/ethnicity, being unemployed, lower income, disability, smoking status, and with chronic conditions were associated with reporting a higher number of mentally unhealthy days. [17,85,88,92,117,120]

However, our findings with regard to alcohol consumption present different results than previous work. Older adults who drank alcohol in the past 30 days had a lower probability of having fair/poor GH and physically unhealthy days. One possible reason for these results may be our use of a different definition of drinkers from that used in other studies. For example, previous studies measured alcohol consumption based on highest-intensity binge drinkers, [119,129] but our study defined drinkers as those who drank at least one drink of any alcoholic beverage such as beer, wine, a malt beverage or liquor in the past 30 days. Secondly, previous studies focused on working age adults, [119,129] while this analysis focused on older adults. Among 2011 BRFSS, almost 60% of adults (aged 18-64) consumed at least one serving of an alcoholic beverage within the past 30 days, while 40% of older adults (aged 65 and more) were non-drinkers. Daeppen et al. examined the association between QOL and drinking patterns via MOS-SF-36, and found that the physical dimension of QOL was not associated with drinking patterns, but with the mental dimension of QOL. [182] Our study findings differ with it that our definition of drinkers is broad and focused on consumption rather than misuse of alcohol. Binge drinking intensity may be more related to HRQOL rather than whether being a drinker. Also, the study target populations are different. Daeppen et al. focused on adults (aged over 18), while our study focused on older adults (aged over 65). Drinking behaviors may be differ by age. Therefore, our study presents a different findings.

4.5.2. County-Level Effects

The county-level findings are also worth noting. Older adults living in higher area deprivation counties had a higher probability of having fair/poor GH and physically unhealthy days when compared to those living in lower area deprivation counties, after adjusting for individual and other county characteristics. Our findings are consistent with previous research. [22,98] Area deprivation was a somewhat stronger predictor of HRQOL than other county-level health resource factors in the current study. Area deprivation also reflects environmental barriers. For example, lacking social and health services, lower access to private and public transportation, poor living conditions, and lacking health-related recreational facilities may influence older adults' health and HRQOL. [183]

Contrary to the physical health findings, we found that older adults living in more deprived areas had better MH HRQOL indicators. Previous studies that examined this topic generally found a negative association between area deprivation and MH HRQOL. [161,184,185] The first reason for this contradiction may be the different methods used to calculate the area deprivation index. For example, our study used Ford and Dzewaltowski's area deprivation index, which is a combination of eight indicators, while other studies used different area deprivation indices, such as area income (poverty), [185] Townsend index, [184] and Welsh Index of Multiple Deprivation. [161] The Ford and Dzewaltowski's area deprivation index is a relative deprivation concept, which is based on social comparison theory. Different from absolute deprivation, relative deprivation is one's condition relative to other members of society, while absolute deprivation is the worst condition in society, such as physical abuse, starvation, and poverty. [131,132] Area income is considered as absolute deprivation, so it may be not represent overall area socioeconomic status. Although Townsend index, [184] and Welsh Index of Multiple Deprivation [161] are relative deprivation indices, the differences of inclusion indicators and calculating formulations may also let to different results.

Second, our MH designation is a subjective concept rather than an objective diagnosis, resulting in differing finding than previous research. [186] The relationship between area deprivation and mental illnesses is still vague. Walters et al. pointed out that area deprivation may not have a main effect on depression because the relationship between area deprivation and depression disappeared after adjusting for individual level factors. [186] This could indicate depression is more explained by individual demographic, socioeconomic, and health factors rather than area level factors. However, the subjective nature of this conceptualization of HRQOL provides a better way to understand how an individual feels in the context of his/her personal life. [187] Our findings may be closer to older adults' authentic MH HRQOL. Although mental illnesses (e.g. depression) have a high prevalence in rural counties, [188] we found both area deprivation and rurality presented negative associations with MH HRQOL among older adults. We may conclude that material deprivation may not influence older adults' MH HRQOL.

4.5.3. Limitations

This analysis was limited by several factors. First, BRFSS data are cross-sectional; thus, we cannot identify the causal relationship among the study characteristics and HRQOL. Extrapolation bias is another limitation; although BRFSS is one of the largest survey databases in the US, we still could not include all counties in this database. Hence, this study may have biases to generalize the probability of HRQOL in older adults for other counties which did not participate BRFSS. We are unable to ascertain the extent to which this bias might prevail in other counties. Clearly, our results could not be applied to smaller area sizes, such as Census blocks or ZIP code area level; however, it may be aggregated to state level. Moreover, our findings cannot be generalized to younger Americans because we only focused on the older population. Finally, BRFSS data contains two main limitations. Due to the self-reported nature of the questionnaire, recall bias, underreporting of health behaviors, and prevalent chronic disease may exist. Our study may not adequately adjusted for diseases' severity and comorbidity. BRFSS randomly selected a household with telephone or an adult with cell phone, and does not sample those who lack access phones and live in institutions, such as long-term care facilities, or skilled nursing homes. Consequently, our study could not represent those more vulnerable older adults who live in facilities or could not access to telephone or cell phone.

4.5.4. Conclusions

Despite adjusting for individual level factors, contextual factors continued to exert an important influence on health outcomes, although results were generally smaller than the effects from individual-level factors. Individual-level characteristics had stronger affect than county-level factors. There are potential implications for the provision of health and social services and more generally for policies affecting community cohesiveness. Our findings provide a basic for developing targeted intervention programs for older adults, allocating resources to deprived areas, and evaluating the future intervention effects.

CHAPTER FIVE

MANUSCRIPT TWO

COUNTY-LEVEL AREA DEPRIVATION AND HEALTH-RELATED QUALITY OF LIFE AMONG OLDER ADULTS IN THE UNITED STATES: A MULTILEVEL, POST-STRATIFICATION APPROACH [ii]

[ii] Lin, Y-H, Probst, J.C., Bennett, K.J., Eberth, J.M., Qureshi, Z. To be summited to *The Journal of Rural Health*.

5.1. Abstract

Objective: The purpose of this study was to develop county-level estimates of poor health-related quality of life (HRQOL) among older U.S. adults, and to identify spatial clusters of area deprivation and poor HRQOL using a multilevel, post-stratification (MPS) approach.

Method: Data from the 2011 and 2012 Behavioral Risk Factor Surveillance System (BRFSS), the 2013-2014 Area Health Resources File (AHRF), and the 2014 Food Environment Atlas Data File were utilized in this study. The dependent variables were HRQOL dimensions, including general health, physical health, and mental health. Ford and Dzealtowski's area deprivation index was used as a county-level fixed effect in multilevel regression analyses. Subsequently, post-stratification for small area estimation (SAE) was conducted to generate county-level probabilities of poor HRQOL in older adults in the U.S. Finally, we employed global and local Moran's I (LISA) testing to evaluate the spatial autocorrelation of county-level probabilities of poor HRQOL in older adults and area deprivation.

Results: The range of county-level probabilities of poor HRQOL in older adults in each state is 0.18-0.35, 0.21-0.32, and 0.14-0.24 for general health, physical health, and mental health, respectively. The spatial autocorrelation tests found that county-level probabilities of poor HRQOL in older adults and area deprivation were spatially dependent.

Conclusion: Bivariate choropleth maps and spatial autocorrelations effectively identify vulnerable counties. These results may help to target interventions towards specific counties, based on the results from our SAEs and spatial clustering tests.

5.2. Introduction

Owing to major medical and public health advances and greater access to health care, Americans are living longer and better than before. Life expectancy at birth in the U.S. rose from 76.8 years in 2000 to 78.8 years in 2013. [2] As life expectancy continues to rise, how to maintain and improve older adults' quality of life (QOL), especially in later years of life, has become a public health challenge. Older adults are seeking ways to maximize their physical, mental, and social well-being to remain independent and active as they age. [2]

The World Health Organization (WHO) defines QOL as "individuals' perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns." [3] Similarly, health-related quality of life (HRQOL) is defined as "a multi-dimensional concept that includes domains related to physical, mental, emotional, and social functioning. It goes beyond direct measures of population health, life expectancy, and causes of death, and focuses on the impact health status has on quality of life." [4] Some researchers consider HRQOL as general QOL, [5] while others mention classify HRQOL as a subset of overall QOL. [6]

HRQOL and well-being is a new topic area for the U.S. Healthy People 2020 initiative, with specific objectives pertaining to physical and mental health. [7] The objective of 'HRQOL and well-being' in Healthy People 2020 is to "increase the proportion of adults who self-report good or better health," including physical health and mental health. It is evaluated across three dimensions: self-rated physical and mental health, overall well-being, and participation in society. [49] However, 'HRQOL and well-being' in Healthy People 2020 focuses on general adult population rather than on specific age groups, but other programs did. At present, Healthy People 2020 indicators suggest that physical health measures are lowest among adults over age 65, while disparities in mental health are less marked. [49] The Centers for Disease Control and Prevention (CDC) conducts the Healthy Aging Program to provide comprehensive activities designed to help older adults live longer and have high-quality, productive, and independent lives. [7]

HRQOL can be measured by the Medical Outcomes Study Short Forms, including SF-12 and SF-36, the Sickness Impact Profile (SIP), the Quality of Well-Being (QWB) questionnaire, the RAND-36, the EuroQol five-dimensional questionnaire (EQ-5D), the Health Utilities Index (HUI), Minnesota Living with Heart Failure Questionnaire (MLHFQ), the World Health Organization Quality of Life (WHOQOL) questionnaire, and so on. [3,8–10] HRQOL questions were added to the Behavioral Risk Factor Surveillance System (BRFSS) in 1993. HRQOL has been widely applied in BRFSS related studies, either as an explanatory variable or an outcome variable. [65,67,68,88,115]

Deprivation is a concept of broadened poverty. Deprivation can be classified at the individual level or area level. Anderson and colleagues defined area deprivation as an area's potential for health risks from ecological concentration of poverty, unemployment, economic disinvestment, and social disorganization." [133] Area deprivation is a component index representing the socioeconomic status of the areas. Elements of area deprivation frequently used including economic disadvantage, unemployment, education, household characteristics, and housing conditions. [136,137] These elements are publically and regularly released by the U.S. Census Bureau.

Small area estimation (SAE) analysis is widely applied to measure area deprivation. A multilevel, post-stratification (MPS) approach was developed to create county level estimates of HRQOL using national data. [189,190] Current studies have applying MPS to generate studies on the prevalence of chronic diseases at county level, such as chronic obstructive pulmonary disease (COPD). [35–37] Our study is the first to use this approach to develop estimates of county level HRQOL using data from BRFSS.

The purpose of this study was to develop county-level estimates of poor health-related quality of life (HRQOL) among older U.S. adults, and to compare the BRFSS direct estimates and model-based SAEs. Furthermore, this study applied spatial analysis to identify spatial clusters of area deprivation and poor HRQOL using a MPS approach.

5.3. Method

5.3.1. Data Sources

This is a cross-sectional study, using from the 2011 and 2012 Behavioral Risk Factor Surveillance System (BRFSS), the 2013-2014 Area Health Resources File (AHRF), and the 2014 Food Environment Atlas Data File. [171,179,180]

For the purpose of this study, we restricted the sample to adults aged 65 and over. After deleting observations with missing values for values in age, general health, physical health, mental health, state, and county, 263,914 respondents (unweighted) remained for analysis.

This study focused on the county-level areal unit rather than a smaller areal unit, such as PCSAs or ZIP codes, because variables of interest in both individual- and county-level datasets were not available at smaller geographic levels. There were 3,141 counties included in the 2013-2014 AHRF. After merging all other data sets and calculating county-level HRQOL probabilities, and excluding the U.S. territories, Alaska, and Hawaii, our total sample size included 263,914 respondents in 2,208 counties within 48 states and the District of Columbia.

5.3.2. Variables

a. Dependent variables

BRFSS contains four HRQOL questions, addressing general health (GH), physical health (PH), mental health (MH), and activity limitations (AL). Due to a large proportion of missing values of AL responses (51.82%), this study excluded AL, and analyzed the other three indicators separately.

GH was divided into two groups, excellent/very good/good and fair/poor, based on previous research. [50,53,65,85,88,115] PH and MH were categorized into two groups: low unhealthy days (first to third quartiles) versus high unhealthy days (fourth quartile). We did not follow other studies' strategy of dichotomizing PH, MH, and AL into infrequent (0-14 days) and frequent (15-30 days) unhealthy days [50,65,80,88,117], because most BRFSS respondents included in the sample reported no physically (61.42%) and mentally (78.37%) unhealthy days in the past 30 days, skewing the distributions.

b. Key explanatory variables and covariates

Area deprivation index. This study applied Ford and Dzealtowski's area deprivation index. [26] We chose this particular index because all elements required to calculate the index were available at the county-level. The index is composed of eight indicators (data year from resources): percent of adults unemployed (2011), percent of adults over 25 years with less than a high school education (2008-2012), percent of households under the federally-designated poverty level (2008-2012), percent of households with more than one person per room (2008-2012), percent of female head of household with children (2010), percent of households with public assistance income (2008-2012), median household income (2011), and percent of households with no access to a vehicle (2010). [26] The data for percent of households with no access to a vehicle was obtained from the 2014 Food Environment Atlas Data File, and other data elements from the 2013-2014 AHRF.

Each indicator was calculated as a standard z-score, by ($z = \frac{x-\mu}{\sigma}$), with a standard normal distribution with a mean of 0 and a standard deviation of 1. Then, all indicators were combined into an area deprivation index score. Higher scores indicates the county is more deprived.

Individual-level covariates included age (aged 65-74, aged 75-84, or aged over 85), gender (male or female), and race/ethnicity (Non-Hispanic White, Africa American, Hispanic, or others), resulting in 24 demographic categories (3*2*4) used for post-stratification of multilevel model results.

Counties were characterized based on 4-level of rurality using Urban Influence Codes: urban (UICs 1, 2), micropolitan (UICs 3, 5, 8), small adjacent (UICs 4, 6, 7) and remote rural (UICs 9, 10, 11, 12). [191] Then, 4-level rurality could be aggregated into 2-level rurality as urban and rural (including micropolitan, small adjacent, and remote rural). Rurality was examined to see whether HRQOL among older adults differed by rurality.

5.3.3. Statistical Analysis

We applied the MPS approach to estimate the probability of three HRQOL indicators for all 2,208 counties in the U.S. We followed four steps of MSP for generating our county-level estimates. [35,36] First, we ran a multilevel (3 level: individual county, state), logistic regression analysis on our weighted sample. We included age, gender, and race/ethnicity at the individual level, area deprivation at the county level, and county and state level random intercepts. The formula for multilevel logistic model is as:

$$\text{logit}(\pi_{ijk}) = \alpha + u_i + v_{ij} + \beta^T X_{ijk} + \epsilon_{ij}$$

where u_is are independent identically distributed (i.i.d) with $\text{N}(0, \sigma_u^2)$, v_{ij}s i.i.d. $\text{N}(0, \sigma_{uj}^2)$, and ϵ_{ij}s i.i.d. $\text{N}(0, \sigma_\epsilon^2)$ as an error term. Note that u_is are states-level random effects and v_{ij}s are county-level random effects which were nested within states. Also, j represents county-level characteristics (i.e., area deprivation) and *k* represents individual-level characteristics (i.e., age, sex, and race/ethnicity). α and β are fixed effects, while α represents the intercept and β is a vector of regression coefficients. We performed our multilevel modeling using the GLIMMIX procedure with 2010-2011 BRFSS data due to the complex survey design. We also utilized the D'Agostino and Goodman modified the BRFSS weighted system for analyzing county-level data. [174] Using W_{county} and C_{county} replace the original model (BRFSS Weight $= W_{state} * C_{state}$) is defined as the equation:

$$W_{county} = W_j = \sum_k (S * \frac{1}{P} * A)_{jk}$$

, and C_{county} is defined as the equation:

$$C_{county} = C_j = \frac{n_{jk}}{W_j}$$

where n_{jk} is the number of people in county j that belong to a particular demographic group (age-by-race-by-sex category) k at the county level. S is for differences in the probability of the respondent's telephone number selection, P is the number of residential telephone numbers in the respondent's household, and A is the number of adults in the respondent's household. [174] The modified weight was calculated by SAS 9.4 (SAS Institute, Inc., Cary, NC) and applied in PROC GLIMMIX (i.e. weight statement).

In our second step, we applied model prediction of county level subpopulations by age, gender, and race/ethnicity to the census population estimates. County area deprivation was used in the prediction model to further adjust for the local socioeconomic status influence on older populations' HRQOL. The expected probability of HRQOL in older adults were obtained for all demographic groups in a counties, while non-sampled county random effects were obtained by applying spatial smoothing on its adjacent counties with random effect. [35,36]

Finally, we generated model-based SAEs via post-stratification. The probability of HRQOL in older adults in county j is the population weighted estimate of the predicted probability of three HRQOL indicators in older adults for all 24 subpopulation groups within a county.

$$P_{ijk} = \frac{\sum_k P_{ijk} * Pop_{ijk}}{\sum_k Pop_{ijk}}$$

where j indicates county-level, and i is state-level. P_{ijk} is the predicted probability for an individual belonging to a particular demographic group (age-by-sex-by-race/ethnicity category) k in county j within state i. Pop represents the population number for each demographic subgroup.

Step four was internal validation. After generating model-based SAEs, we compared them with BRFSS direct estimates for all 48 states and DC and for counties with at least 50 respondents. For BRFSS county-level direct estimates, we calculated the percent of adults reporting poor HRQOL, dividing the number of older adults reporting poor HRQOL by the total number of older adults. For comparing the distributions of our model-based SAEs and BRFSS direct estimates and internal consistency, we conducted basic summary statistics and Pearson correlation coefficients, respectively.

5.3.4. Spatial Analysis

The nearness of geographic units must be quantified when applying spatial analysis [177]. This study employed global and local Moran's I tests (LISA), applying inverse distance methods with row standardization, for evaluating the spatial autocorrelation of older adults' HRQOL and area deprivation. A higher positive Moran's I indicates that values in the neighboring areas tend to cluster, while a lower negative Moran's I implies that higher and lower values are dispersed. [178] Data was exported for spatial analysis and mapping using Microsoft Excel (Microsoft Corporation). Spatial analysis and maps were performed using ArcGIS (Environmental System Research Institute, CA).

5.4. Results

5.4.1. Internal Validation

The Pearson correlation coefficients for correlation between BRFSS model-based estimates and BRFSS direct estimates at the state level were consistently higher than 0.97. Slightly lower correlations were observed at the county level, with correlation coefficients higher than 0.84. Overall, the coefficients for correlation at both state and county levels are significantly correlated. Compared with direct estimates at both state and count levels, BRFSS model-based estimates tended to have a narrower range (the difference between the highest and lowest estimates) (Table 5.1).

Table 5.1: Comparisons of direct state-level and county-level estimates of the HRQOL among older adults with model-based estimates, BRFSS, 2011-2012

Indicator and Type of Estimate	ρ[b]	No.[c]	Minimum	Median	Maximum	Mean	SD	Range[d]
State-Level[a]								
GH HRQOL[h]								
Direct[e]		49	0.18	0.23	0.37	0.25	0.05	0.19
Model-Based[f]	0.976	49	0.18	0.23	0.35	0.25	0.05	0.17
PH HRQOL[i]								
Direct[e]		49	0.21	0.26	0.35	0.26	0.03	0.14
Model-Based[f]	0.970	49	0.21	0.26	0.32	0.26	0.03	0.11
MH HRQOL[k]								
Direct[e]		49	0.13	0.21	0.26	0.21	0.02	0.12
Model-Based[f]	0.975	49	0.14	0.20	0.25	0.20	0.02	0.11
County-Level[g]								
GH HRQOL[h]								
Direct[e]		1050	0.06	0.24	0.59	0.25	0.08	0.53
Model-Based[f]	0.924	1050	0	0.24	0.51	0.26	0.07	0.51
PH HRQOL[i]								
Direct[e]		1050	0.07	0.25	0.69	0.26	0.07	0.62
Model-Based[f]	0.886	1050	0	0.26	0.41	0.26	0.04	0.41
MH HRQOL[k]								
Direct[e]		1050	0.06	0.20	0.46	0.21	0.06	0.41
Model-Based[f]	0.848	1050	0	0.20	0.31	0.20	0.03	0.31

Note: BRFSS: Behavioral Risk Factor Surveillance System. [a] All 48 state and the District of Columbia. [b] Person correlation coefficient, all p<0.001. [c] Number of states or counties included in comparison. [d] Difference between the maximum and minimum values. [e] BRFSS direct survey estimates. [f] Small area estimates based on the multilevel regression and post-stratification approach. [g] Limited to counties with at least 50 respondents. [h]Probabilitiy of having fair/poor general health; [i]Probability of having high physical unhealthy days (≥5 days (fourth quartiles, 74.3%-100%); [i]Probability of having high mentally unhealthy days (≥1 days (fourth quartiles, 79.4%-100%).

5.4.2. Results of Multilevel, Post-Stratification (MPS) Approach

Among individual characteristics, males had a higher probability of having fair/poor GH, but lower probabilities of reporting high physically and mental unhealthy days. The probabilities of having fair/poor GH and high physically unhealthy days increased among successive age groups, but the opposite was found for mentally unhealthy days, which declined with age. Non-White groups had a higher probabilities of poor HRQOL. Older adults living in high area deprivation counties had a higher probabilities of poor general and physical HRQOL, but area deprivation was not associated with MH HRQOL (Table 5.2).

Table 5.2: Multilevel reweighted regression models for probabilities of falling into the poorest quartile for HRQOL among older adults, BRFSS, 2011-2012

	GH HRQOL[a]	PH HRQOL[b]	MH HRQOL[c]
	Estimate(SE)	Estimate(SE)	Estimate(SE)
Intercept	**-1.50(0.03)*** **	**-1.16(0.02)*** **	**-1.11(0.02)*** **
Individual-level			
Gender			
Female(ref)			
Male	**0.04(0.01)*** **	**-0.19(0.01)*** **	**-0.52(0.01)*** **
Age			
65-74(ref)			
75-84	**0.30(0.01)*** **	**0.18(0.01)*** **	**-0.22(0.01)*** **
85+	**0.52(0.02)*** **	**0.27(0.02)*** **	**-0.38(0.02)*** **
Race/Ethnicity			
White(ref)			
Black	**0.68(0.02)*** **	**0.23(0.02)*** **	**0.12(0.02)*** **
Hispanic	**0.99(0.03)*** **	**0.42(0.03)*** **	**0.29(0.03)*** **
Others	**0.45(0.03)*** **	**0.26(0.03)*** **	**0.22(0.03)*** **
County-level			
Area deprivation index			
Low(ref)			
High	**0.28(0.02)*** **	**0.16(0.02)*** **	0.03(0.02)
Variance components			
State level	0.040(0.01)	0.01(0.003)	0.020(0.005)
County level	0.069(0.004)	0.042(0.004)	0.032(0.003)

Note: [a]Probabilitiy of having fair/poor general health; [b]Probability of having high physical unhealthy days (≥5 days (fourth quartiles, 74.3%-100%); [c]Probability of having high mentally unhealthy days (≥1 days (fourth quartiles, 79.4%-100%).**p*<0.05, ***p*<0.01, ****p*<0.001. Values based on SAS PROC GLIMMIX. Entries show parameter estimates with standard errors in parentheses; Ref: reference group.

Table 5.3 shows the average of county-level probabilities of falling into the poorest quartile for HRQOL among older adults in each state. The range of county-level probabilities of poor HRQOL in older adults in each state is 0.18-0.35, 0.21-0.32, and 0.14-0.24 for GH, PH, and MH, respectively. Alabama and Mississippi contain the highest average probability of having fair/poor GH (mean=0.35), while Vermont contains the lowest average (mean=0.18). For the average of county-level probabilities of having physically unhealthy days, Kentucky has the highest average value (mean=0.32), while Minnesota has the lowest average value (mean=0.21). For the average of county-level probabilities of having mentally unhealthy days, Illinois has the highest average value (mean=0.25), while South Dakota has the lowest average value (mean=0. 21).

5.4.2. Spatial Distribution

The geographical distributions of county-level probabilities of HRQOL in older adults and area deprivation are shown in Figure 5.1. As indicated on the map's legend, the highest value (fourth quartile: 75%-100%) indicates the worst deprivation conditions, including higher probabilities of having fair/poor GH, of having physically/mentally unhealthy days, and more deprived conditions, and are represented as darkest red. Intermediate values include the 25%-75% quartiles and low values include the 0-25% quartile.

Figure 5.2 presents bivariate choropleth maps to show whether these trends are parallel. The light pink color indicates the lowest probability of having fair/poor GH and low area deprivation, and it means the county contains the best condition. The dark blue color indicates the highest probability of having fair/poor GH and high area deprivation, and it means the county contains the worst condition.

Table 5.3: The average of county-level probabilities of poor HRQOL among older adults in each state, BRFSS, 2011-2012

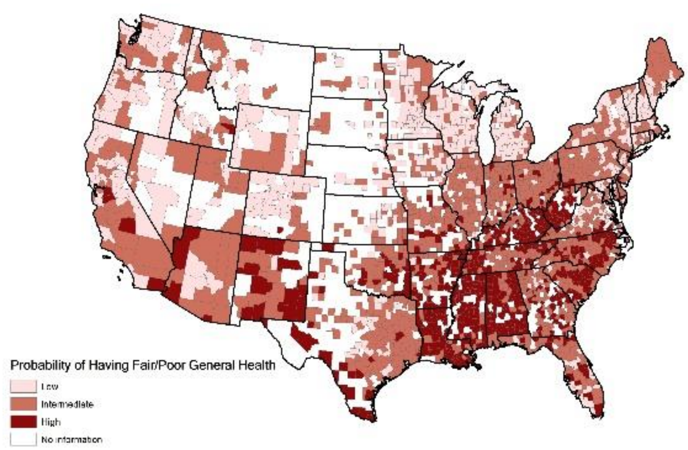
State	n	GH HRQOL				PH HRQOL				MH HRQOL			
		Min.	Max.	Range	Mean±SD	Min.	Max.	Range	Mean±SD	Min.	Max.	Range	Mean±SD
All US	2208	0.00	0.51	0.51	0.26±0.06	0.00	0.41	0.41	0.27±0.04	0.00	0.31	0.31	0.20±0.03
AL	61	0.24	0.45	0.21	0.35±0.04	0.21	0.38	0.17	0.30±0.03	0.17	0.26	0.09	0.21±0.02
AZ	14	0.20	0.34	0.14	0.26±0.04	0.22	0.32	0.10	0.27±0.03	0.17	0.28	0.11	0.22±0.03
AR	55	0.21	0.46	0.25	0.31±0.05	0.22	0.37	0.15	0.31±0.03	0.18	0.27	0.09	0.22±0.02
CA	55	0.15	0.42	0.27	0.23±0.06	0.18	0.37	0.19	0.26±0.03	0.19	0.29	0.10	0.24±0.02
CO	33	0.11	0.37	0.26	0.19±0.06	0.16	0.29	0.14	0.22±0.03	0.15	0.23	0.08	0.18±0.02
CT	8	0.18	0.25	0.07	0.21±0.02	0.24	0.30	0.06	0.27±0.02	0.16	0.24	0.07	0.20±0.02
DE	3	0.23	0.27	0.04	0.24±0.02	0.23	0.27	0.05	0.25±0.02	0.17	0.20	0.03	0.18±0.02
DC	1	0.24	0.24	0.00	0.24± .	0.25	0.25	0.00	0.25± .	0.20	0.20	0.00	0.20± .
FL	65	0.14	0.41	0.26	0.26±0.06	0.19	0.35	0.17	0.27±0.04	0.18	0.30	0.12	0.22±0.03
GA	114	0.20	0.36	0.16	0.28±0.04	0.20	0.33	0.13	0.28±0.03	0.13	0.22	0.09	0.19±0.01
ID	22	0.14	0.31	0.17	0.23±0.04	0.21	0.37	0.16	0.27±0.04	0.16	0.23	0.07	0.20±0.02
IL	83	0.16	0.35	0.19	0.25±0.03	0.22	0.38	0.17	0.29±0.02	0.20	0.30	0.10	0.25±0.02
IN	83	0.21	0.34	0.13	0.27±0.03	0.22	0.34	0.12	0.27±0.02	0.20	0.28	0.08	0.23±0.02
IA	58	0.15	0.27	0.12	0.21±0.02	0.17	0.26	0.09	0.22±0.02	0.14	0.19	0.05	0.16±0.01
KS	35	0.16	0.34	0.18	0.24±0.04	0.18	0.29	0.11	0.23±0.03	0.13	0.21	0.07	0.16±0.02
KY	89	0.24	0.44	0.20	0.34±0.04	0.24	0.38	0.14	0.32±0.03	0.17	0.26	0.10	0.22±0.02
LA	55	0.23	0.48	0.25	0.33±0.04	0.22	0.35	0.13	0.27±0.03	0.15	0.22	0.07	0.18±0.02
ME	16	0.14	0.27	0.13	0.20±0.04	0.18	0.30	0.12	0.24±0.03	0.15	0.25	0.09	0.21±0.02
MD	23	0.17	0.31	0.14	0.22±0.04	0.17	0.31	0.14	0.22±0.03	0.15	0.24	0.09	0.19±0.02
MA	13	0.15	0.32	0.17	0.23±0.05	0.19	0.31	0.13	0.25±0.03	0.15	0.24	0.09	0.20±0.02
MI	71	0.13	0.27	0.14	0.20±0.03	0.16	0.30	0.14	0.24±0.02	0.15	0.24	0.09	0.20±0.02

State	n	GH HRQOL				PH HRQOL				MH HRQOL			
		Min.	Max.	Range	Mean±SD	Min.	Max.	Range	Mean±SD	Min.	Max.	Range	Mean±SD
MN	60	0.16	0.25	0.08	0.20±0.02	0.17	0.25	0.08	0.21±0.02	0.14	0.19	0.05	0.16±0.01
MS	63	0.25	0.47	0.22	0.35±0.04	0.23	0.41	0.18	0.30±0.03	0.16	0.24	0.08	0.19±0.02
MO	75	0.18	0.37	0.19	0.28±0.04	0.21	0.33	0.12	0.26±0.03	0.15	0.21	0.05	0.18±0.01
MT	12	0.14	0.28	0.13	0.21±0.04	0.21	0.27	0.06	0.25±0.02	0.19	0.23	0.04	0.21±0.01
NE	21	0.16	0.26	0.09	0.21±0.02	0.19	0.26	0.07	0.23±0.02	0.15	0.23	0.09	0.18±0.02
NV	8	0.13	0.25	0.12	0.21±0.04	0.21	0.29	0.08	0.25±0.03	0.19	0.26	0.07	0.23±0.02
NH	10	0.17	0.23	0.07	0.19±0.02	0.22	0.25	0.03	0.24±0.01	0.16	0.21	0.04	0.19±0.01
NJ	21	0.17	0.40	0.23	0.25±0.06	0.18	0.31	0.13	0.25±0.03	0.17	0.25	0.08	0.20±0.02
NM	25	0.19	0.38	0.19	0.29±0.05	0.23	0.34	0.11	0.29±0.03	0.17	0.27	0.10	0.20±0.02
NY	61	0.17	0.47	0.30	0.23±0.05	0.22	0.36	0.14	0.27±0.03	0.19	0.31	0.12	0.23±0.02
NC	91	0.20	0.40	0.20	0.29±0.05	0.20	0.34	0.15	0.26±0.03	0.14	0.22	0.08	0.18±0.01
ND	9	0.19	0.26	0.06	0.22±0.02	0.21	0.30	0.09	0.25±0.03	0.18	0.21	0.03	0.20±0.01
OH	87	0.18	0.43	0.25	0.27±0.04	0.22	0.37	0.15	0.28±0.03	0.17	0.24	0.07	0.21±0.01
OK	51	0.19	0.39	0.19	0.28±0.04	0.22	0.34	0.12	0.27±0.03	0.15	0.25	0.09	0.20±0.02
OR	28	0.15	0.24	0.09	0.19±0.03	0.21	0.28	0.06	0.24±0.02	0.17	0.24	0.06	0.20±0.02
PA	64	0.18	0.35	0.16	0.24±0.03	0.20	0.34	0.14	0.26±0.03	0.18	0.28	0.09	0.22±0.02
RI	5	0.18	0.28	0.11	0.21±0.04	0.22	0.31	0.09	0.26±0.03	0.17	0.23	0.06	0.21±0.02
SC	44	0.14	0.42	0.28	0.30±0.06	0.18	0.35	0.16	0.28±0.03	0.15	0.24	0.10	0.20±0.02
SD	14	0.14	0.24	0.10	0.20±0.03	0.18	0.33	0.15	0.22±0.04	0.12	0.19	0.07	0.14±0.02
TN	82	0.21	0.38	0.17	0.30±0.03	0.22	0.34	0.12	0.28±0.02	0.14	0.19	0.05	0.16±0.01
TX	151	0.18	0.51	0.33	0.26±0.06	0.21	0.41	0.20	0.29±0.03	0.18	0.30	0.12	0.22±0.02
UT	17	0.15	0.27	0.12	0.22±0.03	0.21	0.29	0.08	0.26±0.02	0.17	0.27	0.10	0.22±0.03
VT	12	0.14	0.24	0.10	0.18±0.03	0.21	0.26	0.05	0.23±0.02	0.17	0.25	0.08	0.22±0.02
VA	84	0.00	0.34	0.34	0.23±0.07	0.00	0.32	0.32	0.24±0.06	0.00	0.19	0.19	0.16±0.04

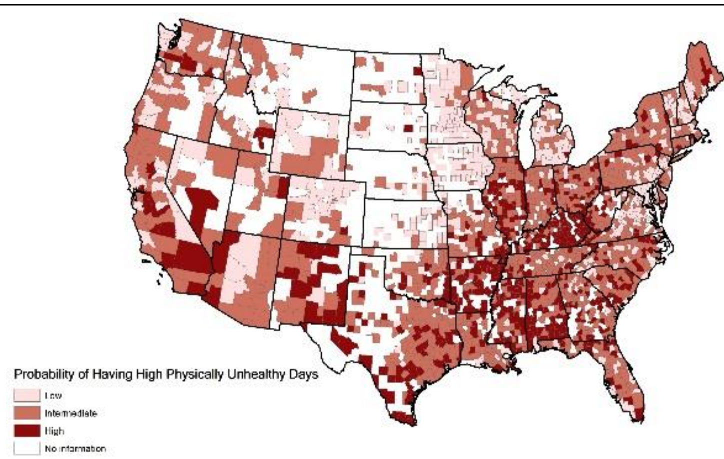
State	n	GH HRQOL				PH HRQOL				MH HRQOL			
		Min.	Max.	Range	Mean±SD	Min.	Max.	Range	Mean±SD	Min.	Max.	Range	Mean±SD
WA	33	0.15	0.28	0.13	0.21±0.04	0.19	0.31	0.11	0.25±0.03	0.16	0.25	0.09	0.20±0.02
WV	42	0.27	0.46	0.18	0.34±0.05	0.23	0.34	0.11	0.28±0.03	0.18	0.24	0.06	0.20±0.01
WI	67	0.16	0.26	0.10	0.20±0.02	0.20	0.32	0.12	0.25±0.02	0.17	0.23	0.06	0.20±0.01
WY	14	0.13	0.27	0.14	0.20±0.04	0.18	0.27	0.09	0.23±0.03	0.17	0.23	0.07	0.19±0.02

Note: GH: general health. PH: physical health. MH: mental health. HRQOL: health-related quality of life. n: the number of counties included in the analysis. Min.: minimum. Max.: Maximum. Range: the range of the probability of poor HRQOL in older adults within each state.

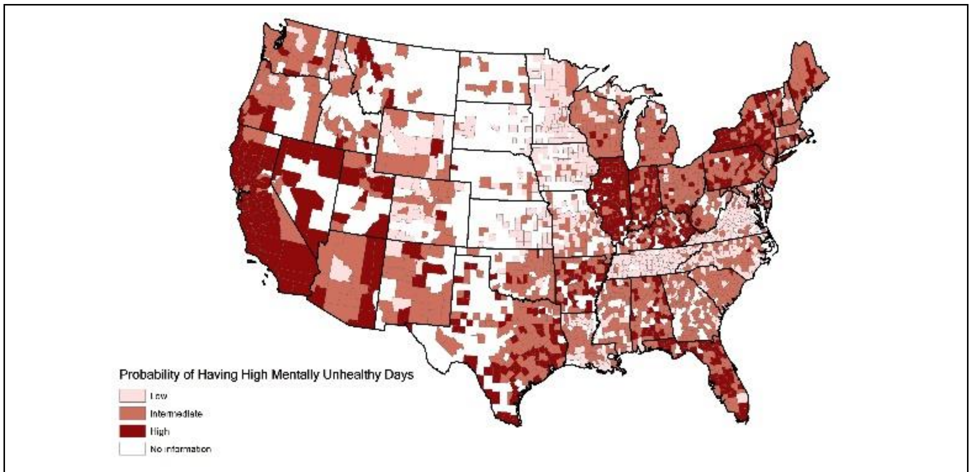
For GH HRQOL and area deprivation, the worst condition counties were mainly located in the South, while the best condition counties were more common in Minnesota, Wisconsin, Iowa, and Colorado. For PH HRQOL and area deprivation, the worst condition counties were also mainly located in the South, and few California counties, while the best condition counties were more common in Minnesota, Iowa, and Colorado. For MH HRQOL and area deprivation, the worst condition counties were mainly located in California, Nevada, and parts of Texas, while the best condition counties were more located at Minnesota, Iowa, and partial Kansas and Colorado.



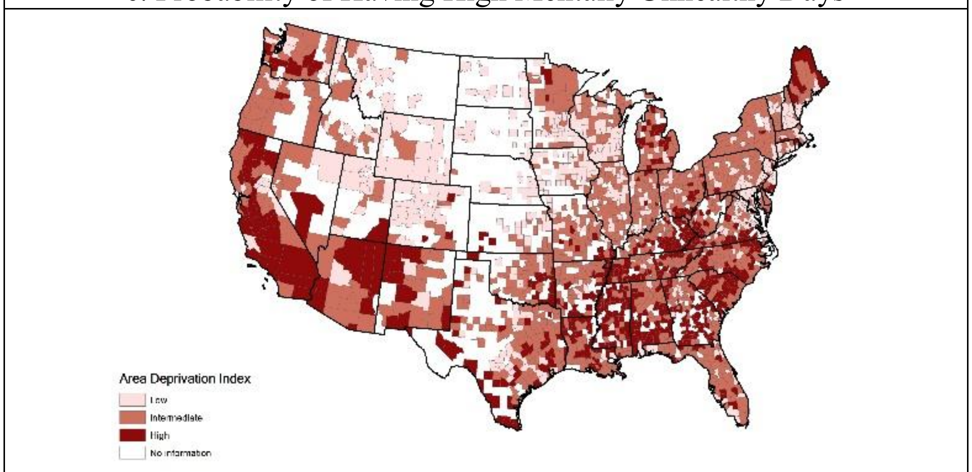
a. Probability of Having Fair/Poor General Health



b. Probability of Having High Physically Unhealthy Days



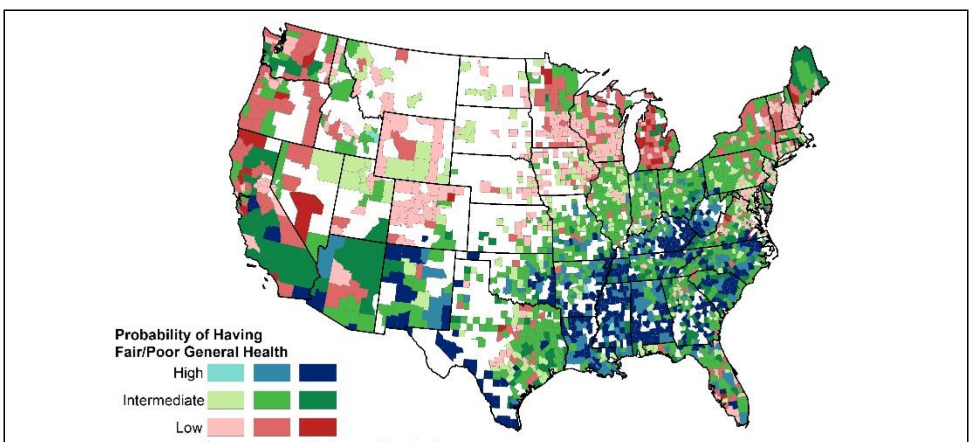
c. Probability of Having High Mentally Unhealthy Days



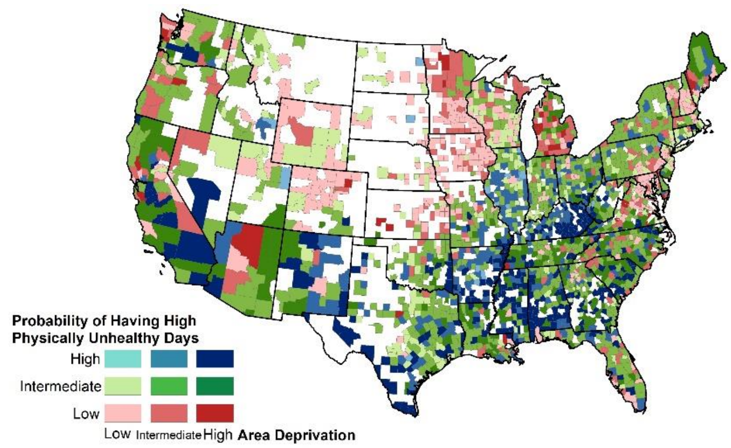
d. Area Deprivation Index

Figure 5.1: Distributions of HRQOL and area deprivation, BRFSS, 2011-2012

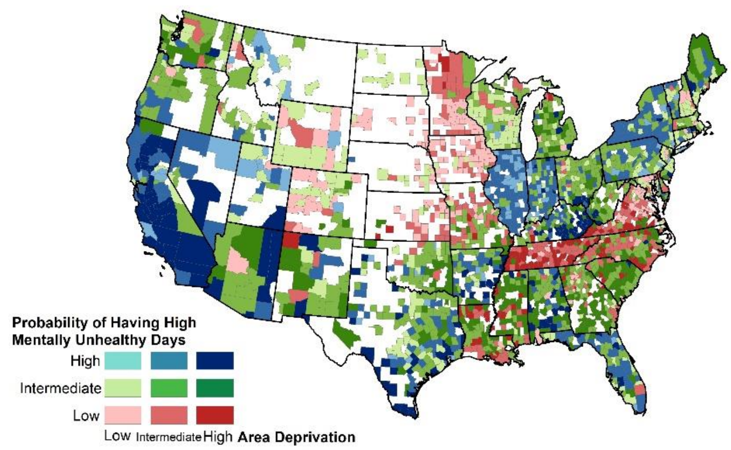
Resources: 2013-2015 Area Health Resource, Food Environment Atlas Data File (2014 Version), and 2014 County Health Rankings.



a. Probability of Having Fair/Poor General Health and Area Deprivation



b. Probability of Having High Physically Unhealthy Days and Area Deprivation



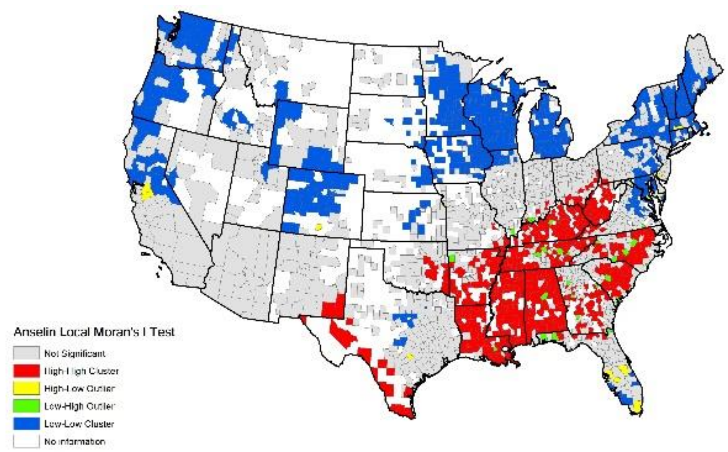
c. Probability of Having High Mentally Unhealthy Days and Area Deprivation

Figure 5.2: Bivariate choropleth maps for HRQOL and area deprivation, BRFSS, 2011-2012

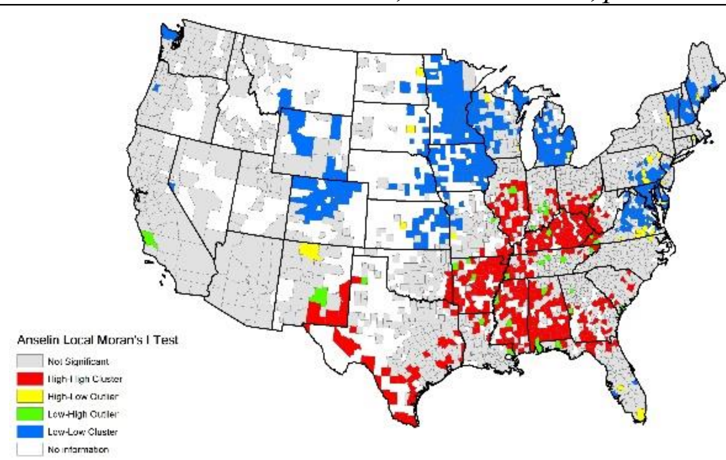
Resources: 2013-2015 Area Health Resource, Food Environment Atlas Data File (2014 Version), and 2014 County Health Rankings.

5.4.3. Spatial Autocorrelation

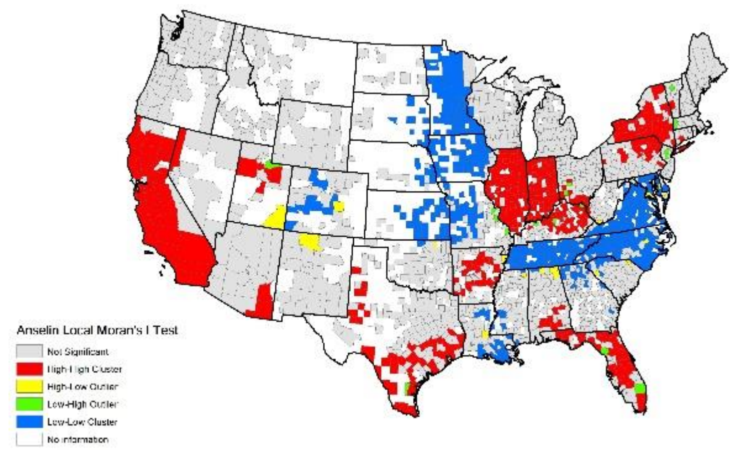
County-level probabilities of poor HRQOL in older adults and area deprivation showed significant spatial clustering using Global Moran's I test. Figure 5.3 presents LISA cluster maps of residuals for county-level probabilities of poor HRQOL and area deprivation. The cluster patterns for probability of having fair/poor GH, of having physically unhealthy days, and area deprivation are similar. Low-low clustering counties (i.e. counties with low scores surrounded by other counties with similar scores) were mainly located in the Pacific, Midwest, and Northeast regions, while high-high clustering counties were located in the South. For probability of having mentally unhealthy days, low-low clustering counties were located in the Northwest Central, Tennessee, North Carolina, Virginia, Maryland, and partially Mississippi, and Louisiana. The high-high clustering counties were mainly located in California, Illinois, Indiana, New York, Florida, and partially Utah, Arizona, Texas, Arkansas, Alabama, and Vermont.



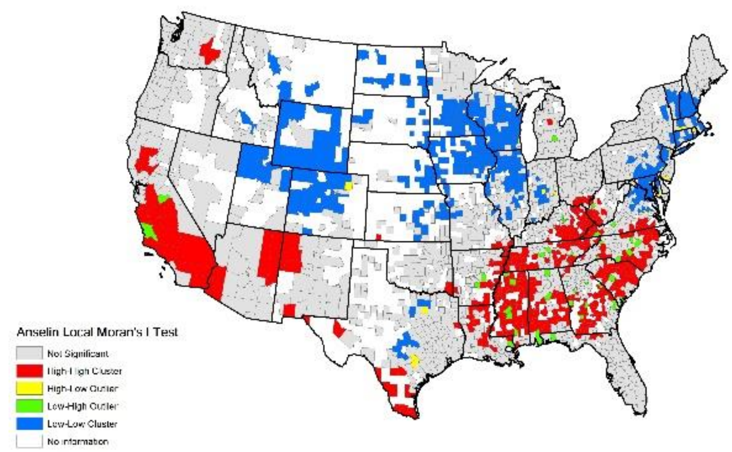
a. Probability of Having Fair/Poor General Health
Autocorrelation: Moran’s test: 0.54, z score: 87.47, *p*-value: <0.0001



b. Probability of Having High Physically Unhealthy Days
Autocorrelation: Moran’s test: 0.41, z score: 67.08, *p*-value: <0.0001



c. Probability of Having High Mentally Unhealthy Days
Autocorrelation: Moran's test: 0.48, z score: 77.70, *p*-value: <0.0001



d. Area Deprivation Index
Autocorrelation: Moran's test: 0.43, z score: 68.67, *p*-value: <0.0001

Figure 5.3: Spatial autocorrelations of HRQOL and area deprivation, BRFSS, 2011-2012
Resources: 2013-2015 Area Health Resource, Food Environment Atlas Data File (2014 Version), and 2014 County Health Rankings.
Note: Blank means no data; applying inverse distance methods with row standardization.

The number of counties of showing significant clustering patterns for each variable displayed in Table 5.4. Appling independent t test by 2-level rurality, the probability of having fair/poor GH (t=-2.98, p=0.0029), of having physically unhealthy days (t=-4.44, p<0.0001), and area deprivation (t=-11.29, p<0.0001) are significantly differentiated by urban/rural designation. Moreover, applying ANOVA by 4-level rurality, the probability of having fair/poor GH (F=7.69, p=<0.0001), of having physically unhealthy days

(F=9.91, p<0.0001), and area deprivation (F=-46.12, p<0.0001) differ significantly by rurality.

Table 5.4: The number counties of clustering patterns and rurality, BRFSS, 2011-2012 (n=2,208)

	Probability of having fair/poor general health[a,b]	Probability of having high physically unhealthy days[a,b]	Probability of having high mentally unhealthy days	Area deprivation[a,b]
Clustering patterns	n(%)	n(%)	n(%)	n(%)
Non-significant	1108(50.18%)	1327(60.10%)	1211(54.85%)	1360(61.59%)
High-High	533(24.14%)	425(19.25%)	458(20.74%)	386(17.48%)
High-Low	16(0.72%)	30(1.36%)	18(0.82%)	18(0.82%)
Low-High	27(1.22%)	34(1.54%)	16(0.72%)	39(1.77%)
Low-low	524(23.73%)	392(17.75%)	505(22.87%)	405(18.34%)
Rurality[a,b]	M±SD	M±SD	M±SD	M±SD
Urban	0.26±0.06	0.26±0.04	0.20±0.03	-0.77±3.42
Rural	0.27±0.07	0.27±0.04	0.20±0.03	0.97±3.81
Micropolitan	0.26±0.06	0.27±0.04	0.20±0.03	0.60±0.38
Small adjacent	0.27±0.06	0.27±0.04	0.20±0.03	1.24±3.67
Remote	0.28±0.08	0.27±0.05	0.20±0.03	1.50±4.05

Note: [a]: p values of independent t test for 2-level rurality <0.05; [b]: p values of ANOVA test for 4-level rurality <0.05.

5.5. Discussion

The primary aim of this paper was to identify spatial clusters in area deprivation and county-level probabilities of having poor HRQOL in older adults. The Global and Local Moran's I test identified spatial clusters for area deprivation and county-level probabilities of having poor HRQOL in older adults, which suggest that the geographical distribution of area deprivation and poor HRQOL may be related to features of the local neighborhood. Comparing state-level average probabilities via MPS and spatial clustering patterns, the states having the highest average probabilities present high-high clusters, and the states having the lowest average HRQOL probabilities present low-low clusters.

We may conclude that both statistical and spatial analyses have consistent results.

Previous studies shown that MPS is a reliable and sensible method for producing SAEs of health indicators using nationwide population-based health surveys. [35,36] Previous studies utilized county poverty at county-level for MPS approach. [35,36] However, we applied the area deprivation index replace county poverty because area deprivation index is more powerful to present county socioeconomic status than county poverty. We did not control for rurality in our multilevel prediction model, but did examine whether there was a statistically significant difference between the means by rurality. Based on this test, we found county-level probabilities of having fair/poor GH and physically unhealthy days were significantly differentiated by rurality. More specifically, rural counties had higher probabilities of having fair/poor GH and physically unhealthy days and worse area deprivation index score than urban counties. However, the probability of having mentally unhealthy days at the county-level was not significantly differentiated by rurality.

Findings regarding differences in the prevalence of mental disorders by rurality are conflicting. [192] Previous studies have noted that the prevalence of mental health illness or other indicators of mental health were not differentiated by rurality, [193,194] while another study has found that rural populations have a higher prevalence of health illnesses. [195] In general, rural areas face many health barriers, including availability, accessibility, and acceptability of health care services.

Bivariate choropleth maps are also a useful tool for visualization of geographical relationships. Our bivariate choropleth maps also useful identify the vulnerable counties (the counties with both high probabilities of poor HRQOL and high area deprivation).

From our study, state and local policy makers could develop adaptive policies based upon local demands and conditions, and target their interventions to the counties with the worst HRQOL or area deprivation.

Limitations

The results of this analysis are subject to some limitations. First, BRFSS is a cross-sectional survey, designed to randomly select households with a telephone or adults with a cell phone. It ignores those who lack to access to phones and live in institutions, such as long-term care facilities, or skilled nursing homes. Due to public use data restrictions, the survey data also do not include all counties in the U.S. Due to the self-reported nature of the questionnaire, recall bias and over/underreporting of health behaviors may exist. Our study modeled county-level probabilities of poor HRQOL using covariates that allow for post-stratification; thus, we may not have adequately adjust for all important individual-level characteristics and health-related factors.

Second, our validation strategy was limited. The County Health Rankings file presents data on county level HRQOL, but focuses on all adults, rather than older adults – making the groups difficult to compare. Moreover, the HRQOL in CHR also came from the BRFSS, so it is not technically external validation. Population-based external validation of model-based SAEs is critical to evaluate the quality of statistical small area estimators. [36] However, we could not find a county-level older adults' HRQOL for doing external validation. Our study provides a comparable county-level older adults' HRQOL and area deprivation for future research. Also, we did internal validation comparing the BRFSS direct estimates and model-based SAEs.

Conclusions

This is the first study to our knowledge to have used a large national survey to validate county-level models based SAEs of poor HRQOL among U.S. older adults. Both bivariate choropleth maps and cluster maps resulting from our Local Moran's I test will be useful in identifying high-risk areas (high-high clustering) for area deprivation and HRQOL in older adults; thus, allowing public health researchers and practitioners to target their interventions to areas of greatest need. The results help to plan interventions directed towards specific counties, as presented by the cluster analysis in LISA.

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