ASSOCIATIONS BETWEEN CO-OCCURRING HEALTH BEHAVIORS, SOCIAL DETERMINANTS OF HEALTH, AND MENTAL HEALTH AMONG A DIVERSE SAMPLE OF AGING ADULTS IN THE US

by

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(Under the Direction of Heather M. Padilla)

ABSTRACT

Influenced by social determinants of health (SDoH), health behaviors are often considered separately, despite being interrelated, contributing to poor health outcomes such as depression and anxiety. The synergistic effects of multiple unhealthy behaviors may increase the risk of anxiety and depression, yet most studies focus on these behaviors one at a time. The American Cancer Society (ACS) Guidelines score, which quantifies adherence to the 2020 ACS diet, alcohol, body weight, and physical activity recommendations for cancer prevention, serves as a measure of co-occurring health behaviors. The purpose of this dissertation was to investigate the association between social determinants of health, co-occurring health behaviors, and mental health in a diverse sample of aging adults in the United States. Two studies were conducted using the Cancer Prevention Study-3 epidemiological cohort to: 1) identify SDoH associated with co-occurring health behaviors captured by ACS Guideline scores and 2) examine the association between 2015 ACS Guideline scores and self-reported mental health outcomes for anxiety and depression in 2021. Aim one was investigated using a cross-

sectional study of 142,085 participants and multivariate ordinal logistic regression models. Participants with higher ACS Guideline adherence (i.e., better co-occurring health behaviors) were more likely to be female, Asian, hold graduate degrees, have household incomes of $125,000 or more, reside in metropolitan, non-food desert areas, be married or living with a partner, and experience no second-hand smoke (SHS) exposure. Two-way joint variable interaction models demonstrated intersectionality among select SDoH. Findings revealed higher ACS Guideline adherence among never married men, metropolitan females, and individuals with no second-hand smoke exposure making $125,000 or more. 112,016 participants were included in the second, longitudinal study addressing aim two. Higher adherence to the ACS Guidelines demonstrated consistent inverse associations with lower odds of future depression and anxiety symptoms. Together, these studies add to our understanding that people's health is significantly affected by sociodemographic, economic, and geographic factors and it is critical that future health promotion strategies consider the complexities associated with SDoH when developing public health approaches for improving co-occurring health behaviors to reduce the risk of poor health outcomes such as cancer, depression, and anxiety.

INDEX WORDS: Social determinants of health, health behaviors, mental health, depression, anxiety, diet, BMI, physical activity, CPS-3

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DEDICATION

To all the neurodivergent kids out there thinking and being told they aren't smart enough to achieve their goals. You ARE. You CAN. And you WILL.

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CHAPTER 1

INTRODUCTION

Brief Overview

The 2020 Coronavirus (COVID-19) pandemic had drastic effects on psychological well-being and mental health, increasing the global prevalence of anxiety and depression by 25%,[179] leading to over $280 billion in annual healthcare costs for mental health services.[3] In 2022, one in five US adults (59.3 million) had a mental illness; with younger adults aged 18 to 25 years old (36.2%), women (26.4%), and multiracial individuals (35.2%) experiencing higher rates of mental illness than any other demographic groups.[105] While various types exist, depression and anxiety are two of the most common mental health disorders,[181,182] stemming from a multitude of social, psychological, and biological factors.[1,103,181,182]

There may be a bidirectional relationship between mental health and health behaviors. Walsh et al. (2013) found depression and anxiety to predict the engagement of unhealthy behaviors (smoking, binge drinking, and fast-food consumption) as coping mechanisms for the negative effects of mental illness. Although temporality could not be established given the cross-sectional design, Buttery et al. (2014) found engaging in multiple health behaviors, including not smoking, regular physical activity (PA), healthy weight/body mass index (BMI), and diet consumption of fruit and vegetables, to be associated with better mental health. Furthermore, the clustering of unhealthy behaviors (i.e., poor diet, low PA, and sedentary behaviors) has been linked to the risk of depression

and anxiety.[5,184] The synergistic effects of multiple unhealthy behaviors may increase the risk of anxiety and depression, yet most studies focus on these behaviors one at a time.[5]

Existing frameworks for mental health prevention and care often ignore the social and environmental conditions that impact risk and protective factors, limiting the understanding of the role of social determinants of health (SDoH). SDoH are social and environmental contextual factors that individually influence the risk of mental illness.[42,183] Evidence of the intertwining, bi-directional relationship between health behaviors, social determinants of health, and mental health suggests that singular health behaviors, including physical activity, healthy diets, healthy weight maintenance, and reduced alcohol consumption alone, can reduce depression risk.[12,21,43,60,95,165] However, more studies are needed to evaluate the longitudinal relationship between co-occurring healthy behaviors (i.e., healthy diet, PA, normal BMI, and limited or no alcohol consumption) and mental health outcomes.

The 2020 American Cancer Society (ACS) Guidelines score, which quantifies adherence to the ACS diet, alcohol, body weight, and physical activity recommendations for cancer prevention, serves as a measure of co-occurring health behaviors. Previously, adherence to all components of the 2006 ACS Guidelines was associated with a lower risk of all-cause death, cardiovascular disease (CVD), and cancer.[98] Compared to the 2006 Guidelines, the 2020 update is more explicit on dietary patterns for individual nutrients and bioactive compounds and emphasizes the recognition of socioeconomic and cultural factors that influence health behaviors.[135] More specifically, the update includes limited or no sugar-sweetened beverages (SSBs) and limited or no highly processed foods.

Components of the ACS Guidelines score are associated with social determinants of health, likely because of the strong influence of socioeconomic and cultural factors.[97,126] Existing evidence consists of primarily cross-sectional studies and very few longitudinal studies, which focus on adolescents and/or smaller sample sizes. There is an opportunity and need to investigate the intersectionality of various social determinants of health on co-occurring health behaviors and their impact on poor mental health outcomes using a large, diverse, prospective sample of U.S. adults. Adherence to the 2020 ACS Guidelines as a measure for capturing co-occurring health behaviors may provide a better understanding of the relationships between SDoH, health behaviors, and mental health; and identify potential health promotion opportunities for improving health behaviors, and thus health outcomes, and reducing the disproportionality of the burden of disease.

Purpose

The purpose of this dissertation is to investigate the association between social determinants of health, co-occurring health behaviors, and mental health in a large, diverse sample of aging adults in the United States. This will be achieved using data from the Cancer Prevention Study-3 (CPS-3), an ongoing prospective cohort study of cancer incidence and mortality initiated by ACS in 2006,[116] and by adopting the two-manuscript dissertation format. CPS-3 enrolled approximately 304,000 participants from across the United States, the District of Colombia, and Puerto Rico and collects triennial follow-up data; 2015 and 2021 follow-up data will be used in the two proposed studies.

Significance and Specific Aims of Manuscript 1

Manuscript 1 will utilize a cross-sectional study design, and 2015 CPS-3 survey data to examine the relationship between a) multiple SDoH (including income, marital

status, education level, rural-urban commuting area (RUCA) codes, food desert status, second-hand smoke exposure, and demographics) and b) health behaviors measured to calculate the ACS Guideline score (i.e. diet, PA, alcohol consumption, and BMI). Ordinal logistic regression models will be used to identify the SDoH associated with co-occurring health behaviors captured by the ACS Guideline score, categorized as diet, physical activity, alcohol consumption, and body mass index (BMI). The proposed study will extend the work previously done in the CPS-3 cohort showing differences in leisure-time moderate-to-vigorous intensity physical activity (LTMVPA) by racial, ethnic, and nativity[126] and poor diet quality independently associated with multiple individual-level socioeconomic and geographic variables.[97] The **specific aim** of Manuscript 1 is to:

1. **Identify the social determinants of health (SDoH) associated with co-occurring health behaviors captured by ACS Guideline scores in the CPS-3 study**.
    a. Examine the relationship between multiple SDoH and health behaviors measured to calculate the ACS Guideline score.
        i. Hypothesis 1a. Higher ACS Guideline scores (indicating adherence to healthy behaviors) will be inversely associated with experiencing multiple SDoH.

Significance and Specific Aims of Manuscript 2

Using a prospective study design, Manuscript 2 will examine the longitudinal associations between 2020 ACS Guidelines scores and self-reported anxiety and depression scores using the 2015 (ACS Guideline score) and 2021 (PHQ-4) CPS-3 surveys. The four-item Patient Health Questionnaire for depression and anxiety (PHQ-4)

assesses anxiety and depression symptoms by asking participants to rate the following items over the past month, with scores ranging from 0 ('not at all') to 3 ('nearly every day'). PHQ-4 items include: 'feeling nervous, anxious, or on edge,' 'not being able to stop or control worrying,' 'feeling down, depressed, or hopeless,' and 'little interest or pleasure in doing things.' Totals of the four items are added together ranging from 0 to 12, with higher scores denoting greater levels of depression and anxiety. The 2020 ACS Guideline score will be examined as a categorical variable (0-2, 3, 4, 5, 6, 7-8) and as a continuous variable. Multivariate logistic regression models will be used to assess the relationship between ACS Guideline scores in 2015 and PHQ-4 scores in 2021. Models will adjust for demographic (age, sex, race/ethnicity, marital status) and socioeconomic (education and income) variables that were associated with health behaviors in Aim 1 (Manuscript 1). This study will extend the work previously done in the CPS-3 cohort demonstrating that physical activity is inversely associated, and sedentary time is positively associated with overall psychological distress, encompassing depression and anxiety symptoms measured by PHQ-4.[127] The **specific aim** of Manuscript 2 is to:

2. **Examine the association between ACS Guideline scores and self-reported mental health outcomes, specifically, anxiety and depression.**
    a. Describe the temporal relationship between ACS Guideline scores (2015) and self-reported anxiety and depression (PHQ-4 collected in 2021).
        i. Hypothesis 2a. ACS Guideline scores will predict anxiety and depression; Higher adherence to the ACS Guidelines (higher scores) will be associated with lower PHQ-4 scores (self-reported anxiety and depression).

CHAPTER 2

LITERATURE REVIEW

Mental Health: Anxiety and Depression

59.3 million (23.1%) U.S. adults had a mental illness in 2022, with younger adults aged 18 to 25 years old (36.2%), women (26.4%), and multiracial individuals (35.2%) experiencing higher rates of mental illness than any other demographic groups.[105] Across the globe, mental illnesses are a leading cause of years lived with a disability and contribute to suicide as a major cause of death.[102] The American Psychological Association (2022) defines mental illness as health conditions that alter emotions, behavior, and/or thinking; and defines mental health as the foundation of emotional, psychological, and social well-being that enables individuals to cope with life's stressors.

Mental health is intrinsic, affecting all people, and influences our abilities to understand ourselves, connect with others, think, learn, work, cope, feel, function, and thrive.[180] It is an integral part of health and well-being; existing on a complex continuum ranging from optimal states of well-being to debilitating suffering and emotional pain.[180] Occurring and changing over one's life, mental health may fluctuate on the continuum depending on situations and stressors experienced at varying times.[180]

Among its many impacts on health and wellness worldwide, the novel Coronavirus (COVID-19) pandemic fueled short-term and long-term stressors creating a global crisis for mental health.[162] Within the first year of the pandemic, the global prevalence of anxiety and depression increased by 25%.[179] Specifically, the 2020 Global

Burden of Diseases, Injuries, and Risk Factors Study (GBD) demonstrated a 28% and 26% increase in major depressive disorder and anxiety disorders, respectively.[38] Increases in psychological distress, including symptoms of depression and anxiety, were associated with the unprecedented, rapid changes in daily life during the pandemic such as stress from potential health impacts of the virus, unemployment and financial insecurity, false information, and public health related social measures.[180] Today, mental health and psychological well-being remain a significant public health concern with depressive and anxiety disorders accounting for 61% of mental health disorders worldwide.[69,179]

Anxiety is the most common mental health disorder in the US, impacting roughly 40 million adults (19.1%).[1] General Anxiety Disorder (GAD) is characterized by excessive and persistent worry, nervousness, and unease about daily events or activities.[1,103,181] Having mild levels of anxiety is a normal, beneficial reaction to stressors; however, individuals with GAD experience frequent, high levels of anxiety for months to years.[103]

An estimated 22.5 million US adults are affected by depression each year.[2] Depression can often co-exist with other mental health conditions, such as anxiety; and is characterized by loss of pleasure in daily life, saddened mood, and reduced interest in activities over time.[182] Both depression and anxiety can occur at any age and can lead to serious health risks.

Anxiety and depression can persist across one's lifetime requiring ongoing treatment; they can involve recurrent episodes, that if left untreated, can significantly affect an individual's daily functioning and quality of life. Symptoms may fluctuate and worsen during stressful times such as physical illness, global pandemics, school exams,

or during times of relationship conflicts.[1] Poor mental health can impact both how long one lives[166] and the quality of life over the years lived.[55]

Risk and Protecting Factors

Both anxiety and depression stem from a multitude of social, psychological (i.e., cognitive and interpersonal factors), and biological factors throughout the lifespan.[1,103,181,182] Risk factors can be categorized as individual factors which includes but is not limited to low education, poor diet, obesity and other chronic diseases, sleep disturbances, and family history/genetic factors; family and community factors such as bullying, job insecurity, abuse (physical, emotional, domestic), and identifying as a minority; and biological factors such as maternal substance use, oxygen deprivation at birth, and high potency cannabis use.[54,180] Sociocultural, environmental, and geopolitical surroundings including inequality, infrastructure, environmental quality, and social stability refer to the structural factors that can contribute to mental health.[8,180]

Protective factors include good physical health, social and emotional skills, physical safety and security, positive social networks, social support, economic stability, equal access to services and healthcare, and equality.[8] For example, social and emotional skills developed during adolescence can provide individuals with the skills to handle stress and daily choices, thus strengthening mental well-being.[8]

While some risk factors for mental illness such as family history, pose equal risks among those with and without chronic diseases, other risk factors such as stress from living with a chronic condition are directly linked to depression and anxiety.[104] Further, engaging in modifiable health behaviors such as physical activity (PA), eating a healthy diet, reduced or no alcohol consumption, and weight maintenance can help combat poor

mental health like that of other, more traditionally thought of chronic diseases such as diabetes, CVD, and obesity.[103,105]

Health Behaviors as Risk and Protective Factors for Depression and Anxiety

In this dissertation, the risk factors of interest are health behaviors that increase one's likelihood of experiencing a chronic disease and, specifically, depression and/or anxiety. Protective factors are defined as health behaviors that reduce one's likelihood and risk of depression, anxiety, and/or other chronic diseases. Modifiable health behaviors can be both risk and protective factors for all chronic diseases. An effort to better understand and address health behaviors emerged in the mid-twentieth century; today, health behaviors account for roughly 35% of premature deaths in the US each year.[9]

Health behaviors are individually taken actions that affect one's health or mortality.[147] They are dynamic and can change over the lifespan, across settings, over time, and across cohorts; they can be evaluated on individual, community, and population levels across a vast variety of behaviors, including but not limited to actions such as sleep, diet, physical activity (PA), smoking cessation, limited alcohol consumption, and weight management.[147]

While often considered an individual-level factor, health behaviors are heavily influenced by cultural norms, marketing, ease, costs, expectations, social implications, and community access.[68] For example, neighborhoods that promote healthy behaviors such as physical activity, healthy eating habits, and community connection often promote access to safe walking paths, parks, and grocery stores.[68] Despite this, there has been an increasing need for research evaluating health behaviors using a sociological lens due to

critiques of existing literature's emphasis on individual choice and responsibility; specifically, those reliant on educating the individual to change their health behavior.[36] By shifting the approach to consider the context in which health behaviors occur, researchers can better understand the social values attached to choices while accounting for societal inequality and power dynamics.[147]

For more than 30 years, United States (US) public health efforts have worked to promote healthy lifestyle behaviors such as consuming a healthful diet, being physically active, maintaining a healthy body weight, smoking cessation, and limiting alcohol intake.[157] A cross-sectional study from 1999 to March 2020 using the National Health and Nutrition Examination Survey (NHANES), demonstrated a modest improvement in overall lifestyle among US adults across five healthy lifestyle factors.[91] This study provides the most comprehensive assessment of US healthy lifestyle behaviors to date, including the following protective factors: never smoking, a healthy diet, sufficient physical activity (PA), moderate or light alcohol consumption, and a healthy body weight.[41,91]

Among individual-level lifestyle trends, Li et al. (2023) found significant improvements in the prevalence of never smoking, meeting sufficient PA levels, and healthy diet consumption. Increased trends in never smoking[37,39] and healthy diet consumption[128,143] are consistent with existing studies, demonstrating increases across both behaviors. Despite advances in modifiable behaviors associated with overall health, alcohol consumption did not change and the prevalence of overall healthy body weight significantly reduced from 33.1% to 24.6% ($p < 0.001$).[91] Importantly, the findings of this study indicated that adhering to a healthy lifestyle was significantly affected by age,

race/ethnicity, education level, and income level.[91] Younger people between the ages of 20 and 34 were more likely to adopt healthy lifestyles over time compared to older populations.[91]

Poor health behaviors (i.e. unhealthy diets, low PA, tobacco smoking, alcohol use) are associated with an increased risk for both mental and physical health conditions.[52,54] Persistent disparities by race/ethnicity, education, and income level indicated that socioeconomic background heavily influences the adoption of healthy behaviors over time. Cross-sectional data revealed that non-Hispanic Black adults and adults with low education and income levels were least likely to report healthy behaviors, and Mexican Americans reported the highest transition from healthy weight to obesity.[91]

Co-Occurrence of Health Behaviors

Examining diverse perspectives, the literature converges on the idea that the co-occurrence of poor health behaviors increases the risk of both mortality and morbidity rates more significantly than the sum of their individual effects.[45,84,109] The insinuated synergist relationship among health behaviors suggests multiple health behavior change (MHBC) interventions are more impactful than those aiming to change one behavior at a time.[20,73,92,122] Health promotion strategies and policies targeting single health behaviors tend to face resistance to health behavior change.[147] Additionally, the interrelationship among health behaviors emphasizes the need to better understand how health behaviors co-occur and contribute to health outcomes. Despite this, a vast majority of literature evaluates the impact of health behaviors individually, rather than as a collective.

The concept of "healthy lifestyles" has gained traction for successfully changing health behaviors by understanding the foundational interplay among them.[36,114] This

approach acknowledges the co-occurrence of health behaviors at the individual level while embracing the influence of social determinants, such as deeply rooted identities (i.e., cultural and social group membership, etc.) and environmental factors (i.e., access to safe built environments, etc.), to promote health behaviors.[36,114,147] Targeting multiple health behaviors rather than a single health behavior produces more successful outcomes. A meta-analysis conducted by Loef and Walach (2012) reported a 66% reduced risk of all-cause mortality when individuals engaged in a combination of at least four healthy behaviors (diet, PA, obesity, smoking, and/or alcohol). There is a strong association between socioeconomic status and the co-occurrence of risky health behaviors among adults.[100,108] A study examining clustered behaviors of smoking, low PA, and risky drinking among older adults of differing socioeconomic statuses (SES) found multiple risky health behaviors were more common among individuals of a lower SES compared to those of higher SES.[144]

Literature investigating health behaviors and mental health is limited. PA has been established as a reliable strategy for reducing depression and anxiety symptoms[13,99,188] and the consumption of well-balanced diets is associated with promoting good mental health.[187] Co-occurring unhealthy behaviors work synergistically to worsen both physical and mental health;[5] however, more research is necessary to understand how co-existing lifestyle factors influence depression and anxiety over time. Understanding how health behaviors co-occur, and impact mental health is important for public health policy and health promotion.

American Cancer Society Guidelines for Diet and Physical Activity

Poor diet and physical inactivity are two of the leading causes of death in the US, including cancer.[135] In 2014, an analysis of the combined effects of maintaining a healthy body weight, consumption of a healthy diet, sufficient physical activity, and limited or reduced alcohol intake accounted for 18.2% of cancer cases and 15.8% of cancer mortality in the US.[72]

To provide health recommendations for reducing cancer risk related to modifiable health behaviors, the American Cancer Society (ACS) published its latest guidelines for diet and physical activity in 2020. The ACS Guidelines for Cancer Prevention was first published in 1984,[6] and has since been updated five times: 1991,[172] 2002,[26] 2006,[85] 2012,[86] and 2020;[135] each time revising to reflect evolving scientific evidence and research. The ACS Guidelines provide evidence-based recommendations for health care professionals, policymakers, and the general public consistent with existing recommendations for chronic disease prevention and health promotion, including the US Department of Health and Human Services (USDHSS) Dietary Guidelines for Americans (ADA),[142] the USDHSS Physical Activity Guidelines for Americans,[158] dietary guidelines for preventing and managing diabetes[50] and heart disease,[22,46,176] the Centers for Disease Control and Prevention (CDC) cancer prevention guidance,[30] and guidelines from the World Cancer Research Fund/American Institute for Cancer Research (WCRF/AICR).[130] The Guidelines advise avoiding obesity by maintaining a healthy body weight throughout life, being physically active, limited or no alcohol consumption, and following a healthy eating pattern.[135]

To our knowledge, there is no existing research evaluating the effects of adhering to all components of the 2020 ACS Guidelines on the risk of mental illness. Previously, adherence to all components of the 2006 ACS Guidelines was associated with a lower risk of all-cause death, cardiovascular disease (CVD), and cancer.[98] McCullough et al. (2011) found following all components of the cancer prevention guidelines significantly reduced the risk of premature death of all-causes. Partial adherence to previous ACS Guidelines has been examined in earlier literature. An observed risk reduction of 19% to 31% for breast cancer incidence was associated with adhering to the 2012 ACS Guidelines.[27,76,153] Furthermore, a randomized controlled trial among perimenopausal and early postmenopausal female cancer survivors found partial adherence to the weight, diet, and PA components of the 2020 ACS Guidelines to potentially reduce breast cancer risk.[56] This study also found that adherence rates were higher among younger participants compared to that of older participants.[56]

Preliminary findings from a manuscript under review found higher individual scores of the 2021 ACS Guidelines for Cancer Survivors, which builds off the 2020 ACS Guidelines for Cancer Prevention, to be associated with a lower risk of all-cause mortality.[185] The study examines the association of following the 2021 ACS Guidelines for Nutrition and Physical Activity for Cancer Survivors with all-cause mortality among obesity-related cancers. Among 7,945 cancer survivors (mean age 68.4 years, 37.8% women), those that followed the ACS Guideline to consume a healthy diet, reduce alcohol intake, maintain a healthy body weight, and engage in physical activity had a 21% lower risk of mortality than those with inconsistent behaviors with the guidelines.[185] Healthy BMI and PA scores demonstrated the strongest association with all-cause

mortality, further supporting that protecting against obesity, a known cause of cancer and contributor to poor mental health, can improve health outcomes. Physical activity demonstrated a strong protective factor among healthy weight and overweight/obese participants.[185] These findings emphasize the importance of adhering to a healthy lifestyle such as one instructed by the recommendations of the ACS Guidelines.

Social Determinants of Mental Health

Over the last two decades, public awareness and advocacy of mental health has resulted in multi-year reductions in public stigma leading to more positive attitudes towards mental health conditions; paralleling the increase of individuals seeking help.[67,111,117] The importance of the psychosocial factors associated with mental health remains a peripheral focus; nonetheless, the World Health Organization (WHO) has stressed the significant need to address environmental influences on mental health,[180] and the United Nations (UN) Sustainable Development Goals identified mental health and well-being as specific outcomes alongside tackling various social determinants of health (SDoH).[161]

SDoH are social and environmental contextual factors that predispose individuals to poor health outcomes and individually influence risk and protective factors for chronic disease and mental illness.[42,183] The National Research Council and Institute of Medicine (2013) distinguish income, accumulated wealth, education, occupational characteristics, and social inequality based on race/ethnicity as the most important social factors determining health. SDoH have direct effects on both risk and protective factors contributing to unhealthy and healthy lifestyles and health equity.

Health equity occurs when everyone has fair and just opportunities to achieve good health and coexists in addressing SDoH.[28] In general, the lower one's socioeconomic conditions, the worse their health.[183] Several social factors can initiate and contribute to poor mental health outcomes. For example, unreliable working conditions and unemployment are linked to higher rates of psychological distress.[129] A longitudinal population-based study conducted amongst a British population suggested a correlation between persistent housing problems and poor mental health in which poor quality housing was predictive of worsened mental health.[118] In the US, cross-sectional studies have linked poorer mental health with food insecurity and poor diet quality.[90,96] Furthermore, a cross-sectional study conducted during the COVID-19 pandemic found identifying to minority groups linked to higher reports of anxiety among college students ($p < 0.01$).[124] Students that were in the minority race at both Predominantly White Universities (PWU) and Historically Black Universities (HBU) reported higher rates of depression than the more dominant race (1.76% compared to 0.53% at PWU, and 11.1% compared to 2.4% at HBU); suggesting racial status may influence depression and anxiety.[124]

SDoH are often linked to physical health; however, a growing body of evidence highlights the association between SDoH and poor mental health.[42,77,78,89,113,134] Mental health is an independent risk factor for overall poor health status, including higher rates of chronic diseases and premature death.[77,78,89,113,134] Furthermore, the vast impact of SDoH on individual and community well-being highlights the long-term health impacts of socioeconomic status (SES) and mental health. Research has shown SES has an inverse dose-dependent relationship with adverse childhood experiences, leading to

developmental disruptions linked to increased prevalence of mental and chronic disease into adulthood.[88,146] There is a significant public health need to better understand the link between mental health and SDoH to improve health equity.[42]

SDoH are the most modifiable targets for intervention, prevention, and promotion of mental health.[81] Across the literature, the link between mental health and social determinants of health is prominent. Exposure to adversity is highly influential and detrimental to mental health; for example, inequities and barriers to healthcare access often leads to difficulties seeking care, taking prescribed medications, and engaging in healthy behaviors.[16,154] This chain reaction results in increased chronic disease risk and higher degrees of depression and anxiety.[104] Furthermore, the prevalence of anxiety and depression varies by sex and age. Across the lifespan, women are 50% more likely to experience depressive or anxiety disorders than men.[119,121,180] Compared to depression, anxiety becomes more prevalent at an earlier age, however, both increase and become more common as individuals age.[119,121,180] Socially marginalized groups including but not limited to sexual minorities, long-term unemployed, homeless, and indigenous peoples have greater risks for mental illness.[119,121,180] Addressing the social determinants of mental health requires a multifaceted approach to better understand how the intersectionality of various SDoH impact health behaviors that protect against and/or lead to mental illness.

Social Determinants of Health (SDoH)

Accounting for nearly 50% of health outcomes, social determinants of health (SDoH) are defined as non-medical factors such as the conditions in which people live, work, grow, born, and age in.[66,68,183] SDoH include both individual characteristics such as

education, income, and health beliefs; as well as social and structural factors including access to built environments, healthy foods, employment, and working life conditions.[66,183] Determinants are influenced by community- and population-level environments and policies; for example, communities that do not provide a grocery store, affordable housing, public transportation, or economic opportunities do not promote health.[59] Thus, SDoH are a multifaceted public health concern; addressing them can improve health equity, providing an equal opportunity for all persons to achieve their best health.[29] Due to their significant impact on individual well-being and health, SDoH are a key focus of Healthy People 2030; further emphasizing the importance of understanding the role social, physical, and economic environments have on health equity.[66,183] There is a wide array of SDoH that contribute to health disparities and inequities such as safe housing, clean water and air, reliable transportation, access to nutritious foods, and built environments such as sidewalks and parks for physical activity.

Five Domains of SDoH

Healthy People 2030 categorizes the various SDoH across five domains: (1) economic stability, (2) education access and quality, (3) health care access and quality, (4) neighborhood and built environment, and (5) social and community context.[66] Economic stability encompasses determinants that impact or relate to an individual's ability to earn a steady income for meeting their health needs; examples include employment, poverty, housing instability, and food insecurity.[66] Research has demonstrated that as education levels increase, the likelihood an individual is to be healthy and live longer increases.[123] Therefore, access to and the quality of education is a significant determinant to one's health. Inadequate access to health care due to lack of

services, insurance coverage, limited resources, and transportation barriers drive preventative health outcomes.[59] Ensuring individuals have access and quality health care is essential to reducing health disparities and promoting health; which in turn can directly reduce chronic disease rates and premature mortality.[59,63]

Determinants that fall under the neighborhood and built environment domain include access to healthy foods, crime and violence, environmental conditions, and the quality of housing.[66] Eating a healthy diet is critical for reducing chronic diseases.[31,84,92,107,128,140,142,143] The 2020-2025 Dietary Guidelines for Americans define a healthy diet as one consisting of nutrient-dense foods and beverages across all food groups, consumed within recommended amounts and caloric limits.[142] It includes a variety of fruits, vegetables, whole grains, low- or fat-free dairy, and protein; added sugars, alcohol intake, sodium, and saturated fats are limited.[142] Reduced access to healthy foods leads to poor nutrition, raising the risk of mental illnesses and chronic diseases such as depression, anxiety, obesity, diabetes, and heart disease. For example, barriers within rural and economically disadvantaged communities lead to disproportionately higher mortality and morbidity rates of chronic diseases, especially those associated with obesity.[19] Compared to urban areas, healthy foods are often more expensive in rural areas; this impacts their availability, leading to a higher abundance of less healthy food and contributing to obesogenic environments characterized by increased chronic disease rates.[19] A cross-sectional study assessing socioeconomic and geographic factors associated with diet quality within ACS's Cancer Prevention Study-3 (CPS-3) cohort, found race/ethnicity, education, income, rural vs urban residence, and residing in a food desert to be independently associated with poor diet quality.[97] Poor diet quality is a

significant risk factor for chronic diseases and can contribute to worsened mental health.[48,149] Crime and violence within a neighborhood can impact individual's ability to safely engage in health behaviors such as PA. Meyer et al. (2014) found poor self-reported mental and physical health to be linked to fears of neighborhood safety. Furthermore, access to safe, clean water and air are basic human needs, and inescapable environmental conditions of daily life that impact one's health.[64]

Substantial evidence over the past 30 years has shown social support as a significant contributor to overall better health, aging, and well-being.[80,132,159] Positive relationships and social support can reduce negative health impacts from depression and chronic diseases.[183] Research suggests social support may serve as a protective factor against mental illness by providing individuals with a sense of stability and increasing how individuals feel about themselves, thus impacting their risk for chronic diseases and mental health.[80] Several studies have found perceived social support and a sense of community to be associated with lower cardiovascular risks.[80,132] Social and community contexts are driven by the conditions people live, work, learn, and age. A deeper understanding of how health behaviors captured in the ACS Guidelines are impacted by socioeconomic and environmental determinants of health is needed to better address health inequities and disparities within at-risk populations and communities.

SDoH Influence on Health Behaviors

Poor health behaviors such as smoking, alcohol consumption, poor diet, and physical inactivity are associated with socioeconomic status and health outcomes.[148] Neighborhoods and environments contribute significantly to individual health behaviors. Mackenbach et al. (2008) found carbohydrate-rich diets, smoking, and excessive alcohol

use as a means for coping with stressful and difficult circumstances. The adoption of risky health behaviors is often the response to stress from social determinants of health.[94,148]

Due to the strong influence social, economic, and cultural factors have on individual choices regarding diet and PA, components of the ACS Guidelines have been used to examine social determinants of health. A 2022 cross-sectional study used the diet score to evaluate the association of diet quality with socioeconomic and geographic factors among US adults.[97] McCullough et al. (2022) found poor diet quality was independently associated with race/ethnicity, education, income, rural vs urban residence, and residing in a food desert. Black participants had a 16% higher risk of poor diet scores than White participants; high income and education levels were protective factors against poor diet quality, however, income only related to diet quality among White participants.[97] Lastly, residing in urban areas served as a protective factor against poor diet quality.[97]

Conceptual Framework

SDoH Conceptual Model

Health and health-related behaviors are profoundly influenced by SDoH. The WHO's Commission on Social Determinants of Health (CSDH) conceptual framework draws on the idea that health behaviors are correlated with a multitude of health outcomes occurring at both individual and population levels (see Figure 2.1).[148] It shifts the traditional lens of individual responsibility to account for the myriads of factors affecting health behaviors. The CSDH seeks to (1) identify SDoH and health inequities, (2) demonstrate the intersectionality and relatedness amongst determinants, (3) illuminate the

mechanisms of SDoH leading to health inequities, and (4) provide a framework for evaluating SDoH according to importance.[148]

The framework models how social, economic, and political factors contribute to socioeconomic positions that classify populations according to income, education, occupation, race/ethnicity, gender, and other factors. The primary mechanism for health inequity generated by socioeconomic position is demonstrated by intermediary determinants of SDoH within the CSDH; including the capacity of a health system to influence differences in exposures, vulnerability, and consequences of illnesses on people's health.[148] The CSDH assumes that compared to higher socioeconomic groups, lower socioeconomic populations live in less favorable neighborhood, housing, and working conditions; leading to higher engagement of risky health behaviors and reduction of protective health behaviors compared to their more privileged counterparts.[148]

Behavioral and biological factors encompass both risk and protective health behaviors such as smoking, diet, alcohol consumption, PA, and genetic factors such as age and sex.[148] Psychosocial or social-environmental factors include stressors (i.e., high debt, negative life events, job strains, etc.) and social support (or lack of). Socioeconomic positions may be a source of long-term stress; contributing to how individuals handle stressful and difficult situations. The CSDH attempts to represent and distinguish between the social causes of health and the determining factors leading to the distribution of causes;[148] thus, the CSDH guides the proposed studies of this dissertation.

Gaps in Literature

The synthesis of existing research illuminates numerous gaps that this dissertation aims to address. The interrelationship amongst health behaviors has been demonstrated, yet few studies investigate this co-occurrence, and the ones that do are primarily cross-sectional.[20,73,87,92,122] Similarly, existing evidence on the relationship between mental health and health behaviors (both independent and co-occurring) consists primarily of cross-sectional studies[25,60,74,109,150,165] and very few longitudinal studies, of which focus on adolescents or young adults,[184] the COVID-19 pandemic,[43,189] and/or smaller sample sizes.[25] There is an opportunity and need to investigate the intersectionality of various social determinants of health on co-occurring health behaviors and their longitudinal association with mental health outcomes using a large diverse, prospective sample of US adults. This dissertation is the first study to the author's knowledge to assess complete adherence to the 2020 ACS Guidelines for Diet and Physical Activity for Cancer Prevention. Complete adherence to the 2020 ACS Guidelines as a measure for capturing co-occurring health behaviors may provide a better understanding of the relationships between SDoH, health behaviors, and mental health; identify potential health promotion opportunities for improving health behaviors; thus, health outcomes and reducing the disproportionality of the burden of disease. The Cancer Prevention Study-3 (CPS-3) study has been used to examine numerous health topics to better understand lifestyle, genetic, and other factors in the etiology of cancer and chronic diseases over the lifetime.[97,116,126] However, CPS-3 has only been used once to evaluate mental health.[127] Investigating mental health with a prospective cohort study such as the

CPS-3 cohort may shed light on mental health across an aging population of US adults; a gap in the literature that this study strives to fill.

Specific Aims

This dissertation aimed to a) identify social determinants of health (SDoH) associated with co-occurring health behaviors captured in the 2020 American Cancer Society (ACS) Guidelines for Diet and Physical Activity for Cancer Prevention score and b) investigate the association between ACS Guideline scores in 2015 and self-reported anxiety and depression in 2021 among a diverse sample of aging adults in the United States. The central hypothesis is that as SDoH increases, ACS Guideline scores will decrease, thus increasing future anxiety and depression. Using the two-manuscript format, this dissertation addresses the following specific aims:

1. **Identify the social determinants of health (SDoH) associated with co-occurring health behaviors captured by ACS Guideline scores in the CPS-3 study** *(manuscript one).*
    a. Examine the relationship between multiple SDoH (including race/ethnicity, income, marital status, education level, work status, rurality, food desert status, and second-hand smoke exposure) and co-occurring health behaviors measured to calculate the ACS Guideline score (i.e. diet, PA, alcohol consumption, BMI).
        i. Hypothesis 1a. Higher ACS Guideline scores (indicating adherence to co-occurring healthy behaviors) will be inversely associated with experiencing multiple SDoH.

2. **Examine the association between ACS Guideline scores and self-reported mental health outcomes for anxiety and depression** *(manuscript two).*
    a. Describe the temporal relationship between ACS Guideline scores (2015) and self-reported anxiety and depression (PHQ-4 collected in 2021).
        i. Hypothesis 2a. ACS Guideline scores will predict anxiety and depression; Higher adherence to the ACS Guidelines (higher scores) will be associated with lower PHQ-4 scores (self-reported anxiety and depression).

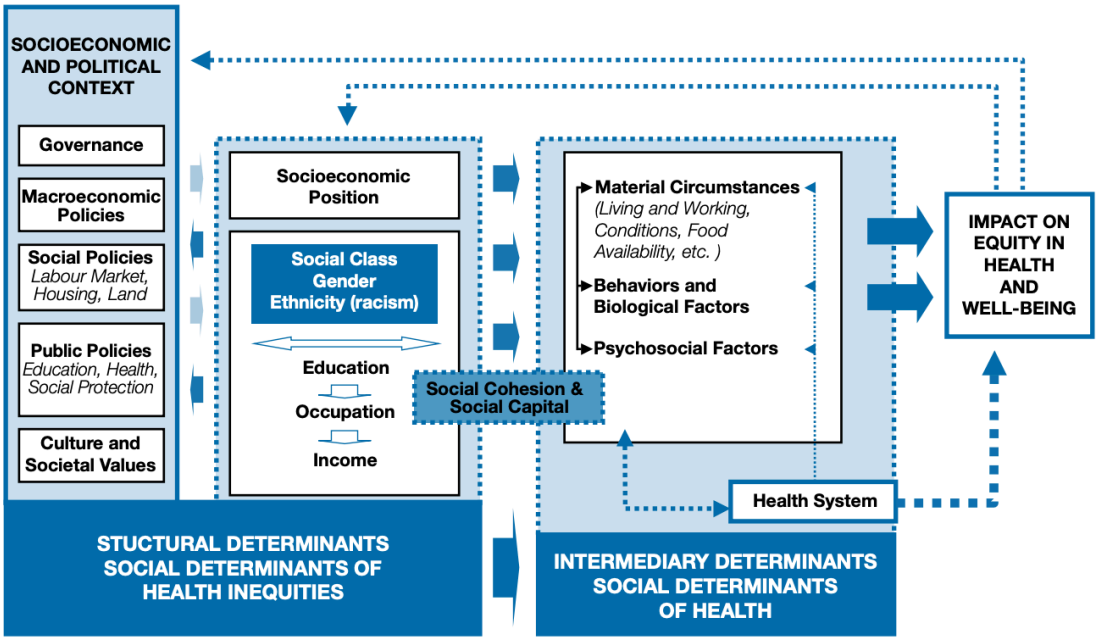

Figure 2.1. Final Form of the CSDH Conceptual Framework[148]

CHAPTER 3

THE ASSOCIATION OF SOCIAL DETERMINANTS OF HEALTH WITH ADHERENCE TO THE AMERICAN CANCER SOCIETY NUTRITION AND PHYSICAL ACTIVITY GUIDELINES FOR CANCER PREVENTION[1]

[1]Chiang K, Padilla HM, Chantaprasopsuk S, Bates-Fraser L, Patel AV, McCullough ML, Callands TA, Muilenburg JL, Rees-Punia E. To be submitted to *JAMA OPEN.*

Abstract

IMPORTANCE: Influenced by social determinants of health (SDoH), health behaviors are often considered separately, despite being interrelated. Understanding the ways health behaviors co-occur, while exploring the intersectionality of SDoH, may present opportunities for improving health equity.

OBJECTIVE: To identify SDoH associated with co-occurring health behaviors captured by American Cancer Society (ACS) Guideline scores in a large US cohort.

DESIGN, SETTING, AND PARTICIPANTS: 142,085 adults in the Cancer Prevention Study-3 were included in this cross-sectional study. Enrollment occurred between 2006 and 2013 at ACS community events across 35 US states, the District of Columbia, and Puerto Rico. Participants completed comprehensive follow-up surveys in 2015. Data was analyzed from June to September 2024 using multivariate ordinal logistic regression.

EXPOSURES: Self-reported race and ethnicity, marital status, education, household income, second-hand smoke exposure, and work status were examined. Rural-Urban Commuting Area codes and food desert status as classified by the US Department of Agriculture's Food Access Research Atlas database were also included as SDoH exposures.

MAIN OUTCOMES AND MEASURES: Co-occurring health behaviors were measured using a 0 to 8 point score quantifying adherence to the 2020 ACS Guidelines for Cancer Prevention on diet, alcohol, body weight, and physical activity. Scores of 8 represented optimal adherence.

RESULTS: Of 142,085 participants, the mean (SD) age was 53 (9.6) years and 79% were women (n = 111,694). 2.4% of women and 1.6% of men received a score of 8.

126,788 of participants identified as White; 3,677 identified as Asian, Native Hawaiian, Pacific Islander, or American Indian individuals; 3,232 identified as Black; 7,767 identified as Latino; and 621 identified as other. Participants with higher ACS Guideline scores were more likely to be female, Asian, hold graduate degrees, have gross household incomes of $125,000 or more, reside in metropolitan, non-food desert areas, be married or living with a partner, and experience no second-hand smoke (SHS) exposure. Joint variable models demonstrating intersectionality of SDoH revealed significant racial disparities among Black participants for socioeconomic factors and higher adherence among never married men, metropolitan females, and individuals with no second-hand smoke exposure making ≥$125,000.

CONCLUSIONS AND RELEVANCE: This study identified groups at the highest risk of poor health behaviors to inform future approaches for advancing health equity.

Introduction

Nearly 50% of health outcomes can be attributed to social determinants of health (SDoH), the non-medical social and environmental factors that influence people's living, working, growing, and aging conditions.[183] SDoH influence health behaviors, including but not limited to diet, physical activity (PA), alcohol consumption, weight management, sleep, and smoking; which are interrelated and often co-occurring.[45,68] Health behaviors are important for disease prevention and historically been investigated for their individual effects, but evolving evidence suggests greater successes among interventions targeting multiple health behaviors.[100,108]

Various demographic, socioeconomic, and geographic factors are important determinants of health behaviors and ultimately health outcomes. Findings from a systematic review investigating the relatedness of modifiable health behaviors attribute lower socioeconomic status (SES) as a key driver to clusters of risky behaviors, such as smoking, low PA, and high alcohol consumption.[108] Moreover, findings from the English Longitudinal Study of Ageing found multiple poor health behaviors to be less common among individuals with higher SES.[144] While the interrelationship amongst health behaviors has been demonstrated, most associations with SDoH are investigated in isolation despite evidence of clustering,[108] and fail to demonstrate the mechanisms in which SDoH intersect to influence health behaviors.[148]

The World Health Organization's (WHO) Commission on Social Determinants of Health (CSDH) conceptual framework provides guidance on identifying SDoH, including how major determinants cluster and interact to influence health behaviors and outcomes.[148] There is a need to understand the ways health behaviors co-occur and

contribute to overall health, while also exploring the intersectionality of social determinants of health; utilizing the CSDH framework may present opportunities for understanding these associations and advance health equity.

The 2020 American Cancer Society (ACS) Guidelines for Cancer Prevention provide lifestyle recommendations for diet, alcohol, body weight, and physical activity. Numerous studies have demonstrated adherence to the ACS Guidelines as a reliable and valid measure for assessing all-cause mortality, cancer, and cardiovascular disease (CVD) risk.[27,76,98] Associations between the ACS diet component and SDoH have been demonstrated. McCullough et al. (2022) found White individuals with limited income, Black individuals, low educational attainment, and residing in a food desert or rural area to increase the risk of poor diet quality. The ACS Guidelines underscore the need to analyze social, economic, and environmental influences that shape dietary and lifestyle choices responsible for driving health inequities in the US.[135] Thus, adherence to the ACS Guidelines may serve as an aggregate measure for diet, PA, alcohol consumption, and body weight.

This cross-sectional study sought to identify social determinants of health (SDoH) associated with co-occurring health behaviors in a diverse and large prospective cohort of aging U.S. adults. We used adherence to the 2020 ACS Guidelines to examine the intersectionality of select SDoH with diet, PA, alcohol consumption, and body weight.

Methods

Study Population

The Cancer Prevention Study-3 (CPS-3), initiated by ACS between 2006 and 2013, is a prospective cohort study examining cancer incidence and mortality across 35

states, including the District of Columbia and Puerto Rico.[116] Over 304,000 participants aged 30 to 65 years without a history of cancer, except basal or squamous cell skin cancer, were enrolled at various community events. At enrollment, participants provided blood samples, written informed consent, and detailed family and lifestyle histories followed by the completion of a baseline survey at home. Repeat surveys were issued triennially to update exposure information. Due to space restrictions and participant burden, dietary assessment was not comprehensively collected until the first follow-up survey in 2015.[116] 186,638 participants returned the 2015 follow-up survey assessing diet, with 177,345 participants (69.9% of the active cohort) completing the CPS-3 Food Frequency Questionnaire (FFQ).[97,116] Further detailed descriptions regarding participant characteristics, cohort descriptions, and recruitment are described by Patel et al. (2017). The CPS-3 is approved by the Institutional Review Board at Emory University.

Exclusions

Complete data from the 2015 CPS-3 survey was necessary for calculating an ACS Guideline score and required to be included in this study. Individuals were excluded from this analysis if they had missing information for physical activity (n=930) or alcohol use (n=197), missing or underweight BMI (n = 3,719), those who did not complete the food frequency questionnaire (FFQ) (n = 9,293), or missing race/ethnicity (n = 1,446). Additional exclusions included 1,309 participants missing two or more sections of the FFQ, 588 participants missing an entire page of the FFQ (paper version), 5,394 participants with improbable energy (kcal), 193 participants missing more than 100-line items on the FFQ, 5,174 participants that were currently pregnant, and 423 for top 0.05% of food groups.

Measures

ACS Guideline Score

An *a priori* score was developed to quantify lifestyle behaviors consistent with the 2020 ACS Guidelines on Nutrition and Physical Activity for Cancer Prevention[135] and an earlier score developed by McCullough et al. (2011). Each of the four guidelines were weighted equally from 0 to 2, with 2 indicating optimal behavior/full adherence; 1 representing partial adherence; and 0 signifying recommendations are not met. Appendix A summarizes the details of this scoring system.

The first recommendation of the 2020 ACS Guidelines is to *"achieve and maintain a healthy body weight throughout life,"* and was scored in this study using height and weight reported in the 2006-2013 baseline survey and weight from 2015 follow-up survey. Assessing BMI across two time points provides a long-term measure of BMI in adulthood across multiple years; this method was used by McCullough et al. (2011) when compiling ACS Guideline scores to assess adherence to all-cause mortality risk. Underweight individuals with a BMI below 18.5 kg/m^2 were excluded. Those with a normal weight BMI of 18.5 to < 25 kg/m^2 at both collection times received an optimal score of 2. Individuals reporting an obese weight status with a BMI of ≥ 30 kg/m^2 at both collections or obese at one collection and overweight (25 to <30 kg/m^2) at another, received the lowest possible score of 0. A score of 1 was given to those who reported a BMI in any other combination (i.e. normal weight and overweight; overweight and normal weight, etc.).

The ACS Guidelines for Physical Activity recommend adults to *"engage in 150-to-300 minutes of moderate-to-vigorous physical activity per week, or 75-to-150 minutes*

of vigorous-intensity physical activity, or an equivalent combination achieving or exceeding the upper limit of 300 minutes per week is optimal."[135] Participant reported weekly average time spent engaging in recreational PA was converted to metabolic equivalent value (MET) scores. One MET is equivalent to the energy expenditure associated with sitting quietly; PA is often rated in exercise research using METs to signify its intensity, ranging from light (< 3.0 METs-hours), moderate (3.0-5.9 METs-hours), and vigorous (6.0 METs-hour or more).[61,158] Therefore, for the physical activity score, MET-hours/week of 15 or more received a score of 2, indicating optimal recommendation levels; MET-hours/week ranging from 7.5 to 15 METs earned a score of 1, and MET-hours/week less than the minimum weekly recommendation of 7.5 METs received a 0.

The third ACS Guideline recommends following a healthy eating pattern, detailed extensively in previous literature.[135] Survey and sex-specific intake quartiles were created for intake and varieties of fruit and vegetables; and intakes of whole grains, red/processed meats, sugar-sweetened beverages (SSBs), and highly processed food or refined grains. Higher scores were associated with those in the higher quartile of intakes and varieties for fruits and vegetables (0-3 points) and whole grain intake (0-3 points). Scores were inversed with higher consumptions of red/processed meats (3-0 points) and SSBs and HPF/RG intake (combined and totaling to 3-0 points). The four dietary sub-scores were then summed to create a diet score ranging from 0 to 12; with 12 indicating optimal diet quality. To ensure diet received the same weight as the other three factors in the ACS Guidelines, diet scores were rescaled on a 0-to-2-point scale where 0 was given to those with <4 on the 12-point scale; 1 point for 4 to <8; and 2 points for scores between 8 to 12.

The ACS Guidelines recommend it is best to refrain from drinking alcohol; those that choose to should, *"limit their consumption to no more than 1 drink per day for women and 2 drinks per day for men."*[135] The least favorable score of 0 was awarded to those who consume >1 drink/day for women and >2 drinks per day for men; 1 point was given to those who drank ≤ 1 drinks/day for women and ≤ 2 drinks/day for men; nondrinkers (0 drinks/day) received 2 points.

Total ACS Guideline scores were then compiled by the sums of each category, with overall scores ranging from 0, denoting recommendations were not met; to 8, full adherence/optimal behaviors. Small numbers in analysis led to overall ACS scores in the tail distributions (0, 1, and 2 for lowest scores; 7 and 8 for highest scores) to be combined.

Exposure Variables: Social Determinants of Health

The WHO's Commission on Social Determinants of Health (CSDH) conceptual framework[54] and Healthy People 2030 domains for SDoH guided the selection of social, economic, and geographical factors measured in this study among the CPS-3 cohort. Demographics (i.e., age, gender, race/ethnicity, and marital status); economic stability (work status and income); neighborhood/environment factors (i.e., urban/rural residence, residing in a food desert, and second-hand smoke exposure); and education level were used as exposure variables.

Ethnicity was assessed during enrollment using the question, "Do you consider yourself to be Hispanic or Latina?" with response options of "no" and "yes." Self-reported race was assessed by the question, "What is your race? (mark ***all*** that apply)," and included the following response options: 'White;' 'Black or African American;'

‘American Indian or Alaskan Native;’ ‘Asian;’ ‘Native Hawaiian or Pacific Islander;’ and/or ‘other.’ Race and ethnicity were categorized as Asian, Native Hawaiian, Pacific Islander, or American Indian (grouped due to small numbers); Black; Latino; and other. Participants were asked, “Which of the following describes your **current** gross household income (before taxes)?” The following were response options, “Less than $15,000,” “$15,000-$24,999,” “$25,000-$49,999,” “$50,000-$99,999,” “$100,000-$149,999,” “$150,000 or more.” Due to small sample sizes within these categories, household income categories were collapsed into “Less than $50,000,” “$50,000-<$75,000,” “$75,000 to <$100,00,” “$100,000 to <$125,000”, and “$125,000 or more.” Work status was measured by asking, “What is your **current** work status?” and quantified as ‘work full-time for pay (hereby as full-time);’ ‘work part-time for pay (hereby called part-time);’ ‘retired;’ ‘volunteer;’ ‘homemaker;’ ‘disabled;’ ‘student;’ and ‘unemployed.’ Homemaker, unemployed, disabled, student, and volunteer were collapsed and categorized as ‘Other.’

Rural-urban commuting area (RUCA) code and residence in a food desert were assessed using variables previously classified by US census tracts and described by McCullough et al. (2022). Participant residence (RUCA) was categorized as ‘metropolitan,’ ‘micropolitan,’ ‘small town’, and ‘rural’ to assess the difference among ACS Guideline scores among various residential settings. Residing in a food desert was measured using the existing variable developed by McCullough et al. (2022) based on the US Department of Agriculture Food Access Research Atlas database, in which CPS-3 participants were categorized as living in food deserts, ‘yes’ or ‘no.’

Participants were asked, “In the past 6 months, how often were you around the tobacco smoke of other people?” Participants could choose between the following response options: ‘Never,’ ‘<1 day/week,’ ‘1-2 days/week,’ ‘3-6 days/week,’ and ‘Every day.’ The US Surgeon General and CDC report any exposure to second-hand smoke is harmful;[32,62] therefore, second-hand smoke was categorized as “any” and “never.” Smoking status was categorized as “never,” “current,” and “former.”

Joint exposure variables, selected *a priori* and guided by the CSDH framework, were created to assess the intersectionality among various SDoH and ACS Guideline scores. Joint variables containing the RUCA variable collapsed ‘small town’ and ‘rural’ into ‘small town/rural’ due to sparsity within these categories.

Statistical Analysis

Ordinal logistic regression models were used to assess SDoH factors associated with co-occurring health behaviors measured by ACS Guideline scores. Model 1 adjusted for age, sex, and energy intake; model 2 was mutually adjusted to include all main exposures; and mutually adjusted two-way joint variable interaction models were used to explore the influence of intersectionality among various SDoH on ACS Guideline scores. Statistical significance of joint variables was evaluated using Type III Wald analysis of deviance tests. The outcome reference group in all models was set at “0-2;” therefore, all results displayed odds of having higher ACS Guideline scores than the lowest category of 0-2. P-values <0.05 were considered statistically significant. All analyses were conducted in R Studio Pro 2024.04.1 running R version 4.4.0.

Results

111,694 women (79%) and 30,391 men (21%) with a mean (SD) age of 53 (9.6) years were included in the final analytic cohort (n = 142,085). Only 2.4% of women and 1.6% of men received a score of 8, indicating optimal recommendations were met. 89% of participants identified as White; 2.6% identified as Asian, Native Hawaiian, Pacific Islander, or American Indian individuals; 2.3% identified as Black; 5.5% identified as Latino; and 0.4% identified as other. Table 3.1 displays participant characteristics according to ACS Guideline scores. Participants with higher ACS Guideline scores (i.e. 7-8) were more likely to be female, Asian, hold graduate degrees, have gross household incomes of $125,000 or more, reside in metropolitan, non-food desert areas; be married or living with a partner; and experience no second-hand smoke (SHS) exposure.

Associations of individual SDoH and ACS Guideline scores

After adjusting for age, sex, and energy intake (model 1; Table 3.2), all main exposures were statistically significant and independently associated with ACS Guideline scores. Race and ethnicity were strongly associated with guideline adherence, with Asian, Native Hawaiian, Pacific Islander, or American Indian participants exhibiting 43% higher odds of higher ACS Guideline scores compared to their White counterparts (OR = 1.43, 95% CI $[1.43, 1.43]$). Black and Latino participants had 32% lower odds of higher ACS scores (OR = 0. 68, 95% CI $[0.68,\ 0.68]$) and 6% (OR = 0. 94, 95% CI $[0.94, 0.94]$), respectively. Lower income was associated with significantly reduced odds of adherence, with participants earning less than $50,000 having 51% lower odds (OR = 0.49, 95% CI $[0.47,\ 0.50]$) compared to those earning $125,000 or more. Similar trends were observed for education, as individuals with a high school education or less had 51%

lower odds of adherence (OR = 0.49, 95% CI [0.49, 0.50]), while those with a graduate degree had 33% higher odds (OR = 1.33, 95% CI [1.30, 1.36]) compared to college graduates. Living in nonmetropolitan areas, residing in a food desert, and second-hand smoke (SHS) exposure of any kind were independently associated with lower ACS Guideline scores (Table 3.2).

In the fully adjusted model (model 2), associations between Latino individuals and those never married were no longer statistically significant (Table 3.2). Additionally, the odds of higher ACS Guideline scores among divorced, separated, or widowed participants went from being 16% lower in model 1 (OR =0.84, 95%CI [0.81, 0.86]) to 7% higher in model 2 (OR = 1.07, 95% CI [1.05, 1.10]) compared to those married or living with a partner. Across both models, working full-time was associated with lower ACS Guideline scores (Table 3.2). Aside from noted exceptions, associations between SDoH and ACS scores attenuated after mutually adjusting for all other main exposures (model 2; Table 3.2).

Joint associations of intersecting SDoH and ACS Guideline scores

There were notable sex differences in how marital status influenced ACS Guideline adherence. Among those who never married, men were more likely, and women were less likely to adhere compared to women married or living with a partner (Table 3.4; Figure 3.1). Female metropolitan participants had higher ACS Guideline scores compared to all other sex and residential group combinations (Table 3.4; Figure 3.2). Joint associations among sex and race/ethnicity suggested Black female participants had 39% lower odds of high ACS Guideline scores compared to White females (OR = 0.69, 95% CI [0.69, 0.69]); the highest risk of low ACS Guideline adherence among all

race and gender combinations (Table 3.3; Figure 3.4). Higher ACS Guideline scores were associated with not working full-time across both sexes except for men in the other category, who had 5% lower odds compared to full-time working women (OR = 0.95, 95% CI [0.95, 0.95]; Figure 3.3).

Protective associations were seen among higher income and education levels; however, this was not the case across all racial and ethnic groups. Across all education and income levels, Black participants had significantly lower odds of ACS Guideline adherence compared to the reference groups (Table 3.3; Figure 3.6). Asian, Native Hawaiian, Pacific Islander, or American Indian participants earning $125,000 or more had 40% higher odds of higher ACS Guideline scores compared to White participants in the same income bracket (OR = 1.40, 95% CI [1.40, 1.41]). Regardless of race and ethnicity, participants earning lower incomes had lower scores (Table 3.3; Figure 3.5). ACS Guideline adherence decreased as income lowered across participants with and without SHS exposure compared to individuals earning $125,000 or more with no SHS exposure (Table 3.5; Figure 3.7).

Discussion

In this study, race and ethnicity, income, marital status, educational attainment, rural vs urban residence, living in a food desert, work status, and second-hand smoke (SHS) exposure were all independently associated with co-occurring health behaviors measured by the ACS Guideline scores for cancer prevention. Lower socioeconomic status (i.e., lower income, lower education) and rural living were associated with lower adherence. Second-hand smoke exposure was also a strong predictor of lower adherence; while being retired, having higher education, or identifying as Asian, Native Hawaiian,

Pacific Islander, or American Indian were associated with higher guideline scores/adherence.

Higher income and education did not have protective associations across all racial groups. Among Black participants with advanced degrees, the odds of high ACS Guideline adherence were 17% lower compared to that of White college graduates. Previous work found similar findings predicting mortality rates among the highest-educated Black individuals were comparable to lower-educated Asian and Hispanic individuals.[23] Educational attainment has been demonstrated as a significant influence on health and longevity, with notable differences among race and ethnic groups.[110] As education increases, physical activity, alcohol consumption, and diet quality tend to decrease among Black and Latino populations compared to White counterparts.[14,40,97,138] Longstanding associations between race and educational attainment have reported White individuals experience greater health benefits from education across races and ethnicities.[175] A cross-sectional study using NHANES data investigating the interaction between education and race on ideal cardiovascular health (CVH) measured by Life's Simple 7 (i.e., smoking, BMI, PA, diet, total cholesterol, blood pressure, and blood glucose) found Black and Asian individuals to have smaller CVH benefits as education increased.[75] Conversely, our study found Asian participants with graduate degrees to have the highest odds of co-occurring health behaviors compared to White college graduates. Studies investigating the intersectionality of identifying as Asian and educational attainment on health behaviors are limited and needed to better understand the potential dynamics underlying our findings.

The strong association between lower socioeconomic status (SES) and lower adherence to ACS Guidelines is consistent with previous research indicating that financial and educational barriers can impede access to health-promoting resources and behaviors.[15] Collectively, engaging in individual and co-occurring health behaviors, such as those measured by the ACS Guidelines for diet, PA, BMI, and alcohol intake was associated with higher SES. Across all races and ethnicities, participants earning lower incomes had lower odds of co-occurring health behaviors compared to White participants earning $125,000 or more. Black participants across all income levels demonstrated significantly lower odds of adhering to the ACS Guidelines. The lack of protective effects of higher income and education among certain racial groups, particularly Black individuals, may reflect systemic inequities and cultural differences in health behaviors. Thus, highlighting the need to better understand factors influencing co-occurring health behaviors in these populations.

Joint associations between marital status and sex are worth noting. Never married men were 1.24 times more likely to have a higher ACS score compared to married women; whereas, never married women had 11% lower odds. This is not consistent with existing literature, as most research links marriage with numerous protective physical and mental health outcomes. For example, a meta-analysis of 7,881,040 individuals found being unmarried to increase health risks among never married men and women, conferring a higher risk among unmarried men.[170] Furthermore, numerous studies have found married adults to have lower mortality[136] and morbidity risks,[170] mental disorders,[79] lower blood pressure, and reduced substance use of tobacco, alcohol, and cannabis,[139] compared to nonmarried adults. Single and divorced persons have

consistently demonstrated negative health outcomes compared to their married counterparts.[133] Social scientists have attributed these protective effects to a variety of reasons including selection effects, in which marriage is more likely to occur among better-adjusted, happier, and healthier individuals.[71] Other reasons include improved economic well-being leading to increased access to healthcare and reduced financial stress,[137] and increased social connection leading to emotional fulfillment and the promotion of healthy behaviors such as eating healthy and regular exercise.[160,177] Unlike our findings, men typically benefit more from the health promoting effects of marriage compared to women.[152,170] In contrast, Ortega et al. (2011) found married individuals to have lower physical activity levels compared to single individuals. Our results illuminate underlying complexities associated with the influence of marital status and sex on health behaviors, warranting further investigation.

Health and well-being are significantly impacted by the neighborhoods people reside in.[65] Harmful exposures such as second-hand smoke, access to healthy foods (i.e. residing in a food desert), and rural-urban differences among health behaviors contribute to health disparities and outcomes.[65,125] For example, alcohol consumption is higher among those residing in rural areas compared to urban residents;[53] and those residing in urban, metropolitan areas have better diet quality and physical activity levels than nonmetropolitan areas.[97,125] In this study, individuals residing in all nonmetropolitan areas compared to metropolitan and those residing in food deserts had lower ACS scores. Healthy diets and lifestyles are impacted by access to healthy foods.[66] Residing in a food desert is defined as being farther than 10 miles from the nearest grocery store in rural settings and one mile farther in metropolitan and micropolitan settings.[163] Compared to

food deserts, metropolitan areas have more opportunities to engage in healthy behaviors, including safer built environments for PA and access to healthier foods.[66] Moreover, there are sex disparities associated with diet, PA, and alcohol consumption; Men consume more alcohol and engage in more physical activity,[47,126,151,173,174] and healthy eating behaviors are more prevalent among women.[186] Despite established disparities among individual health behaviors, there is little evidence investigating how gender and residential settings affect co-occurring health behaviors. Our study contributed to this gap, finding higher odds of co-occurring health behaviors among metropolitan women than any other residential and gender combination.

Across all income levels, individuals who were exposed to second-hand smoke (SHS) had lower odds of adhering to the ACS Guidelines compared to those never exposed to SHS with gross household incomes of $125,000 or more. The dose-response of income among participants never experiencing SHS exposure was more clear than those with any SHS exposure. However, our findings may serve as a proxy for persistent and established disparities in SHS exposure.[145,156] In 2013-2014, SHS exposure was experienced by 47.9% of Americans living below the poverty line compared to 21.2% of those above the poverty line; 38.6% of renters compared to 19.2% of homeowners; 50.3% of non-Hispanic Blacks compared to 21.4% of non-Hispanic Whites; and 30.7% of people with less than a high school education compared to 10.8% of individuals with college degrees or higher.[156] According to Wang et al. (2023), individuals with household incomes below 130% of the Federal Poverty Level (FPL) are more frequently exposed to SHS than those with household incomes exceeding 350% of the FPL. SHS exposure was associated with less co-occurring health behaviors in this study. These disparities

underscore the need for targeted public health interventions to reduce SHS exposure among vulnerable populations and highlight the associations SHS may have with co-occurring health behaviors.

Limitations

Due to the high proportions of women, participants with higher income and education levels, and the lack of racial and ethnic diversity within CPS-3, the findings of this study may not be generalizable to the US population. Nonetheless, this large, nationwide cohort had ample numbers to investigate the association of SDoH and co-occurring health behaviors. This study relied on self-reported data; therefore, the assessment of lifestyle factors was subject to measurement error. Furthermore, the findings of this study were generally consistent with nationally representative samples. The grouping together of certain race and ethnic groups and rural-urban resident areas to preserve statistical power was another limitation of this study, as variations within these groups are expected.

Conclusions

Understanding how various demographic, socioeconomic, and geographic factors intersect to influence co-occurring health behaviors for diet, physical activity, BMI, and alcohol consumption is an important knowledge gap for addressing health disparities to achieve health equity. While ample research investigates how SDoH individually impact single health behaviors, our findings provide evidence on the mechanisms in which major determinants cluster and influence co-occurring health behaviors. Additional research is needed to clarify interactions responsible for shaping disparities among health behaviors to inform future public health approaches.

Tables

Table 3.1. Participant characteristics according to ACS Guideline scores among aging adults in the Cancer Prevention Study-3 (CPS-3)

	ACS Guideline Scores					
	0-2	**3**	**4**	**5**	**6**	**7-8**
Characteristic	(n = 18,744)	(n = 20,567)	(n = 27,205)	(n = 29,808)	(n = 25,242)	(n = 20,519)
Age, mean	51	52	52	52	53	53
Sex						
Female	15,664 (84%)	16,311 (79%)	20,648 (76%)	22,508 (76%)	19,513 (77%)	17,050 (83%)
Male	3,080 (16%)	4,256 (21%)	6,557 (24%)	7,300 (24%)	5,729 (23%)	3,469 (17%)
Race and ethnicity						
Asian, Native Hawaiian, Pacific Islander, or American Indian	308 (1.6%)	467 (2.3%)	684 (2.5%)	792 (2.7%)	721 (2.9%)	705 (3.4%)
Black	617 (3.3%)	546 (2.7%)	650 (2.4%)	622 (2.1%)	480 (1.9%)	317 (1.5%)
Latino	1,115 (5.9%)	1,199 (5.8%)	1,510 (5.6%)	1,547 (5.2%)	1,350 (5.3%)	1,046 (5.1%)
White	16,640 (89%)	18,271 (89%)	24,228 (89%)	26,716 (90%)	22,576 (89%)	18,357 (89%)
Other	64 (0.3%)	84 (0.4%)	133 (0.5%)	131 (0.4%)	115 (0.5%)	94 (0.5%)
Income, $						
<50,000	4,013 (21%)	3,732 (18%)	4,360 (16%)	4,156 (14%)	3,107 (12%)	2,350 (11%)
50,000 to <75,000	3,895 (21%)	3,997 (19%)	5,015 (18%)	5,092 (17%)	3,925 (16%)	3,099 (15%)
75,000 to <100,000	3,518 (19%)	3,799 (18%)	4,937 (18%)	5,098 (17%)	4,276 (17%)	3,330 (16%)
100,000 to <125,000	2,903 (15%)	3,277 (16%)	4,422 (16%)	4,819 (16%)	4,099 (16%)	3,277 (16%)

125,000 or more	4,208 (22%)	5,452 (27%)	8,030 (30%)	10,164 (34%)	9,372 (37%)	8,051 (39%)
Unknown/missing	207 (1.1%)	310 (1.5%)	441 (1.6%)	479 (1.6%)	463 (1.8%)	412 (2.0%)
Education level						
High school or less	2,052 (11%)	1,972 (9.6%)	2,211 (8.1%)	1,932 (6.5%)	1,268 (5.0%)	728 (3.5%)
Some college or 2-y degree	6,796 (36%)	6,635 (32%)	7,894 (29%)	7,526 (25%)	5,490 (22%)	3,676 (18%)
College graduate	5,919 (32%)	6,801 (33%)	9,389 (35%)	10,605 (36%)	9,235 (37%)	7,495 (37%)
Graduate degree	3,910 (21%)	5,095 (25%)	7,608 (28%)	9,645 (32%)	9,165 (36%)	8,575 (42%)
Unknown/missing	67 (0.4%)	64 (0.3%)	103 (0.4%)	100 (0.3%)	84 (0.3%)	45 (0.2%)
Rural-urban commuting area						
Metropolitan	14,404 (77%)	16,228 (79%)	21,677 (80%)	24,437 (82%)	21,195 (84%)	17,527 (85%)
Micropolitan	1,969 (11%)	1,960 (9.5%)	2,422 (8.9%)	2,461 (8.3%)	1,793 (7.1%)	1,339 (6.5%)
Small town	609 (3.2%)	595 (2.9%)	816 (3.0%)	728 (2.4%)	564 (2.2%)	364 (1.8%)
Rural	388 (2.1%)	375 (1.8%)	524 (1.9%)	425 (1.4%)	308 (1.2%)	224 (1.1%)
Unknown/missing	1,374 (7.3%)	1,409 (6.9%)	1,766 (6.5%)	1,757 (5.9%)	1,382 (5.5%)	1,065 (5.2%)
Residing in a food desert						
No	15,749 (84%)	17,626 (86%)	23,548 (87%)	26,205 (88%)	22,435 (89%)	18,434 (90%)
Yes	1,615 (8.6%)	1,528 (7.4%)	1,887 (6.9%)	1,838 (6.2%)	1,422 (5.6%)	1,020 (5.0%)
Unknown/missing	1,380 (7.4%)	1,413 (6.9%)	1,770 (6.5%)	1,765 (5.9%)	1,385 (5.5%)	1,065 (5.2%)
Work status						
Full time	13,859 (74%)	14,651 (71%)	19,083 (70%)	20,237 (68%)	16,344 (65%)	12,247 (60%)
Part time	1,626 (8.7%)	1,930 (9.4%)	2,738 (10%)	3,497 (12%)	3,388 (13%)	3,513 (17%)
Retired	1,687 (9.0%)	2,253 (11%)	3,150 (12%)	3,635 (12%)	3,292 (13%)	2,766 (13%)
Other	1,247 (6.7%)	1,355 (6.6%)	1,712 (6.3%)	1,918 (6.4%)	1,729 (6.8%)	1,543 (7.5%)
Unknown/missing	325 (1.7%)	378 (1.8%)	522 (1.9%)	521 (1.7%)	489 (1.9%)	450 (2.2%)

Marital status						
Married or living with partner	13,514 (72%)	15,298 (74%)	20,643 (76%)	22,995 (77%)	19,806 (78%)	16,104 (78%)
Never married	1,835 (9.8%)	1,677 (8.2%)	2,100 (7.7%)	2,107 (7.1%)	1,576 (6.2%)	1,412 (6.9%)
Divorced, separated, or widowed	3,180 (17%)	3,324 (16%)	4,109 (15%)	4,291 (14%)	3,537 (14%)	2,817 (14%)
Unknown/missing	215 (1.1%)	268 (1.3%)	353 (1.3%)	415 (1.4%)	323 (1.3%)	186 (0.9%)
Second-hand smoke exposure (days/wk)						
Never	10,831 (58%)	12,577 (61%)	17,259 (63%)	20,117 (67%)	18,149 (72%)	15,803 (77%)
Any	7,832 (42%)	7,883 (38%)	9,810 (36%)	9,559 (32%)	6,976 (28%)	4,625 (23%)
Unknown/missing	81 (0.4%)	107 (0.5%)	136 (0.5%)	132 (0.4%)	117 (0.5%)	91 (0.4%)
Smoking status						
Never	11,980 (64%)	13,518 (66%)	18,564 (68%)	20,701 (69%)	18,115 (72%)	15,403 (75%)
Current	966 (5.2%)	841 (4.1%)	876 (3.2%)	714 (2.4%)	393 (1.6%)	177 (0.9%)
Former	5,788 (31%)	6,191 (30%)	7,737 (28%)	8,371 (28%)	6,716 (27%)	4,913 (24%)
Unknown/missing	10 (<0.1%)	17 (<0.1%)	28 (0.1%)	22 (<0.1%)	18 (<0.1%)	26 (0.1%)

Table 3.2. Social determinant of health factors independently associated with ACS Guideline adherence[a]

	Model 1[b]				Model 2[c]			
Characteristic	**N**	**OR**	**95% CI**	**p-value**	**N**	**OR**	**95% CI**	**p-value**
Sex								
Female	111,694	**1 [Ref]**	**1 [Ref]**		111,694	**1 [Ref]**	**1 [Ref]**	
Male	30,391	0.99	0.96, 1.01	0.2	30,391	0.94	0.92, 0.97	<0.001
Race and ethnicity								
White	126,788	**1 [Ref]**	**1 [Ref]**		126,788	**1 [Ref]**	**1 [Ref]**	
Asian, Native Hawaiian, Pacific Islander, or American Indian	3,677	1.43	1.43, 1.43	<0.001	3,677	1.35	1.34, 1.35	<0.001
Black	3,232	0.68	0.68, 0.68	<0.001	3,232	0.73	0.73, 0.73	<0.001
Latino	7,767	0.94	0.94, 0.94	<0.001	7,767	1	0.99, 1.00	0.4
Other	621	1.13	1.13, 1.13	<0.001	621	1.18	1.18, 1.18	<0.001
Income, $								
<50,000	21,718	0.49	0.47, 0.50	<0.001	21,718	0.65	0.64, 0.67	<0.001
50,000 to <75,000	25,023	0.59	0.58, 0.61	<0.001	25,023	0.75	0.73, 0.77	<0.001
75,000 to <100,000	24,958	0.66	0.65, 0.68	<0.001	24,958	0.79	0.77, 0.81	<0.001
100,000 to <125,000	22,797	0.74	0.72, 0.76	<0.001	22,797	0.83	0.81, 0.86	<0.001
125,000 or more	45,277	**1 [Ref]**	**1 [Ref]**		45,277	**1 [Ref]**	**1 [Ref]**	
Marital status								
Married or living with partner	108,360	**1 [Ref]**	**1 [Ref]**		108,360	**1 [Ref]**	**1 [Ref]**	
Never married	10,707	0.81	0.78, 0.83	<0.001	10,707	0.96	0.93, 0.99	0.007
Divorced, separated, or widowed	21,258	0.84	0.81, 0.86	<0.001	21,258	1.07	1.05, 1.10	<0.001

Education level								
College graduate	49,444	**1 [Ref]**	**1 [Ref]**		49,444	**1 [Ref]**	**1 [Ref]**	
High school or less	10,163	0.49	0.49, 0.50	<0.001	10,163	0.58	0.57, 0.60	<0.001
Some college or 2-y degree	38,017	0.61	0.60, 0.63	<0.001	38,017	0.69	0.67, 0.70	<0.001
Graduate degree	43,998	1.33	1.30, 1.36	<0.001	43,998	1.27	1.25, 1.30	<0.001
Rurality (RUCA)								
Metropolitan	115,468	**1 [Ref]**	**1 [Ref]**		115,468	**1 [Ref]**	**1 [Ref]**	
Micropolitan	11,944	0.72	0.70, 0.74	<0.001	11,944	0.85	0.82, 0.87	<0.001
Small town	3,676	0.68	0.68, 0.69	<0.001	3,676	0.84	0.84, 0.84	<0.001
Rural	2,244	0.64	0.64, 0.64	<0.001	2,244	0.77	0.77, 0.77	<0.001
Residing in a food desert								
No	123,997	**1 [Ref]**	**1 [Ref]**		123,997	**1 [Ref]**	**1 [Ref]**	
Yes	9,310	0.72	0.69, 0.75	<0.001	9,310	0.87	0.84, 0.91	<0.001
Second-hand smoke exposure								
Never	94,736	**1 [Ref]**	**1 [Ref]**		94,736	**1 [Ref]**	**1 [Ref]**	
Any	46,685	0.61	0.60, 0.62	<0.001	46,685	0.7	0.69, 0.71	<0.001
Work status								
Full time	96,421	**1 [Ref]**	**1 [Ref]**		96,421	**1 [Ref]**	**1 [Ref]**	
Part time	16,692	1.62	1.57, 1.66	<0.001	16,692	1.62	1.57, 1.66	<0.001
Retired	16,783	1.26	1.22, 1.29	<0.001	16,783	1.32	1.28, 1.36	<0.001
Other	9,504	1.17	1.13, 1.22	<0.001	9,504	1.27	1.24, 1.31	<0.001

[a] Total score ranged from 0 to 8, with higher scores indicating better adherence to ACS Guidelines for Cancer Prevention. Reference group = 0-2, indicating low ACS scores.

[b] Adjusted for age, sex, and energy intake.

[c] Adjusted for age, sex, energy intake, and mutually adjusted for all main exposures.

Table 3.3. Social determinant of health factors associated with ACS Guideline adherence by race and ethnicity[a]

	Race and Ethnicity									
	AAPI		Black		Latino		White		Other	
	n	OR (95%CI)	n	OR (95%CI)	n	OR (95%CI)	n	OR (95%CI)	n	OR (95%CI)
Sex[b]										
Female	2,731	1.34 (1.34, 1.35)	2,712	0.69 (0.69, 0.69)	6,020	0.98 (0.98, 0.99)	99,785	**1 [Reference]**	446	1.17 (1.17, 1.17)
Male	946	1.26 (1.26, 1.26)	520	0.92 (0.92, 0.92)	1,747	0.97 (0.97, 0.97)	27,003	0.94 (0.91, 0.96)	175	1.12 (1.12, 1.12)
Income, $[c]										
<50,000	555	0.78 (0.78, 0.78)	925	0.43 (0.43, 0.44)	1,622	0.61 (0.61, 0.61)	18,465	0.66 (0.65, 0.68)	151	0.73 (0.73, 0.73)
50,000 to <75,000	534	1.01 (1.01, 1.01)	732	0.55 (0.55, 0.55)	1,418	0.75 (0.75, 0.76)	22,222	0.75 (0.73, 0.77)	117	0.97 (0.97, 0.97)
75,000 to <100,000	604	1.14 (1.14, 1.14)	522	0.65 (0.65, 0.66)	1,315	0.82 (0.82, 0.82)	22,415	0.78 (0.76, 0.80)	102	1.16 (1.16, 1.16)
100,000 to <125,000	580	1.06 (1.06, 1.06)	391	0.70 (0.70, 0.70)	1,161	0.86 (0.86, 0.86)	20,597	0.83 (0.81, 0.86)	68	0.66 (0.66, 0.66)
125,000 or more	1,356	1.40 (1.40, 1.41)	620	0.70 (0.70, 0.70)	2,153	1.01 (1.01, 1.01)	40,976	**1 [Reference]**	172	1.15 (1.15, 1.15)
Education level[d]										
High school or less	145	0.61 (0.61, 0.61)	142	0.56 (0.56, 0.56)	557	0.64 (0.64, 0.65)	9,293	0.58 (0.57, 0.60)	26	0.68 (0.68, 0.68)
Some college or 2-y degree	801	0.86 (0.86, 0.86)	818	0.56 (0.56, 0.56)	2,292	0.66 (0.66, 0.67)	33,937	0.69 (0.68, 0.71)	169	0.74 (0.74, 0.74)
College graduate	1,236	1.27 (1.27, 1.27)	1,030	0.74 (0.74, 0.74)	2,513	1.04 (1.04, 1.04)	44,460	**1 [Reference]**	205	1.15 (1.15, 1.15)
Graduate degree	1,483	1.94 (1.94, 1.94)	1,225	0.83 (0.83, 0.83)	2,357	1.23 (1.22, 1.23)	38,714	1.27 (1.25, 1.30)	219	1.61 (1.61, 1.61)

[a]For exposures with statistically significant interactions, p-int <0.001. ACS Guideline adherence is on a 0-8 scale, with higher scores indicating better scores. Reference group for ACS Guidelines was 0-2, indicating low adherence.

[b]Model included age, energy intake, race/ethnicity, income, marital status, education, RUCA, residence in a food desert, second-hand smoke exposure, work status, and a race*sex joint variable.

[c]Model included age, sex, energy intake, marital status, education, RUCA code, residence in a food desert, second-hand smoke exposure, work status, and a race*income joint variable.

[d]Model included age, sex, energy intake, income, marital status, RUCA code, residence in a food desert, second-hand smoke exposure, work status, and a race*education joint variable.

Table 3.4. Social determinant of health factors associated with ACS Guideline adherence by sex[a]

	Female		Male	
Characteristic	**n**	**OR (95% CI)**	**n**	**OR (95% CI)**
Marital status[b]				
Married or living with partner	83,601	**1 [Reference]**	24,759	0.92 (0.90, 0.95)
Never married	8,919	0.89 (0.87, 0.92)	1,788	1.24 (1.23, 1.24)
Divorced, separated, or widowed	18,926	1.07 (1.05, 1.10)	2,332	0.96 (0.96, 0.97)
Rurality[c]				
Metropolitan	90,511	**1 [Reference]**	24,957	0.92 (0.90, 0.95)
Micropolitan	9,488	0.82 (0.79, 0.85)	2,456	0.88 (0.87, 0.88)
Small town/Rural	4,771	0.79 (0.78, 0.79)	1,149	0.85 (0.85, 0.85)
Work status[d]				
Full time	73,096	**1 [Reference]**	23,325	0.99 (0.97, 1.02)
Part time	15,167	1.67 (1.62, 1.72)	1,525	1.28 (1.28, 1.28)
Retired	12,729	1.36 (1.32, 1.40)	4,054	1.19 (1.18, 1.20)
Other	8,549	1.33 (1.42, 1.43)	955	0.95 (0.95, 0.95)

[a]For exposures with statistically significant interactions, p-int <0.001. ACS Guideline adherence is on a 0-8 scale, with higher scores indicating better scores. Reference group for ACS Guidelines was 0-2, indicating low adherence.

[b]Model included age, energy intake, race/ethnicity, income, education, RUCA code, residence in a food desert, work status, second-hand smoke exposure, and a joint marital status*sex variable.

[c]Model included age, energy intake, race/ethnicity, income, education, marital status, residence in a food desert, work status, second-hand smoke exposure, and a joint RUCA*sex variable.

[d]Model included age, energy intake, race/ethnicity, income, education, RUCA code, marital status, residence in a food desert, second-hand smoke exposure, and a joint work status*sex variable.

Table 3.5. Association of second-hand smoke (SHS) exposure and ACS Guideline scores by income[a]

	Never			Any		
Income level, $[b]	**N**	**OR**	**95% CI**	**N**	**OR**	**95% CI**
<50,000	18,465	0.66	0.65, 0.68	9,448	0.45	0.44, 0.47
50,000 to <75,000	12,123	0.65	0.63, 0.66	9,506	0.53	0.51, 0.54
75,000 to <100,000	16,239	0.76	0.74, 0.78	8,605	0.57	0.55, 0.59
100,000 to <125,000	15,560	0.83	0.81, 0.85	7,146	0.57	0.55, 0.59
125,000 or more	33,792	**1 [Ref]**	**1 [Ref]**	11,326	0.67	0.65, 0.69

[a]For exposures with statistically significant interactions, p-int <0.001. ACS Guideline adherence is on a 0-8 scale, with higher scores indicating better scores. Reference group for ACS Guidelines was 0-2, indicating low adherence.

[b]Model included age, sex, energy intake, income, education, RUCA code, marital status, residence in a food desert, second-hand smoke exposure, and a joint SHS*income variable.

Figures

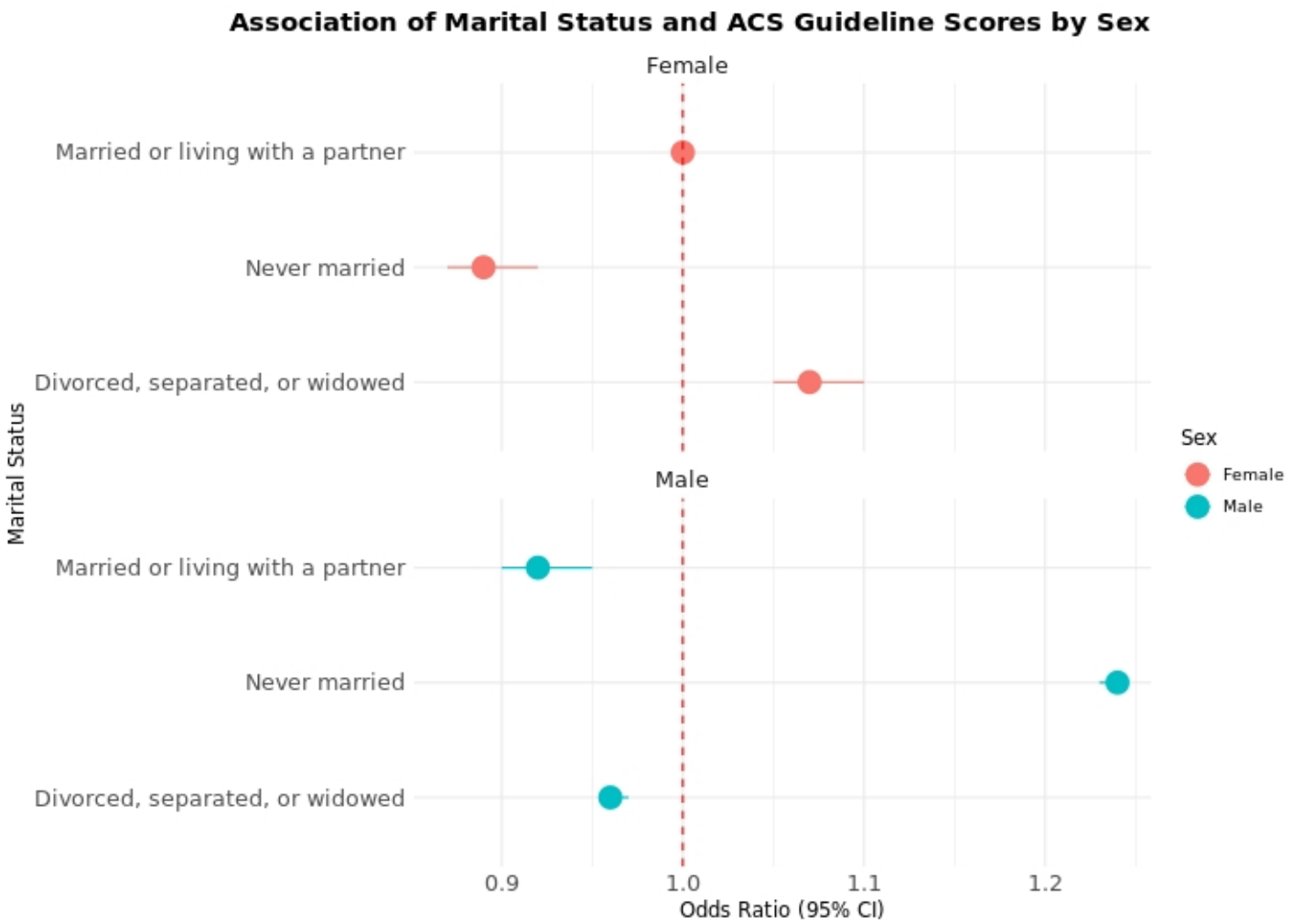

Figure 3.1. Associations of marital status and ACS Guideline scores by sex.

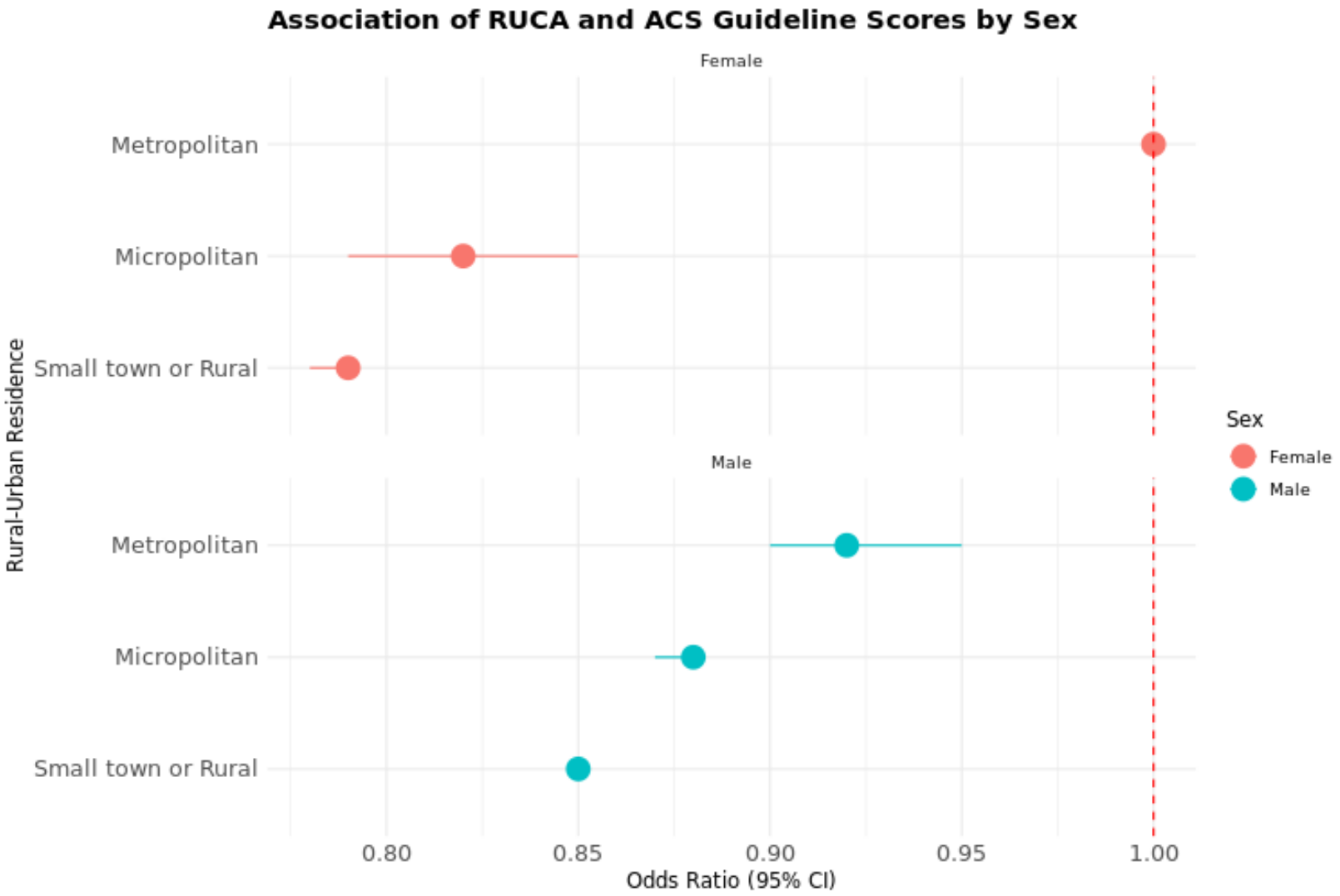

Figure 3.2. Associations of RUCA code and ACS Guideline scores by sex.

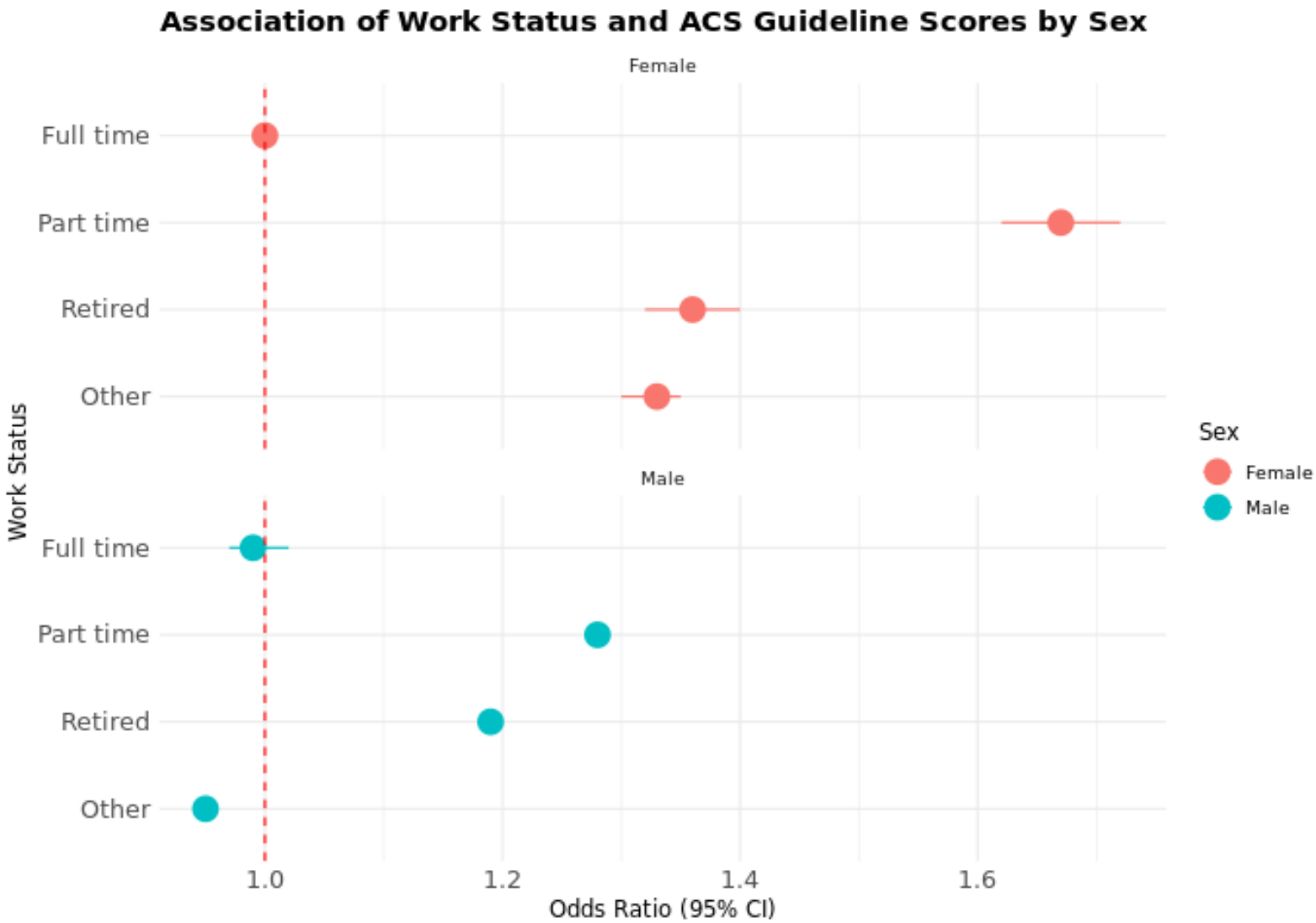

Figure 3.3. Associations of work status and ACS Guideline scores by sex.

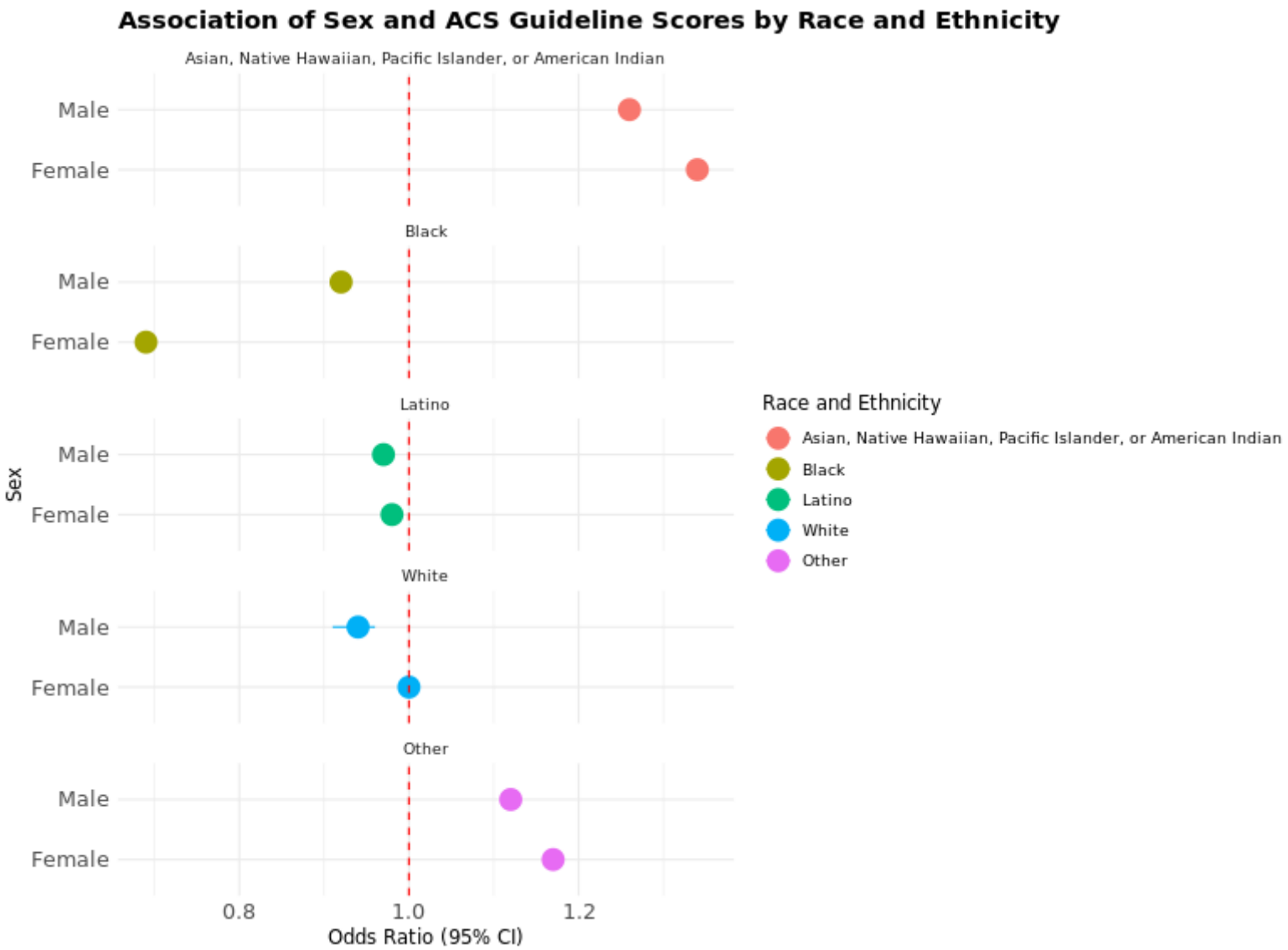

Figure 3.4. Association of sex and ACS Guideline scores by race and ethnicity.

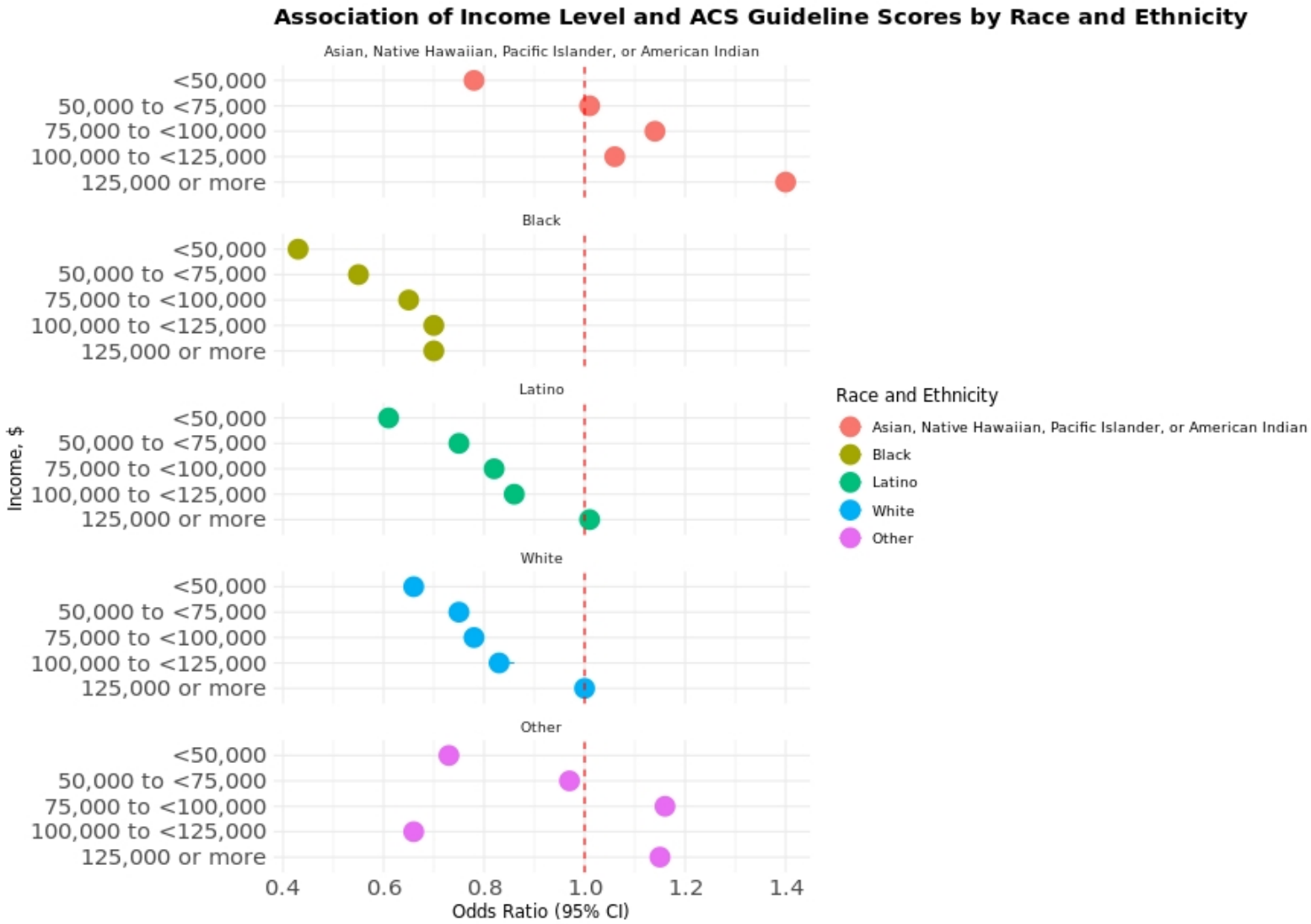

Figure 3.5. Association of income level and ACS Guideline scores by race and ethnicity.

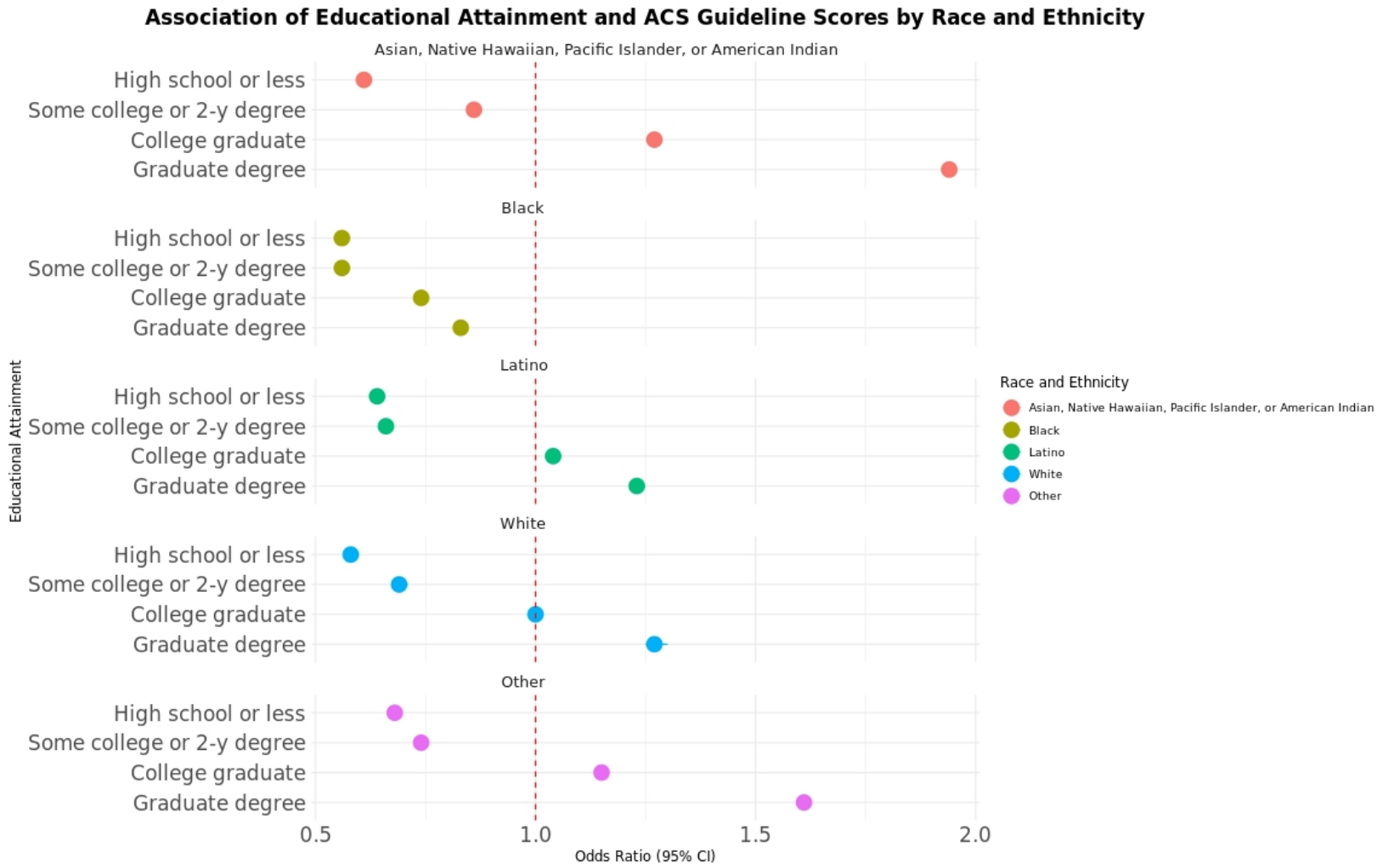

Figure 3.6. Association of educational attainment and ACS Guideline scores by race and ethnicity.

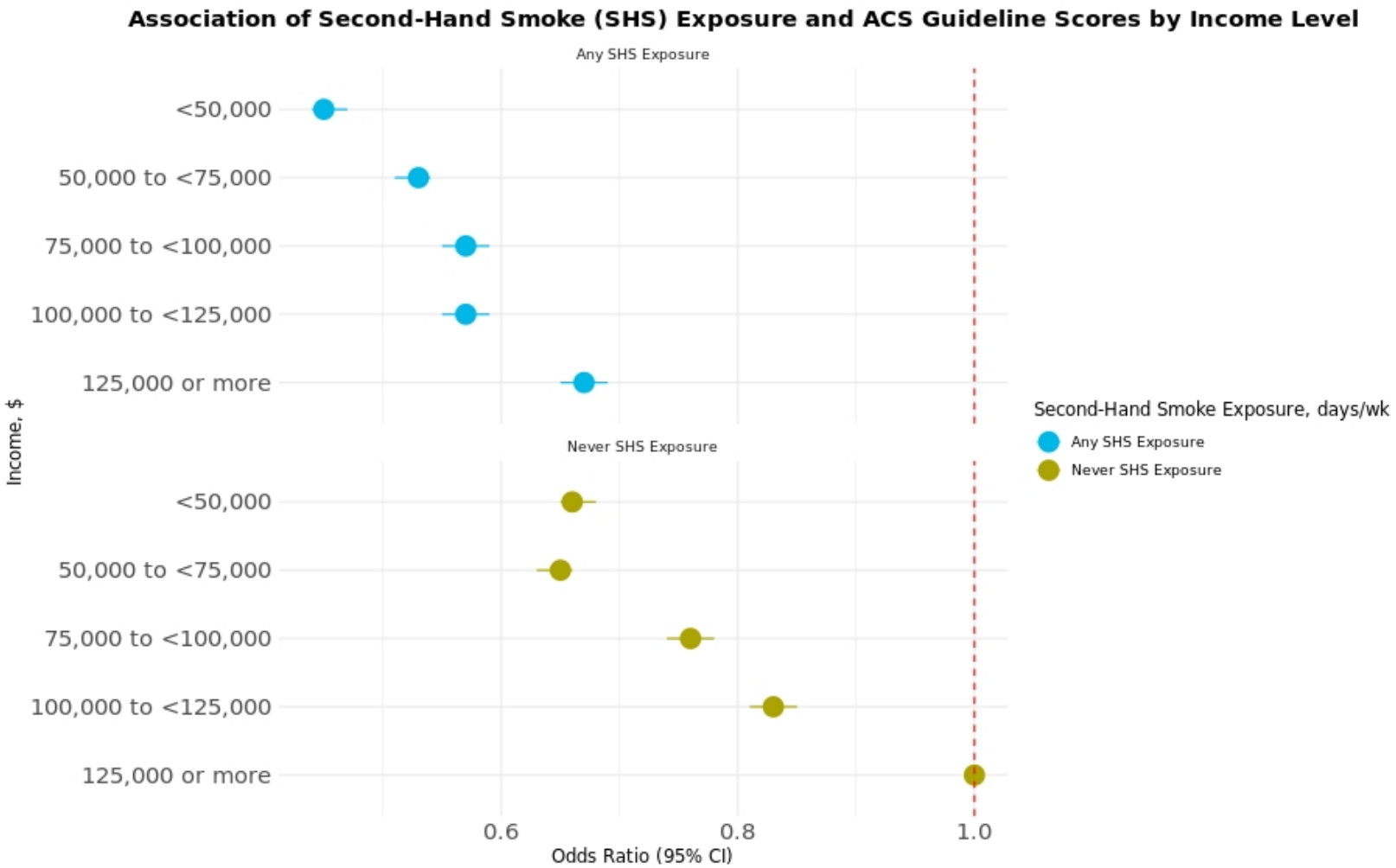

Figure 3.7. Association between second-hand smoke (SHS) exposure and ACS Guideline scores by income level.

CHAPTER 4

CO-OCCURRING HEALTH BEHAVIORS ON MENTAL HEALTH OUTCOMES AMONG LARGE, DIVERSE AGING POPULATION IN THE US[2]

[2]Chiang K, Rees-Punia E, Chantaprasopsuk S, Patel AV, Bates-Fraser L, Shams-White M, Callands TA, Muilenburg JL, Padilla HM. To be submitted to *Journal of Preventative Medicine.*

Abstract

INTRODUCTION: To examine the longitudinal association of adhering to the American Cancer Society (ACS) Guidelines for Cancer Prevention in 2015 and self-reported anxiety and depression in 2021.

METHODS: Participants included 88,643 women (79%) and 23,273 men (21%) with a mean (SD) age of 53 (10) years old in the Cancer Prevention Study-3. The ACS Guideline score captures co-occurring health behaviors including diet, alcohol consumption, body weight, and physical activity (PA), ranging from 0 to 8, with higher scores indicating higher adherence. Associations between ACS Guideline scores and self-reported anxiety and depression via Patient Health Questionnaire-4 (PHQ-4) were assessed using multivariate logistic regression models adjusted for age, sex, energy intake, and other sociodemographic factors. Further analysis included: 1) a sensitivity analysis excluding participants with pre-existing depression and/or anxiety and those taking medications for depression and/or anxiety (n = 66,594); and 2) a stratified analysis restricted to 107,699 participants, accounting for the occurrence of the COVID-19 pandemic during follow-up years.

RESULTS: Among 112,016 participants, 32% reported both depression and anxiety, 10% reported anxiety symptoms, and 6.6% had symptoms of depression. Participants with higher adherence to the ACS Guidelines, were less likely to experience future symptoms of depression and/or anxiety compared to those with lower adherence (OR = 0.58; 95% CI: 0.55-0.61). Supplemental analyses resulted in attenuated, though still statistically significant findings, addressing concerns of reverse causality.

CONCLUSION: These findings suggest that following the recommended health behaviors outlined in the ACS Guidelines for Cancer Prevention is associated with a decrease in future symptoms of depression and anxiety.

Introduction

Increasing the global prevalence of anxiety and depression by 25%,[179] the Coronavirus (COVID-19) pandemic had drastic effects on psychological wellbeing and mental health; leading to over $280 billion in annual healthcare costs for mental health services.[3] In 2022, one in five US adults (59.3 million) had a mental illness.[105] Stemming from a multitude of social, psychological, and biological factors,[1,103,181,182] depression and anxiety are two of the most common mental health disorders.[181,182] Both depression and anxiety increase the risk for other diseases[35] and suicide;[102] disrupting daily functioning, quality of life,[55] and longevity.[166] Risk and protective factors for depression and anxiety include modifiable health behaviors, such as diet, physical activity (PA), alcohol consumption, weight management, sleep, and tobacco use.[51]

There may be a bidirectional relationship between mental health and health behaviors.[17,18,115] Unhealthy behaviors (i.e., smoking, binge drinking, poor diet including fast-food consumption, and sedentary behaviors) are more prominent among people with mental illnesses,[51] as engagement may potentially act as a coping mechanism for negative effects and has been demonstrated to be predicted by anxiety and depression.[167] Furthermore, clusters of unhealthy behaviors demonstrate synergistic effects and are linked to increasing an individual's risk of anxiety and depression,[5,184] yet most studies focus on singular behaviors.[5] Inversely, research has found healthy lifestyle behaviors to be negatively associated with depression and anxiety.[74,150,189] Illustrated by cross-sectional associations, adopting multiple health behaviors (i.e., not smoking, regular PA, maintaining a healthy body weight, and consuming a diet high in fruits and vegetables) may improve mental health outcomes.[25] Few studies have evaluated the longitudinal

relationship between multiple health behaviors and mental health. Most evidence focuses on individual health behaviors and physical health outcomes using cross-sectional data and small sample sizes; thus, it is unclear how the combination of multiple health behaviors impact future depression and anxiety outcomes.

The American Cancer Society's (ACS) Guideline score, which quantifies adherence to the 2020 ACS diet, alcohol, body weight, and physical activity recommendations for cancer prevention, can serve as a measure of co-occurring health behaviors. The ACS Guidelines seek to provide evidence-based recommendations for reducing cancer risk related to promoting overall health and share many features with other organizations' guidelines.[11,135,142,164] Adherence to the ACS Guidelines has been demonstrated among healthy populations to be associated with reduced mortality risk[98] and social determinants of health (SDoH);[33] nonetheless, its effects on depression and anxiety have not yet been investigated.

The present study aims to examine longitudinal associations between co-occurring health behaviors for diet, physical activity, body weight, and alcohol consumption captured by ACS Guideline scores in 2015 and self-reported anxiety and depression in 2021 in a subset population from a large, nationwide prospective cohort of aging U.S. adults. We hypothesize that high adherence to the ACS Guidelines will be associated with lower levels of anxiety and depression.

Methods

Study Population and Design

The Cancer Prevention Study-3 (CPS-3) is an ongoing prospective study on cancer incidence and mortality.[116] Nearly 304,000 participants aged 30 to 65 years with

no cancer history (except basal or squamous cell skin cancer) were enrolled at American Cancer Society (ACS) fundraising and recruitment events between 2006 and 2013. CPS-3 participants completed baseline surveys on demographics, lifestyle, and health history, and continue to receive repeat surveys every three years to update exposure information. Further detailed description regarding participant characteristics, cohort descriptions, and recruitment are described by Patel et al. (2017). The Institutional Review Board at Emory University approved all aspects of CPS-3.

A prospective longitudinal study design was used to investigate associations between adhering to the ACS Guidelines in 2015 and self-reported anxiety and depression in 2021 among the CPS-3 cohort. Participants were excluded for missing information on race and ethnicity (n = 1,124), physical activity (n = 708), alcohol use (n = 145), food frequency questionnaire (FFQ) (n = 9,293), 2021 CPS-3 survey responses (n = 34,383), underweight or missing BMI (n = 2,968), incomplete 2021 Patient Health Questionnaire-4 (n = 22,420), and those current pregnant at the time of survey collection (n = 3,958). Additional participant exclusions included 7,484 for poor FFQ reporting (defined elsewhere[155]), 343 in the top 0.05% intake of ACS diet score food groups, and 11,805 missing/invalid 24-hour activity grid information.

Measures

ACS Guideline Scores

Based on the 2020 ACS Guidelines for Diet and Physical Activity for Cancer Prevention[135] and an *a priori* score developed by McCullough et al. (2011), ACS Guideline scores captured in 2015 were used to quantify co-occurring health behaviors for body mass index (BMI), diet, physical activity (PA), and alcohol consumption.

Calculated on a scale from 0 to 8, higher scores indicated optimal behaviors, and lower scores reflected low concordance to the 2020 ACS Guidelines. Scoring and detailing of the ACS Guidelines were previously outlined by Chiang et al. (UNDER REVIEW 2024).

Depression and Anxiety

The four-item Patient Health Questionnaire (PHQ-4) from the 2021 CPS-3 survey was used to measure anxiety and depression. PHQ-4 is an ultra-brief, self-reported questionnaire used for detecting depression and anxiety disorders.[57] PHQ-4 consists of two items for depression (PHQ-2) and two items for Generalized Anxiety Disorder-2 (GAD-2) symptoms.[57] Previous studies support the reliability and validity of using PHQ-4 (Cronbach's alpha = 0.85) and its subscales, PHQ-2 (Cronbach's alpha = 0.81) and GAD-2 (Cronbach's alpha = 0.82) as alternatives to their lengthier counterparts, PHQ-9 and GAD-7.[34,57,83] Participants were asked "In the last month, how often have you been bothered by the following problems*?"* PHQ-4 items are detailed in Appendix B and included: 'feeling nervous, anxious, or on edge;' 'not being able to stop or control worrying;' 'feeling down, depressed, or hopeless;' and 'little interest or pleasure in doing things.' Each of the four items were scored on a 4-point Likert scale ranging from 0 ('not at all') to 3 ('nearly every day'). Total PHQ-4 scores ranged from 0 to 12 and were determined by adding together the scores of each of the four items, with higher scores indicating greater levels of depression and anxiety.[57] PHQ-4 scores (representing both depression and anxiety symptoms) were categorized as: normal (0-2; referent), mild (3-5), moderate (6-8), and severe (9-12). Due to sparsity, responses for mild (3-5), moderate (6-8), and severe (9-12) were dichotomized and PHQ-4 was categorized as: normal (0-2)

and mild-to-severe (3-12). Sub-scores for depression (PHQ-2) and anxiety (GAD-2) were used to indicate high (≥3) or low (<3) depression or anxiety symptoms.

Accounting for the COVID-19 Pandemic

To account for the occurrence of the COVID-19 pandemic during the follow-up years of this study, PHQ-4 data pertaining to participant's responses during the pandemic were assessed. The leading PHQ-4 question was modified to, "During the COVID-19 pandemic, how often have you been bothered by the following problems?" and listed the same PHQ-4 items with the following response options: 'Less often,' 'About the same,' and 'More often.' Responses were summed on a range from -4 to 4, with more negative scores indicating PHQ-4 (i.e., depression and anxiety symptoms) lessened/decreased during COVID-19 and more positive scores indicating PHQ-4 worsened/increased during COVID-19.

Covariates

Numerous sociodemographic characteristics are known risk factors for anxiety and depression; therefore, a priori covariates were selected.[81,118,119,129] Demographic information for sex, age, and race/ethnicity were measured at baseline (2006-2013). Educational attainment, income, work status, and marital status were assessed using 2015 CPS-3 data.

Statistical Analysis

The association between ACS Guideline scores and self-reported mental health outcomes (i.e. symptoms of anxiety and/or depression via PHQ-4 and its' subscales) were evaluated using multivariate logistic regression models. Models were adjusted for: 1) age,

sex, and energy intake and 2) additionally adjusted for sociodemographic factors (i.e. race/ethnicity, income, work status, education, and marital status).

A sensitivity analysis was performed to address concerns of reverse causality and temporality by excluding participants with pre-existing depression and/or anxiety and those taking medications for depression and/or anxiety in 2015 and/or 2021 (model 3). To account for the occurrence of the COVID-19 pandemic during the follow-up years, a stratified analysis was run to assess associations by changes in PHQ-4 scores during the COVID-19 pandemic. All analyses were conducted in R Studio Pro 2024.04.1 running R version 4.4.0 with a statistical significance of <0.05 p-values.

Results

Sociodemographic and health characteristics of participants are detailed in Table 4.1. 112,016 participants were included in the final analytic sample, of which, 79% (n = 88,643) were female with a mean (SD) age of 53 (10) years old. In 2021, 6.6% of participants had symptoms of depression (n = 7,343), 10% experienced symptoms of anxiety (n = 11,404), and 32% reported both depression and anxiety (n = 36,147). 72% of participants (n = 12,108) with ACS Guideline scores of 7-8 in 2015 had normal PHQ-4 scores in 2021.

Across all models, as ACS Guideline scores increased in 2015, symptoms for depression and/or anxiety in 2021 decreased. As shown by model 1 in Table 4.2, participants scoring 7-8 had lower odds of experiencing depression and anxiety (OR = 0.58, 95% CI $[0.55, 0.61]$) compared to those with low scores (0-2) (Figure 4.1). Controlling for confounders slightly attenuated the strength of associations (model 2 in Table 4.2; Figure 4.2); scores of 7-8 were associated with lower odds of depression (OR

= 0.43, 95% CI [0.39, 0.47]) and anxiety symptoms (OR = 0.62, 95% CI [0.57, 0.67]) compared to participants with low scores. Excluding participants with pre-existing depression and/or anxiety and those taking medications for depression and/or anxiety in 2015 and 2021 yielded similar, less protective associations as the primary results (model 3 in Table 4.2; Figure 4.3).

Associations due to pandemic-related changes in depression and anxiety

During the COVID-19 pandemic, 38% of participants reported increased depression and anxiety (n = 41,436), 21% increased their alcohol intake (n = 23,043), 32% decreased their intake of healthy foods (n = 36,219), and 15% decreased physical activity (n = 16,469). Table 4.3 shows results stratified by changes in PHQ-4 scores during COVID-19 to account for the occurrence of the pandemic within study follow-up years (n = 107,699). The protective associations of adhering to the ACS Guidelines in 2015, remained consistent among participants reporting no and worsened change. Participants whose PHQ-4 score lessened during the pandemic had a less clear dose-response (Figure 4.4) and a weakened association between high ACS scores (7-8) and symptoms of depression and anxiety (OR = 0.80, 95% CI [0.67, 0.94]). Furthermore, higher adhering participants (i.e., ACS scores of 7-8) with no or worsened change in PHQ-4 scores experienced greater protective effects by adhering to the ACS Guidelines compared to their counterparts reporting decreased scores (OR = 0.55; 95% CI [0.51, 0.59] and OR = 0.62; 95% CI [0.57, 0.67], respectively).

Discussion

This study is the first to our knowledge to examine prospective associations between adhering to co-occurring behaviors of diet, PA, body weight, and alcohol

consumption recommended by the 2020 ACS Guidelines for Cancer Prevention and mental health outcomes. Higher adherence to the ACS Guidelines demonstrated consistent inverse associations with lower odds of future depression and/or anxiety symptoms across all models. These findings suggest that individuals who follow healthier lifestyle behaviors, as captured by ACS Guideline adherence, may experience better mental health outcomes over time. To address the potential of reverse causality and temporality, we demonstrated that while less pronounced, the association between ACS Guideline and PHQ-4 scores were consistent when excluding participants with pre-existing depression and/or anxiety and those taking medication for depression and/or anxiety. The results of this sensitivity analysis were interpreted in the context of our primary findings and reinforced the validity of our main analysis.

Numerous studies have explored the impact of health behaviors on mental health.[10,74,165,169] Findings from a meta-analysis found engaging in multiple healthy behaviors lower one's risk of depression by approximately 50%.[169] Furthermore, a cross-sectional study among women in college found that high unhealthy behaviors (i.e., poor diet quality, sleep duration, alcohol consumption, and tobacco or nicotine use) were associated with more severe depression and anxiety symptoms.[10] Our study adds that adults that engaged in multiple protective health behaviors captured by adhering to the 2020 ACS Guidelines for Cancer Prevention had lower odds of experiencing future depression and/or anxiety symptoms. Aspects of individual's social behavior and environment have also been demonstrated to have similar protective associations with mental health. Velten et al. (2014) found regular PA, smoking cessation, healthy body weight, reduced alcohol consumption, and regular social interaction reduced depression

and anxiety. Moreover, access to safe built environments can often reduce the risk of poor mental health by increasing outdoor opportunities for PA.[120,178] While the importance of targeting health behaviors remains a significant focus for reducing poor mental health, several key health organizations have stressed the need to include environmental and psychosocial factors as well.[67,111,117]

The social determinants of health (SDoH) are non-medical, social and environmental factors that influence health behaviors and predispose individuals to poor health outcomes.[42,183] Identifying causal inferences between mental health and SDoH remain a significant public health priority.[4,81] In this study, adjusting for sociodemographic factors slightly reduced the protective effects of adhering to the ACS Guidelines on future depression and anxiety symptoms. Preliminary findings from Chiang et al. (UNDER REVIEW 2024) demonstrated several SDoH, including race and ethnicity, income, educational attainment, marital status, rural vs urban residence, second-hand smoke exposure, and living in a food desert to be significantly associated with ACS Guideline adherence. Specifically, higher levels of education and income, residing in metropolitan, non-food desert areas, being married or living with a partner, and no second-hand smoke exposure increased adherence of co-occurring health behaviors.[33] Together, these findings suggest SDoH may mediate the protectiveness of adhering to health guidelines. For example, lower socioeconomic status (SES) is a risk factor for worsened mental health and vice versa.[4,183] Cross-sectional studies in the US suggest food insecurity, poor diet quality, and unreliable work conditions lead to worsened mental health outcomes.[90,96,129] On the contrary, poor mental health can negatively impact SES and other SDoH by creating barriers to socioeconomic

improvements; contributing to reduced income and employment, which in turn increases further mental health risks.[178] Future research is warranted to understand the complex and cyclic relationship of how SDoH influence health behaviors that protect against and/or lead to depression and anxiety.

The COVID-19 pandemic disrupted normal routines, bringing on rapid and unforeseen changes to daily life. Some evidence demonstrates the pandemic allowed for more time to engage in protective health behaviors such as preparing homemade food[131] and increased physical activity;[44] while others experienced increased depression and anxiety symptoms,[24,58,141] weight gain,[70] sedentary behavior,[49] alcohol consumption,[82] and worsened dietary habits.[12] There were numerous factors that occurred during COVID-19 that could have influenced the associations this study found among pandemic-related changes in PHQ-4 scores. Participants reporting decreased symptoms of depression and anxiety during COVID-19 were inconsistent in our analyses, presenting a less clear dose-response than participants with no or worsened symptoms of depression and anxiety. Only 11% of participants (n = 12,384) reported their depression and anxiety symptoms lessened during the pandemic, perhaps reducing the magnitude of associations due to low statistical precision and/or indicating no causal association. COVID-related changes in PA and mental health within CPS-3 have been investigated. Rees-Punia et al. (2021) found that compared to those who remained physically active, individuals who were or became inactive during the pandemic reported more depression. It is possible other pandemic-related changes could be driving the reduced protective effects of ACS Guideline adherence among participants reporting lessened PHQ-4 scores during COVID. Exploring the subpopulation of people within this study with increased PA (n =

37,256), decreased alcohol intake (n = 8,955), and increased intake of healthy foods (n = 30,516) during the pandemic with PHQ-4 scores in 2021 may provide insight into how COVID could have impacted the protective effects associated with ACS Guideline adherence against future poor mental health.

Strengths and Limitations

Notable strengths of this study include its prospective design with a 6-year follow-up period, incorporating data collected both before and after the pandemic; large sample size; the capacity to control for confounding variables; and the utilization of survey measures that have proven valid and reliable across diverse populations. Furthermore, this study is the first of these authors' knowledge to assess complete adherence to the 2020 ACS Guidelines for Cancer Prevention as a measure of co-occurring health behaviors in relation to mental health outcomes for depression and anxiety. Reverse causation bias may exist, but the possibility is low as results from a sensitivity analysis excluding participants with pre-existing anxiety and/or depression diagnoses and those taking medication for depression and/or anxiety across both timepoints were largely unchanged, and this bias would tend to attenuate the associations. The occurrence of the COVID-19 pandemic over this study's follow-up years is an additional limitation. To address this, a stratified analysis was conducted to assess differences in PHQ-4 scores "over the past month" in 2021 and changes to PHQ-4 scores "during the COVID-19 pandemic." Participants were past the height of the pandemic and retrospectively responded to questions measuring PHQ-4 changes during COVID. Therefore, responses and results may not have as accurately measured depression and anxiety during the pandemic as questionnaires gathered during the height of 2020, but

rather perceptions of participant's mental health during that time. Due to the lack of variability across PHQ-4 scores, particularly among moderate and severe symptoms, predicting the longitudinal effects of engaging in health behaviors on varying severities of depression and anxiety were unable to be explored. PHQ-4 is not a clinical diagnosis but rather was developed as a quick measure to detect symptoms of depression and anxiety. Further research is warranted to explore associations of co-occurring health behaviors and mental health outcomes utilizing diagnostic data.

Conclusions

The temporal associations identified in this study indicate that adopting multiple healthy behaviors may offer protective benefits against future poor mental health outcomes. As the prevalence of depression and anxiety continue to increase, investigating the complex relationship between mental health and health behaviors (both independent and co-occurring) remains a public health priority.

Tables

Table 4.1. Participant Characteristics by Patient Health Questionnaire-4 (PHQ-4).

Characteristic	Total (n = 112,016)	PHQ-4 Scores			
		Normal (n = 75,869)	Mild (n = 28,574)	Moderate (n = 5,558)	Severe (n = 2,015)
Age, mean (SD)	53 (10)	53 (9)	51 (10)	49 (10)	49 (10)
BMI, mean (SD)	27.5 (6.0)	27.1 (5.8)	27.9 (6.3)	28.6 (6.9)	29.7 (7.7)
Recreational physical activity, mean (SD), MET-h/wk	28 (33)	30 (34)	26 (32)	24 (30)	23 (32)
Sex					
Female	88,643 (79%)	58,125 (77%)	23,958 (84%)	4,817 (87%)	1,743 (87%)
Male	23,373 (21%)	17,744 (23%)	4,616 (16%)	741 (13%)	272 (13%)
Race and ethnicity					
White	100,863 (90%)	68,462 (90%)	25,709 (90%)	4,934 (89%)	1,758 (87%)
Asian, Native Hawaiian, Pacific Islander, or American Indian	2,741 (2.4%)	1,821 (2.4%)	702 (2.5%)	156 (2.8%)	62 (3.1%)
Black	2,207 (2.0%)	1,541 (2.0%)	502 (1.8%)	109 (2.0%)	55 (2.7%)
Latino	5,753 (5.1%)	3,774 (5.0%)	1,531 (5.4%)	325 (5.8%)	123 (6.1%)
Other	452 (0.4%)	271 (0.4%)	130 (0.5%)	34 (0.6%)	17 (0.8%)
Alcohol intake (2015)					
Nondrinker	29,529 (26%)	19,614 (26%)	7,572 (26%)	1,631 (29%)	712 (35%)
Drinker	82,487 (74%)	56,255 (74%)	21,002 (74%)	3,927 (71%)	1,303 (65%)
Work status					
Full time	75,344 (67%)	50,853 (67%)	19,383 (68%)	3,774 (68%)	1,334 (66%)
Part time	13,626 (12%)	9,275 (12%)	3,469 (12%)	670 (12%)	212 (11%)
Retired	13,919 (12%)	10,242 (13%)	3,093 (11%)	442 (8.0%)	142 (7.0%)
Other	7,047 (6.3%)	4,186 (5.5%)	2,060 (7.2%)	529 (9.5%)	272 (13%)
Unknown/missing	2,080 (1.9%)	1,313 (1.7%)	569 (2.0%)	143 (2.6%)	55 (2.7%)

Income, $					
125,000 or more	37,269 (33%)	26,801 (35%)	8,620 (30%)	1,419 (26%)	429 (21%)
<50,000	15,709 (14%)	9,518 (13%)	4,482 (16%)	1,178 (21%)	531 (26%)
50,000 to <75,000	19,312 (17%)	12,529 (17%)	5,282 (18%)	1,092 (20%)	409 (20%)
75,000 to <100,000	19,732 (18%)	13,262 (17%)	5,169 (18%)	977 (18%)	324 (16%)
100,000 to <125,000	18,294 (16%)	12,486 (16%)	4,668 (16%)	841 (15%)	299 (15%)
Unknown/missing	1,700 (1.5%)	1,273 (1.7%)	353 (1.2%)	51 (0.9%)	23 (1.1%)
Education level					
College graduate	39,908 (36%)	27,064 (36%)	10,227 (36%)	1,955 (35%)	662 (33%)
High school or less	6,945 (6.2%)	4,680 (6.2%)	1,737 (6.1%)	379 (6.8%)	149 (7.4%)
Some college or 2-y degree	27,906 (25%)	18,434 (24%)	7,286 (25%)	1,525 (27%)	661 (33%)
Graduate degree	36,961 (33%)	25,473 (34%)	9,262 (32%)	1,686 (30%)	540 (27%)
Unknown/missing	296 (0.3%)	218 (0.3%)	62 (0.2%)	13 (0.2%)	3 (0.1%)
Marital status					
Married or living with partner	86,093 (77%)	59,540 (78%)	21,314 (75%)	3,939 (71%)	1,300 (65%)
Never married	8,364 (7.5%)	4,951 (6.5%)	2,568 (9.0%)	590 (11%)	255 (13%)
Divorced, separated, or widowed	16,258 (15%)	10,463 (14%)	4,377 (15%)	983 (18%)	435 (22%)
Unknown/missing	1,301 (1.2%)	915 (1.2%)	315 (1.1%)	46 (0.8%)	25 (1.2%)
ACS Scores (2015)					
0-2	14,127 (13%)	8,528 (11%)	4,164 (15%)	1,012 (18%)	423 (21%)
3	15,952 (14%)	10,168 (13%)	4,431 (16%)	964 (17%)	389 (19%)
4	21,267 (19%)	14,175 (19%)	5,586 (20%)	1,101 (20%)	405 (20%)
5	23,671 (21%)	16,462 (22%)	5,839 (20%)	1,021 (18%)	349 (17%)
6	20,227 (18%)	14,428 (19%)	4,705 (16%)	823 (15%)	271 (13%)
7-8	16,772 (15%)	12,108 (16%)	3,849 (13%)	637 (11%)	178 (8.8%)
Depression symptoms (PHQ-2)					
Low	104,673 (93%)	75,869 (100%)	26,747 (94%)	2,057 (37%)	0 (0%)
High	7,343 (6.6%)	0 (0%)	1,827 (6.4%)	3,501 (63%)	2,015 (100%)

Anxiety symptoms (GAD-2)					
Low	100,612 (90%)	75,869 (100%)	24,060 (84%)	683 (12%)	0 (0%)
High	11,404 (10%)	0 (0%)	4,514 (16%)	4,875 (88%)	2,015 (100%)
Depression and Anxiety (PHQ-4) during COVID-19					
Unchanged	53,978 (50%)	40,067 (55%)	11,287 (40%)	1,991 (37%)	633 (32%)
Worsened	41,436 (38%)	22,702 (31%)	14,468 (52%)	3,041 (56%)	1,225 (62%)
Lessened	12,384 (11%)	9,664 (13%)	2,205 (7.9%)	387 (7.1%)	128 (6.4%)
Unknown	4,218	3,436	614	139	29
Alcohol intake during COVID-19					
Unchanged	78,972 (71%)	55,786 (74%)	18,507 (65%)	3,406 (62%)	1,273 (64%)
Increased	23,043 (21%)	13,828 (18%)	7,203 (25%)	1,518 (28%)	494 (25%)
Decreased	8,955 (8.1%)	5,575 (7.4%)	2,591 (9.2%)	573 (10%)	216 (11%)
Unknown	1,046	680	273	61	32
FFQ during COVID-19					
Unchanged	44,725 (40%)	33,324 (44%)	9,222 (32%)	1,588 (29%)	591 (30%)
Increased good food	30,516 (27%)	20,785 (28%)	7,744 (27%)	1,488 (27%)	499 (25%)
Decreased good food	36,219 (32%)	21,397 (28%)	11,462 (40%)	2,450 (44%)	910 (46%)
Unknown	556	363	146	32	15
Physical activity during COVID-19					
Unchanged	57,578 (52%)	42,065 (56%)	12,683 (45%)	2,130 (39%)	700 (35%)
Increased	37,256 (33%)	21,593 (29%)	11,763 (41%)	2,787 (51%)	1,113 (56%)
Decreased	16,469 (15%)	11,737 (16%)	3,959 (14%)	596 (11%)	177 (8.9%)
Unknown	713	474	169	45	25

Table 4.2. Associations between ACS Guideline scores and symptoms for depression and anxiety

	Model 1 *Adjusted for age, sex, and energy intake*				**Model 2** *Additionally adjusted for sociodemographic factors*[a]				**Model 3**[b] *Sensitivity analysis, excluding pre-existing diagnosis and medication use*			
ACS Scores	**N**	**OR**	**95% CI**	**p-value**	**N**	**OR**	**95% CI**	**p-value**	**N**	**OR**	**95% CI**	**p-value**
Depression and Anxiety (PHQ-4)												
0-2	14,127	**1 [Ref]**	**1 [Ref]**		14,127	**1 [Ref]**	**1 [Ref]**		6,865	**1 [Ref]**	**1 [Ref]**	
3	15,952	0.88	0.84, 0.92	<0.001	15,952	0.89	0.85, 0.94	<0.001	8,560	0.97	0.90, 1.05	0.5
4	21,267	0.79	0.75, 0.83	<0.001	21,267	0.81	0.77, 0.84	<0.001	12,338	0.94	0.87, 1.01	0.086
5	23,671	0.69	0.66, 0.72	<0.001	23,671	0.71	0.68, 0.74	<0.001	14,688	0.87	0.81, 0.94	<0.001
6	20,227	0.62	0.59, 0.65	<0.001	20,227	0.65	0.62, 0.68	<0.001	12,984	0.84	0.78, 0.90	<0.001
7-8	16,772	0.58	0.55, 0.61	<0.001	16,772	0.6	0.57, 0.63	<0.001	11,159	0.78	0.73, 0.85	<0.001
Depressive Symptoms (PHQ-2)												
0-2	14,127	**1 [Ref]**	**1 [Ref]**		14,127	**1 [Ref]**	**1 [Ref]**		6,865	**1 [Ref]**	**1 [Ref]**	
3	15,952	0.8	0.74, 0.87	<0.001	15,952	0.83	0.77, 0.90	<0.001	8,560	0.96	0.79, 1.16	0.7
4	21,267	0.63	0.59, 0.68	<0.001	21,267	0.67	0.62, 0.72	<0.001	12,338	0.8	0.67, 0.96	0.018
5	23,671	0.51	0.47, 0.55	<0.001	23,671	0.55	0.51, 0.60	<0.001	14,688	0.71	0.59, 0.85	<0.001
6	20,227	0.43	0.39, 0.47	<0.001	20,227	0.48	0.44, 0.52	<0.001	12,984	0.68	0.56, 0.82	<0.001
7-8	16,772	0.38	0.35, 0.42	<0.001	16,772	0.43	0.39, 0.47	<0.001	11,159	0.66	0.54, 0.81	<0.001
Anxiety Symptoms (GAD-2)												
0-2	14,127	**1 [Ref]**	**1 [Ref]**		14,127	**1 [Ref]**	**1 [Ref]**		6,865	**1 [Ref]**	**1 [Ref]**	
3	15,952	0.91	0.85, 0.98	0.011	15,952	0.93	0.87, 1.00	0.044	8,560	1.01	0.87, 1.17	>0.9
4	21,267	0.79	0.74, 0.85	<0.001	21,267	0.82	0.76, 0.87	<0.001	12,338	0.93	0.81, 1.07	0.3
5	23,671	0.68	0.64, 0.73	<0.001	23,671	0.71	0.67, 0.76	<0.001	14,688	0.87	0.75, 0.99	0.04
6	20,227	0.63	0.59, 0.68	<0.001	20,227	0.67	0.62, 0.72	<0.001	12,984	0.83	0.72, 0.96	0.01
7-8	16,772	0.58	0.54, 0.62	<0.001	16,772	0.62	0.57, 0.67	<0.001	11,159	0.84	0.72, 0.97	0.017

[a]Sociodemographic factors included race/ethnicity, income, work status, education level, and marital status.

[b]Model adjusted for sex, age, energy intake, and sociodemographic factors.

Table 4.3. Associations of ACS Guideline adherence and PHQ-4 scores stratified by changes during the COVID-19 pandemic[a]

ACS Scores	Unchanged				Worsened				Lessened			
	N	OR	95% CI	p-value	N	OR	95% CI	p-value	N	OR	95% CI	p-value
0-2	6,786	**1 [Ref]**	**1 [Ref]**		5,174	**1 [Ref]**	**1 [Ref]**		1,681	**1 [Ref]**	**1 [Ref]**	
3	7,689	0.85	0.79, 0.91	<0.001	5,836	0.87	0.81, 0.94	<0.001	1,892	1.03	0.88, 1.20	0.7
4	10,466	0.77	0.72, 0.82	<0.001	7,490	0.8	0.75, 0.86	<0.001	2,481	0.9	0.78, 1.05	0.2
5	11,481	0.67	0.63, 0.72	<0.001	8,663	0.68	0.64, 0.74	<0.001	2,589	0.88	0.76, 1.02	0.093
6	9,577	0.58	0.54, 0.62	<0.001	7,697	0.66	0.62, 0.71	<0.001	2,153	0.76	0.65, 0.89	<0.001
7-8	7,979	0.55	0.51, 0.59	<0.001	6,576	0.62	0.57, 0.67	<0.001	1,588	0.8	0.67, 0.94	0.009

[a]Model adjusted for sex, age, energy intake, and sociodemographic factors.

Figures

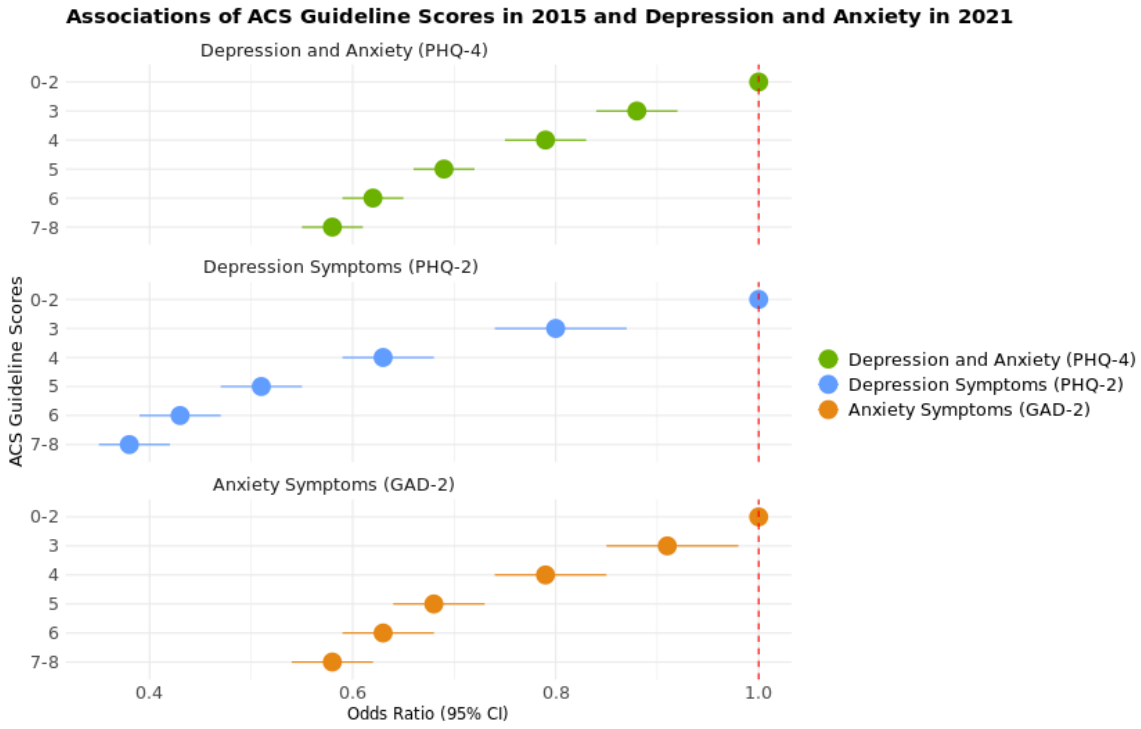

Figure 4.1. Associations of ACS Guideline scores in 2015 and symptoms of depression and/or anxiety in 2021. Model adjusted for sex, age, and energy intake (model 1).

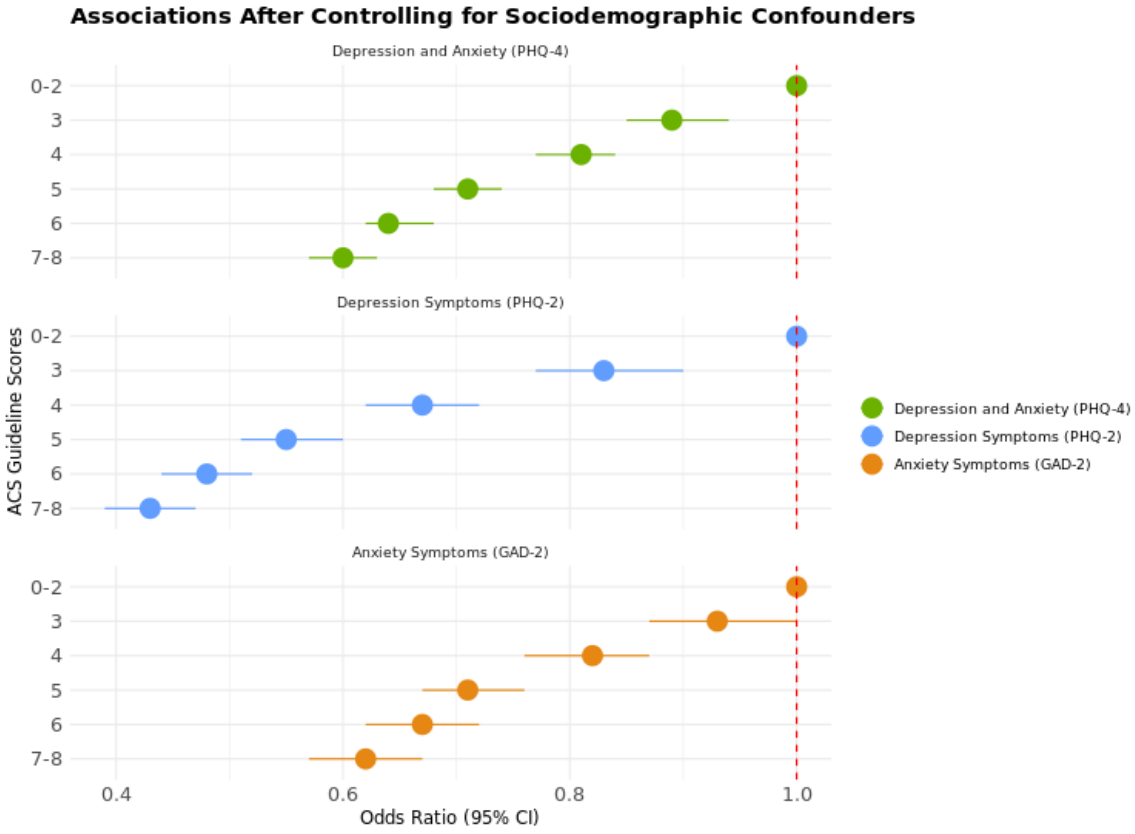

Figure 4.2. Associations of ACS Guideline scores in 2015 and symptoms of depression and/or anxiety in 2021 after controlling for sociodemographic confounders. Model adjusted for sex, age, energy intake, race/ethnicity, income, work status, education, and marital status (model 2).

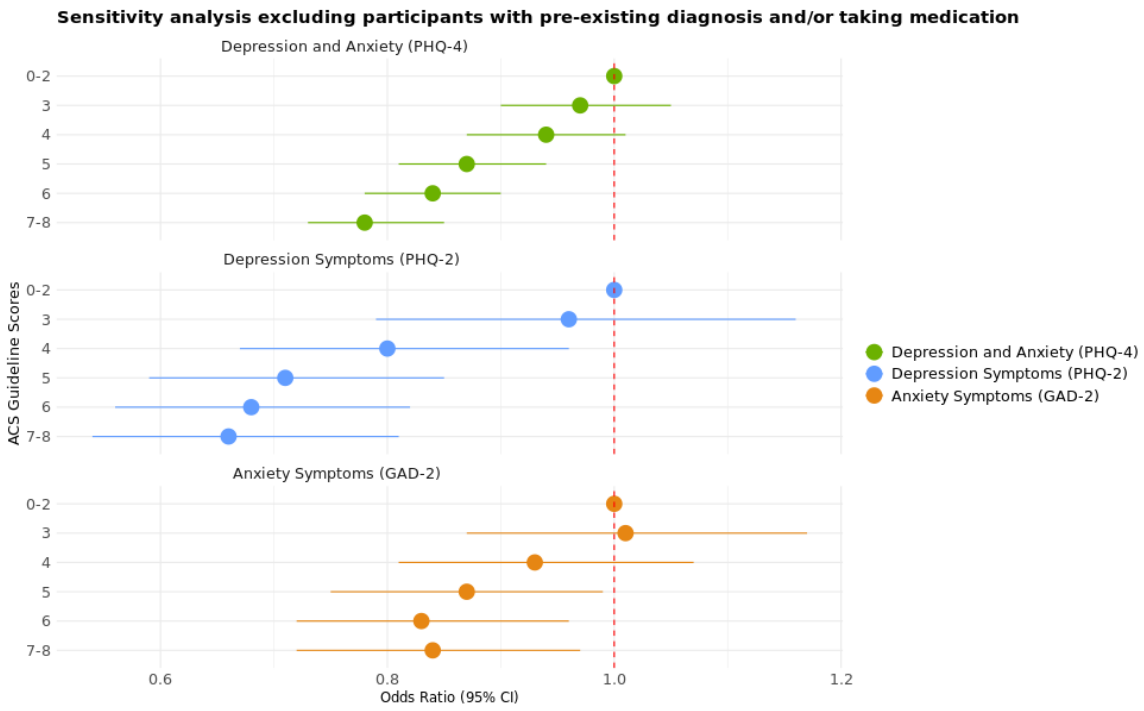

Figure 4.3. Associations ACS Guideline adherence and future depression and/or anxiety excluding participants with pre-existing diagnosis for depression and/or anxiety and those taking medication for depression and/or anxiety in 2015 and 2021.

Model adjusted for sex, age, energy intake, race/ethnicity, income, work status, education, and marital status.

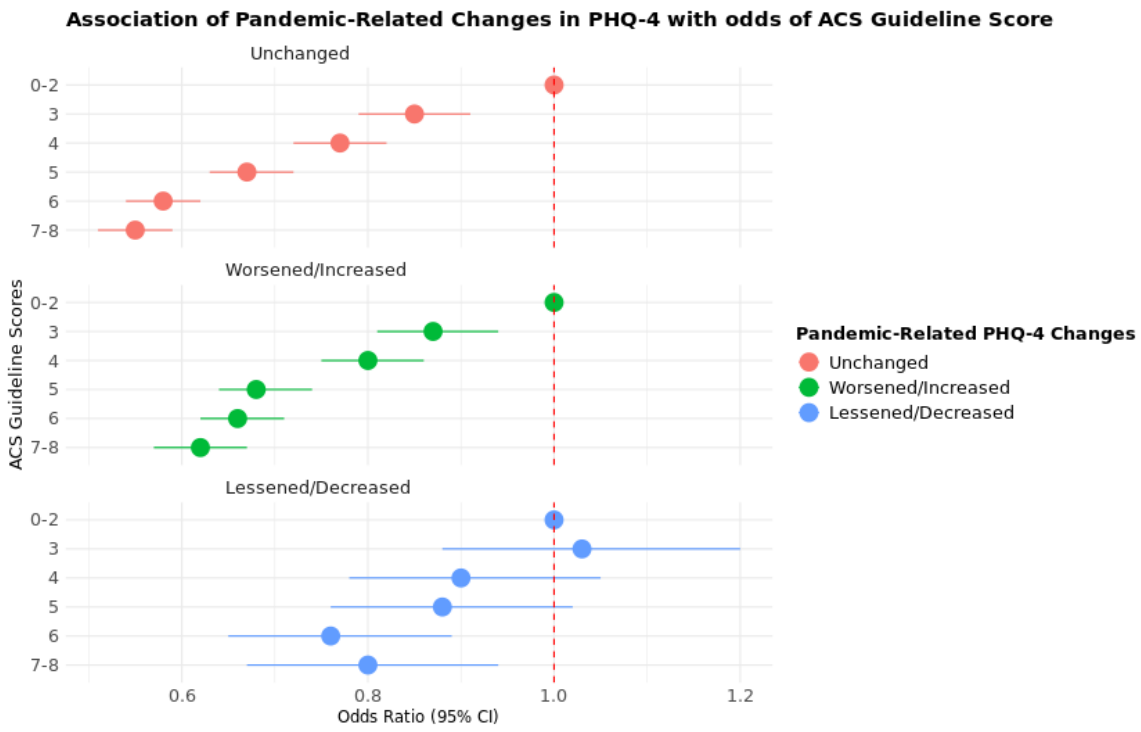

Figure 4.4. Associations of ACS Guideline scores in 2015 and PHQ-4 in 2021 stratified by pandemic-related changes in depression and anxiety. Model adjusted for sex, age, energy intake, race/ethnicity, income, work status, education, and marital status.

CHAPTER 5

CONCLUSIONS

Introduction

Relationships among social determinants of health (SDoH), health behaviors, and mental health outcomes are complex, interrelated, and dynamic. While bidirectional relationships are clear across the literature,[51] numerous calls have been made for understanding the mechanisms in which SDoH intersect to influence health behaviors (individual and co-occurring) and contribute to mental health.[4,42,81] Understanding the inherent complexity of these associations may reveal strategies for advancing health equity. For decades, health organizations have released guidelines for healthy lifestyle behaviors to prevent chronic diseases and poor health outcomes.[135,15821,30,130] A synthesis of existing evidence demonstrates associations of adhering to these guidelines with substantial reductions in cancer risk, cardiovascular disease (CVD), and morbidity,[76,98] with benefits extending among individuals with fewer resources and historically marginalized racial and ethnic groups.[153,171] However, research investigating adherence to health guidelines as a measure for co-occurring health behaviors and associations with SDoH and prospective mental health outcomes are limited. The purpose of this dissertation was to examine associations between social determinants of health, co-occurring health behaviors captured by adhering to the ACS Guidelines for Cancer Prevention, and future symptoms of depression and anxiety in a large, diverse sample of aging U.S. adults. Due to the complex and bidirectional nature of these associations, two studies were used and described in Chapter 3 and Chapter 4 of this dissertation.

Chapter 3 Summary

In Chapter 3, associations among SDoH and co-occurring health behaviors were examined using data from the Cancer Prevention Study-3 (CPS-3) 2015 follow-up survey. The final analytic cohort included 142,085 participants with a mean age of 53 years old, composed of 79% women (n =111,694) and 89% White participants (n = 126,788). Ordinal logistic regression and two-way joint variable interaction models were used to cross-sectionally assess associations between SDoH exposures and co-occurring health behaviors captured by adhering to the ACS Guidelines for Cancer Prevention. To reflect adherence to the ACS Guidelines for diet, body mass index (BMI), physical activity (PA), and alcohol consumption, a 0 to 8 point score was computed, with 8 points representing optimal adherence. Exposure measures included race and ethnicity, gross household income, marital status, educational attainment, rural-urban commuting area (RUCA) codes, food desert status, second-hand smoke (SHS) exposure, and work status. Overall, all SDoH exposures were statistically significant and independently associated with ACS Guideline adherence. Guided by the WHO Commission on Social Determinants of Health (CSDH) conceptual framework, novel joint interactions demonstrating the intersectionality among various SDoH exposures were found, illuminating several significant disparities. Racial disparities among Black participants were the most prominent among socioeconomic factors, in which Black women experienced 39% lower odds of high ACS Guideline scores (i.e., 7-8) compared to White women and the protective effects associated with educational attainment did not apply to Black participants as they did to White participants. Across all races, lower income levels were associated with lower ACS Guideline scores. Compared to married women, never

married men had 24% higher odds of higher ACS Guideline scores, whereas women counterparts had lower odds by 11%. Higher ACS Guideline adherence was associated with not working full-time among women, part-time and retired men; metropolitan women; those making $125,000 or more; and individuals with no second-hand smoke exposure. These findings illuminate the complex, intersecting, and significant impact SDoH have on multiple health behaviors.

Chapter 4 Summary

Prospective associations between co-occurring health behaviors for diet, alcohol consumption, BMI, and PA in 2015, captured by adherence to the ACS Guidelines for Cancer Prevention, and depression and anxiety symptoms in 2021 were examined in Chapter 4. Data from CPS-3 follow-up surveys in 2015 and 2021 were used to create a final analytic cohort of 88,643 women (79%) and 23,373 men (21%) with a mean age of 53 years old. Multivariate logistic regression models were used to examine associations between ACS scores and future symptoms of depression and anxiety measured by the Patient Health Questionnaire-4 (PHQ-4). PHQ-4 is an ultra-brief, reliable, self-reported measure for detecting depression and anxiety, with sub-scores for depression (PHQ-2) and anxiety (GAD-2) symptoms.[83] Higher adherence to the ACS Guidelines was associated with significantly lower odds of future anxiety and depression symptoms. To address the potential for reverse causality, results from a sensitivity analysis restricted to 66,594 participants (59.5%) that did not have pre-existing depression and/or anxiety nor were taking medications for depression and/or anxiety in 2015 or 2021 demonstrated associations consistent the primary results. Stratification by changes in PHQ-4 scores during the COVID-19 pandemic revealed participants that experienced decreased anxiety

and depression symptoms had a less clear dose-response relationship compared to those with no or worsened changes in PHQ-4 scores. The temporal associations revealed in this study suggest adhering to the ACS Guidelines for Cancer Prevention may provide protective effects against poor mental health outcomes in the future.

Key Findings

This research has revealed several key findings. The conclusions drawn from these studies confirm the importance of considering SDoH factors when developing targeted interventions and policies to improve co-occurring health behaviors and reduce disparities, particularly among cancer prevention behaviors. The findings of Chapter 3 identified significant sociodemographic, economic, and geographic predictors of co-occurring health behaviors and highlighted disparities based on race/ethnicity, sex, income, education, SHS exposure, marital status, and work status. These findings underscore the importance of considering the complex intersectionality of SDoH shaping disparities among co-occurring health behaviors when developing and informing future public health approaches. Findings from the prospective longitudinal study presented in Chapter 4 suggested adhering to the ACS Guidelines for Cancer Prevention may predict associations of better mental health outcomes in the future. Though the strength varied across models, these associations held true when accounting for various sociodemographic factors, excluding those with pre-existing conditions and medication use, and accounting for the occurrence of the COVID-19 pandemic. The research presented in this dissertation illustrates the importance of exploring the intersectionality of social determinants of health on co-occurring health behaviors and their prospective impact on mental health outcomes.

Strengths

The studies of this dissertation were the first of my knowledge to assess complete adherence to the 2020 ACS Guidelines for Cancer Prevention as a measure of co-occurring health behaviors and in relation to mental health outcomes. Mental health outcomes in CPS-3 have only been explored by Rees-Punia et al. (2021), thus the findings of Chapter 4 expanded the usage of CPS-3 to investigate mental health among an aging population of this size. Due to the magnitude of sample sizes used in these studies, the point estimates for 95% confidence intervals among associations were provided by R with great confidence. These studies included men and women of varying ages residing in the United States. Limited research is available on women in the US; across both studies, women were the majority sex represented in each study population which allowed these studies to contribute to reducing sex disparities in scientific research. Due to the robustness of measures captured by the CPS-3 surveys, the cross-sectional study in Chapter 3 evaluated a multitude of sociodemographic, economic, and geographic factors demonstrated to impact individual health behaviors and outcomes. Additionally, the use of joint variable models illustrated the mechanisms in which social determinants intersect to characterize and influence individual's health risk. Key strengths of the study presented in Chapter 4 include the prospective study design with 6 years of follow-up, with data collected before and after the pandemic; ability to control for confounders; and the use of survey measures that have demonstrated both validity and reliability across various populations.

Limitations

The research presented in this dissertation may be limited by the reliance of self-reported data captured in the CPS-3 studies and are subject to recall bias. Findings from these studies may not be generalizable to the U.S. population, as CPS-3 has a comparatively higher proportion of women, and consists of participants with relatively higher income, educational attainment, and minimal racial and ethnic diversity. CPS-3 participants are generally more physically active than the US population and ACS diet scores may not be representative of an ideal diet in all populations as the FFQ likely lacked some important foods in different subpopulations assessed, such as Asian, Hawaiian Native, and Pacific Islander participants, thus further limiting generalizability.

Summary and Future Directions

To achieve health equity and reduce disparities, it is critical to understand how SDoH are associated with health behaviors (both individual and co-occurring) and their longitudinal effects on health outcomes, such as depression and anxiety. While the interrelationship between health behaviors has been demonstrated, emerging studies exploring the co-occurrence of these behaviors are mostly cross-sectional in nature.[20,73,87,92,122] Similarly, research examining the link between mental health and health behaviors (both independent and co-occurring) also tends to rely on cross-sectional data, with limited longitudinal studies available.[25,60,74,109,150,165] In this dissertation, I provide evidence that the ACS Guidelines for Cancer Prevention can serve as a measure for co-occurring health behaviors and SDoH significantly impact individual's adherence to health behaviors. Further, through the WHO CSDH framework, I demonstrated ways in which SDoH may intersect to drive these associations and increase the magnitude of

their effects. Lastly, I revealed adherence to the ACS Guidelines as a predictor for future symptoms of depression and anxiety.

Based on these results, for practitioners, I suggest the promotion and education of adhering to health recommendations for co-occurring health behaviors, such as the ACS Guidelines for Cancer Prevention, as a protective measure against poor mental health outcomes among individuals at risk. When doing so, I stress the importance of considering all potential SDoH factors influencing an individuals' health status to ensure approaches are tailored to reduce and eliminate potential barriers and disparities.

Regarding future research, stronger causal evidence is required. Thus, I recommend utilizing clinical diagnostic data to further confirm associations demonstrated with adhering to co-occurring health behavior recommendations and mental health outcomes. Additionally, utilizing longitudinal mental health monitoring may strengthen causal inference among mental health and SDoH for primary prevention as most existing evidence is observational and thus subject to selection and confounding biases.[81]

Findings from Chapter 3 suggest second-hand smoke (SHS) exposure may be a proxy for socioeconomic status in general, therefore, I propose we expand the analyses presented in Chapter 3 to exploring the interaction between SHS exposure and food desert status within CPS-3 to further test this hypothesis. Furthermore, I suggest future studies explore what may be driving the association among never married men in the marital status and sex joint variable model in Chapter 3, perhaps by looking at marital status and income level using an ad hoc to stratify by the number of people in the household. Results may provide insight into confounding variables influencing the associations demonstrated in this dissertation. The general direction of the associations

found in Chapter 3 were consistent with the findings of McCullough et al. (2022), who investigated SDoH on ACS diet scores. As a result, I suggest we expand beyond the scope of this dissertation to assess ACS Guideline scores for BMI, Alcohol, and PA individually to better understand which factors had the biggest impact on each component.

Eating a healthy diet, engaging in regular PA, limited or no alcohol consumption, and maintaining a healthy body weight are individual behavioral factors that collectively contribute vastly to one's health. It is critical future public health approaches consider the complexity of relationships described in this dissertation when developing interventions, education, and policy efforts to advance health equity and reduce poor health outcomes.

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APPENDICES

APPENDIX A

INTERPRATION OF ACS GUIDELINE SCORING

BMI, *kg/m^2*	
0	≥30 at any time point
1	Other combinations
2	18.5 - < 25 at both time points
Physical activity, *MET-h/wk*	
0	< 7.5
1	7.5 - < 15
2	15+
Diet	
0	1st tertile (< 4)
1	2nd tertile (4 - <8)
2	3rd tertile (8-12)
Alcohol intake, *drinks/day*	
0	> 1 *(women);* > 2 *(men)*
1	≤ 1 *(women);* ≤ 2 *(men)*
2	Nondrinker
Total ACS Guideline Score, *0 to 8 scale*	
0	Zero adherence
4	Partial adherence
8	Full adherence

Scores are weighted equally on a low to high scale, with higher scores indicating better health and adherence and low scores indicating poor adherence and health.

APPENDIX B

SCORING PATIENT HEALTH QUESTIONNAIRE-4 FOR DEPRESSION AND ANXIETY (PHQ-4)

How often have you been bother by the following problems?		Not at all	Several Days	More than half the days	Nearly every day
GAD-2.2	Feeling nervous, anxious, or on edge	0	1	2	3
GAD-2.2	Not being able to stop or control worrying	0	1	2	3
PHQ-2.1	Feeling down, depressed, or hopes	0	1	2	3
PHQ-2.2	Little interest or pleasure in doing things	0	1	2	3