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# Development and Validation of a Multidimensional Experimental Screening Instrument to Measure Multiple Barriers Associated with Adult dietary Practices: A Secondary Analysis of NHANES Datasets 2011-2012

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**Abstract**

Dietary practices, which are complex and reflective of one's life experience, are influenced by intrinsic and extrinsic factors. Given that good nutrition is the underpinning of good health, it is prudent to measure factors associated with dietary practices. While instruments are available to assess factors associated with diet, none are designed to simultaneously measure the multi-dimensional nature of barriers associated with dietary practices. The aim of this dissertation was to develop a multidimensional instrument that can be used as a screening tool by practitioners to determine barriers associated with adult dietary practices. This dissertation compendium includes four manuscripts reporting results from: 1) an integrative review describing food insecurity interventions for African Americans in the United States; 2) a study that established content validity for a hypothesized multidimensional instrument designed to identify barriers to dietary practices; 3) an analysis to identify constructs within and validate the hypothesized multidimensional instrument; and 4) an exploratory secondary analysis to examine the relationships between dietary health status (DHS) and selected participant demographic characteristics and clinical outcomes. Results from the integrative review (Manuscript 1) suggested that multi-level interventions that address barriers influencing dietary access and choices demonstrated the greatest efficacy in improving access to healthful foods compared to one-dimensional interventions. Manuscript 2 established content validity for 12 theory-based domains comprised of variables that represent barriers associated with adult dietary practices. Manuscript 3 developed the DHS instrument, designed to measure barriers associated with dietary practices and tested

the psychometric properties of this instrument. Exploratory factor analysis described in Manuscript 3 revealed adequate construct and internal validity of the DHS instrument and for the 10 subscales that comprise DHS. Manuscript 4 showed that participants who are older than 45 years, minorities, (Black, Hispanic or Other race), live in larger households, are not married, and have abnormal A1c or blood pressure levels were more likely to have lower DHS scores compared to their counterparts. These findings suggest these groups might have more barriers to adhering to healthful dietary practices than their counterparts, possibly increasing their risk for chronic diseases.

The knowledge gained from this dissertation will guide future refinement of the DHS instrument. Ultimately, refining the DHS instrument so that it can accurately identify multiple barriers to dietary practices could have far reaching implications for education, practice, and policy.

**Keywords**: Multidimensional, multi-level, instrument development, screen, validity, reliability, community, intervention, dietary practice, factors, barriers, variables, Behavior Change Wheel, Theoretical Domains Framework,  domain, Food insecurity/food security

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**Introduction**

Consuming an unhealthful diet is a well-established and well-known risk factor for many chronic diseases, including hypertension, hyperlipidemia, diabetes, and stroke (1, 2). Hence, it is not surprising that diet has been reported to be the leading modifiable risk factor for chronic diseases, attributed to 24% of deaths and 14% of disability-adjusted life-years in the United States (1). Adhering to a healthful diet is not simple, suggesting the need to explore factors that influence dietary practices.

Dietary practices, which are complex and reflective of one's life experience, are influenced by a multitude of intrinsic and extrinsic factors. Dietary practices are well known to be influenced by five broad factors -- economic (cost and income), physical (access, education and skills), social (culture and social context), psychological (mood and stress), and cognitive (i.e. beliefs and knowledge) (3-5). All can act as barriers to adherence of good dietary practices. In addition, how much each factor explains or influences dietary practices is highly individualized (6, 7). To improve the health of U.S. adults, healthcare practitioners need a practical screening tool to identify barriers associated with dietary practices so individualized prevention plans can be prepared. As barriers to dietary practices are rarely one dimensional, the multi-dimensional nature of dietary practices needs to be examined.

Three well-designed instruments -- National Health and Nutrition Examination Survey (NHANES), What We Eat in America [WWEIA] 24-hour dietary recall, and Household Food Security Supplemental Module HFSSM) -- are available to assess dietary practices. However, all aim to monitor the U.S. population as a whole so they are not practical for use to measure adult dietary practices (8-10). To our knowledge, no

validated instruments are currently available that measure barriers at the individual level and that can be administered in a clinical/community setting.

NHANES is a survey used to monitor the health and nutritional status of adults and children in the United States. Data are collected in two-year cycles and organized into five sections (demographics, dietary, examination, laboratory, and questionnaire). Although NHANES has many strengths (i.e. multiple components assessed and generalizable sample of the health and nutrition needs of the population), in its entirety it is not practical as a screening tool in a clinical/community setting to identify barriers to good dietary practices of individuals (8, 9). The 18-item Household Food Security Supplemental (HFSSM) has similar limitations as NHANES, in that it is also designed to assess the food security status of the U.S. population as a whole (10). As such, the HFSSM is a reliable measure of a household's financial capacity to buy nutrient-dense foods, however, it does not measure if household members have knowledge about nutrient-dense foods, food preparation skills, nor does it measure whether household members consume a nutritionally adequate diet. Moreover, both NHANES and HFSSM are cumbersome to administer and have complex scoring algorithms. In contrast, the Mini Nutrition Assessment (MNA) and DETERMINE are both valid and reliable nutritional assessment instruments that can be used in the clinical/community settings (11, 12) . However, they were specifically designed to screen for malnutrition in the older population, which limits their use with the general population.

Another limitation is that a multidimensional score cannot be generated from these instruments. For the purpose of this study, the term "multidimensional" refers to multiple but separate behavioral dimensions comprising multiple factors that may

influence a behavioral concept, such as dietary practices. This is similar to Edwards's

definition of multidimensional as a number of similar but separate dimensions that may

be viewed as one concept (13). The literature shows that dietary practices are almost

always a combination of inadequate nutritional intake linked to multiple other factors

(either in the physical, psychological, cognitive, or social dimensions) (3-5). Moreover,

these factors are intertwined as barriers to dietary practices are rarely one-dimensional.

McLeroy and colleagues' Social Ecological Model (SEM) describes the five

(intrapersonal, interpersonal, organizational, communal, and political factors) interactive

characteristics of individuals and environments that influence health behavior and health

outcomes (6). Essential to the SEM are the concepts of multiple levels of influence and

reciprocal causation. Specifically, this theory assumes that behavior affects and is

affected by multiple levels of influence and that individual behavior shapes and is shaped

by ones' environmental context (6). Thus, it is vital to simultaneously measure the

multiple, intertwined barriers to dietary practices. Because barriers may be related to one

another and the dimensions which they represent may be correlated and theoretically

related, generating a multidimensional score produced by summing all dimensions

involved may capture the true phenomenon of the multidimensional nature of barriers to

adult dietary practices as a whole. This is one unique attribute of the instrument

developed in this compendium as it was designed to produce a multidimensional score by

summing all presumed subscale that represents a theory-based dimension that may be a

barrier to healthful dietary practices. Generating a multidimensional score is important

because it reveals whether barriers to an individual's dietary practices exists at all and if

barriers exists, whether there are few or many barriers. Furthermore, based on the

generated score, further investigation may be warranted to capture exactly where barriers exist and which barriers have the strongest influences on dietary practices, the individual subscales could be use.

In 2011 the Affordable Health Care Act implemented the "Annual Wellness Visit" (AWV). The aim for offering AWV is to provide an individualized prevention plan to individuals to maintain their health and prevent chronic diseases (14, 15). The AWV includes: a 1) health risk assessment (HRA) (self-reported medical/family history, list of medications and supplements, and list of all medical providers); 2) assessment (measurements: height, weight, body mass index, blood pressure, and depression, cognitive, and functional ability screening); and 3) individualized health plan (list of conditions/risks with interventions; health screening and immunizations schedule; appropriate referrals to health education or preventive services); and voluntary advanced care planning (preparing an advance directive if the patient is receptive). While AWV maybe a comprehensive approach it has two major limitations: 1) individuals must be 65 years and older and receiving Medicare; and 2) no single screening instrument is recognized by the Centers for Medicare & Medicaid Services (CMS) for use in the AWV (14, 15). Practitioners have the option to use any nationally-recognized screening instrument. Having to search and choose from a multitude of instruments is cumbersome for practitioners. Moreover, the selected instrument might not measure dietary practices. Given the importance of unhealthful dietary practices as a risk factor for many chronic diseases, it would be prudent to measure multiple dimensions (e.g. physical, psychological, cognitive, or social context) associated with dietary practices. An appropriate instrument, accurately identifying barriers based on theory in behavior

change, could more reliably inform prevention-based interventions, particularly those that center on prevention of chronic diseases, the most common cause of death in the United States.

The knowledge gained from this research has far-reaching implications, particularly for practice. For example, practitioners may use DHS to screen adults thoroughly for barriers to their dietary practice at longer visits, e.g., during regular primary care annual exams and health specialty or wellness clinics; therefore, prompting an individualized intervention plan of care. Ultimately, the capacity of DHS to accurately identify individuals with multiple barriers to dietary practices will inform education, and policy.

**Frameworks**

The Behavioral Change Wheel (BCW), hub COM-B system, and the Theoretical Domains Framework (TDF) together provided a systematic approach to identify variables that are key determinants of adult dietary practices. Datasets from NHANES were used to assign those variables to their theory-based domains.

The BCW was developed to provide a comprehensive approach to guide the development of behavior change interventions (16). Its framework consists of three main layers: 1) sources of behavior (hub), 2) intervention functions, and 3) policy categories. However, because the focus of this study was to identify barriers associated with adult dietary practices, only the framework's hub, the COM-B, was used. The COM-B system recognizes that behavior is part of an interacting system involving three components: capability, opportunity, and motivation (16) (Figure 1).

Psychological or physical ability to enact the behavior → Capability

Reflective and automatic mechanisms that activate or inhibit behavior → Motivation

Physical and social environment that enables the behavior → Opportunity
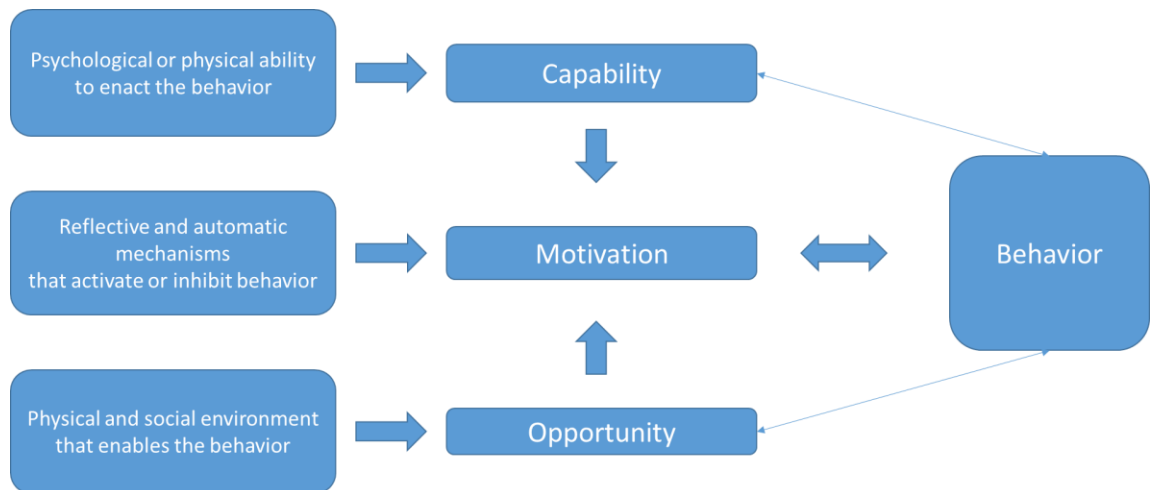
Behavior

Michie et al (2011) Implementation Science

**Figure 1: The COM-B system: Behavior occurs as an interaction between three necessary conditions**

The TDF was developed from multiple behavioral change theories, the framework can be used to identify barriers relevant to behavior change and to design interventions to address these barriers (17, 18). The TDF comprises 14 domains representing barriers: knowledge; skills, social/professional role and identity, beliefs about capabilities, optimism, beliefs about consequences, reinforcement, intentions, goals, memory, attention and decision processes, environmental context and resources, social influences, and emotional and behavioral regulation (17). Researchers have used the TDF to develop theory-based questionnaires to identify and understand potential factors influencing human behavior and to guide the design of effective interventions (19-21). The framework was developed over the last decade by Michie and colleagues (18) and refined in 2012 by Cane and colleagues(17). Both frameworks are interconnected because each domain of the TDF relates to a COM-B component. The linkage between the TDF and COM-B is illustrated below in Figure 2.

Adopted from Dr. Michie, 'Development and Validation of the Theoretical Domains Framework'
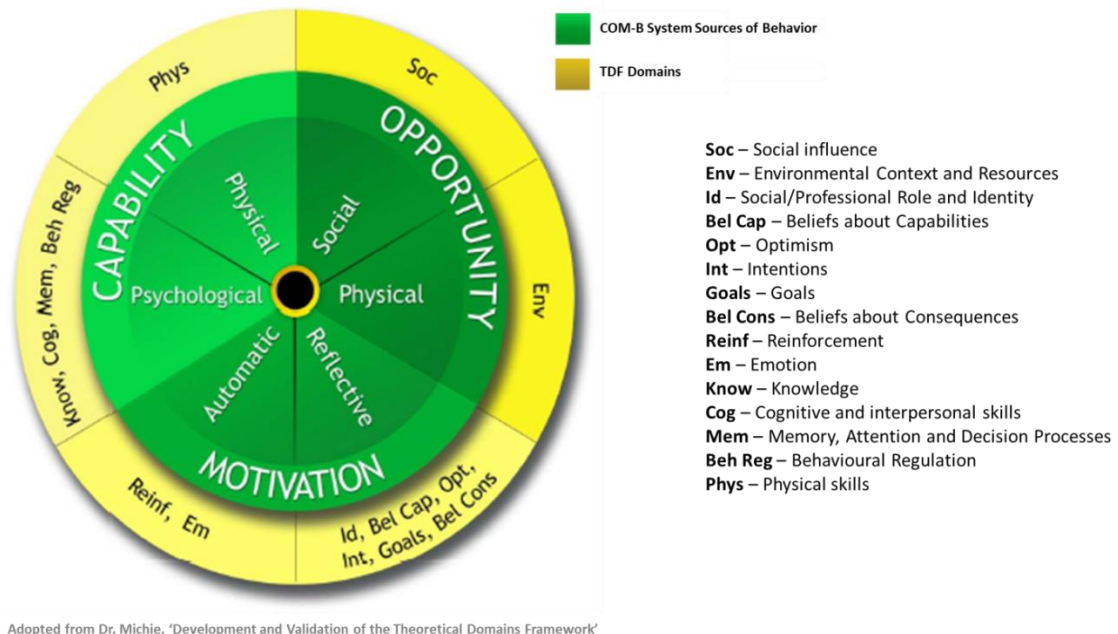
**Figure 2: TDF domains within their appropriate COM-B components**

**Datasets and Population**

Three of the four manuscripts within this dissertation used the NHANES 2011-

2012 data. NHANES is a core program of the National Center for Health Statistics

(NCHS), a branch of the U.S. Centers for Disease Control and Prevention (CDC) (8).

NHANES was designed to assess the health and nutritional status of adults and children

in the United States (9). NHANES collects demographic, socioeconomic, dietary, and

health-related data through a combination of in-home interviews conducted by highly

trained dietary and health interviewers with physical examinations and laboratory

assessments performed by physician, and medical and health technicians in mobile

centers (9). NHANES data are collected in two-year cycles and are organized into five

sections: 1) demographics, 2) dietary, 3) examination, 4) laboratory, and 5) questionnaire

(9). NHANES has many strengths: 1) the sample is selected to represent the U.S.

population of all ages; 2) select groups are oversampled to better estimate attributes of the

groups (age 60 and older, African Americans, and Hispanics); 3) the health needs of the

population are identified; 4) the datasets are used by researchers and organizations around

the world; 5) datasets are available to the public free of charge and can be accessed on the

internet; and 6) results from the data can inform health and nutritional policies (8, 9). In

particular, the 2011-2012 NHANES datasets were chosen because, in addition to the

above strengths, at the time of this study, those datasets included the most current 24-

hour dietary recall data, as well as data on multi-ingredient foods converted into their

appropriate amounts and Food Pyramid (FP) components from What We Eat in America

(WWEIA), made available through the corresponding NHANES dietary data agency.

Specifically, the 2011-2012 NHANES datasets used for this project included 13,431

individuals selected to participate (9). Of those selected, 9,756 completed the interview,

and 9,338 participants were examined (9). Of those, 3,705 participants met inclusion

criteria for this study: 1) individuals had to be age 20 years or older, assuming younger

individuals may not have full autonomy over their diet and 2) data relevant to this study

were collected during in-home interviews and health examination. Participants who

reported being pregnant were excluded, as pregnant women might have atypical dietary

patterns. An exempt status for this study was obtained from the Institutional Review

Board of the Bioethics Committee (IRB) of the Medical University of South Carolina

(MUSC).

**Manuscript 1**

This manuscript describes an integrative review, part of the preliminary work that

supported the need to investigate using a multidimensional approach to identifying

barriers to adult dietary practices in order to guide the development of individualized,

comprehensive interventions. This review explored the available evidence on community-based food insecurity, defined as "limited or uncertain availability of nutritionally adequate and safe foods or limited or uncertain ability to acquire acceptable foods in socially acceptable ways"(22) interventions for African Americans in the United States. Results suggested that multi-level interventions that address multiple factors (intrinsic and extrinsic factors) influencing dietary access and choices (e.g. aspect of poverty, knowledge, skills and environmental context) demonstrated the greatest efficacy in improving access to healthy foods compared to one-dimensional interventions alone.

**Manuscript 2**

The methods used to establish preliminary content validity for selected variables obtained from the NHANES database and that were assigned to specific theory-based behavioral domains are described in this manuscript. The validated variables are considered as items of a conceptualized instrument that can be used to simultaneously measure the multidimensional nature of dietary practices. Three major steps are described: 1) conceptualization of a multidimensional instrument Dietary Health Statute (DHS); 2) identification of potential items for the conceptualized instrument based on two behavioral theoretical frameworks [Behavioral Change Wheel (BCW), COM-B components, and Theoretical Domains Framework (TDF) domains] from among variables within the National Health and Nutrition Examination Survey 2011-2012 datasets; and 3) establishment of content validity for the potential items within their assigned theory-based domains utilizing an expert review panel during the validation process. As a result of expert feedback, content validity was established for 12 theory-based domains comprised of key determinants that influence adult dietary practices.

**Manuscript 3**

This manuscript aims to assess the structure and conduct psychometric testing of the instrument. The results of an exploratory factor analysis (EFA) are described in this manuscript. Associations of the observed variables, with underlying latent variables, were assessed along with constructs of the conceptualized multidimensional instrument. The 12 theory-based domains comprised of factors that can potentially influence adult dietary practice were used to form the dimensions of the instrument. Once the conceptualized multidimensional instrument was developed, the psychometric properties of the instrument and identified subscales were evaluated. The EFA resulted in a 10-factor solution, suggesting the DHS consists of 10 subscales that can be used to measure barriers to dietary practices. Subscales can be used independently or combined to form the DHS instrument as a whole. Results indicate the DHS is a valid and reliable instrument to simultaneously measure barriers to dietary practices.

**Manuscript 4**

A secondary analysis of the NHANES 2011-2012 datasets using the novel DHS instrument was reported in Manuscript 4. This analysis aimed to investigate potential associations between participant DHS total scores and selected demographic and clinical characteristics. Findings suggested that participants older than 45 years, minorities, (Black, Hispanic or other race), those living in larger households, those not married, as well as those with abnormal A1c levels or blood pressure were more likely to have lower DHS scores, indicating that these groups may have more barriers to dietary practices compared to their counterparts, therefore, may be at increased risk for chronic diseases.

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**Manuscript 1: A Social Ecological View of Food Insecurity Interventions in African Americans communities**

**Abstract**

African-American households in the United States remain disproportionally affected by food insecurity despite national efforts to reduce this disparity. Thus, it is paramount to effectively address food insecurity in African-American communities. This review explores the published evidence on community-based food insecurity interventions guided by the Social Ecological Model targeting African Americans in the United States Of the 312 studies retrieved, six were relevant for this review after duplicates were removed and screening against inclusion criteria was applied. Results indicated that: 1) interventions sought to improve access to healthful foods; 2) interventions addressing food insecurity on multiple levels of the Social Ecological Model were more effective than single-level interventions; and 3) multi-leveled interventions that addressed aspects of poverty demonstrated the greatest efficacy. Thus, further research on the development and testing of multi-level food insecurity interventions, which address aspects of poverty are needed to improve food security in African-American communities.

**Keywords**: Food insecurity/food security, community, African American, Social Ecological Model/SEM and intervention.

## Introduction

One in nine people worldwide struggle with food insecurity (FI), [Food and Agriculture Organization of the United Nations (FAO), 2015]. FI can lead to malnutrition (FAO, 2015), a medical condition with substantial undesirable consequences. In the United States, FI disproportionally affects African-American communities (Chilton et al., 2009). In fact, according to the USDA, 26.1% of African-American households struggle with FI compared to only 10.5% of their White, non-Hispanic counterparts. In an attempt to address FI, the USDA Food and Nutrition Service (FNS) administer various national nutrition assistance programs. Despite these efforts, FI persists (Chilton et al., 2009) and overall rates in recent years have remained stagnant (Coleman-Jensen et al., 2014). Therefore, the effectiveness of national programs needs reevaluation and community-based alternatives should be examined. Due to their ubiquitous role in today's healthcare systems, nurses are in a unique position to address FI. However, nurses must be knowledgeable of the resources available in their communities to effectively combat FI. The purpose of this integrative review was to explore the available evidence on community-based FI interventions in African-American communities in order to guide nurses to appropriately disseminate available resources thereby improving the food security status of the community as a whole.

## Food Insecurity Interventions in African-American Communities

As a global public health phenomenon, FI has been linked to type 2 diabetes, obesity, cardiovascular diseases, as well as poor mental health (Townsend, Peerson, Love, Achterberg, & Murphy, 2001) in developed regions of the world. The most quoted definitions of FI is from the U.S. Department of Agriculture (USDA) and the FAO. The

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USDA defines FI as "limited or uncertain availability of nutritionally adequate and safe foods or limited or uncertain ability to acquire acceptable foods in socially acceptable ways" (2014). For example, if households are food insecure, they might resort to scavenging, stealing, maternal buffering (mothers limiting their own food intake to provide more for their children) or other coping strategies, such as eating foods that are less preferred, borrowing food, and skipping meals (Maxwell, 1996). Similarly, FI is defined by the FAO as "a situation that exists when people lack secure access to sufficient amounts of safe and nutritious food for normal growth and development as well as an active healthy life" (2015). In practice, in the United States FI is measured as an economic variable using the Household Food Security Supplemental Module (HFSSM), a self-report survey that focuses on the household level (National Research Council, 2006). A household is considered food insecure if one or more members struggle with FI (Bickel, Andrews, & Carlson, 1998).

Even when food is available, it may not be accessible to all households even in developed countries, such as the United States (Labadario, McHiza, Steyn, Gericke, Maunder, Davids, & Parker, 2011). According to the USDA 2014 statistics on food security status of U.S. households, 14% of all households are affected by FI (Coleman-Jensen, Rabbitt, Gregory, & Singh, 2014). However, vulnerable populations at greater risk for poor health status exhibited substantially higher prevalence of FI (Shi & Stevens, 2005). For example, according to the USDA report, 22.4% of Hispanic and 26.1% of African American households struggle with FI compared to 10.5% of White non-Hispanic households (Coleman-Jensen et al., 2014). Moreover, the USDA report indicated that 19.2% of households with children, 21.7% of households with children

headed by a single man, and 35.3% headed by a single woman were food insecure (Coleman-Jensen et al., 2014). In addition, FI is most prevalent in the South (15.1%) compared to the Northeast (13.3%), Midwest (13.8%) and the West (13.1%). These numbers suggest a strong relationship between FI and socioeconomic status, gender, race/ethnicity, and to a lesser extent geographic region (Shi, Stevens, Faed, &Tsai, 2008; Bryant & Stevens, 2006 and Shi & Stevens, 2005).

The idea of FI in the United States may be unfathomable to many, however, FI is integrally linked to social and economic determinants, such as poverty and lack of adequate education, income, and access to health care (Chilton et al., 2009 and DeRose, Messer & Millman, 1998). Thus, it is not surprising that FI is a problem in many poor communities, areas where exposure to unsafe living conditions exists (Chilton et al., 2009). This is particularly true for African Americans living in resource-poor communities (Ver Ploeg et al., 2012). In an attempt to address FI, the USDA Food and Nutrition Service (FNS) administers various national nutrition assistance programs, such as the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC), Supplemental Nutrition Assistance Program (SNAP), and child nutrition programs (USDA FNS, 2014 and Chilton & Rose, 2009). Yet, FI persists despite these efforts by the USDA to increase food security (Chilton et al., 2009). In fact, the overall rates for 2012, 2013 and 2014 have remained stagnant (Coleman-Jensen et al., 2014), suggesting the effectiveness of the nutrition assistance programs on the national level needs reevaluation and community-based alternatives should be examined. Additionally, due to their frequent interactions and role as case managers, patient health educators, and advocates, nurses are in the unique position, to assess and address FI in any setting.

Therefore, it is critical for nurses to be knowledgeable of resources patients have available to them within their communities to effectively address FI.

Food security is influenced by intrapersonal, interpersonal, institutional, environmental, and political factors (McLeroy, Bibeau, Steckler, & Glanz, 1988). In other words, FI is a multifaceted problem, therefore, interventions addressing FI should use a multifaceted approach (Chilton et al., 2009). Consequently, assessing the effectiveness of FI interventions through the multiple levels of influence of the SEM is appropriate. The purpose of this integrative review was to explore the available evidence on community-based FI interventions in African-American communities in the United States through the lens of the SEM. This review focuses on community-based FI interventions as described by the USDA community food security initiative (USDA Economic Research Service, 2015). The initiative focuses on preventive community-based strategies that: 1) improve access of low-income households to healthful nutritious food supplies; 2) increase the self-reliance of communities in providing for their own food needs; and 3) promote comprehensive responses to local food, farm, and nutrition issues (USDA Economic Research Service, 2015). Examples of these strategies include farmers markets (boost incomes of small local farmers and increase consumers' access to fresh produce); community-supported agriculture programs (provide small-scale farmers with economic stability while ensuring consumer members high-quality produce, often at below retail prices); farm-to-school initiatives (help local farmers sell fresh fruits and vegetables directly to school meals programs); and SNAP outreach programs (help increase the number of eligible households that participate in the SNAP) (USDA Economic Research Service, 2015).

## Methods

**Theoretical Framework**

The Social Ecological Model (SEM) provides a theoretical framework of the relationship among factors identified as influencing health. SEM emphasizes that health and health behaviors are influenced by intrapersonal, interpersonal, organizational, communal, and political factors (McLeroy et al., 1988). Accordingly, the SEM is the guiding theoretical framework for this integrative review. Intrapersonal factors include individual characteristics such as knowledge, attitude, behavior, self-concept, skills, thought processes, beliefs, perceptions, cues to action and perceived barriers (Gregson et al., 2001). Also included at this level are individual characteristics, such as gender, racial/ethnic identity, education, economic status, goals and age. Interpersonal processes are sources of influence shown to be important in health-related behaviors of individuals (McLeroy et al., 1988). They include interpersonal relationships with-family members, friends, neighbors, contacts at work, acquaintances, and other members of the community. Organizational factors include social institutions with organizational characteristics and formal (and informal) rules and regulations for operation. These factors play a vital role in health promotion. At this level, regulations or policies to promote health through systems and structural changes are instituted. Communal factors include social networks, formal or informal groups (families, personal friendship networks, and neighborhoods), and relationships among these organizations and groups (McLeroy et al., 1988). Political factors include local, state, and national laws and policies (McLeroy et al., 1988). Health policies, at the local, regional and national level, are necessary to develop initiatives to promote population health. Because all five levels

play a significant role in addressing FI, the SEM provides an appropriate theoretical framework to guide exploration of FI interventions in African-American communities. However, not all levels have the same effect on FI interventions. The magnitude of influence increases from the intrapersonal to political level. For example, policies can initiate changes that influence entire systems of service delivery and consumer communications, while FI interventions at the intrapersonal level can initiate changes at the individual level only (Gregson et al., 2001 and McLeroy et al., 1988). Nevertheless, all levels address different aspects of FI and thus interventions accounting for all SEM levels should have the most positive impact on the food security status of the community.

**Design**

Whittemore and Knafl's (2005) integrative review framework was adopted to inform this review to maintain rigor and transparency. The authors began with a clear description of the problem under investigation and defined the purpose of the review. Next, the theoretical framework was selected to guide this review followed by a comprehensive literature search. Subsequently, data extraction, data analysis and comparison of the reviewed literature were completed.

**Literature Review**

A literature search was undertaken to explore the available evidence on community-based FI interventions in the United States for African Americans. Details extracted from eligible studies were organized in (M1) Table 1, (M1) Table 2 and (M1) Table 3.

**Search Criteria**

A comprehensive search was conducted, spanning 2005 to the end of March 2016. The following databases were searched: scientific journal databases of PubMed, Cumulative Index to Nursing and Allied Health Literature (CINAHL), PsycINFO and Scopus. The following search terms were employed: ("food insecurity" OR "food security" OR "food desert" OR "nutritional status" OR "Food environment" OR "food pantry" OR "food availability" OR "dietary consumption") AND (intervention OR "food program" OR "nutrition program" OR "food assistance") AND ("blacks" OR "African American" OR "African Americans" OR "Humans") AND ("US" OR "U.S." OR "USA" OR "United States") AND ("Minority" OR "Community" OR "Neighborhood" OR "Poverty Area" OR "African American") AND ("Socioeconomic Factors" OR "Poverty" OR "Low-Income"). The search strategy yielded 144 studies in PubMed, 11 in CINAHL, 13 in PsycINFO and 144 in Scopus. A total of 312 studies were identified. After the removal of duplicates, a total of 239 studies remained [(M1) Figure 1 presents an overview of the literature search].

**Inclusion Criteria**

The 239 studies were screened using the following four inclusion criteria: (a) peer-reviewed research study; (b) published between 2005 and 2016; (c) investigating a community-based FI intervention in the United States as described by the USDA community food security initiative; and (d) focusing on African Americans. Of the 239 studies, 36 met these criteria and six were relevant to this review.

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│ Articles initially identified through│
│   database searches (n=312)          │          ┌──────────────────────────────┐
│                                      │─────────▶│ Duplications removed: n=73     │
│        PubMed: n=144                 │          └──────────────────────────────┘
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│        Scopus: n=144                 │
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│   Abstract review (n=239)            │─────────▶│ community-based food insecurity intervention│
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│ Full articles retrieved for thorough │─────────▶│ Article excluded based on full review for  │
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**(M1) Figure 1: Search Results**

## Results

The six studies eligible for this review focused on community-based interventions to improve access to healthy foods in low-income, predominately African-American communities. All studies were conducted in the United States with various states and cities being represented. The authors of study 1 (Cummings et al., 2014), evaluated the impact of a new 41,000-square-foot, large-scale supermarket in an African-American community reported to be a food-desert in Philadelphia, PA. Freedman et al., 2011), who conducted study 2, implemented and evaluated the "Veggie Project" in an African-American community in Nashville, TN. This intervention addressed FI in three ways with: 1) onsite farmers markets; 2) vouchers redeemable at the farmers markets; and 3) education sessions about healthy foods for youth participants. Study 3 (Martin et al., 2013)  implemented and examined the efficacy of their "Freshplace" food pantry

intervention in a predominately African-American community in Hartford, CT. Similar to

Freedman's voucher program, Racine et al. (2011), who conducted Study 4, investigated

the possibility of combatting FI among African American WIC participants via vouchers

for fruits and vegetables redeemable at farmers markets in Washington, DC, and

Charlotte, NC. In contrast to the interventions above, Gittelsohn et al. (2013), Study 5,

addressed FI by turning recreational facilities in African-American communities in

Baltimore into "Baltimore Healthy Eating Zones" (BHEZ) by promoting the consumption

of healthy foods. Lastly, Odoms-Young et al. (2014), Study 6, investigated if changes in

WIC food package policy would improve healthy home food availability and dietary

intake for predominately Hispanic and African-American households participating in the

WIC program in Chicago, IL. From each study, the following details were extracted and

charted into (M1) Table 1 1 -- author, purpose, population, setting, design, and outcomes.

Each study was then viewed through the lens of the SEM framework. Characteristics of

the interventions and components of SEM addressed are summarized in (M1) Table 2 and

(M1) Table 3, respectively.

**Study 1: Supermarket-oasis in a food desert**

As part of a state initiative to improve access to healthy foods in underserved

neighborhoods, Cummings et al. (2014) evaluated the impact of a brand new supermarket

built in a food desert in a predominately African-American community in Philadelphia,

PA. Evaluation of the supermarket six months after opening was based on the following

three primary outcomes: 1) BMI was calculated by self-reported height and weight; 2)

fruit and vegetable intake was assessed with the Block Food Frequency Questionnaire;

and 3) perceptions of food access were assessed using a five-item scale. Results indicated

that slightly less than 30% of the 1,440 participants of this pre-post quasi-experimental longitudinal study made the new supermarket their primary store. In addition, slightly more than 50% of participants reported they shopped at the new supermarket occasionally. Moreover, the researchers noted that based on the results of the five-item scale, participants perceived that access to healthy foods had improved significantly. In particular, the choices and quality of foods were perceived to have increased, and the cost of fruit and vegetables was perceived to have decreased. However, data analysis of participant BMI or amount of fruits and vegetables consumed revealed no significant changes, indicative of poor intervention efficacy. By solely providing access to healthy foods, this intervention only addressed the communal level of the SEM. Even though this level is associated with a high impact on health changes, the intervention approach appears to lack efficacy. Combining additional aspects of the SEM might have led to more encouraging results.

**Study 2: Veggie Project not just a farmer's market**

In a mixed methods case study approach, Freedman et al. (2011) implemented and examined the effect of their "Veggie Project" intervention in four low-income, African-American communities in Nashville, TN. The intervention was designed to address FI by: 1) providing on-site farmers markets with healthy food choices at Boys and Girls Clubs in the community; 2) offering the Super Shopper Voucher Program (SSVP) to participants; and 3) encouraging youth participants in the community to consume more healthy foods through the Youth Leader Board (YLB). Effect was determined through interviews with adult stakeholders and themes gathered from youth journals. As such, the "Veggie Project" intervention addressed the intrapersonal, the organizational, and the

communal level of the SEM. In particular, the YLB addressed the intrapersonal level of the SEM in two ways. First, the 227 participants were educated on agriculture, nutritional aspects of healthy foods including fruits and vegetables, and on overcoming barriers to accessing healthy foods. Second, participants took food-related field trips and attended a cooking academy. The organizational level was addressed by providing eligible participants with up to $20 in vouchers, through the SSVP, redeemable for fresh fruits and vegetables at on-site farmers markets, thereby reducing the barriers of healthy food affordability. The Veggie Project intervention also addressed the communal level of the SEM by directing 34 farmers markets to visit and sell healthy foods at four Boys and Girls Clubs in the community to increase access to healthy foods. According to the YLB journals, the intervention addressed barriers to accessing healthy foods in the study communities as well as to provide an opportunity to develop job skills and improve personal health. The SSVP was evaluated by measuring the average amount of money spent by Super Shoppers and non-Super Shoppers on both fruits and vegetables. Results indicated that those who possessed vouchers (Super Shoppers) were more likely to purchase fruits and vegetables compared to those who had no voucher (non-Super Shoppers). These results revealed that the voucher program affected individuals' purchasing power leading to a significant increase in food security status of the community. Moreover, the project became a vehicle for parents and youth to engage in conversations about healthy eating. Overall, the positive intervention results as well as interviews with adults and the journals of the youth suggest that interventions addressing multiple-levels of the SEM may lead to superior intervention outcomes.

**Study 3: Freshplace a new type of food-pantry**

Martin et al. (2013) implemented and examined the impact of "Freshplace", a new type of food pantry intervention designed to promote food security in a predominately African-American community in Hartford, CT. Freshplace provided its 228 members with: a) a client-based food-pantry and other on-site services (communal level); b) monthly motivational interviews by trained professionals to reinforce positive changes/behaviors in their lives (intrapersonal level); and c) referrals to other community services (organizational level). Similar to the Veggie Project, Freshplace tackled FI on multiple levels, which lead to positive results. Based on the Missouri Community Action Family Self-Sufficiency Scale, the monthly motivational interviews had a positive impact on Freshplace members. In particular, results indicated that self-sufficiency among intervention participants improved significantly over a period of 12 months, while self-sufficiency remained stagnant in the control group. Moreover, in an attempt to improve the food security status of the community Martin et al., (2013) addressed the key underlying causes of poverty, such as underemployment, unstable housing, and mental health issues by providing intervention participants with referrals to other needed services. As a result, Freshplace members' fruit and vegetable intake increased after only three months. Over a period of one year, members were less than half as likely to experience very low food security compared to the control group. The intervention was successful in improving self-sufficiency and overall diet quality of intervention participants and food security status of the community as a whole.

**Study 4: Vouchers for WIC participants**

In a quasi-experimental study Racine et al. (2010) explored the impact vouchers redeemable for fruits and vegetables at local farmers markets had on the food security

status among African Americans in Washington, DC, and Charlotte, NC. Through the

Farmers market Nutrition Program (FMNP), the participants received vouchers worth

$30 redeemable for fresh fruits and vegetables at local approved farmers markets. As

such, the intervention addressed the organizational level of the SEM only. Racine and

colleagues' (2010) evaluated changes in the fruit and vegetable intake of the women post

intervention using the National Cancer Institute's 17-item Multifactor Screener, which

measures daily fruit and vegetable intake, fruit juice intake, consumption of high-fat

foods, and intake of high-fiber foods. The authors reported that depending on the

participant groups (those with prior Framers market experience and those without) and

their location (Washington, DC, versus Charlotte, NC), between 40%-60% of participants

who did not have the resources to purchase fruits and vegetables before took advantage of

the FMNP. These results suggest that vouchers redeemable for healthy foods can reduce

economic barriers and may improve the food security status of low-income communities.

Yet, simply reducing the economic barrier does not solve the FI problem, as almost half

of the participants did not take advantage of the voucher program. Lack of knowledge

about the importance of consuming healthy foods, or the location of the farmers markets

as well as inadequate access to transportation to and from the farmers market, might all

have been contributing factors to the low utilization rate.

**Study 5: Baltimore Healthy Eating Zones**

In contrast to previous interventions, Gittelsohn and colleagues (2013) employed

an entirely different approach to addressomg FI in Baltimore, MD. Instead of providing

vouchers to the community Gittelsohn designed "Baltimore Healthy Eating Zones"

(BHEZ) by encouraging six recreation centers, 21 corner stores, and carry-outs in

African-American neighborhoods in Baltimore, MD, to promote a healthier lifestyle. The study addressed three levels of the SEM. First, the intrapersonal level was addressed through education programs to promote healthy food-purchasing and consumption behavior via verbal and visual communications, cooking demonstrations and taste tests. Secondly, interpersonal level was addressed via peer educators reinforcing healthy lifestyle messages in BHEZ. For example, peer educators tailored health behavioral messages for their peers by creating educational illustrations that were then displayed at local corner stores and recreation centers. Lastly, the communal level was addressed by encouraging local corner stores and carry-outs to offer more healthy foods and promote a healthier lifestyle by appropriately labeling their products. In particular, storeowners were asked to increase the stocking of healthier foods and to place shelf labels increasing the visibility of healthy foods. Local carry-outs were encouraged to modify their menus to advertise healthier food choices. The authors did not report the efficacy of the peer educators addressing the intrapersonal level of the SEM.  At its core, the intervention had potential to lead to significant improvement of the food security status of the community as peer educators have been used successfully before to promote a healthier lifestyle (Stock et al., 2007). However, results indicated that the targeted number of peer educator visits per recreation center was unmet. In particular, while Gittelsohn and colleagues (2013) intended for high interaction rates between peer educators and the 242 participants of the study, the number of peer educators who dropped out during interactive sessions gradually increased. Moreover, only 7% of the corner stores reported the presence of a peer educator even in the initial phases of the intervention, while no peer educators were present during the later phases of the study. In general, the concept of employing peer

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educators and addressing three levels of the SEM could lead to an improvement in the food security status of the community, however, due to poor execution, intervention standards were not met and quantifiable results were not provided.

**Study 6: Changing WIC food package policy**

The last reviewed study, a natural experiment, addressed FI at the political level of the SEM only. Odoms-Young et al. (2014) investigated whether changes to the WIC food package policy would improve the food security status of 273 recipients of WIC in a low-income African-American and Hispanic community in Chicago, IL. In particular, the intervention aligned the WIC package received by participants more closely with updated nutrition science, current dietary recommendations, and nutritional suggestions to address the high rate of obesity among WIC participants. Hence, the WIC food package was expanded to include a wider variety of foods. For instance, the WIC food package was revised to include more fruits and vegetables, more foods with reduced fat (e.g. low-fat milk), more whole grains options (e.g. brown rice, oatmeal, and whole-wheat bread) and more cultural food preferences. Odoms-Young and colleagues (2014) studied the impact of this food package revision on dietary changes of participants and home food availability before and six months after the policy change. Results indicated that dietary changes varied by racial/ethnic group. Although none of the participating groups met the recommended consumption of fruits and vegetables, fruit consumption increased among Hispanic mothers, but not among Hispanic children, African-American children or African-American mothers. In addition, there was no significant change in vegetable consumption for mothers or children in any of the groups. However, intake of low-fat dairy products increased among Hispanic mothers, Hispanic children and African-

American children, yet, not in African-American mothers. Another encouraging result was the increase in the availability of low-fat dairy and whole grain food products in participant homes, suggesting there may be a long-term impact of the intervention on the participating households that could lead to a significant improvement in the food-security status of the community. Even in the short term, the intervention results revealed that by simply changing the WIC package policy to reflect the current state of nutrition science, the food security status of individuals and entire families could be impacted, demonstrating the power and effectiveness of policy changes.

## Discussion

FI exists whenever the availability of nutritionally adequate, safe foods or the ability to acquire personally acceptable foods in socially acceptable ways is limited or uncertain (Campbell, 1991). FI has substantial consequences for the general health of a population; consequently, it has been the subject of many scientific studies in recent years. Evidence indicates that families of low socioeconomic status consume diets of poor nutritional quality (Larson et al., 2013). Therefore, it is not surprising that African Americans have higher prevalence of FI in the United States compared to their White and Hispanic counterparts (Coleman-Jensen, 2014). While interventions on the national level have shown little improvement in the food security status of African-American communities, several interventions on the community level have been implemented in recent years to address FI in African-American communities. The purpose of this integrative review was to explore the current research on these community-based FI interventions in the United States.

Most of the reviewed FI interventions sought to improve access to healthful foods in low-income African-American communities in urban areas. In particular, farmers markets vouchers, availability of on-site or local farmers markets and/or client-choice food pantries, as well as motivational counseling sessions were all valuable in reducing barriers to purchasing healthy foods, reinforcing behavior change, and improving food security status of the community. Moreover, three of the six interventions addressed FI on multiple levels of the SEM, while the other three addressed only one SEM level. Interventions addressing FI on multiple levels of the SEM were more effective at improving access to food than interventions that only employed one SEM level. Unfortunately, none of the interventions approached improving access to healthy foods combining all levels of the SEM.

Three studies implemented a single SEM component intervention. Racine and colleagues' (2010) intervention, included an organizational change to Farmers market Nutrition Program policy to incorporate a voucher program. Although the voucher program affected individual purchasing power, results also indicated that a lack of knowledge of the location of farmers markets and issues with transportation were contributing factors to the low voucher utilization rates among participants. Although this intervention was geared at a higher level of impact (organizational), it is likely that a multi-level intervention would have improved the efficacy of the intervention. For example, including the interpersonal level by educating participants about the location of the farmers markets or by making available transportation to and from farmers markets sites, may have enhanced the success of the intervention. The second single-level intervention by Cummings et al. (2014) investigated change in food security status of a

community labeled a food desert by building a brand new supermarket in the community to increase access to healthful foods. Although a moderate improvement was found in resident perceptions of food accessibility, the convenience of having a new supermarket in the neighborhood had no impact on BMI or fruit and vegetable intake six months post intervention. Perhaps re-evaluation of BMI or fruit and vegetable intake after a longer period of time will reveal improved efficacy of the intervention. Yet, it is more likely that layering multiple SEM levels to address contextual factors, such as economic resources (organizational) and food preferences or food knowledge (intrapersonal), would have led to improvements in BMI and fruit and vegetable intake. In addition, engaging community residents as stakeholders and understanding the neighborhood context prior to building may have promoted the adoption of the new supermarket as well as assure its sustainability. The third single-level intervention involved the revision of the WIC food package policy. Odoms-Young et al. (2014) evaluated the effects of this policy change on dietary patterns and related health outcomes in low-income children and their caregivers. Results demonstrated the strength of the intervention at the political level of the SEM, the level of highest impact, as fruit consumption and intake of low-fat dairy products increased among many participants. Moreover, an increase in the availability of low-fat dairy and whole grain food products in the homes of participants was recorded, suggesting there may be a positive long-term impact of the intervention on the participating households. However, results also showed that African-American mothers did not significantly increase their intake of dairy products. This might be attributable to the fact that 80% of African Americans are or perceive to be lactose intolerant (Bailey et al., 2013; Keith et al. 2011). Addressing any perceived or actual lactose intolerance that

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may exist in African-American mothers, and thereby including the interpersonal level in this intervention, may have increased their intake of dairy products. Furthermore, had an intrapersonal level been incorporated into this intervention, such as educating participants about healthful food choices, may have increased the intake of fruits and vegetables as well.

The other half of the reviewed studies incorporated three SEM level interventions. The first intervention by Freedman et al. (2011) included the intrapersonal, organizational, and communal levels of the SEM. To improve access to healthy food, economic, knowledge and location barriers were addressed. For example, the intrapersonal component addressed knowledge and self-efficacy through the use of education and food-related fieldtrips. In addition, the community component was addressed by providing on-site community farmers markets at local Boys and Girls Clubs. Moreover, organizational changes allowed for the incorporation of a voucher program. The voucher program proved to be effective in increasing the purchasing power of individuals and thereby alleviating economic barriers. This approach of combining the three SEM levels contributed to the program's overall success for both youth and adult participants. The second multi-level intervention by Gittelsohn et al. (2013) addressed the intrapersonal, interpersonal, and communal components of the SEM. Multiple community venues were used in this intervention to encourage participants to upgrade their food purchasing behavior. Peer-educators addressed inter- and intrapersonal levels through direct and indirect interactions encouraging a healthier lifestyle among participants. Although peer educators as mentors have been used successfully in other studies to raise health awareness (Stock et al., 2007), the use of peer-educators in this

intervention was suboptimal. As a result, the intervention's overall impact on members of the intervention community could not be evaluated in this study. However, according to Shin and colleagues (2015) who later evaluated the impact of the Baltimore Healthy Eating Zones, the intervention fostered positive change in BMI. In particular, a decrease in BMI for overweight or obese low-income female African American youths was noted. Through the food pantry intervention Freshplace, Martin et al. (2013) addressed the intrapersonal, organizational and communal levels of the SEM. As a result, this intervention was successful in improving food security status, self-sufficiency as well as diet quality for intervention participants. The authors understood that in order to sustainably improve members' food security status, underlying causes of poverty, such as underemployment, unstable housing, and mental health issues, had to be addressed simultaneously. That is why members received personalized services beyond providing members access to food. Moreover, Freshplace members received nutritional training and counseling sessions to increase their knowledge of healthy foods and foster their sense of empowerment to live a healthy lifestyle even beyond the intervention period. This unique and elaborate array of services lead to the most promising improvement of food security status among participants of all reviewed studies.

While sufficient information in the literature exists on the governmental efforts addressing FI through various nutrition assistance programs, there is a shortage of data on community-based FI interventions, in particular, for African-American communities. Of the community-based FI interventions found, the majority did not address FI directly, but rather focused on specific undesired health outcomes such as obesity, anxiety and depressive symptoms. The studies that did address FI only incorporated either one or

three SEM levels. None addressed all five SEM levels. However, because FI is a multi-dimensional issue, FI interventions should be as well. Hence, comprehensive approaches addressing all SEM levels of FI, should maximize the improvement in food security status of African-American communities and are lacking in current literature. Limitation in available funding might partially be responsible for deterring researchers from conducting these types of comprehensive studies, which might be the reason for the absence of interventions that encapsulate all SEM levels.

Furthermore, there was no published research on community-based FI interventions in rural areas as all reviewed studies were implemented in large cities. A shortcoming in the literature as rural areas have higher FI rates, have fewer services available for families experiencing FI and exhibit lower levels of educational attainment than metropolitan areas.

Several limitations in the conduct of this review exist. First, the studies reviewed form a relatively small sample focused on community-based FI interventions in African-American communities. It is possible that community-based food programs exist, that are not published in peer-reviewed journals and thus are not included in this review. For example, locally organized community gardens, farmers markets, food pantries and church based programs exist, however might not publish their efficacies in scientific journals and thus would not be included in this review. Secondly, it is possible that relevant research was omitted by the search criteria used for this review. Third, only interventions conducted in the United States and published in the past ten years (2005-2016) were included to capture the current state of community-based FI interventions. Lastly, the review focused on African-American communities only, which may have led

to omission of other interventions that captured areas of relevance as well. Despite these limitations, this review highlights the complexities of addressing the multi-faceted problem of FI, the pros and cons of effective intervention implementation and the benefits of interventions that address FI on multiples levels of the SEM.

Despite national efforts to reduce FI, the rate of FI remained stagnant over recent years and continues to disproportionally plague African-American households. FI interventions geared directly at African-American communities might play a crucial role to remedy this disparity. Yet, there is little evidence on community-based FI interventions for African Americans in the literature. In fact, only six studies were identified that addressed the issue of FI in African-American communities in the United States. Analysis of these studies shows that interventions incorporating more than one SEM level led to superior improvements in the food security status of these communities. In addition, multi-leveled FI interventions that addressed aspects of poverty beyond improving the availability to healthful foods demonstrated the greatest efficacy in improving food security. However, community-based FI interventions for African Americans that incorporated all SEM levels are missing in the literature. Moreover, even though rural communities are more severely affected by FI than metropolitan areas, none of the reviewed interventions were implemented in rural communities. Thus, to improve the food security status of African-American communities in the United States, the development and testing of community-based, multi-leveled FI interventions, accounting for aspects of poverty beyond nutritional considerations, for both rural and urban communities should be the goal of future food security research.

Nurses' concerted roles in all aspects of patient care puts them in a unique position to identify and address FI in their respective settings. However, for nurses to efficiently combat FI, they have to rely on effective interventions and need to be knowledgeable about available resources for patients in their communities.

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**(M1) Table 1: Information extracted from review articles**

| Study | Purpose | Population | Design | Intervention | Outcomes |
|---|---|---|---|---|---|
| **Study 1**<br><br>Cummings et al, 2014 | **Supermarket in food desert:** Evaluated the impact of new supermarket in a food desert in a low-income, predominantly African-American community in Philadelphia. | Total N=1,440<br>Interv. N =723<br>Control N =717 | Pre-post quasi-experimental longitudinal design | 41,000-square-foot supermarket in intervention area.<br>Comparison area received no new supermarket. Follow-up 6 months post-intervention | 26.7% of the community adopted the new supermarket as their primary store, and 51.4% used it for food shopping occasionally. No significant differences in BMI values and daily fruit & vegetable intake between participants in the intervention and the control group were measured for those that made the new supermarket their primary, secondary or occasional store. Yet, based on a follow-up survey the sample population perceived the idea of a supermarket with healthy food choices as a positive one. |
| **Study 2**<br><br>Freedman, et al, 2011 | **Veggie Project:** Examine impact of farmers markets in four low-income, minority, urban, predominately African-American communities in Nashville, TN. | N =227 | Case study using mixed methods approach | The Veggie Project multi-component farmers markets intervention<br>(a) onsite farmers markets<br>(b) Super Shopper Voucher Program (SSVP)<br>(c) Youth Leader Board (YLB). | **(a) Framers Market:**<br>Stakeholders thought the markets were conveniently located, the produce was reasonably priced, and a wide variety of high-quality fresh fruits and vegetables were offered.<br>**(b) Super Shopper Voucher Program:**<br>Super Shoppers purchased more than non-Super Shoppers. Super Shoppers made statistically significantly more purchases than non-Super-Shoppers.<br>**(c) Youth Leader Board:**<br>Parents and youth engaged in conversations about healthy eating. YLB journals revealed that the youth participants believed that that the Veggie Project addressed barriers to accessing healthy foods in their communities, provided an opportunity to develop job skills, and influenced their health |
| **Study 3**<br><br>Martin et al, 2013 | Examine the impact of **"Freshplace"** a food pantry intervention program in a predominately African-American community in Hartford, CT, designed to promote food security. | Total N=228<br>Interv. N=113<br>Control N=115 | Randomized parallel-group study w/ equal randomization | **Intervention Members**<br>(a) Food pantry (Freshplace) a client-choice pantry<br>(b) Monthly motivational interviews with project manager<br>(c) Targeted referrals to community services<br><br>**Control Group**<br>Participants went to traditional food pantries and received bags of food. | **Three month post intervention**<br>Members demonstrated a significant increase in average fruit & vegetable scores<br><br>**One year post intervention**<br>1) Members were less than half as likely as the control group to experience very low food security<br>2) Members had a significant increase in self-sufficiency scores compared to the control group.<br>3) increased fruits and vegetables by one serving per day compared to the control group<br><br>**(d)** No significant differences in fruit and vegetable scores over time in the control group |
| **Study 4**<br><br>Racine et al, 2010 | Explore impact of **farmers markets vouchers** for fruits & vegetables among WIC participants in predominately | N=179 | Quasi-experimental pilot study | Vouchers for fruits and vegetables for WIC participants in Washington, DC | 40% of participants went to farmers markets to buy fruits & vegetables. |

| Study | Purpose | Population | Design | Intervention | Outcomes |
|---|---|---|---|---|---|
| | African-American communities in Washington DC and Charlotte, NC | | | | |
| **Study 5**<br><br>Gittelsohn, et al, 2013 | Study impact of **Baltimore Healthy Eating Zones** (BHEZ) in 6 recreation centers and 21 corner stores and carry outs in African American neighborhoods in Baltimore. | N=242 | Quasi-experiment study | Encourage, corner stores, recreation centers and carry-outs to offer more healthy foods in BHEZ in six interventions and seven control zones. Peer Educators were employed to encourage the youth to change their food-purchasing patterns through point-of-purchase interventions, augmented with behavioral messages in other community settings. | Targeted number of peer educator visits per recreation center was unmet. While the authors intended for high interaction rates between peer educators and the 242 participants of the study, the number of peer educators who dropped out during interactive sessions gradually increased. Moreover, only 7% of the corner stores reported the presence of a peer educator even in the initial phases of the intervention, while no peer educators were present during the later phases of the study. Quantifiable impact on the community was not provided. |
| **Study 6**<br><br>Odoms-Young et al, 2014 | Investigate impact of change in **WIC food package policy** on home food availability and dietary intake for predominately Hispanic and African American households participating in WIC in twelve WIC clinics in Chicago, IL | N =273 | Natural experiment | **Intervention Members**<br>a) Received a WIC food package with a wider variety of foods, including fruits & vegetables, whole grains, & cultural food<br>b) Obtained monthly fruit and vegetable voucher | **Six months post intervention**<br>1) Fruit consumption and low-fat dairy increased significantly among Hispanic mothers, Hispanic children and African-American children<br>2) Fiber intake increased significantly among Hispanic children<br>3) Increased home food availability of low-fat dairy and whole grains |

**(M1) Table 2: Description of SEM components of interventions addressed by each review**

| Author, Date | Intrapersonal | Interpersonal | Organizational | Communal | political |
|---|---|---|---|---|---|
| **Study 1**<br><br>Cummings et al, 2014 | Not addressed | Not addressed | Not addressed | New large-scale supermarket on the community level. | Not addressed |
| **Study 2**<br><br>Freedman, et al, 2011 | Participants in YLB program: 1) received education on agriculture, nutritional aspects foods, and barriers to accessing healthy foods 2) went on food-related fieldtrips (city-wide farmers market, supermarket, local farms, cooking academy) | Not addressed | SSVP participants receive up to $20 vouchers redeemable at the farmers markets<br><br>YLB program participants ran each farmers market (market set-up and clean up, food pricing and marketing and food sales) | 34 on-site farmers markets at in the community each market supplied with similar products from 11 local farms | Not addressed |
| **Study 3**<br><br>Martin et al, 2013 | Monthly motivational interview with project manager. Access to other educational services such as cooking classes. | Not addressed | Scheduled appointment to Freshplace, where members choose their own food from a majority of fresh and perishable food. Unlimited access to traditional food pantries. Tailored referrals to community services or on site services (6-week Cooking Matters class | Access to Freshplace where members choose their own healthy foods. Support to access other community services. Unlimited access to traditional food pantries. | Not addressed |
| **Study 4**<br><br>Racine et al, 2010 | Not addressed | Not addressed | WIC enrolled Pregnant women received vouchers redeemable for fresh fruits and vegetables at local approved farmers markets | Not addressed | Not addressed |
| **Study 5**<br><br>Gittelsohn et al, 2013 | Education program on healthy food consumption (via taste tests, cooking demonstrations and communications) | Peer educators (local youth) assisting to reinforce BHEZ messages | Not addressed | Corner-stores, carry outs and recreational centers in the community were encouraged to promote healthy foods and lifestyles. | Not addressed |
| **Study 6**<br><br>Odoms-Young et al, 2014 | Not addressed | Not addressed | Not addressed | Not addressed | Mother and child enrolled in WIC revised food package policy to change diet. |

**(M1) Table 3: Levels of the SEM represented in articles**

| Articles ⟍ SEM levels | Study 1 Cummings et al., 2014 | Study 2 Freedman, et al., 2011 | Study 3 Martin et al., 2013 | Study 4 Racine et al., 2010 | Study 5 Gittelsohn et al., 2013 | Study 6 Odoms-Young et al., 2014 |
|---|---|---|---|---|---|---|
| **Intrapersonal** | | X | X | | X | |
| **Interpersonal** | | | | | X | |
| **Organizational** | | X | X | | | |
| **Communal** | X | X | X | X | X | |
| **Political** | | | | | | X |

**Manuscript 2: Establishing Content Validity for a Hypothesized Multidimensional Instrument: A Consensus Approach**

**Abstract**

**Background:** Dietary practices are influenced by a multitude of intrinsic and extrinsic factors. Accurately and simultaneously measuring these factors could inform individualized interventions, particularly those that center on prevention of chronic diseases, the most common cause of death in the United States. Instruments are available to assess factors associated with diet, but none are designed to simultaneously measure multiple barriers influencing adult dietary practices in a clinical/community setting. The aim of this study was to describe the protocol used to establish preliminary content validity for selected variables obtained from the NHANES database that could be items on a hypothesized instrument that measures barriers to dietary practices.

**Methods:** Seven steps were conducted to complete the study: 1) develop operational definitions for each behavior change domain and assign each variable to a behavior change domain based on two theoretical frameworks that guided the study; 2) identify variables from NHANES database; 3) review selected variables to ensure no important sections and variables were overlooked during the initial critical stage; 4) evaluate variables assigned to each TDF domain to solicit input about whether the variables accurately reflected their underlying prospective domains; 5) expert review of variables and assignment to domain to gain consensus on variable fit within an assigned domain; and 6) validate the variables. The contributors were a "working" group (n =4) and an "expert review panel" (n =4).

**Results:** A total of 170 variables representing twelve domains were identified as potential factors that could influence adult dietary practice. These domains were: *knowledge*,

*optimism*, *beliefs about consequences*, *reinforcement*, *memory*, *attention and decision processes*, *environmental context* and *resources*, *social influences*, *emotion*, *behavioral regulation*, *health identity*, and *functional status*.

**Conclusion:** Expert review, as described in this paper, was critical to establishing content validity for 12 theory-based domains. The variables that comprise each domain can be used to create a scale to identify influences on adult dietary practices.

**Keywords:** content validity, multidimensional, instrument, establish, dietary practice, factors, variables, Behavior Change Wheel, Theoretical Domains Framework, behavioral domain

## Background

Eating an unhealthful diet is a well-established and well-known risk factor for many chronic diseases -- hypertension, hyperlipidemia, diabetes, and stroke [1, 2]. Hence, it is not surprising that diet has been reported to be the leading modifiable risk factor associated with 24% of deaths and 14% of disability-adjusted life-years in the United States in 2010 [1]. Adhering to a healthful diet is not simple, suggesting the need to further explore factors that influence dietary practices.

Dietary practices, which are complex and reflective of one's life experience, are influenced by a multitude of intrinsic and extrinsic factors. The literature shows that dietary practices are influenced by five broad factors -- economic (cost and income), physical (access, education and skills), social (culture and social context), psychological (mood and stress), and cognitive (i.e. beliefs and knowledge) [3, 4, 5]. All can be viewed as barriers to implementation of good dietary practices. In addition, how much each factor explains or influences dietary practices is highly individualized [6, 7]. To improve the health of U.S. adults, healthcare practitioners need a practical tool to identify barriers associated with dietary practices so individualized prevention plans can be prepared. Moreover, barriers to dietary practices are rarely one dimensional; suggesting the need to examine the multi-dimensional nature of dietary practices.

Although three instruments -- National Health and Nutrition Examination Survey (NHANES), What We Eat in America (WWEIA) 24-hour dietary recall and Household Food Security Supplemental Module (HFSSM) -- are available to assess dietary practices, these were designed to monitor the U.S. population and are not practical for use as a screening tool. Diet plays a crucial role in health promotion and chronic disease

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prevention. Poor diet, is one of four modifiable health risk behaviors (physical inactivity,

tobacco use, and excessive alcohol use) responsible for premature death and disability

related to chronic diseases [8]. Because diet-related chronic diseases are among the most

preventable, an instrument to measure barriers to adult dietary practices serves two broad

purposes.  First, it could identify individuals who are at increased risk for chronic

diseases.  Secondly, it could be used to develop effective individualized interventions to

prevent or reduce his/her risk of chronic diseases. To our knowledge, no validated

instruments are available that measure barriers to dietary practices.

NHANES is used to monitor the health and nutritional status of adults and

children in the United States. Data are collected in two-year cycles and organized into

five sections (demographics, dietary, examination, laboratory, and questionnaire).

Although NHANES has many strengths (i.e. multiple components assessed and

generalizable sample of the health and nutrition needs of the population), in its entirety it

is not practical as a screening tool to be used in a clinical/community setting to identify

barriers to healthful dietary practices [9, 10]. The 18-item Household Food Security

Supplemental (HFSSM) has similar limitations as NHANES, in that it is also designed to

assess the food security status of the U.S. population as a whole [11]. As such, the

HFSSM is a reliable measure of a household's financial capacity to buy nutrient-dense

foods, however, it does not measure if household members have knowledge about

nutrient-dense foods, food preparation skills, nor does it measure whether household

members consume a nutritionally adequate diet. Moreover, both population-based

surveys are cumbersome to administer. In contrast, the Mini Nutrition Assessment

(MNA) and DETERMINE are both valid and reliable nutritional assessment instruments

that can be used in the clinical/community settings [12, 13]. However, they were specifically designed to screen for malnutrition in the older population, which limits their use with the general population.

Another limitation is that the instruments do not allow for scores to be generated that are based on the multidimensional nature of barriers to dietary practices. For the purpose of this study, the term "multidimensional" refers to multiple but separate behavioral dimensions comprising multiple factors that may influence a behavioral concept (dietary practice). This is similar to Edwards's definition of multidimensional as a number of similar but separate dimensions that may be viewed as one concept [14]. The literature shows that dietary practices are almost always a combination of inadequate nutritional intake linked to multiple other factors (either in the physical, psychological, cognitive, or social dimension) [3-5]. Moreover, these factors are intertwined and are rarely one dimensional. McLeroy and colleagues' Social Ecological Model (SEM) describes the five (intrapersonal, interpersonal, organizational, communal, and political factors) interactive characteristics of individuals and environments which influence health behavior and health outcomes [6]. Essential to the SEM are the concepts of multiple levels of influence and reciprocal causation. Specifically, behavior affects and is affected by multiple levels of influence and individual behaviors shape and are shaped by ones' environmental contexts [6]. Thus, it is vital to simultaneously measure the multiple, intertwined barriers to dietary practices.

Furthermore, in 2011 the Affordable Health Care Act implemented the "Annual Wellness Visit" (AWV). The aim for offering AWV is to provide an individualized prevention plan to individuals to maintain their health and prevent chronic [15, 16]. The

AWV includes a 1) health risk assessment (HRA) (self-reported medical/family history, list of medications and supplements, and list of all medical providers); 2) anthropometric and clinical assessment (measurements: height, weight, body mass index, blood pressure, and depression, cognitive, and functional ability screening); and 3) an individualized health plan (list of conditions/risks with interventions; health screening and immunizations schedule; appropriate referrals to health education or preventive services; and voluntary advanced care planning [preparing an advance directive if the patient is receptive]. While AWV maybe a comprehensive approach, it has two major limitations: 1) individuals must be 65 years and older and receiving Medicare and 2) no single screening instrument is recognized by the Centers for Medicare & Medicaid Services (CMS) for use in the AWV [15, 16]. Practitioners have the option to use any nationally-recognized screening instruments. Practitioners having to search and choose from a multitude of nationally- recognized instrument could be a cumbersome task. In addition, a comprehensive screening instrument that can be used in a clinical/community setting and not specific to a subgroup of the adult population is necessary to obtain data on the possible underlying barriers to dietary practices.

Given the importance of dietary practices as a risk factor for many chronic diseases, it would be prudent to measure barriers associated with dietary practices. An ideal screening instrument should include all dimensions (e.g. physical, psychological, cognitive, or social context) that have been shown to influence behavior in general. This paper describes a hypothesized instrument aimed to assess the multidimensional nature of barriers influencing adult dietary practices and the methods used to establish preliminary content validity for the instrument. With the appropriate instrument, accurately

identifying these barriers based on theory in behavior change, could inform interventions, particularly those that center on prevention of chronic diseases, the most common cause of death in the United States.

**Theoretical Framework**

The Behavior Change Wheel (BCW), hub COM-B system (Capability, Opportunity, motivation and behavior), and the Theoretical Domains Framework (TDF) [17, 18], informed a theory-based systematic approach to identify variables believed to influence adult dietary practices. The variables were derived from the NHANES datasets 2011-2012 and each assigned to an exclusive theory-based domain for inclusion on the instrument.

The BCW, formed by combining multiple behavior change frameworks, provides a comprehensive approach to developing behavior change interventions [17]. Its framework consists of three main dimensions; however, because the focus of this study is to identify factors that influence adult dietary practice, only the framework's hub, the COM-B was used. The COM-B system recognizes that behavior is part of an interacting system involving three components: capability, opportunity, and motivation [17].

In addition to BCW, the TDF was also used as it combines behavioral change theories into one framework to identify barriers relevant to behavior change and to design practical interventions to address those barriers [17, 18]. The TDF comprises 14 domains representing barriers: 1) knowledge, 2) skills, 3) social/professional role and identity, 4) beliefs about capabilities, 5) optimism, 6) beliefs about consequences, 7) reinforcement, 8) intentions, 9) goals, 10) memory, attention and decision processes, 11) environmental context and resources, 12) social influences, 13) emotion, and 14) behavioral regulation

[18] ((M2) Table 1). Researchers have used the TDF to develop theory-based instruments aimed to identify and understand potential factors influencing human behavior as well as to guide the design of effective interventions [19-21]. This framework was developed over the last decade by Michie and colleagues [22] and refined in 2012 by Cane et al. [18]. Both frameworks are interconnected as each domain of the TDF relates to a COM-B component.

**Study Aim**

This study was conducted to develop and validate an instrument to measure the multidimensional nature of barriers associated with adult dietary practices. First, the hypothesized instrument is described followed by the seven steps to achieve consensus.

**Step 1: Hypothesized Instrument**

The Dietary Health Status (DHS) instrument was created using a composite of variables from the NHANES 2011-2012 datasets. Selection of variables was guided by the BCW, hub COM-B system, and the TDF. For this study, DHS is defined as an instrument that measures the multidimensional nature of barriers associated with adult dietary practices. DHS was conceptualized as consisting of three core dimensions based on the assumption that assessment of the three could result in a more accurate assessment of factors influencing dietary practices: Dietary Access (DA), Dietary Quality (DQ), and Dietary State-Of-Mind (DS). However, it was also anticipated that to more precisely identify the behavioral domains involved in influencing dietary practices, the three dimensions were divided into eight sub-dimensions ((M2) Table 2). The presumed eight scales may typically be used separately and can be summed to obtain a total DHS scale. DHS was conceptualized as being measured on a 100-point scale ranging from 0 (severe)

to 100 (excellent). Lower DHS scores will indicate an increased dietary risk, with multiple factors influencing an individual's dietary practices. Higher scores, on the other hand, will indicate a decreased risk for poor dietary practices.

## Methods

First, variable items were identified that were considered while using two behavioral theoretical frameworks and establishing content validity through a review panel eliciting expert opinion from experienced researchers in behavioral, social, and nutritional sciences. Secondly, a panel of expert reviewers examined whether the preliminary list of identified variables obtained from NHANES 2011-2012 datasets assigned to their defined theoretical behavioral domains accurately reflected their underlying prospective domains. This was an important step to establish content validity, ensuring the instrument was inclusive of all TDF domains demonstrated to influence adult dietary practices, thus, ensuring the multidimensionality of the instrument. Lastly, variable fit was validated within an assigned domain. This study was exempted as a human subject research by the Institutional Review Board of the Bioethics Committee of the Medical University of South Carolina.

### Datasets and Target Population

NHANES datasets were selected because they are designed to assess the health and nutritional status of adults and children in the United States, which was the overall focus of this investigation. Further, NHANES is a nationally representative sample of non-institutionalized U.S. residents [9, 10]. In particular, the 2011-2012 NHANES data sets were used in conjunction with WWEIA because these datasets included the most current 24-hour dietary recall data with multi-ingredient foods converted into their

appropriate amounts and Food Pyramid components by WWEIA. Specifically, WWEIA disaggregates the multi-ingredient foods reported by NHANES participants through the 24-hour dietary recall data, and converts the foods into their appropriate amounts and Food Pyramid (FP) components (i.e. converted amounts of fruit, vegetables, grains, protein foods, dairy, oils, added sugars, solid fats, and alcoholic drinks). The information obtained from WWEIA datasets is critical to calculate the Healthy Eating Index (HEI) components and the overall scores from dietary recall data. The interviews, conducted in participant homes, address health status, disease history, and the diet of the participant and other household members. The health examinations, performed in mobile exam centers, include measures of blood pressure, height and weight, oral health screens, and blood and urine tests [9, 10]. The data obtained from the interviews and health examinations are organized into five sections: 1) demographics, 2) dietary, 3) examination, 4) laboratory, and 5) questionnaire. The 2011-2012 NHANES data files are available for public use and were obtained from the NHANES site directly for this study [10]. These datasets included 13,431 selected individuals, of those, 9,756 completed the survey interview, and 9,338 underwent health examinations. A total of 3,705 participants met inclusion criteria for this study [10]: 1) aged 20 years or older, assuming younger individuals may not have full autonomy over their diet; and 2) data relevant to this study were collected during in-home interviews and health examination. Individual cases were excluded if 1) demographic and clinical data relevant to our analysis were missing, or 2) pregnancy was reported as pregnant women may have atypical dietary patterns.

**Expert Reviewers**

A group of expert reviewers (N=6) was identified. Of those, two declined because of time constraints. The four reviewers who agreed to participate have expertise in the behavioral and social and/or nutritional sciences. Reviewers were tasked with providing their expert opinion on a proposed list of variables that had been preliminarily assigned to the theoretical domains that comprise the TDF. Additionally, a main working group, consisting of the principal investigator (PI) and three health researchers, refined and validated the findings and responses from the expert reviewers.

**Procedure**

The study was conducted between May and October 2017 using a series of procedural tasks [(M2) Table 3], planned and facilitated by the PI. Records were kept of all meetings and tasks. The process included six steps: 1) identifying variables relevant to the study overall focus; 2) conducting a working group evaluation of the identified variables; 3) assigning identified variables to the COM-B components, developing operational definitions for each TDF domain, and assigning variables to each domain; 4) conducting a working group evaluation of the variables assigned to each TDF domain; 5) implementing an expert reviewer evaluation of the variable assigned to each TDF domain; and 6) completing a working group validation of the domain list.

**(M2) Table 1: Procedural tasks carried out to complete this study**

| **Principal Investigator** |
| --- |
| Explore datasets and identify variables relevant to the study's focus |
| **Principal Investigator and one working group member (n=2)** |
| 4 meetings to: 1) evaluate identified relevant variables; 2) assign identified variables to the Behavioral Change Wheel (BCW), COM-B components; 3) develop operational |

| |
|---|
| definitions for each Theoretical Domains Framework (TDF) domain; 4) and assign variables to each domain; and 5) generate task instructions for expert panel review |
| **Working group (n=4)** |
| 1 meeting to evaluate the identified variables, TDF domain operational definitions, the variables preliminarily assigned to their prospective TDF domains |
| **Expert reviewers (n=4)** |
| Task emailed to experts with a three week deadline |
| **Main working group (n=4)** |
| 2 meetings to review and discuss expert reviewer's responses and to reach a consensus to validate the final domain list |

**Step 1: Exploring the NHANES 2011-2012 datasets and WWEIA component guided by the BCW hub COM-B and TDF to identify all variables relevant to the study's focus.**

Initially, all five sections (demographics, dietary, examination, laboratory, and questionnaire) of the 2011-2012 NHANES [9, 10] and WWEIA 24-hour dietary [23] corresponding component were explored to extract all relevant items considered to represent factors that may influence adult dietary practice (Figure 1). All variables from the five sections and the WWEIA recalls, 133 files and 18 components (sub-sections of the five sections NHANES above) were saved into an Excel spread sheet. Eeach variable was independently reviewed by the PI. At this phase, a variable was only labeled "relevant" or "not relevant" to the study focus (including the future prospective studies) ((M2) Figure 1).
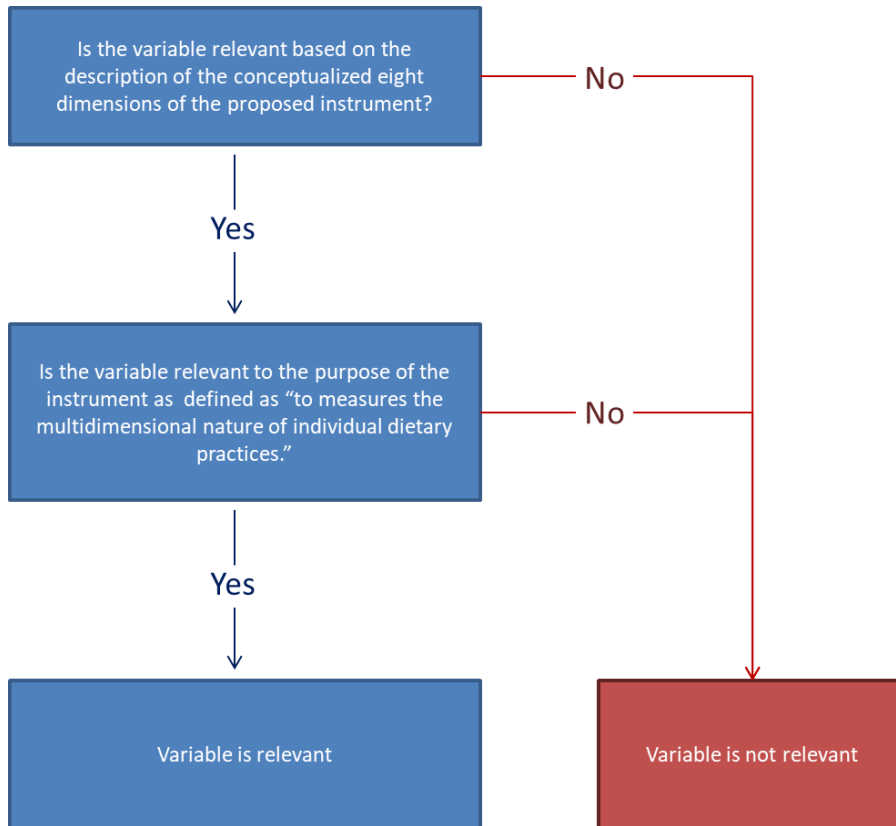
**(M2) Figure 1: Flow chart for identifying variables relevant to this study focus**

**Step 2: Evaluating and validating preliminary NHANES variables**

Following the initial review of the NHANES datasets and the WWEIA 24-hour dietary recalls, the preliminary lists of "relevant" or "not relevant" variables was presented to the main working group. The aim of this procedure was to ensure no important sections and variables were overlooked during the initial critical stage. The main working group evaluated the relevance of each variable based on the two theoretical frameworks (COM-B and TDF) guiding the study. Group feedback resulted in modification to the number of considered variables. The working group reached a consensus as to "relevant" or "not relevant" variables; however, additional variables from additional files identified were to be included based on the description of the TDF domains, operational definition of the TDF domains, and the focus of this study.

**Step 3: Assigning Variables to a COM-B component and 14 TDF domains**

The two aims were: 1) to organize the variables into the three interacting behavior systems that capture their meaning and 2) to expand the COM-B components into highly specific domains as each of the 14 TDF domains relates to one of the COM-B components. Variables identified as relevant were then assigned to a COM-B component, based on the components description and the NHANES variable description: 1) capability, 2) opportunity, and 3) motivation.

Following the assignment of variables into their appropriate COM-B components, the original description of the TDF domain, the theoretical constructs that made up the domain, and this study's dietary focus were used to generate operational definitions for each theoretical domain. The operational definition was used to refine variables by assigning them into their defined 14 theoretical domains that comprise the TDF. Generated and refined operationalized domain definitions were then reviewed by the working group. Feedback from the working group on how well the operational definitions captured the theoretical constructs that made up the domain, and this study's dietary focus, resulted in refinement of the domain operational definitions ((M2) Table 4). Subsequent to operationalizing the domains, variables assigned to the COM-B components were discussed and related to the 14 theoretical domains of the TDF. Determination of each variable fit within each of the 14 TDF domains was based on: (1) the specific description of the TDF domain; (2) the theoretical constructs that made up the TDF domain; (3) the researchers' operationalized definition of each TDF domain; and (4) the description of each NHANES variable as defined by NHANES. The operational definitions were generated based on the original TDF domain description and the

domains' theoretical construct. Furthermore, the original interview questions from NHANES for each of the items were used to help clarify each domain to determine the variable fit. Lastly, all variables were assigned exclusively to one domain. The aim of this procedure allowed the PI to expand the COM-B components into highly specific domains as each of the 14 TDF domains relates to one of the COM-B components.

**Step 4: Evaluating preliminary variable assignment to the 14 TDF domains**

The aim of the expert panel review was to solicit input from a range of perspectives about whether the variables accurately reflected their underlying domains in order to establish content validity. Following variable domain assignment, each domain and its assigned variables were independently evaluated by a researcher from the working group for coherence, exclusivity, and fit to assigned domain. This process was completed in four consecutive meetings over four weeks during which a consensus by all researchers of the working group was reached.

**Step 5: Expert review of the variable assignment to the 14 theoretical domains**

Subsequently, feedback was solicited from a panel of four reviewers with expertise in behavioral and social health and/or nutritional research. Following the preliminary assignment of variables to the 14 prospective theoretical domains, expert reviewers independently evaluated the list of variables in their assigned domains. The variable fit within an assigned domain was evaluated based on: (1) specific description of the TDF domain; (2) theoretical constructs that made up the TDF domain; (3) PI's operationalized definition of each TDF domain; and (4) description of each of NHANES variable. Reviewers were asked to complete the following within three weeks: (1) provide their expert opinion as to whether a variable belonged to the domain it was

preliminarily assigned and (2) re-assign the variable to another domain for a better fit if necessary. Each reviewer could select a response from a drop-down list of Yes/No options for each variable, with "yes" indicating the variable belonged to the assigned domain or "no" indicating the variable did not belong to the assigned domain. If the option "no" was selected, the reviewer was asked to re-assign the variable to another domain that was a better fit. Reviewers were allowed to re-assign a variable only to one other domain (Task instructions for expert reviewers, Appendix A).

**Step 6: Validating the variable items assigned domain**

After receiving all completed tasks from reviewers, responses were reviewed and summarized. A discussion was undertaken by the working group to address any "no" responses and re-assignment of variables to another domain. After a series of meetings and independent evaluation, final consensus was reached; this generated a final list of domains encompassing their appropriate variable items.

<div align="center">

**Results**

</div>

**Exploring the NHANES 2011-2012 datasets and WWEIA component guided by the BCW hub COM-B and TDF to identify all variables relevant to the study's focus**

Five sections of the NHANES 2011-2012 datasets and the WWEIA component were explored, 148 data files were reviewed, and a total of 3,948 variables were identified. Of the 148 data files, 133 were used to identify variables relevant to the study. The remaining 15 files, which were limited access files, were not considered relevant to the study, and thus were excluded. A total of 24 of the 133 data files were considered relevant to the study; 170 variables were identified as relevant to this study. Of the 170 variables, 99 were assigned to "capability", 28 were assigned to "opportunity", and 43 were designated for "motivation."

**Developing operational definitions for each TDF domain and refining variables by assigning them into their defined 14 theoretical domains that comprise the TDF**

The 170 identified variables were assigned to 13 of the 14 TDF domains: knowledge (3), skills (4), social/professional role and identity (12), optimism (10), beliefs about consequences (5), reinforcement (7), intentions (1), goals (1), memory, attention and decision processes (13), environmental context and resources (15), social influences (13), emotion (7), and behavioral regulation (79). One TDF domain the "beliefs about capabilities" could not be represented by any of the variables.

**Evaluating preliminary variable assignment to the 14 theoretical domains**

Evaluation and discussion regarding whether the preliminary variables accurately reflected their underlying prospective domains led to further refinement. An initial concern of the working group was that some of the operational definitions were considered ambiguous, which led to questions regarding the variable fit with an assigned specific domain. Consequently, the operational definition of the TDF domain in question was refined, and variables were reassigned to their new prospective domains if needed. After cross checking the definitions against the descriptions of the TDF domains, the theoretical constructs that made up the TDF domains and the descriptions of each NHANES variable, the working group agreed that the operational definitions appropriately defined their respective domains.

**Expert reviewer evaluation of the variable assigned domain**

The following concerns were raised regarding the preliminary list of variables and their assigned 14 theoretical domains:

- Similarities existed among variables assigned to the "skill" domain and those assigned to the "behavior regulation" domain. Eliminating the ''skills" domain was suggested.

- The variables assigned to the "Social/professional role and identity" domain were not a good fit with this domain or to any of the other 13 TDF domains.

- The distinctions among the domains goal, intention, optimism, and emotion were ambiguous and required further clarification.

- For 26 variables, no TDF domain existed.

Reviewing the description of the 14 TDF domains, TDF theoretical constructs, the operationalized definition of each TDF domain, and description of each of NHANES variable, it was agreed that the skills, social/professional role and identity, goal and intention domains be eliminated and two new domains -- health identity and functional status -- were created.

**Validating the evaluated variable in their assigned domain**

Discussion about whether the variables accurately reflected their underlying domains directed further refinement. Consensus led to two variables being assigned to the TDF domain *"beliefs about capabilities*" that could not previously be represented. Furthermore, variables in the "*skills"* domain were re-assigned to the *"behavioral regulation"* domain, eliminating the skills domain. During this process the variables for which no domain previously existed were assigned to the two new domains: 14 to *"health identity"*; and 12 to *"functional status."* The working group agreed after the domains were refined that the variables accurately reflected their underlying domains. Overall, a total of 12 domains (knowledge, optimism, beliefs about consequences,

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reinforcement, memory, attention and decision processes, environmental context and resources, social influences, emotion, behavioral regulation, health identity and functional status) were validated, including the two new domains ((M2) Table 4). Ten domains were included from the 14-domain version of the TDF domains. The four TDF domains not captured by NHANES variables were "*social/professional role and identity, goal, intention, and skills*" ((M2) Table 5).

**(M2) Table 2: Four TDF domains not captured by NHANES 2011-2012 variables**

| TDF theoretical domain | TDF domain description | Study's adapted domain description |
|---|---|---|
| **Skills** | An ability or proficiency acquired through practice | The competence or capacity that help a person routinely manage otherwise his/her diet and health in a productive manner, making appropriate dietary choices, staying healthy, and engaging in sports and recreational activities |
| **Social/professional role and identity** | A coherent set of behaviors and displayed personal qualities of an individual in a social or work setting | A coherent set of dietary and health promotion behaviors and displayed personal qualities of an individual in a social setting |
| **Intentions** | A conscious decision to perform a behavior or a resolve to act in a certain way | Readiness/commitment to make healthy dietary choices, stay healthy and engage in sports and recreational activities |
| **Goals** | Mental representation of outcomes or end states that an individual wants to achieve | An aim or an objective a person wants to achieve concerning their diet and health |

**Discussion**

This study established content validity on set of variables obtained from NHANES 2011-2012 datasets and WWEA 24 dietary recall data to be considered as items during the development of a hypothesized instrument to assess the multidimensional nature of dietary practices. In particular, this study sought to ensure variables making up the

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instrument were fully inclusive of all theory-based domains influencing dietary practices. Reliably identifying factors influencing dietary practices is vital to informing effective interventions and to reduce diet-sensitive chronic diseases. Expert consultant review responses as described in this study added valuable data to establish preliminary content validity for the variables that will be used to develop a multi-dimensional instrument that can identify factors influencing adult dietary practice simultaneously. Variables from the NHANES 2011-2012 datasets and the WWEIA component were identified as accurately reflecting their underlying TDF domains. Our total list of domains includes two new domains, *"health identity"* and *"functional status."* The *"health identity"* domain was defined by the researchers as *a person's sense of self/identity in view of a health characteristic that he/she may have to identify with or has identified with*. Although being told you have a risk factor or a disease does not mean you have integrated this into your identity, according to Kralik and colleagues; illness can either take a hold of an individual's life partially or completely [24]. In addition, Karnilowicz stated culture plays an influential role on an individual's sense of control and self-belief when it comes to illness or disease [25]. In particular, an individual goes through necessary shifts in identity to adapt to living with a life altered illness then what life was for him/her prior to the illness [25]. The *"functional status"* domain is defined by the researchers as *any functional limitations caused by long-term physical, mental, and emotional problems or illness that impact a person ability to make appropriate life choices and to engage in activities that promote a healthy lifestyle*.

The TDF framework was originally developed for implementation research by health professionals and was designed for that target audience. Therefore, the TDF

framework fit, in the context of our population, might not be ideal. Although the framework has been used by various researchers in questionnaire development, most investigators have aimed to identify factors that may impede the implementation of evidence-based practice. Cane and colleagues suggested that 14 domains were necessary to analyze influences on behavior [18]. Although all 14 domains may be relevant, only 10 could be represented in this exploratory study. Therefore, four domains of this version of the TDF could not be represented as no variable considered relevant to these domains existed within the NHANES 2011-2012 datasets. Nevertheless, the resulting ten TDF domains and two additional domains from this study were well represented, and variables that constituted the COM-B components well represented three conditions required for behavior change to occur. Moreover, both frameworks are interconnected because each domain of the TDF relates to a COM-B component; thus, our 12 domains consist of variables that may be key determinants to influence adult dietary practices.

One reason to explain why four domains of the TDF are not represented within the NHANES 2011-2012 datasets, is that this was an existing dataset, not collected for the purpose of this study, and therefore available data were not comprehensive. Additionally, while potentially useful, these domains may not comprehensively identify all factors that influence dietary practices, as not all TDF domains were captured by the NHANES 2011-2012 datasets. The use of these explanatory domains may: 1) assist researchers seeking to identify barriers to dietary practices for a greater understanding of these barriers; 2) inform the development of a screening tool that can reliably and simultaneously assess the multidimensional nature of barriers to adult dietary practices; and 3) inform effective individualized interventions.

## Conclusions

Our behavioral domains provide a guide to relevant variables that may be key barriers to adult dietary practices. The variables represented in each domain could be used to assess barriers to dietary practices specific to that domain. These variables can be used as items on an instrument to assess barriers to dietary practices and to determine if an increase in the number of barriers to dietary practice can predict increased risk for diet sensitive chronic diseases.

Finally, the knowledge gained from this study can be used to inform the development of an instrument intended to simultaneously measure multiple barriers to adult dietary practices in order to inform the development of effective individualized interventions. Because multiple factors influence adult dietary practices, simultaneously identifying barriers to dietary practices will create a broader picture of adult dietary practices. Ultimately an instrument that can accurately identify individuals with multiple barriers to dietary practices will have implications for practice, education, and policy.

## Abbreviations

BCW: Behavior Change Wheel; COM-B: Capability, Opportunity, motivation and behavior; TDF: Theoretical Domains Framework; NHANES: National Health and Nutrition Examination Surveys; WWEIA: What We Eat in America; DHS: Dietary Health Status.

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**(M2) Table 3: Theoretical Domains Framework (TDF) 14 domain version, domains description, and 84 theoretical constructs**

| Theoretical Domain | Cane et al., 2012 Domain Description | Theoretical Construct |
|---|---|---|
| 1. Knowledge | An awareness of the existence of something | 1. Knowledge (including knowledge of condition /scientific rationale)<br>2. Procedural knowledge<br>3. Knowledge of task environment |
| 2. Skills | An ability or proficiency acquired through practice | 4. Skills<br>5. Skills development<br>6. Competence<br>7. Ability<br>8. Interpersonal skills<br>9. Practice<br>10. Skill assessment |
| 3. Social/professional role and identity | A coherent set of behaviors and displayed personal qualities of an individual in a social or work setting | 11. Professional identity<br>12. Professional role<br>13. Social identity<br>14. Identity<br>15. Professional boundaries<br>16. Professional confidence<br>17. Group identity<br>18. Leadership<br>19. Organizational commitment |
| 4. Beliefs about capabilities | Acceptance of the truth, reality, or validity about an ability, talent | 20. Self-confidence<br>21. Perceived competence<br>22. Self-efficacy<br>23. Perceived behavioral control<br>24. Beliefs<br>25. Self-esteem<br>26. Empowerment<br>27. Professional confidence |
| 5. Optimism | The confidence that things will happen for the best | 28. Optimism<br>29. Pessimism<br>30. Unrealistic optimism<br>31. Identity |
| 6. Beliefs about consequences | Acceptance of the truth, reality, or validity about | 32. Beliefs<br>33. Outcome expectancies |

| | outcomes of a behavior in a given situation | 34. Characteristics of outcome expectancies<br>35. Anticipated regret<br>36. Consequents |
|---|---|---|
| 7. Reinforcement | Increasing the probability of a response by arranging a dependent relationship, or contingency | 37. Rewards (proximal/distal, valued/not valued, probable/improbable)<br>38. Incentives<br>39. Punishment<br>40. Consequents<br>41. Reinforcement<br>42. Contingencies<br>43. Sanctions |
| 8. Intentions | A conscious decision to perform a behavior or a resolve to act in a certain way | 44. Stability of intentions<br>45. Stages of change model<br>46. Trans theoretical model and stages of change |
| 9. Goals | Mental representation of outcomes or end states | 47. Goals (distal/proximal)<br>48. Goal priority<br>49. Goal/target setting<br>50. Goals (autonomous/controlled)<br>51. Action planning<br>52. Implementation intention |
| 10. Memory, attention and decision processes | The ability to retain information, focus selectively on aspects of the environment, and choose between two or more alternatives | 53. Memory<br>54. Attention<br>55. Attention control<br>56. Decision making<br>57. Cognitive overload/tiredness |
| 11. Environmental context and resources | Any circumstance of a person's situation or environment that discourages or encourages the development of skills and abilities, independence, social competence | 58. Environmental stressors<br>59. Resources/material resources<br>60. Organizational culture /climate<br>61. Salient events/critical incidents<br>62. Person x environment interaction<br>63. Barriers and facilitators |
| 12. Social influences | Those interpersonal processes that can cause | 64. Social pressure<br>65. Social norms |

| | an individual to change their thoughts, feelings, or behaviors | 66. Group conformity<br>67. Social comparisons<br>68. Group norms<br>69. Social support<br>70. Power<br>71. Intergroup conflict<br>72. Alienation<br>73. Group identity<br>74. Modelling |
|---|---|---|
| 13. Emotion | A complex reaction pattern, involving experiential, behavioral, and physiological elements, by which the individual attempts to deal with a personally significant matter or event | 75. Fear<br>76. Anxiety<br>77. Affect<br>78. Stress<br>79. Depression<br>80. Positive/negative affect<br>81. Burn-out |
| 14. Behavioral regulation | Anything aimed at managing or changing objectively observed or measured actions | 82. Self-monitoring<br>83. Breaking habit<br>84. Action planning |

**(M2) Table 4: DHS and its dimensions abbreviation and description**

| Terms | Description |
|---|---|
| **Whole Instrument** | |
| Dietary Health Status (DHS) | Comprises 8 sub-dimensions |
| **Three overarching dimensions** | |
| Dietary Access (DA) | Comprises individuals' financial resources, food security status, and access to local and federal governmental nutritional/food assistance programs, as well as non-governmental resources through community efforts that might influence diet. |
| Dietary Quality (DQ) | Comprises type of diet consumed, habits that might influence the quality of diet consumed [substances/drugs (i.e. illicit and non-illicit, alcohol, nicotine, marijuana)], practices such as eating out or carryout, and physical functioning. |
| Dietary State-Of Mind (DS) | Comprises an individual's perception and knowledge about diet, health, and disease, as well as his/her mental and emotional functioning that reflect the state-of-mind regarding diet in general. |
| **Eight Subdimensions** | |
| Dietary Food Status (DFS) | |
| Dietary Resource  (DRS) | |
| Dietary Quality Sub  (DQS) | |
| Dietary Quantity  (DQN) | |
| Dietary Habits (DHB) | |
| Dietary Perception (DP1) | |
| Dietary Knowledge (DKW) | |
| Dietary Psyche (mental state)(DP2) | |

**(M2) Table 5: Twelve domains captured by NHANES 2011-2012 variables in this study including 10 TDF domain and two new created domains, with TDF domain descriptions and study researchers' operational descriptions**

| TDF Theoretical Domain | TDF Domain Description | Study Operational Description |
|---|---|---|
| Knowledge | An awareness of the existence of something | An awareness of the dietary guidelines, their general health and health risks factors and the benefits of sports and recreational activities |
| Beliefs about capabilities | Acceptance of the truth, reality, or validity about an ability, talent, or facility that a person can put to constructive use | A person's belief about self-confidence, control, or performance concerning making appropriate dietary choices, staying healthy and engaging in sports and recreational activities |
| Beliefs about consequences | Acceptance of the truth, reality, or validity about outcomes of a behavior in a given situation | A person's subjective rating of his/her general health, diet, and weight and his/her belief about the outcomes of making appropriate dietary choices, staying healthy and engaging in sports and recreational activities |
| Reinforcement | Increasing the probability of a response by arranging a dependent relationship, or contingency, between the response and a given stimulus | Internal or external responses to a person's behavior that affect the likelihood of making appropriate dietary choices, staying healthy and engaging in sports, fitness and recreational activities [Social Cognitive Theory (SCT)] |
| Memory, attention and decision processes | The ability to retain information, focus selectively on aspects of the environment, and choose between two or more alternatives | The ability to retain information concerning diet and health and to be able to focus on making appropriate dietary and health choices |
| Environmental context and resources | Any circumstance of a person's situation or environment that discourages or encourages the development of skills and abilities, independence, social competence, and adaptive behavior | Any characteristics of the socio-political context, organization, and the person that discourages or encourages a person to make appropriate dietary choices, stay healthy and engage in sports and recreational activities |
| Social influences | Those interpersonal processes that can cause an individual to change their thoughts, feelings, or behaviors | A person's association with people and situations in society that dictates the way he/she thinks about things that might affect his/her diet, health, and sports and recreational activity |

| | | level |
|---|---|---|
| Behavioral regulation | Anything aimed at managing or changing objectively observed or measured actions | All the things a person does concerning their diet, health and sports and recreational activities |
| Optimism | The confidence that things will happen for the best, or that desired goals will be attained | A person's confidence that things will happen for the best; never give up hope or look at the bright side of life |
| Emotion | A complex reaction pattern, involving experiential, behavioral, and physiological elements, by which the individual attempts to deal with a personally significant matter or event | A subjective psychophysiological experience that might affect a person's likelihood of making appropriate dietary and health choices, and engaging in sports and recreational activities |
| **Health Identity** | **New domain created; not part of TDF** | A person sense of self/identity in view of a health characteristic that he/she may have to identify with or has identified with |
| **Functional Status** | **New domain created; not part of TDF** | Any functional limitations caused by long-term physical, mental, and emotional problems or illness that impact a person ability to make appropriate life choices and to engage in activities that promote a healthy lifestyle |

## Manuscript 3: Development and Validation of a Multidimensional Instrument: Assessing barriers to dietary practices

### Abstract

**Background and Purpose:** The purpose of this validation study was to develop a psychometrically sound instrument that can simultaneously measure multiple barriers to dietary practices.

**Methods:** Content validity was established for instrument items using an expert review. Exploratory factor analysis was used to assess validity and reliability was determined by Cronbach's alpha values.

**Results:** The factor analysis supported a 10-component solution, which explained 61% of the total variance. Cronbach's alpha was 0.67 for the instrument total scale and ranged from 0.55-0.87 for the subscales.

**Conclusion:** Results suggest the instrument and subscales had sufficient construct and internal validity . This exploratory study is an important first step toward future refinements of the instrument.

**Keywords:** instrument development, validity, reliability, dietary practice, barriers, Theoretical Domains Framework

## Introduction

Consuming an unhealthful diet is a well-established and well-known risk factor for many chronic diseases -- hypertension, hyperlipidemia, diabetes, and stroke (Murray et al., 2013; Yoon, Bastian, Anderson, Collins, & Jaffe, 2014). Hence, it is not surprising that diet was reported to be the leading modifiable risk factor associated with 24% of deaths and 14% of disability-adjusted life-years in the United States in 2010 (Murray et al., 2013). Adhering to a healthful diet is not simple, suggesting the need to further explore factors that influence dietary practices.

Dietary practices, which are complex and reflective of one's life experience, are influenced by a multitude of intrinsic and extrinsic factors. Dietary practices are influenced by five broad factors -- economic (cost and income), physical (access, education and skills), social (culture and social context), psychological (mood and stress), and cognitive (i.e. beliefs and knowledge) (Dibsdall, Lambert, Bobbin, & Frewer, 2003; Haynes-Maslow, Parsons, Wheeler, & Leone, 2013; U.S. Department of Health and Human Services and U.S. Department of Agriculture [HHS & USDA], 2015). All of these factors can be viewed as barriers to implementation of good dietary practices. In addition, how much each explains or influences dietary practices is highly individualized (McLeroy, Bibeau, Steckler, & Glanz, 1988; Shepherd, 1999). To improve the health of U.S. adults, healthcare practitioners need a practical tool to identify barriers associated with dietary practices so individualized prevention plans can be prepared. Moreover, barriers to dietary practices are rarely one dimensional; suggesting the need to examine the multi-dimensional nature of dietary practices. The current study had two aims: 1) develop an instrument that simultaneously measures the multidimensional nature of

barriers associated with adult dietary practices and 2) test the psychometric properties of this instrument. The Behavioral Change Wheel (BCW), COM-B components, and Theoretical Domains Framework (TDF) have been used to identify barriers relevant to behavior change and to design practical interventions to address these barriers (Cane, O'Connor, & Michie, 2012; Michie et al., 2005; Michie, van Stralen, & West, 2011). Both frameworks (BCW and TDF) guided this study and the development of the conceptualized instrument.

**Background and Conceptual Framework**

While three instruments -- National Health and Nutrition Examination Survey (NHANES), What We Eat in America [WWEIA] 24-hours dietary recall and Household Food Security Supplemental Module HFSSM) -- are available to assess diet-related practices, these were designed to monitor the U.S. population and are not practical for use as a screening tool in a clinical/community setting. To our knowledge, currently no instruments are available that measure barriers associated with adult dietary practices.

NHANES is a survey used to monitor the health and nutritional status of adults and children in the United States. Data are collected in two-year cycles and organized into five sections (demographics, dietary, examination, laboratory, and questionnaire). Although NHANES has many strengths (i.e. multiple components assessed and generalizable sample of the health and nutrition needs of the population), in its entirety it is not practical to be used as a screening tool in a clinical/community setting to identify barriers to good dietary practices of individuals (Centers for Disease Control and Prevention [CDC], 2017; National Health and Nutrition Examination Surveys [NHANES], 2017).

The 18-item Household Food Security Supplemental (HFSSM) has similar

limitations as NHANES, in that is also designed to assess the food security status of the

U.S. population as a whole (Coleman-Jensen, Rabbitt, Gregory, & Singh, 2016). As such,

the HFSSM is a reliable measure of a household's financial capacity to buy nutrient-

dense foods, however, it does not measure if household members have knowledge about

nutrient-dense foods, food preparation skills, nor does it measure whether household

members consume a nutritionally adequate diet. Moreover, both population-based

surveys are cumbersome to administer. In contrast, the Mini Nutrition Assessment

(MNA) and DETERMINE are both valid and reliable nutritional assessment instruments

that can be used in the clinical/community settings (Vellas et al., 1999; van Bokhorst de

van der Schueren, Realino Guaitoli, Jansma , & de Vet, 2014) . However, these

instruments were specifically designed to screen for malnutrition in the older population,

which limits their use with the general population.

Another limitation is that the instruments do not generate scores that are based on

the multidimensional nature of barriers associated with adult dietary practices. For the

purpose of this study, the term "multidimensional" refers to multiple but separate

behavioral dimensions comprising multiple factors that may influence a behavioral

concept (dietary practice). This is similar to Edwards's definition of multidimensional as

a number of similar but separate dimensions that may be viewed as one concept (2001).

The literature shows that dietary practices are almost always a combination of inadequate

nutritional intake linked to multiple other factors (either in the physical, psychological,

cognitive, or social dimension) (Dibsdall et al., 2003; Haynes-Maslow et al., 2013; HHS

& USDA, 2015). Moreover, these factors are intertwined; barriers to dietary practices are

rarely one-dimensional. McLeroy and colleagues' Social Ecological Model (SEM) describes the five (intrapersonal, interpersonal, organizational, communal, and political factors) interactive characteristics of individuals and environments which influence health behavior and health outcomes (1988). Essential to the SEM are the concepts of multiple levels of influence and reciprocal causation. Specifically, it assumes that behavior affects and is affected by multiple levels of influence and that individual behavior shapes and is shaped by ones' environmental contexts (McLeroy et al., 1988). Thus, it is vital to simultaneously measure the multiple, intertwined barriers to dietary practices.

Furthermore, in 2011 the Affordable Health Care Act implemented the "Annual Wellness Visit" (AWV). The aim for offering AWV is to provide an individualized prevention plan to individuals to maintain their health and prevent chronic diseases (Hughes, 2011; Mancuso, 2013). The AWV includes: 1) a health risk assessment (HRA) (self-reported medical/family history, list of medications and supplements, and list of all medical providers); 2) assessment (measurements: height, weight, body mass index, blood pressure, and depression, cognitive, and functional ability screening); and 3) individualized health plan (list of conditions/risks with interventions; health screening and immunizations schedule; appropriate referrals to health education or preventive services; and voluntary advanced care planning (preparing an advance directive if the patient is receptive). While AWV maybe a comprehensive approach, it has two major limitations: 1) individuals must be 65 years and older and receiving Medicare and 2) no single screening instrument is recognized by the Centers for Medicare & Medicaid Services (CMS) for use in the AWV (Hughes, 2011; Mancuso, 2013). Practitioners have

the option to use any nationally-recognized screening instruments. Practitioners having to search and choose from a multitude of nationally-recognized instrument presents a cumbersome task. Given the importance of dietary practices as a risk factor for many chronic diseases, it would be prudent to also measure all dimensions (e.g. physical, psychological, cognitive, or social context) associated with dietary practices. With the appropriate instrument, accurately identifying these barriers based on theory in behavior change, results could inform interventions, particularly those that center on prevention of chronic diseases, which are the most common cause of death in the United States. The purpose of this exploratory validation study was to develop an instrument to assess the multiple dimensions potentially influencing adult dietary practices. The overall purpose of this instrument is to measure multiple barriers to dietary practices simultaneously. Therefore, a novel instrument was proposed to measure barriers associated with dietary practices.

An important step is to establish the content validity of variables considered as items on the new instrument. One aim was to verify that the instrument is inclusive of all the TDF domains demonstrated to influence individuals' behavior. This process: 1) described the instrument; 2) identified potential items based on two behavioral frameworks BCW COM-B components and TDF domains from among variables within the NHANES 2011-2012 datasets; and 3) established content validity for the potential items within their assigned theory-based domains by an expert review panel. Content validity was established for 12 theory-based domains that comprised key determinants of adult dietary practice ((M3) Table 2). The variables assigned to these 12 domains were considered as items on this instrument to assess barriers to dietary practices.

The TDF was one of two theories used to guide the study. TDF combines behavioral change theories into one framework. The framework is used by researchers to identify barriers relevant to behavior change and to design practical interventions to address these barriers (Cane et al., 2012; Michie et al., 2005). TDF comprises 14 domains representing barriers to behavior: knowledge, skills, social/professional role and identity, beliefs about capabilities, optimism, beliefs about consequences, reinforcement, intentions, goals, memory, attention and decision processes, environmental context and resources, social influences, and emotion and behavioral regulation (Cane et al., 2012). Researchers have used the TDF to develop theory-based questionnaires to identify and understand potential factors influencing human behavior and to guide the design of effective interventions (Beenstock et al., 2012; Huijg et al., 2014; Taylor, Parveen, Robins, Slater, & Lawton, 2013). The framework was developed over the last decade by Michie and colleagues and refined in 2012 by Cane and colleagues.

**Conceptualized Instrument**

The Dietary Health Status (DHS) instrument was created using a composite of variables from the NHANES 2011-2012 datasets. Selection of variables was guided by the BCW, hub COM-B system, and the TDF. For this study, DHS is defined as an instrument that simultaneously measures the multidimensional nature of barriers associated with adult dietary practices.

DHS was conceptualized as consisting of three core dimensions based on the assumption that assessment of the three could result in a more accurate assessment of factors influencing dietary practices: Dietary Access (DA), Dietary Quality/Quantity (DQ), and Dietary State-Of-Mind (DS). However, it was also anticipated that to more

precisely identify the behavioral domains involved in influencing dietary practices, the

three dimensions would be divided into eight sub-dimensions (

(M3) Table 3). The presumed eight scales may be typically used separately and can be summed to obtain a total DHS scale. DHS was conceptualized as being measured on a 100-point scale ranging from 0 (severe) to 100 (excellent). Lower DHS scores indicate an increased risk for poorer dietary practices, whereas multiple barriers may be influencing an individual's dietary practice. Higher scores, on the other hand, indicate a decreased risk for poorer dietary practices, where few if any barriers may be influencing an adult dietary practice. Based on a recent search of the literature, DHS is a novel instrument designed to simultaneously measure multiple barriers associated with adult dietary practices.

## Methods

### Design and Data Collection

The current study is a secondary data analysis of NHANES years 2011-2012 datasets. NHANES were chosen because they are designed to assess the health and nutritional status of U.S. adults and children. In particular, the 2011-2012 NHANES datasets were chosen because, at the time of the current study, those datasets had the most current 24-hour dietary recall data that were converted into their appropriate amounts and Food Pyramid (FP) components by WWEIA. NHANES collects data from a nationally representative sample of participants from among non-institutionalized U.S. residents (CDC 2017; NHANES, 2017). The data NHANES obtained from the interviews and health examinations are organized into five sections: 1) demographics, 2) dietary, 3) examination, 4) laboratory, and 5) questionnaire. Specifically, WWEIA disaggregates the multi-ingredient foods reported by NHANES participants through the 24-hour dietary recall data, then converts the foods into their appropriate servings and Food Pyramid (FP)

components (i.e., converted amounts of fruit, vegetables, grains, protein foods, dairy, oils, added sugars, solid fats, and alcoholic drinks). The information obtained from WWEIA datasets is critical to calculate the Healthy Eating Index (HEI) components and the overall scores from dietary recall data. The HEI was created by the U.S. Department of Agriculture (USDA) to assess the dietary quality of participants in compliance with the USDA the dietary guidelines (Guenther et al., 2013).

The 2011-2012 NHANES data files are available for public use and were obtained from the NHANES site for this study. This study was exempted as a human subject research by the Institutional Review Board of the Bioethics Committee of the Medical University of South Carolina.

**Sample for the Present Study**

The National Health and Nutrition Examination Survey public-use dataset provides data for 3705 participants who met inclusion criteria. Participants were selected based on the following inclusion criteria: 1) aged 20 years or older and 2) all races and ethnicities for whom data relevant to this study were collected during in-home interviews and health examinations. Participants were excluded if they: 1) were missing demographic and clinical data relevant to the analysis or 2) reported pregnancy because pregnant women may have atypical dietary patterns.

**Instrument development procedures**

The following steps were used to develop the DHS instrument: Prior to the current study, the 12 theory-based domains that comprised 170 key determinants of adult dietary practices in a prior study along with 13 other anthropometric and clinical variables. First, a total of 72 variables were selected for inclusion on the new instrument.

Selection was based on the following inclusion criteria: 1) only variables relevant to the purpose of the instrument were considered; 2) relevant variables had to fit a validated TDF domain or one of the two newly created domains in the prior study; and 3) relevant variables had to, in theory, pertain to disease or health risk related to the study's dietary focus regarding increased risk for diet-sensitive chronic disease. The following 12 theory-based domains comprising 72 variables were included in forming the DHS instrument: knowledge, functional status, environmental context and resources, social influences, memory, attention and decision processes, optimism beliefs about consequences, beliefs about capabilities, reinforcement, emotion, and health identity.

Secondly, to generate items relevant to assess a particular construct, variables were combined. A total of 26 items were generated to conceptualize six constructs -- quality, quantity, habits, resources, perception, and physical function. As indicators for dietary quality, eight items were generated from the NHANES -- WWEIA Total Nutrient Intakes day 1 and day 2 data conceptualized the construct "quality." These items were used to assess the dietary quality of participants in compliance with the federal dietary guidance. Quantity: To assess the conceptualized construct "quantity" four anthropometric measurements were used as items as predictors for obesity among participants: body mass index (BMI) in kg/m2 as weight indicator, waist circumference (WC) in cm, average sagittal abdominal diameter (SAD) in cm, and body fat (BF) in percentage. BMI was calculated dividing participants' weight by their height, and BMI was classified according to the World Health Organization (WHO) into four categories: 0 => 30 Obese, 1 =25-30 overweight, 2 =18.5-25 normal weight, 3 =16-18.5 mild to moderately underweight, and 4 =< 16 underweight. Abdominal obesity measured by WC

defined by American Heart Association/National Heart, Lung, and Blood Institute was adopted, with recommended cut off points of ≥102 cm and ≥88 cm for male and female, respectively. Because no set universal cutoff exists for SAD, and cutoff varies across studies and countries, the adopted cutoffs to indicate abdominal obesity were > 23.1 cm for males and > 20.1 cm for females (Duarte Pimentel, Portero-McLellan, Maestá, Corrente, & Burini, 2010). The SAD was subtracted from the cutoff since it was sex-based in order to compare data from males and females. Using the calculated BMI, participants' body fat BF % was calculated using an age and sex specific prediction equation: BF% = [(1.20 x BMI) + (0.23 x age)-(10.8 x sex)-5.4; sex (males =1, females =0)] (Deurenberg et al., 2001). The cut offs adopted to indicate abdominal BF%: BF% > 25 for males and > BF% 35 for female are those most frequently cited in the literature (Gomez-Ambrosi et al., 2012).

Five items related to the conceptualized construct "habits" were generated to assess illicit and legal (including alcohol and cigarette use) substance use, and weekly fast food consumption among participants. For example, one item, "In the last 12 months have you consumed cigarettes or alcohol" is the combination of three separate variables. A response options for this item were: "yes" consumed a score of 0 (bad) or "no" did not consumed, a score 3 (good). The time referenced was in the last 12 months and with frequency referring to >1 drink/day or fast food >2 meals /wk.

To assess the conceptualized construct "resource", three items were generated based on if participants received SNAP or Food Stamp benefits and received emergency food from church, food pantry, or food bank, or eating in soup kitchen, as well as the ratio of family income to poverty. For example, one item was generated by combining

two variables, "receive SNAP or Food Stamp benefits" and "received emergency food from church, food pantry, or food bank, or eat in soup kitchen." Response options this this item were "yes" to one or both assistance, a score of 1 or "no", a score of 0.

Three items were generated to the conceptualized construct "perception." Each item was generated based on participant self-reported weight, general health, and diet compared to their actual measured value. The items were created to assess if participants perceived weight, general health and diet quality deviated from the actual measured values of weight, general health and diet. For example, the weight perception score was calculated based on the difference between what a participant perceived their weight to be and what their actual weight is (indicated by measured BMI value). An item was assigned a score ranging from 0 – 2, with lower values indicating more deviation from actual value and higher values indicating more accuracy between perception and reality of what was being measure. For instance, if a participant perceived his/her weight as normal and his/her actual weight is normal, a maximum score of 2 was assigned. However, if participant perceived his/her weight as normal, but he/she is instead overweight, a score of 1 was assigned, only because his/her perception deviates from what the actual weight is. Additionally, if a participant perceived his/her weight is normal, but instead is obese, he/she was assigned a score of 0. BMI was calculated dividing their weight by their height and it was classified according to World Health Organization (WHO) into four categories (0 = > 30 Obese, 1 = 25 - 30 overweight, 2 = 18.5 - 25 normal weight, 3 = 16 - 18.5 mild to moderately underweight, and 4 = < 16 underweight).

To conceptualize the construct "physical function" three items were generated to assess physical limitation, i.e., problems with walking, working, or preparing meals. For instance, the item "did you have problems with one or more walking for a quarter mile, limitations from working, difficulty preparing meals" was generated by combing three variables. Response options were "yes" to 1 or more conditions, a score of 0 (bad) and "no", a score of 1.25 (good).

The dimension of DHS can operate as their own scale and can be assessed independently to investigate specific factors influencing diet when needed. The sums of all perspective dimensions that form the DHS scale. DHS contains both dichotomized responses and three, or more categorical responses, with high values indicating "bad" and lower values indicating "good." The DHS total score is calculated by summing all sub-dimension scores. The levels of severity of DHS obtained using responses from the questionnaire items were obtained by making cut-points derived from the dimension on a continuous whole number scale. Lastly, DHS was designed to simultaneously measure the multidimensional nature of barriers associated with adult dietary practices. While the qualitative motivation for the choice of dimensions may appear obvious, statistical analyses are necessary to determine if indeed the instrument captures those multiple dimensions to justify their inclusion in DHS instrument development.

Based on this theoretical perspective, exploratory factor analysis (EFA) was used to identify items that can be grouped into sets of related constructs to obtain a more parsimonious description of what each construct represents. In addition to examining DHS validity through factor analysis, reliability was examined using Cronbach's alpha. NHANES data for 3705 participants who met inclusion criteria were used. With this

sample size and the final 46 items, the subject to variable ratio was 80:1, for a

hypothesized number of factors of 12; the degree of over-determination, i.e., the number

of items divided by the number of factors, equaled 3.8. This approach of examining the

ratio of subjects to items has been used to calculate accurate sample size. A widely used

rule of thumb is that the subject to items ratio for exploratory factor analysis should be at

least 10:1 (Polit, 2010, p. 337). According to this recommendation, this study has greater

than acceptable subject to item ratio and thus a greater than sufficient sample size.

**Data analysis**

Data were imported into SPSS version 24.0 (IBM Corp, 2016) and screened prior

to analysis based on the principal components analysis (PCA). Data were examined for

outliers. Extreme values were evaluated and retained as legitimate data values according

to the NHANES data processing protocol. A total of 5637 cases data were excluded as

they did not meet this study inclusion criterion or were cases with missing values. The

number of components to extract and retain was determined using: 1) Kaiser-Guttman

rule of values ≥1; 2) scree plot, and 3) parallel analysis (used along with the scree plot to

confirm the numbers of the extracted components to retain). For the purpose of this

analysis, a minimum factor loading of 0.30 or above was required, but no cross loading of

0.30 or above was permitted. The Varimax, Promax rotation, and Direct Oblimin were

contrasted to examine the interpretation of factors that were consistent with the

instrument underlying theory.

Factorability of the resulting initial 53 items was examined using the Kaiser-

Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity.

Results demonstrated that five of 53 items were not compatible for factor analysis. These

items, comprising the domain "social influences", were then excluded from the analysis. A total of 48 items were included in the factor analysis. The initial run of the 48 items resulted in a KMO below the recommended value of 0.7. Omitting the problematic item increased the KMO to 0.69. A total of 47 items were then included in the final analysis.

## Results

**Construct validity of the DHS**

The factorability of the 47 items was examined. The correlation matrix revealed that all 47 items correlated at least moderately ($r \geq 0.3$) with at least one other item, suggesting factorability. The KMO measure of sampling adequacy was 0.7. This value met the recommended value of 0.7, which is considered "fair" (Polit, 2010). The Bartlett's test of sphericity was statistically significant ($\chi 2$ (1081) $= 95029.6$, $p < .001$), further indicating appropriateness of factor analysis for these data. Given these overall indicators, factor analysis was deemed to be suitable with all 47 items.

Principal components analysis was performed, and initial eigenvalues indicated that the first 11 components had eigenvalues greater than 1.0 with a range from 6.2 to 1.1, which explained 62% of the variation. In addition, inspection of the scree plot revealed noticeable slope changes between a possible three component solution and a
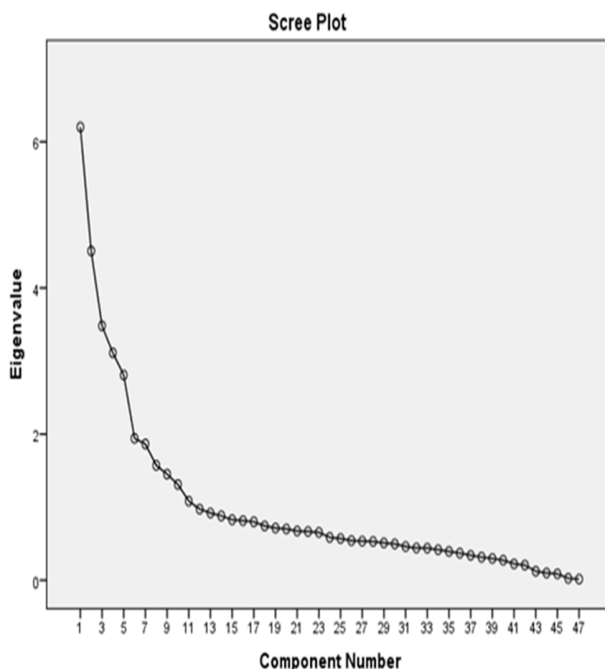


**(M3) Figure 1: Scree plot for an eleven component solution**

four, between a six component solution and a seven, as well as between a 10 and an 11 component solution [(M3) Figure 1].

Component solutions for three, four, six, seven, and ten-components were examined in addition to the eleven-factor model using Varimax, Direct Oblimin, and Promax rotations of the component loading matrix. The ten-component solution was preferred and retained based on a simpler conceptual interpretation. Additionally, results of a parallel analysis also confirmed a ten-component solution. Between three and eight items ranging from 0.34 to 0.99 loaded on each component in the ten-component solution. Subsequent analyses of the ten-component solution revealed little difference between Varimax, Direct Oblimin, and Promax rotation techniques for interpretation of the components. However, Promax rotation was retained for the final ten-component solution because it presented slightly higher component loadings compared to Varimax and Direct Oblimin ((M3) Table 4). Varimax is the most widely used type of orthogonal rotation (rotation of factors that are uncorrelated with one another). In contrast, Promax is one technique of Oblique rotation, i.e., rotation of factors that are correlated with one another, which was assumed for factors for the DHS. Additionally, the analyses resulted in the removal of one item. The item "*How many days feel anxious*" loading on component 1 (r=0.66) was removed because its absence resulted in a substantial increase of Cronbach's alpha for this component (from 0.41 to 0.85) and increased the Cronbach's alpha for the entire DHS instrument from 0.54 to 0.67. Since component 1 was well defined by 8 other items, the item *"How many days feel anxious"* did not contribute meaningfully to the construct being measured.

The revised ten-component solution explained 61% of the total variation with loadings of the 46 items ranging from 0.34 to 0.99. Factor loading values ranged from low (0.40) to moderate (0.70) (Costello, & Osborne, 2005, p. 4). The following item loaded only 0.34 on the "habits" dimensions; "In the last 12 months have you consumed cocaine, heroin or methamphetamine?" Although communality of less than 0.40 suggests that an item is unrelated to the other items in the component, the item was retained because it contributed to the interpretability of the components. The item was meaningful to it well-defined component, and therefore, the item was retained.

Between three and eight items loaded for each component in the ten-component solution. Furthermore, one item loaded on to multiple components. The item that asks about the individual's education level, *"Education level"* loaded on components 8 and 10. This item was retained on component 10 because it loaded slightly higher. Component 1 was well defined by eight items with loadings ranging from 0.58 to 0.83. This component appeared to capture the individual's mental and emotional state and was labeled "*mental and emotional state.*" Four items loaded onto component 2 with high loadings above 0.82. This component appeared to capture the individual's body composition and was labeled "*anthropometrics.*" Component 3 was well defined by 5 items with loadings as low as 0.34 to as high as 0.97. This component appeared to capture the individual's food consumption and illicit and non-illicit substance use (including alcohol and cigarettes) and was labeled "*habits.*" Component 4 was well defined by five items loading as low as 0.56 to as high as 0.89. Component 4 appeared to capture individual medical/health condition and was labeled *"health identity."* Component 5 was well defined by seven items with loadings ranging from 0.48 to 0.99.

The theme of this component involved adult dietary intake; this component was labeled as *"diet quality."* Four items loaded onto component 6 with loadings above 0.74. This component appeared to capture individual knowledge regarding medical/health risks from a health professional and was labeled *"reinforcement."* Three items loaded on component 7 above 0.85. The theme of this component involved individual perceptions of weight, general health, and diet compared to actual weight, health, and diet. This component was labeled *"perception."* Three items loaded on component 8 in the 0.76 to 0.80 range. Individual financial resources and access to food/nutritional assistance appeared to be captured on this component. Thus, component 8 was labeled *"resource."* Component 9 was well defined by 4 items with loadings ranging from 0.50 to 0.82. The theme of this component involved individual physical function due to long-term physical, mental, or emotional problem, or illness. Component 9 was labeled *"functional status."* Finally, three items loaded on component 10 ranging from 0.45 to 0.90. The theme of this component involved individual awareness of the nutritional guidelines and the level of education completed. Component 10 was labeled *"knowledge."*

**Internal consistency**

Cronbach's alpha was 0.67 for the overall instrument and ranged from 0.55-0.87 for the subscales ((M3) Table 1). The most frequently cited recommendation for Cronbach's alpha is 0.70 and above. The four subscales (Functional Status, Resource, Knowledge, and Diet Quality) and the full scale DHS did not meet this minimum criterion of 0.70 for alpha. No substantial increases in alpha for any of the scales could have been achieved by eliminating additional items. Because the study goal was to create the DHS instrument, which multiple dimensions, the investigators interpreted component

1 as the Mental/Emotional State subscale, component 2 as the Anthropometrics subscale,
component 3 as the Habits subscales, component 4 as the Diet quality subscale,
component 5 as the Reinforcement subscale, component 6 as the Health Identity subscale,
component 7 as the Perception subscale, component 8 as the Resource subscale,
component 9 as the Functional Status subscale, and component 10 as the Knowledge
subscale. Combining the 10 subscales into one score seemed justified due to the
moderately high correlations between the 10 components and total scores.

**(M3) Table 1: Descriptive statistics for the DHS scale and 10 subscales (N =3705)**

| Scales | No. of items | M (SD) | Cronbach's α |
|---|---|---|---|
| DHS (total scale) | 46 | 87.60(18.27) | .67 |
| Mental/Emotional State | 8 | 2.57(3.83) | .85 |
| Anthropometrics | 4 | 2.55.(2.36) | .87 |
| Diet Quality | 7 | 55.58(15.33) | .69 |
| Health Identity | 5 | 1.14(1.53) | .81 |
| Perception | 3 | 5.37(1.90) | .83 |
| Habits | 5 | 12.10(14.64) | .81 |
| Knowledge | 3 | 2.90(1.61) | .55 |
| Reinforcement | 4 | 2.24(1.50) | .84 |
| Resource | 3 | 3.90(2.00) | .64 |
| Functional Status | 4 | 0.46(0.78) | .65 |

## Discussion

The focus of this validation study was to develop a the DHS instrument adult dietary
which can assess barriers to adult dietary practices. Our findings suggest that DHS is a

valid and reliable instrument consisting of 10 subscales that can be used independently. The 10 subscales include a combination of the 12 validated behavioral domains and the eight conceptualized sub-dimensions from the prior study. The combination of the 12 validated domains that comprise key determinants demonstrated to influence adult dietary practice and the conceptualized sub-dimensions (i.e. quality, quantity, habits, and perception) are believed to be more inclusive of other potential determinants that influence adult dietary practice and, thus, increase the risk for diet related diseases. For example, evidence in the literature shows that a diet high in calories, fat, sodium, and sugar is strongly associated with overweight and obesity. Consequently, being overweight or obese greatly increases one's risk for many chronic diseases. Because body composition can play an import role in a person's health, items were generated as predictors for obesity among participants. These items became the subscale anthropometric after factor analysis. Defined as the study of the dimensions (size and shape) of the human body, i. e., measurement of bone, muscle, and adipose (fat) tissue (Utkual, & Ercan, 2015), the anthropometrics component is particularly important because misreporting of dietary intake has been demonstrated with NHANES data, particularly related to the underreporting of energy intake. Additionally, underreporting of energy intake is found to be higher in overweight and obese persons as well as in women (Ahluwalia, Dwyer, Terry, Moshfegh, & Johnson, 2016). The items that made up the "habits" subscale were generated using a similar rationale. Substances have been demonstrated to alter individual mental capacity. Altered mental capacity may affect diet, i.e., not eating an adequate amount of food through the day, or consuming foods lacking adequate nutrients. Additionally, a particular substance may have a different effect on

what individuals consume, as well as how much and how frequently foods are consumed.

For example, substances labeled stimulus may suppress appetite, leading to improper

calorie consumption, or other substances may lead to an increase in appetite, causing

weight gain.

**Factor analysis**

Moreover, the Cronbach's α was used to test DHS and the subscales' internal

consistency. With 0.70 considered as acceptable as the most frequently cited

recommendation, the following three subscales would be considered inadequate:

"resource and functional status"0.64 and 0.65, respectively, and "knowledge," a 3-item

subscale with an alpha of 0.55, even though the inter-item correlation was reasonably

high (0.43). However, Nunnally (1967) indicated that an alpha between 0.50-0.60 is

adequate for an exploratory study such as this one (as cited in Peterson, 1994, p. 381). Of

note, higher subscale alphas are expected in comparison to DHS whole scale alpha,

because Cronbach's α describes the extent to which all the items are correlated. Since the

subscales are independent of each other, lower inter-related/correlation between them is

expected. Therefore, combining the scales would result in a lower alpha by statistical

design. Alpha sometimes might be misleading because of its sensitivity to test length;

technically, the more items, the more reliability; however, at the same time more burden

to the respondents.

It is also worth mentioning that, following the results of initial factor analysis, this

study excluded one of the 12 validated domains, "social influences." The items (i.e., age,

sex, race/ethnicity, marital status, and household size) encompassing this domain did not

meet the KMO of .70 requirement. Additionally, DHS was hypothesized as consisting of

three overarching dimensions: 1) Dietary Access (DA), 2) Dietary Quality/Quantity (DQ), and 3) Dietary State-Of- Mind (DS). In particular, the authors speculated that validated domains would collapse into these three dimensions. The theorized three-component solution was supported as the domains emerged strongly as separate dimensions, that consequence does not affect the instrument psychometric properties. This confirms that DHS 10 subscales could be furthered combined into three subscales as conceptualized.

Overall, psychometric properties of DHS and its subscales were indicative of good instrument reliability and validity. In essence, the results demonstrated that the instrument was capable of accurately, reliably, and validly assessing barriers that influence adult dietary practices.

The methods used in this instrument development and validation study have limitations to consider when interpreting the results. First, this study was conducted for exploratory purposes. While useful as a first step, the dimensions do not comprehensively assess all barriers that are associated with adult dietary practices. Our aim was to ensure the instrument is fully inclusive of 14 TDF domains suggested by Cane and colleagues (2012) as necessary to analyze influences on behavior thus ensuring the multidimensionality of DHS. Yet, five domains of this version of the TDF were not included in our analysis. Four of these domains could not be represented because, no variables relevant to these domains existed within the NHANES datasets used, and one domain was excluded from the analysis because items that made up the domain were not appropriate for factor analysis. Additionally, the TDF framework was originally developed for implementation research, with a targeted population of health

professionals. Therefore, our framework fit may not be completely adoptable. Although the TDF framework has been used by various researchers in questionnaire development, most investigators have dealt with identifying factors that may impede the implementation of evidence-based practice. Furthermore, several items were specifically designed to assess a particular construct, therefore making these items not easily adaptable in settings requiring screening for adult dietary practices.

## Conclusion

Our findings affirm DHS's multidimensionality, thus providing evidence that DHS can assess the multiple barriers associated with adult dietary practices. While this instrument might be impractical as a screening tool in some clinical settings, the instrument might be a useful tool to assess adults thoroughly for barriers influencing their dietary practices, in particular, factors that increase the risk for diet-related diseases. Those individuals could be screened during longer visits, such as during health specialty or wellness clinics, regular primary care annual exams, by researchers, or health organization research. A recommendation for future refinement of DHS and subscales is to include: all 14 TDF domains, geographic information because DHS may vary by different regions, and more practical items to increase utilization in other clinical settings.

**Relevance to nursing practice, education or research**

DHS is a novel instrument designed to be relevant across different settings to capture the multidimensional nature of barriers associated with adult dietary practices, i.e. intrinsic and extrinsic factors simultaneously. Our results suggest sufficient construct and internal validity of the DHS instrument and subscales. This exploratory study is an important first step to refine the DHS instrument, which may ultimately establish DHS

predictive validity. In a next step, DHS discriminant validity will be investigated. The knowledge gained from this study may inform the development of a more comprehensive DHS instrument, one that includes all TDF domains known to influence behavior as well as a simpler instrument that can be used in the clinical/community setting to screen for barriers to adult dietary practices.

Ultimately, the capacity of DHS to accurately identify individuals with multiple barriers to dietary practices will have implications for practice, education, and policy. First, practitioners could use the DHS to screen adults for barriers to adhering to healthful dietary practices at longer visits, such as during regular primary care annual exams and health specialty or wellness clinics, hence informing an individualized intervention plan of care. These results may also lead to intervention training for the developers of nutrition and health interventions, ensuring a multidimensional approach is used in intervention development and implementation. For example, training seminars/workshops may be developed to understand the multiple needs of individuals at dietary risk and how to intervene using a multidimensional approach that is individualized. Lastly, the results may help clinics/communities, administrators in nutrition and health organizations to identify individuals who have multiple barriers to dietary practices, to better understand the multiple needs of these individuals, and to develop individualized strategies that better address barriers to dietary practices together.

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**(M3) Table 2: Twelve domains captured by NHANES 2011-2012 variables used to develop Dietary Health Status and their descriptions. The domains include 10 original TDF domains and two new created domains**

| TDF theoretical domain and two new domains created | Study Researchers Operational Description |
|---|---|
| **Knowledge** | An awareness of the dietary guidelines, their general health and health risks factors and the benefits of sports and recreational activities |
| **Beliefs about capabilities** | A person's belief about self-confidence, control, or performance concerning making appropriate dietary choices, staying healthy and engaging in sports and recreational activities |
| **Beliefs about consequences** | A person's subjective rating of his/her general health, diet, and weight and his/her belief about the outcomes of making appropriate dietary choices, staying healthy and engaging in sports and recreational activities |
| **Reinforcement** | Internal or external responses to a person's behavior that affect the likelihood of making appropriate dietary choices, staying healthy and engaging in sports, fitness and recreational activities [Social Cognitive Theory (SCT)] |
| **Memory, attention and decision processes** | The ability to retain information concerning diet and health and to be able to focus on making appropriate dietary and health choices |
| **Environmental context and resources** | Any characteristics of the socio-political context, organization, and the person that discourages or encourages a person to make appropriate dietary choices, stay healthy and engage in sports and recreational activities |
| **Social influences** | A person's association with people and situations in society that dictates the way he/she thinks about things that might affect his/her diet, health, and sports and recreational activity level |
| **Behavioral regulation** | All the things a person does concerning their diet, health and sports and recreational activities |
| **Optimism** | A person's confidence that things will happen for the best; never give up hope or look at the bright side of life |
| **Emotion** | A subjective psychophysiological experience that might affect a person's likelihood of making appropriate dietary and health choices, and engaging in sports and recreational activities |
| **Health Identity**[*] | A person sense of self/identity in view of a health characteristic that he/she may have to identify with or has identified with |
| **Functional Status**[*] | Any functional limitations caused by long-term physical, mental, and emotional problems or illness that impact a person ability to make appropriate life choices and to engage in activities that promote a healthy lifestyle |

* The two new domains that were created by the study researchers during the preliminary content validation.

**(M3) Table 3: DHS and its dimensions abbreviation and description**

| Terms | Description |
|---|---|
| **Whole Instrument** | |
| Dietary Health Status (DHS) | Comprises 8 sub-dimensions |
| **Three overarching dimensions** | |
| Dietary Access (DA) | Comprises individuals' financial resources, food security status, and access to local and federal governmental nutritional/food assistance programs, as well as non-governmental resources through community efforts that might influence diet. |
| Dietary Quality (DQ) | Comprises type of diet consumed, habits that might influence the quality of diet consumed [substances/drugs (i.e. illicit and non-illicit, alcohol, nicotine, marijuana)], practices such as eating out or carryout, and physical functioning. |
| Dietary State-Of Mind (DS) | Comprises an individual's perception and knowledge about diet, health, and disease, as well as his/her mental and emotional functioning that reflect the state-of-mind regarding diet in general. |
| **Eight Subdimensions** | |
| Dietary Food Status (DFS) | |
| Dietary Resource (DRS) | |
| Dietary Quality (DQS) | |
| Dietary Quantity (DQN) | |
| Dietary Habits (DHB) | |
| Dietary Perception (DP1) | |
| Dietary Knowledge (DKW) | |
| Dietary Psyche (mental state) (DP2) | |

**(M3) Table 4: Promax-rotated component loadings among NHANES 2011-2012 participants' responses to the 46 items**

| Item No. | Items | Component | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1 | Feeling down, depressed, or hopeless | 0.827 | | | | | | | | | |
| 2 | Feeling bad about yourself | 0.796 | | | | | | | | | |
| 3 | Trouble concentrating on things | 0.739 | | | | | | | | | |
| 4 | Difficulty these problems have caused | 0.719 | | | | | | | | | |
| 5 | Have little interest in doing things | 0.714 | | | | | | | | | |
| 6 | Thought you would be better off dead | 0.609 | | | | | | | | | |
| 7 | Poor appetite or overeating | 0.584 | | | | | | | | | |
| 8 | Feeling tired or having little energy | 0.582 | | | | | | | | | |
| 9 | Waist Circumference | | 0.904 | | | | | | | | |
| 10 | Average Sagittal Abdominal Diameter | | 0.899 | | | | | | | | |
| 11 | Body Mass Index | | 0.861 | | | | | | | | |
| 12 | Body fat | | 0.818 | | | | | | | | |
| 13 | All drugs or substances and fast food | | | 0.973 | | | | | | | |
| 14 | Cigarettes, alcohol, fast food, or weed | | | 0.97 | | | | | | | |
| 15 | Weed and fast food | | | 0.772 | | | | | | | |
| 16 | Cigarettes and alcohol | | | 0.703 | | | | | | | |
| 17 | Hard drugs | | | 0.335 | | | | | | | |
| 18 | Ever been told three out of six | | | | 0.894 | | | | | | |
| 19 | Ever been told four out of six | | | | 0.878 | | | | | | |
| 20 | Ever been told two out six | | | | 0.852 | | | | | | |
| 21 | Ever been told one out of six | | | | 0.703 | | | | | | |
| 22 | Ever told on 2 or more different visits had hypertension | | | | 0.562 | | | | | | |
| 23 | HEI score | | | | | 0.985 | | | | | |
| 24 | Empty Cal consume | | | | | 0.645 | | | | | |
| 25 | Grains consume | | | | | 0.62 | | | | | |
| 26 | Fruits consume | | | | | 0.615 | | | | | |
| 27 | Proteins Score | | | | | 0.548 | | | | | |
| 28 | Veggies consume | | | | | 0.498 | | | | | |
| 29 | Sodium + fats consume | | | | | 0.475 | | | | | |
| 30 | Doctor told you to reduce fat/calories | | | | | | 0.87 | | | | |
| 31 | Doctor told you to exercise | | | | | | 0.806 | | | | |
| 32 | Doctor told you to reduce salt in diet | | | | | | 0.789 | | | | |
| 33 | Doctor told you to lose weight | | | | | | 0.759 | | | | |
| 34 | Perception deviate from average | | | | | | | 0.955 | | | |
| 35 | Perception measures deviate | | | | | | | 0.882 | | | |
| 36 | When perception deviate, how much it deviate | | | | | | | 0.851 | | | |
| 37 | Receive government and community food assistance | | | | | | | | 0.8 | | |
| 38 | Ratio of family income to poverty | | | | | | | | 0.778 | | |
| 39 | Food security status | | | | | | | | 0.764 | | |
| 40 | Problems with two or more | | | | | | | | | 0.816 | |
| 41 | Did you have problems with one or more | | | | | | | | | 0.804 | |
| 42 | Physical difficulties for more than 1 wk. in the last 30 days | | | | | | | | | 0.531 | |
| 43 | Experience confusion/memory problems | | | | | | | | | 0.501 | |
| 44 | Heard of Food Pyramid | | | | | | | | | | 0.897 |
| 45 | Heard of MyPyramid | | | | | | | | | | 0.881 |
| 46 | Education level | | | | | | | | 0.424 | | 0.449 |

## Manuscript 4: Examining the relationships between Dietary Health Status and selected participants' demographic and clinical characteristics

## Abstract

**Background:** Dietary practices, which are complex and reflective of one's life experience, are influenced by intrinsic and extrinsic factors. Given that good nutrition is the underpinning of good health, it is prudent to measure the multiple barriers associated with dietary practices

**Objective:** To investigate associations between participant Dietary Health Status (DHS) total scores, that simultaneously measure barriers known to influence dietary practices, and select demographic and clinical characteristics.

**Method:** A secondary analysis of the NHANES 2011-2012 data for eligible adults (n =3705) was conducted. Associations between demographic and clinical characteristics, and DHS scores were investigated using t-test, ANOVA, chi square test, and multiple linear regression.

**Results:** Age, race/ethnicity, household size, marital status, family income, hemoglobin A1c, and blood pressure were statistically significantly related to DHS total score. Participants older than 45 years, minorities, (Black, Hispanic or Other race), those living in larger households, those not married, as well as those with abnormal A1c levels or blood pressure were more likely to have lower DHS scores.

**Conclusion:** Findings suggest these groups may have multiple barriers that may increase their risk for poorer dietary practices. Therefore, to improve the health of adults in America, practitioners need an efficient screening instrument to identify barriers to adults' dietary practices.

## Introduction

The health of an individual is impacted by diet, which in turn is strongly associated with quality of life. On average, U.S. Americans consume diets high in calories, fat, sodium, and sugar and low in calcium and fiber (Martinez Steele, Baraldi, Louzada, Moubarac, Mozaffarian, &Monteiro, 2016; Department of Health and Human Services and U.S. Department of Agriculture [HHS & USDA], 2015). A calorie-dense diet that lacks sufficient essential nutrients is a major modifiable risk factor for overweight and obesity, which in turn may lead to chronic diseases (Shepherd, 1999; Castro-Quezada, Román-Viñas, & Serra-Majem, 2014). Moreover, diet is a well-established and well-known risk factor for many chronic diseases, such as cardiovascular diseases, hypertension, hyperlipidemia, diabetes, cancer, osteoporosis, and stroke. Hence, it is not surprising that diet was reported to be the leading modifiable risk factor associated with 24% of deaths and 14% of disability-adjusted life-years in the United States in 2010 (Murray et al., 2013).

Dietary practices, which are complex and reflective of one's life experience, are influenced by a multitude of intrinsic and extrinsic factors. Dietary practices are influenced by five broad factors -- economic (cost and income), physical (access, education and skills), social (culture and social context), psychological (mood and stress), and cognitive (i.e. beliefs and knowledge) (Dibsdall, Lambert, Bobbin, & Frewer, 2003; Haynes-Maslow, Parsons, Wheeler, & Leone, 2013; U.S. HHS &USDA, 2015). All can be viewed as barriers to implementation of good dietary practices. In addition, how much each explains or influences dietary practices is highly individualized (McLeroy, Bibeau, Steckler, & Glanz, 1988; Shepherd, 1999). To improve the health of U.S. adults,

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healthcare practitioners need a practical tool to identify barriers associated with dietary practices so individualized prevention plans can be prepared. Therefore, this study used a novel instrument, Dietary Health Status (DHS), designed to measure multiple barriers associated with dietary practices. DHS was used to investigate potential associations between participant DHS total scores and selected demographic and clinical characteristics. There were three aims: 1) explore the prevalence of DHS (including sub-dimensions) among participants; 2) examine the relationship between DHS and age, sex, race/ethnicity, marital status, and household size; and 3) determine if DHS level predicts increased risk for diet sensitive chronic diseases hypertension, diabetes, and hypercholesterolemia among participants. There were two hypotheses: 1) DHS scores are lower among adults 20-44 years of age and adults 65 and older compared to adults 45-64, minorities compared to whites, females compared to males, not married compared to married, and for larger household size compared to smaller household size and 2) Individuals who have lower levels of DHS are more likely to have hypertension, hypercholesterolemia, or diabetes.

**Background**

Given that good nutrition is the underpinning of good health, it is prudent to measure the multiple barriers influencing dietary practices. Although three instruments (National Health and Nutrition Examination Survey (NHANES), What We Eat in America [WWEIA] 24-hour dietary recall and Household Food Security Supplemental Module HFSSM) are available to assess diet-related practices, these were designed to monitor the U.S. population and are not practical for use in a clinical/community setting.

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In contrast, the Mini Nutrition Assessment (MNA) and DETERMINE are both valid and reliable nutritional assessment instruments that can be used in the clinical/community settings (Secher, Soto, Villars, Abellan van Kan, & Vellas, 2007; Vellas et al., 1999; van Bokhorst de van der Schueren, Realino Guaitoli, Jansma , & de Vet, 2014) but were specifically designed to screen for malnutrition in the older population, limiting their use with the general population. Due to the limitations of these instruments, DHS was developed to simultaneously measure multiple barriers influencing adult dietary practices within a clinical/community setting. The development was guided by two behavioral theoretical frameworks [Behavioral Change Wheel (BCW) COM-B components and Theoretical Domains Framework (TDF) domains] (Cane, O'Connor, & Michie, 2012; Michie, Johnston, Abraham, Lawton, Parker, & Walker, 2005). These frameworks are used by researchers to identify barriers relevant to behavior change and to design practical interventions to address these barriers. A first study addressed the aims to propose a conceptualized instrument, establish content validity for the potential items for the instrument, and ensure that the instrument is fully inclusive of domains demonstrated to influence individuals' behavior, thus ensuring the multidimensionality of the scale. Based on findings from this study, a subsequent study had the two aims to: 1) develop an instrument that measures the multidimensional nature of adults' dietary practices and 2) test the psychometric properties of this instrument. Details of these two studies are reported elsewhere.

Diet is also a major modifiable risk factor of chronic diseases (Murray et al., 2013 and Yoon et al. 2014), therefore, screening adults in the clinical/community setting to identify barriers to good dietary practices is vital. Knowledge gain from this study may

help shed light on barriers to adult dietary practices in the United States and help guide individualized interventions, particularly those that center on prevention of chronic diseases, which are the most common cause of death in the United States.

**Methods**

**Design and Data Collection**

The current study was a secondary analysis of data from the NHANES datasets years 2011-2012. NHANES were selected because they are particularly designed to assess the health and nutritional status of adults and children in the United States the overall focus of this investigation. In particular, the 2011-2012 NHANES datasets were chosen because, at the time of the current study, those datasets included the most current 24-hour dietary recall data, converted into their appropriate amounts, and Food Pyramid (FP) components from What We Eat in America (WWEIA). The information obtained from WWEIA datasets was critical to calculate the Healthy Eating Index (HEI) components and the overall scores from dietary recall data. The NHANES survey is used to collect data every two-years, combining interviews with physical examinations and laboratory assessment (Centers for Disease Control and Prevention [CDC], 2017; National Health and Nutrition Examination Surveys [NHANES], 2017). The interviews, conducted in participant homes, are designed to determine health status, disease history, and the diet of the participant and other household members. The health examinations, performed in mobile exam centers (MEC), include measures of blood pressure, height and weight, oral health screens, and blood and urine tests (CDC, 2017; NHANES, 2017).

The data obtained from the interviews and health examinations are categorized into five sections: 1) demographics, 2) dietary, 3) examination, 4) laboratory, and 5) questionnaire.

The 2011-2012 NHANES data files are available for public use and were obtained from the NHANES site directly for this study. An exempt status for this study was given by the Institutional Review Board of the Bioethics Committee (IRB) of the Medical University of South Carolina (MUSC).

**Sample**

The National Health and Nutrition Examination Survey public-use dataset provided data for 3705 participants who met inclusion criteria for this study: 1) age 20 years or older, assuming younger individuals may not have full autonomy over their diet; and 2) data relevant to this study were collected during in-home interviews and health examination. Individual cases were excluded if the participant reported pregnancy, as pregnant women may have atypical dietary patterns.

**Data Analysis Preparation**

The NHANES data are provided in multiple files. For this study, an analytical data file was created by using variables obtained from five sections: 1) Demographics, 2) Dietary, 3) Examination, 4) Laboratory, and 5) Questionnaire. The following procedures were carried out to prepare the data for analysis: 1) data files were downloaded from the NHANES website and imported into SPSS; 2) files were screened and cases irrelevant to this study were deleted; 3) each participant's unique sequence identification number was then used to merge the data files; and 4) variables were re-coded as appropriate for this analysis.

**Survey Weights**

NHANES assigns each participant sample weights to account for the complex random sampling method used to obtain a nationally representative sample of participants from among non-institutionalized U.S. residents. This includes oversampling, survey non-response, and post-stratification.

**Measures**

A novel multidimensional instrument, DHS was used in this study to investigate barriers dietary practices among NHANES 2011-2012 participants. The DHS instrument was constructed by creating a composite of variables from the NHANES 2011-2012 datasets, guided by two behavioral theoretical frameworks BCW COM-B components and TDF domains (Cane, O'Connor, & Michie, 2012; Michie, Johnston, Abraham, Lawton, Parker, & Walker, 2005). Validation of the DHS instrument was reported in a prior study (M3). In brief, DHS is a 46-item instrument that consists of 10 subscales (*mental/emotional status, anthropometrics, health identity, perception, habits, reinforcement, quality, resource, knowledge, and functional status*). Each subscale represents a dimension that may be a barrier to dietary practices. As subscales represent barriers, they may be used independently to assess adult dietary practices. DHS total score was produced by summing all the 10 subscale weighted scores implemented by researchers (for a full version of the DHS instrument see (M4) Figure 1). In this algorithm, lower values indicated "bad" and higher values indicated "good." The level of severity of DHS was obtained by developing cut points derived from the dimension on a continuous scale. DHS is measured on a 100-point scale ranging from 0 (severe) to 100 (excellent). Lower DHS scores indicate an increased dietary risk, where multiple barriers may be influencing an adult dietary practice. Thus, lower DHS scores suggest "severe,

poor or subpar" dietary health status. Higher scores, on the other hand, indicate a decreased dietary risk, where few if any barriers may be influencing an adult dietary practice. Hence, higher DHS scores suggest "adequate, good, or excellent" dietary health status ((M4) Table 1). To define relevant cut-points for six DHS categories (sever, poor, subpar, adequate, good, and excellent), the investigators used relevant findings from the literature regarding characteristics of the DHS score distribution. In particular, the DHS score distribution was analyzed to check for normality. Even though the test of normality indicated that the data are not normally distributed (skewness index -.22), normality was assumed. According to the Central Limit Theorem, as the sample size increases, normality parameters becomes more restrictive, it becomes harder to declare that the data are normally distributed (Polit, 2010, p. 89). Moreover, a descriptive analysis was conducted to retrieve the central tendency and standard deviation of DHS scores. Results reflect current findings in the literature that about 35% of Americans are obese or overweight (American Heart Association, 2018). Thus, the investigators decided to use the 35% cut off as representative, since being overweight or obese greatly increases one's risk for many chronic diseases such as high blood pressure, high cholesterol, or high blood sugar particularly (Murray et al., 2013 and Yoon et al., 2014) and because NHANES data represent a random sample of the general U.S. population at risk for diet sensitive diseases. Therefore, the first cut-off point was chosen so that 35% of the participants fall in the at-risk category of the instrument. As normality was assumed, all participants with a DHS score of roughly -0.375 standard deviations ($\sigma$) below the central tendency were considered at risk. Consequently, 65% of the population was considered not to be at risk. The other cut-points were determined based on how many standard

deviations they differed from the average DHS score. In particular, participants

considered "adequate" scored a DHS score between -0.375σ and +0.375σ of the average

DHS score. Participants exhibiting a DHS score deviating from the mean by -0.375σ to -

1σ were deemed to have a "subpar" dietary health status. Participants deviating by more

than -1σ but less than -2σ were considered "poor." Participants deviating by more than -

2σ were considered "severe." Individuals scoring higher than +0.375σ but less than +1σ

were given a "good" dietary health status, while those scoring higher than +1σ were

labeled "excellent."

**(M4) Table 1: DHS score summary and categories of associated outcome. Lower scores indicate insufficiency while higher scores indicate sufficiency**

| Outcome | Score |
|---------|-------|
| Severe | <36 |
| Poor | 36- 50. |
| Subpar | 51 – 59 |
| Adequate | 60 – 70 |
| Good | 71 – 78 |
| Excellent | >78 |

DHS was validated utilizing factor analysis (FA) and principal components analysis in a

previous study. A ten-component solution explaining 61% of the total variation was

retained. Cronbach's alpha for the subscales reliabilities ranged from 0.55 to 0.87 and

0.67 for the entire DHS instrument ((M4) Table 2).

**(M4) Table 2: Descriptive statistics for the DHS scale and 10 subscales (N =3705)**

| Scales | No. of items | M (SD) | Cronbach's α |
|--------|-------------|--------|-------------|
| DHS (total scale) | 46 | 87.60(18.27) | .67 |
| Mental/Emotional State | 8 | 2.57(3.83) | .85 |
| Anthropometrics | 4 | 2.55.(2.36) | .87 |
| Diet Quality | 7 | 55.58(15.33) | .69 |

| | | | |
|---|---|---|---|
| Health Identity | 5 | 1.14(1.53) | .81 |
| Perception | 3 | 5.37(1.90) | .83 |
| Habits | 5 | 12.10(14.64) | .81 |
| Knowledge | 3 | 2.90(1.61) | .55 |
| Reinforcement | 4 | 2.24(1.50) | .84 |
| Resource | 3 | 3.90(2.00) | .64 |
| Functional Status | 4 | .46(.78) | .65 |

**Demographic variables**

Five core demographic variables (*age, sex, race/ethnicity, household size* and
*marital status*) were included in this analysis. In the 2011-2012 dataset, age is top-coded
at 80 years of age and was used as both continuous and categorical variable (20-44 years,
45-64 years, and 65 years and older). *Race/ethnicity* was categorized into four groups:
White, Hispanic, and Black, Asian and Other race/ethnicity. *Marital status* was recoded
into the following two groups: Married or living with partner, and Unmarried, separated,
widowed, or divorced. *Household size,* ranging from 1 to 7 or more members was
recoded to into 2 groups -- household size of 1 or 2 members, and 3 members or more.
Socioeconomic status was operationalized using *Ratio of family income to poverty* (range
0 – 4.99) and *level of education completed* categorized into four groups: less than high
school, high school, some college or associate degree, and college grad or above.

**Clinical variables**

This study focused on identifying barriers influencing adult dietary practices that
are associated with diet-sensitive chronic diseases, which might increase one's

cardiovascular risk. In particular, the primary outcomes of interest were increased risk for the following diet-sensitive chronic diseases: 1) hypertension, 2) diabetes, and 3) hypercholesterolemia. Increased risk for these diet-sensitive chronic diseases was defined as lower DHS scores with lower scores being suggestive of "severe, poor or subpar" dietary health status. Hypertension, diabetes, and hypercholesterolemia were assessed based on the following laboratory measurements -- the average of three systolic and diastolic blood pressure (SBP and DBP), total cholesterol (TC), and glycohemoglobin (HbA1c), respectively. The standardized cut-off values for the diet-sensitive chronic diseases hypertension, hypercholesterolemia, and diabetes were defined by the following criteria according to the American Heart Association (AHA), American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines (ACC/AHA Task Force ), and American Diabetes Association (ADA): 1) blood pressure based on researchers cut points: DBP ≥90 mmHg (stage 2 ), DBP >80 mmHg and DBP <=90 mmHg (stage 1) and DBP <80 SBP >120 mmHg (borderline) (AHA, 2018); 2) TC based on the Adult Treatment Panel (ATP III) guidelines: ≥240 mg/dl (high), 200-239 mg/dl (borderline high) and <200 mg/dl (desirable) (Whelton et al., 2017, p. 19); and 3) hemoglobin A1C: HbA1C ≥6.5% (diabetes), HbA1 ≥5.7% to <6.4 % (prediabetes), and HbA1C <5.7% (normal) (ADA, 2018).

**Data Analysis**

A secondary analysis of the NHANES data was carried out using SPSS version 24.0 (IBM Corp, 2016). Due to the complex sampling scheme of the NHANES data collection, a complex sample plan file was created in SPSS Complex Samples analysis for the 2011-2012 NHANES datasets. To account for the oversampling the two-year

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sample weights WTMEC2YR and the design variables SDMVSTRA for strata and SDMVPSU for clusters were included in all analyses. Normality was examined using histograms, scatter plots, boxplots, and summary statistics. Data were examined for outliers. Values recognized as extremes values using SPSS were evaluated but retained as legitimate data values according to NHANES data processing protocol.

Descriptive and inferential analyses were performed with SPSS Complex Sample analyses. A general descriptive analysis was conducted on participant demographic characteristics (age, sex, race/ethnicity, marital status, household size, ratio of family income to poverty, and education level), and clinical characteristics (SBP, DBP, TC, and HbA1c). Frequency distributions and proportions (%) were obtained for categorical variables; means (m) and standard error of the mean (SE) were reported for continuous variables.

Inferential statistics, specifically independent t-test or one-way ANOVA, were used to compare mean DHS total scores by levels of sociodemographic and clinical characteristics, as well as the diet sensitive chronic diseases: hypertension (Normal, Elevated, Stage 1 hypertension, Stage 2 hypertension), diabetes (normal, prediabetes, diabetes), and hypercholesterolemia (normal, borderline, high cholesterol). Further, the relationship between DHS and age, sex, race/ethnicity, marital status, and household size, hypertension, diabetes, and hyperlipidemia, simultaneously, was examined using multiple linear regressions. In addition, Chi-square tests were used to compare differences in the percentages of age groups, sex, race/ethnicity, marital status, and household size across DHS categories. Significance level α was set at 0.05.

**Results**

**Descriptive statistics**

In this study (N =3705), males and females were equally presented (50.3% vs. 49.7%, respectively). Participants ranged in age from 20 to 80 with a mean age of 47.4 years. The majority of the participants were White (70.3%); most participants (65.6%) reported having at least college education or higher. Participants' average family income was 3x the poverty level. The majority (61.5%) indicated being married or living with a partner and slightly more than half (56.3%) reported having ≥3 persons in their household. Furthermore, clinically, participants had an average blood pressure of 120.8/72.7 mmHg, total cholesterol of 196 mg/dl, and A1c level of 5.7% [(M4) Table 3].

**(M4) Table 3: Demographic and clinical characteristics of participants included in the analysis of NHANES datasets 2011-2012 as pertaining to study criteria (N =3705). Percent for categorical variables and Mean (M) and Standard Error (SE) for continuous variable**

| Variable | Complex samples) M(SE) or Percent |
|---|---|
| **Age (years)** | 47.4 (0.90) |
| **Sex** | |
|   Male | 50.3% |
|   Female | 49.7% |
| **Race and Ethnicity** | |
|   Hispanic | 12.8% |
|   White | 70.3% |
|   Black | 10.2% |
|   Asian | 4.0% |
|   Other race | 2.8% |
| **Education** | |
|   Less than high school | 14.2% |
|   High school | 20.1% |
|   Some college or associate degree | 32.8% |
|   College grad or above | 32.8% |
| **Ratio of family income to poverty** | 3.0 (.11) |
| **Household size** | |
|   1-2 member | 56.3% |

| | |
|---|---|
| 3 or more members | 43.7% |
| **Marital Status** | |
| Married or living with partner | 61.5% |
| Unmarried, separated, divorced or widowed | 38.5% |
| **Clinical characteristics** | |
| Systolic blood pressure (mmHg) | 120.8 (.64) |
| Diastolic blood pressure (mmHg) | 72.7 (.58) |
| Total cholesterol (mg/dL) | 196.0 (1.24) |
| Hemoglobin A1c (%) | 5.7 (.03) |

**DHS and subscales scores among participants**

When examining DHS as a total scale, on average participants scored 64.2/100 indicating the majority of participants had adequate DHS. Each subscale (Mental/Emotional State, Knowledge, Perception, Reinforcement, Health Identity, Resources, Functional Status, Habits, Quality, and Anthropometrics) of DHS was evaluated individually. The descriptive statistics pertaining to scores for each subscale are presented in (M4) Table 4. Mean scores for the 10 domains ranged from 3.1-12. On average, the strongest indicators of influence to adult dietary practices were *anthropometrics,* followed by p*erception, quality,* and *resource*.

**(M4) Table 4: Mean (M) and Standard Error (SE for DHS total score and subscales (N =3705)**

| Scale | Complex samples |
|---|---|
| Dietary Health Status (DHS) total score | 64.2 (0.69) |
| Subscales | |
| Mental/Emotional State | 4.0 (0.04) |
| Knowledge | 7.4 (0.17) |
| Perception | 3.1 (0.03) |
| Reinforcement | 7.5 (0.09) |
| Health Identity | 7.9 (0.09) |
| Resources | 12.0 (0.27) |
| Functional Status | 4.6 (0.03) |
| Habits | 4.0 (0.04) |

| | |
|---|---|
| Quality | 10.0 (0.10) |
| Anthropometrics | 3.9 (0.14 |

(M4) Table 5 summarizes results from the independent group t-tests or one-way ANOVA (M4). Younger and Asian participants, and those who were married or living with a partner had higher mean DHS scores compared to their counterparts (p<.001). Differences in DHS scores were observed between the 20-44 year olds and 45-64 (65.8 ± .8 vs 63.1 ± .8, p<.001) after adjustment for multiple comparisons. No significant differences were observed between the 45-64 and the ≥65 years group (p =.776) after adjustment for multiple comparisons. Similarly, for race/ethnicity, mean differences existed for all race/ethnicity groups compared to Whites after adjustment for multiple comparisons. No significant differences were observed in mean DHS scores between males and females or household size. When comparing mean DHS scores for clinical variables, DHS scores were higher for participants who had normal A1c levels compared to those who had prediabetes and diabetes (p<.001) as well as those with normal blood pressure compared to those who had elevated blood pressure, Stage 1 hypertension, and Stage 2 hypertension (p<.001). See table 5 for actual mean values. Moreover, after adjustment for multiple comparisons, differences in DHS total score were significant for "Prediabetes" and "diabetes, compared to "normal A1c." Similarly, for blood pressure, mean differences for DHS existed for all levels (elevated, stage 1 hypertension, and stage 2 hypertension compared to the group with normal blood pressure after adjustment for multiple comparisons. No significant differences were observed in mean DHS scores for participants having/not having high cholesterol (p =0.982).

**(M4) Table 5 Comparison of mean DHS total score by levels of demographic and clinical characteristics using independent groups t-tests or one-way ANOVA)**

| Group Characteristic | DHS total score (mean ± standard error) | Test statistic t or F(df) | p-value |
|---|---|---|---|
| **Age** | | $F(2,16) = 10.1$ | .001 |
| 20-44 | 65.8 ± .8 | | .001* |
| 45-64 (Reference variable for Post Hoc) | 63.1 ± .8 | | |
| 65 and over | 62.8 ± .8 | | .776* |
| **Sex** | | $t(1,17) = 1.9$ | .081 |
| Male | 64.7 ± .8 | | |
| Female | 63.8 ± .7 | | |
| **Race/ethnicity** | | $F(4,14) = 32.2$ | .001 |
| White (Reference variable for Post Hoc) | 65.7 ± .8 | | |
| Black | 58.1 ± 1 | | .001* |
| Hispanic | 59.8 ± .9 | | .001* |
| Asian | 70.9 ± .7 | | .001* |
| Other Race | 60.2 ± 2 | | .008* |
| **Household size** | | $t(1,17) = 1.6$ | .134 |
| 1 to 2 member | 64.9 ± .7 | | |
| 3 or more members | 63.4 ± 1 | | |
| **Marital Status** | | $t(1,17) = 6.2$ | .001 |
| Married | 65.4 ± .6 | | |
| Unmarried | 62.3 ± .9 | | |
| **Hemoglobin AIC** | | $F(2,16) = 144.8$ | .001 |
| Normal (Reference variable for Post Hoc) | 66.6 ± .6 | | |
| Prediabetes | 60.3 ± .9 | | .001* |
| Diabetes | 51.7 ± 1 | | .001* |
| **Total cholesterol** | | $F(2,16) = .02$ | .982 |
| Normal | 64.3 ± .7 | | |
| Borderline | 64.2 ± .7 | | |
| High Cholesterol | 64.2 ± 1.1 | | |
| **Blood Pressure** | | $F(3,15) = 14.1$ | .001 |
| Normal (Reference variable for Post Hoc) | 66.2 ± .9 | | |
| Elevated | 62.4 ± .5 | | .001* |
| Stage 1 hypertension | 63.6 ± .7 | | .001* |
| Stage 2 hypertension | 61.0 ± 1.5 | | .001* |

\* Post Hoc (sequential Sidak)

**Linear regression models with DHS total score as dependent variable adjusted for**

**all independent variables simultaneously.**

The results of multiple linear regression analysis indicated age, race/ethnicity, household size, marital status, ratio of family income to poverty, hemoglobin A1c, and diastolic blood pressure are statistically significantly related to DHS score holding all other variables in the model constant. No significant relationships with DHS were exhibited by the independent variables sex, systolic blood pressure, and total cholesterol ((M4) Table 6). Results indicated older participants had lower DHS scores when all other variables were held constant. Specifically, for each additional year of age, DHS scores decreased by 0.1 if all other variables were held constant. Moreover, DHS scores were positively correlated to family income to poverty ratio, indicating that for each one unit increase in the ratio of family income to poverty, DHS scores increased by 3.2 when all other variables were held constant. The remaining independent variables, A1c and DBP exhibited a negative correlation with DHS scores. In other words, for each 1 unit increase of A1c or DBP, DHS scores decreased by 3.2 or 0.07, respectively, if all other variables were held constant. Race/ethnicity was also important in predicting DHS scores. Specifically, compared to Whites, Blacks scored on average 3.4 points lower on the DHS scale, while Asians had, on average, 4.9 points higher DHS total scores (both p=0.001) when all other variables were held constant. Finally, smaller households demonstrated DHS scores that were, on average, 1.74 points higher than those of larger households when adjusting for all other variables. Similarly unmarried participants on average scored 1.08 points lower on the DHS scale than married participants [(M4) Table 6] holding all other variables constant.

**(M4) Table 6: Multiple linear regression models with DHS total score as dependent variable adjusted for all independent variables simultaneously**

| Group characteristics | Estimates | Standard Error | 95% CI | P- |
|---|---|---|---|---|

| | | (SE) | | value |
|---|---|---|---|---|
| **Age** | -.10 | .02 | [-.13; -.06] | .001 |
| **Sex** | | | | .103 |
| Male | .69 | .40 | -.16-1.5 | |
| Female | Reference variable | | | |
| **Race/ethnicity** | | | | |
| Hispanic | -2.5 | .60 | [-3.7; -1.2] | .001 |
| Other Race | -2.0 | 1.1 | -4.3-.27 | .080 |
| Black | -3.4 | .58 | [-4.6; -2.2] | .001 |
| Asian | 4.9 | .73 | 3.3-6.4 | .001 |
| White | Reference variable | | | |
| **Household size** | | | | |
| 1 to 2 members | 1.7 | .63 | 0.42-3.1 | .013 |
| 3 or more members | Reference variable | | | |
| **Marital Status** | | | | |
| Married | 1.1 | .36 | .32-1.8 | .008 |
| Unmarried | Reference variable | | | |
| **Ratio of family income to poverty** | 3.2 | .15 | 2.9-3.5 | .001 |
| **Hemoglobin AIC** | -3.2 | .29 | [-3.8; -2.6] | .001 |
| **Systolic blood pressure** | -.04 | .02 | -.08-.00 | .068 |
| **Diastolic blood pressure** | -.07 | .02 | [-.11; -.03] | .003 |
| **Total cholesterol** | .01 | .00 | -.00-.01 | .150 |

Finally, Chi-square tests were used to test the two hypotheses: 1) DHS score categories are lower among adults 20-44 and adults 65 and older compared to adults 45-64, minorities compared to whites, females compared to males, unmarried compared to married, and for larger household size compared to smaller household size and 2) Individuals who have DHS scores in lower categories are more likely to have hypertension, hypercholesterolemia, and diabetes. Chi-Square results were statistically significant (all p<-0.022) for all demographic and clinical characteristics except for two [household size and total cholesterol (p =0.121 and p =0.304, respectively)] [(M4) Table

7]. The hypothesis that DHS score categories were lower among adults 20-44 and adults

65 and older compared to adults 45-64 was partially supported. Specifically, proportions

of adults 45 and older were higher in the lower DHS categories and lower in the higher

DHS categories. This suggests that younger adults had higher DHS scores than middle-

aged to older adults. In contrast, the hypothesis that DHS score categories were lower

among females compared to males and unmarried compared to married participants was

supported by the results with proportions of females, and unmarried being higher in the

lower DHS categories and lower in higher DHS score categories compared to their

counterparts. Additionally, for minorities, more Black, Hispanic, and Other race

participants were in the lower DHS categories and fewer in higher DHS score categories

compared to Whites, while there were fewer Asians in the lower DHS categories and

more in the higher DHS categories compared to Whites ((M4) Table 7). Proportions of

individuals with hypertension and diabetes were higher in the lower DHS categories and

lower in the higher DHS categories supporting our hypothesis. This pattern was also true

for pre-diabetes and borderline and stage I hypertension but not for total cholesterol

[(M4) Table 7]. When comparing mean *Hemoglobin AIc, Total cholesterol, Systolic*

*Blood Pressure* and *Diastolic Blood Pressure* by DHS scores categories, A1c and SBP

were higher for participants with lower DHS scores and lower for participants who had

higher DHS scores [(M4) Table 8].

**(M4) Table 7: Comparison of DHS categories by level of demographic and clinical characteristics using Chi-square tests**

| | DHS categories (%) | | | | | | Chi –Square Pearson | p-value |
|---|---|---|---|---|---|---|---|---|
| **Characteristics** | Severe | Bad | Subpar | Adequate | Good | Excellent | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Age** | | | | | | | 57.6 | .016 |
| 20-44 | 28.1% | 33.9% | 40.5% | 41.0% | 48.1% | 52.2% | | |
| 45-64 | 53.1% | 44.5% | 40.7% | 40.9% | 36.1% | 33.3% | | |
| 65 and over | 18.9% | 21.6% | 21.6% | 18.1% | 15.8% | 14.4% | | |
| **Sex** | | | | | | | 22.8 | .022 |
| Male | 42.0% | 39.8% | 51.7% | 51.2% | 53.7% | 49.4% | | |
| Female | 58.0% | 60.2% | 48.3% | 48.8% | 46.3% | 50.6% | | |
| **Race/ethnicity** | | | | | | | 267.5 | .001 |
| White | 43.2% | 57.1% | 63.9% | 66.8% | 77.1% | 79.9% | | |
| Black | 34.3% | 16.6% | 13.0% | 12.3% | 7.2% | 3.9% | | |
| Hispanic | 17.9% | 20.0% | 17.0% | 15.4% | 9.1% | 7.0% | | |
| Asian | 0.8% | 1.1% | 1.3% | 3.5% | 4.3% | 7.6% | | |
| Other Race/ethnicity | 3.7% | 5.2% | 4.8% | 2.0% | 2.3% | 1.6% | | |
| **Household size** | | | | | | | 28.8 | .121 |
| 1 to 2 members | 47.1% | 53.9% | 53.4% | 52.1% | 62.6% | 58.1% | | |
| 3 or more members | 52.9% | 46.1% | 46.6% | 47.9% | 37.4% | 41.9% | | |
| **Marital Status** | | | | | | | 71.2 | .002 |
| Married or living with partner | 31.3% | 50.6% | 57.3% | 63.5% | 62.0% | 69.2% | | |
| Unmarried, separated, divorced or widowed | 68.7% | 49.4% | 42.7% | 36.5% | 38.0% | 30.8% | | |
| **Hemoglobin AIC** | | | | | | | 543.3 | .001 |
| Normal | 27.9% | 52.3% | 60.1% | 71.6% | 83.8% | 90.2% | | |
| Prediabetes | 21.3% | 25.4% | 25.2% | 21.0% | 14.0% | 8.6% | | |
| Diabetes | 50.8% | 22.3% | 14.8% | 7.4% | 2.2% | 1.3% | | |
| **Total cholesterol** | | | | | | | 18.6 | .304 |
| Normal | 57.1% | 54.0% | 57.4% | 59.3% | 57.0% | 56.0% | | |
| Borderline | 21.0% | 29.8% | 30.1% | 30.0% | 27.8% | 29.8% | | |
| High Cholesterol | 21.9% | 16.2% | 12.5% | 10.7% | 15.2% | 14.3% | | |
| **Blood Pressure** | | | | | | | 97.9 | .001 |
| Normal | 22.5% | 36.2% | 41.4% | 43.1% | 48.7% | 58.1% | | |
| Elevated | 47.0% | 37.7% | 34.5% | 33.4% | 29.8% | 24.2% | | |
| Stage 1 hypertension | 15.5% | 15.5% | 15.6% | 16.5% | 15.2% | 12.7% | | |
| Stage 2 hypertension | 15.0% | 10.6% | 8.5% | 6.9% | 6.3% | 4.9% | | |

## Discussion:

The objective of this study was to use a newly developed and validated instrument DHS to measure barriers to adults' dietary practices. In the present study using nationally representative data, several associations were detected worth noting. Overall, participants were fairly healthy with average blood pressure, total cholesterol and A1c level all within normal values. Moreover, the majority of participants had adequate DHS (total scale)

which suggests fewer barriers to dietary practices. This is not a surprise since the average had family income 3x the poverty level, were college educated, and had smaller household sizes. This indicates that many participants had the financial resources to: 1) acquire nutrient dense foods and 2) afford resources that would improve their overall dietary practices. These findings do not represent the national averages at the times the study was conducted. In 2011, the family poverty rate was 11.8 percent (U.S. Census Bureau, 2016) and in 2012-2016, 30.3% of the general population had bachelor degree or higher; and on average 2.64 persons lived in a household (U.S. Census Bureau, American Community Survey [ACS] and Puerto Rico Community Survey [PRCS], 2018). However, significant differences in mean DHS existed between levels of demographic and clinical characteristics, specifically age, race/ethnicity, ratio of family income to poverty, household size, marital status, A1c levels and blood pressure values.

DHS total scores were found to decrease with age, suggesting that older adults may have more barriers to dietary practices than younger adults. Specifically, significant differences in scores existed between the age groups 20-44 and 45 –64 years, but not between the age groups 45–64 and 65 and older suggesting that younger adults had better DHS scores (fewer barriers to dietary practices) than middle to older adults. This finding is consistent with the literature. Getting older comes with a variety of life changes that can influence dietary practices; particularly in the physical and psychosocial domains (Drewnowski, 2001; Leslie & Hankey, 2015). Race/ethnicity also played an important role in predicting DHS scores (DHS total and DHS category). Specifically, compared to Whites, Blacks had the worst DHS scores, while Asians had the best. This suggests that minorities, except for Asians, were more likely than Whites to have more barriers to

dietary practices. According to the literature, minority race and ethnic groups experience diet-related disparities, therefore, exhibiting poorer dietary quality and health outcomes compared to Whites (Satia, 2009). Consequently, the U.S has placed a high priority on reducing dietary and health disparities in race/ethnic groups (Satia, 2009). DHS scores were also found to be positively correlated to the ratio of family income to poverty, which suggests that individuals with lower DHS scores may have fewer financial resources, which acts as a barrier to dietary practices compared to those with higher DHS scores. Households' socioeconomic status (SES) has been consistently shown to be positively correlated with diet quality (Chen, Cheskin, Shi, & Wang, 2011; Satia, 2009). Strong differences existed between household sizes after multiple comparison adjustments, where smaller households had higher DHS scores than larger households. This suggests that larger households may have had more barriers to dietary practice. It is logical to think that having more members in a household would require more resources to maintain the household. Similarly, significant differences in DHS scores existed between marital status categories. Participants who were not married on average scored lower on the DHS scale than married participants suggesting participants who are not married may have more barriers to dietary practices. This is consistent with prior research, indicating that marriage and long-term partnerships usually share resources, thereby enhancing their SES status.  In situations where resources are pooled together and expenses may be shared, financial resources may not be much of a barrier, if at all to dietary practices. Furthermore, apart from marital status age, SES, and household size are among eligibility criteria for the Supplemental Nutrition Assistance Program (SNAP). The DHS total scale may reveal that there were few to no barriers to an adult dietary

practice. Future analyses will be used to further examine this relationship by applying the DHS subscales. For example, because the total score indicated that younger participants exhibited the highest DHS and the oldest had the lowest DHS, examination of the subscale "quality," might determine that the oldest exhibit the highest mean and the youngest the lowest in this particular domain. Therefore, to capture exactly where barriers exist and which barriers have the strongest influences on adult dietary practices, the individual DHS subscales could be used.

As an additional finding, DHS total scores were only significantly associated with A1c levels and blood pressure. DHS total scores for abnormal A1c levels as well as blood pressure were different from those with normal levels when compared. These findings suggest differences in barriers to dietary practices exist for those who may be at increased risk for diabetes and/or those who have diabetes. Moreover, in evaluations of SBP and DBP (independently) when all other variables were held constant, mean DBP was found to be significantly associated with DHS, but not SBP. This suggests that A1c and DBP values both played an important role in predicting DHS scores; as DHS scores increased, A1c and DBP values decreased (or vice versa). This information is important because being able to identify individuals and those barriers to dietary practices that may affect their risk for chronic diseases, provides the ability to individualize interventions, which may include referral to service. No significant differences in DHS total scores were observed between levels of total cholesterol. The lack of association between DHS scores and cholesterol is reflected in the literature. Studies have shown that the amount of cholesterol intake from foods does not affect the amount of cholesterol circulating in the blood as much as previously thought (Ginsberg et al., 1995; Perez-Tilve et al., 2010).

DHS total scores appeared to be more strongly associated with diabetes than blood pressure. One reason why this stronger association may exist might be that diabetes may be more sensitive to diet, whereas hypertension and hypercholesterolemia may be more sensitive to medication adherence.

Significant differences existed between DHS categories (six groups; severe, bad, subpar, adequate, good and excellent), and demographic characteristics. DHS score categories, lower categories were more often found among adults 45 years and above and less often for adults 20-44. Similarly, lower DHS score categories were found more often for females and unmarried participants compared to their counterparts ($p = .022$ and $p = .002$, respectively). The hypothesis that individuals with lower DHS scores are more likely to have hypertension, hypercholesterolemia, or diabetes, was only supported for hypertension, and diabetes (both $p = .001$). The hypothesis that DHS score categories are lower among adults 20-44 and adults 65 and older compared to adults 45-64 was partially supported as scores were only lower for adults 65 and older compared to adults 45-64. This suggests participants 20-44 may have fewer barriers to dietary practices than those age 45 and older. In contrast, the hypothesis that DHS score categories were lower among females compared to males, and unmarried compared to married participants was supported by the results with proportions of females, and unmarried being higher in the lower DHS categories and lower in higher DHS score categories compared to their counterparts. This suggests that females and unmarried participants may have more barriers to dietary practices. Additionally, more minority participants, (Black, Hispanic, and other race) were more likely to score in the lower DHS categories (severe, bad or subpar DHS) and the higher categories (adequate, good or excellent DHS) compared to

Whites. This was the opposite for Asians, who were fewer in the lower DHS categories and more in the higher DHS categories. This suggests that most minority groups may have more barriers to dietary practices compared to Whites. The hypothesis that individuals who have DHS scores in lower categories are more likely to have hypertension, hypercholesterolemia, or diabetes was only supported for diabetes and hypertension, but not for hypercholesterolemia.

Finally, the DHS instrument was designed to simultaneously measure barriers by summing the 10 subscales or using each subscale individually. Each subscale represents an evidence-based domain that may influence behaviors. The subscales can be used to further investigate where barriers exist and which barriers have the strongest influences on adult dietary practices. The identified barriers can then be addressed together through individualized interventions. The subscales contribute to the strength of the DHS instrument, however, examining relationships between each subscale and demographic and clinical characteristics is beyond the scope of this study. A summary of average subscale scores among study participants is provided in (M4) Table 4.

This study has several important strengths. First, it is based on nationally representative data collected from a large sample. Second, this instrument generates scores that are based on the multidimensional nature of dietary practices. Psychometric testing revealed the instrument can validly and reliably assess the multidimensional nature dietary practices. These findings may help shed light on barriers to adult dietary practices in the United States and help guide individualized interventions, particularly those that center on prevention of chronic diseases, the most common cause of death in the United States.

This study has several limitations. First, the data were collected six years ago, therefore, study outcomes may depend on when the data were collected, and if changes in the economy affected these outcomes results may not be applicable. However, at the time of this study, the NHANES datasets were the only available datasets that included the most current 24-hour dietary recall, multi-ingredient foods converted into their appropriate amounts and Food Pyramid (FP). Second, although the DHS instrument was designed to be multidimensional it may not capture all relevant barriers to dietary practices. These other unknown factors may explain some of the variability not accounted for in the regression model for DHS scores in this study. One or more of these limitations may provide a rationale for future research to refine the DHS as a multidimensional instrument.

In conclusion, DHS scores were strongly associated with demographic and clinical characteristics. Participants older than 45 years, minorities, (Black, Hispanic or Other race), those living in larger households, those not married, as well as those with abnormal A1c levels or blood pressure were more likely to have lower DHS scores. These findings suggest that these groups may have more barriers to dietary practices compared to their counterparts, therefore, may be at increased risk for chronic diseases. These findings are supported in the literature.

Dietary practices are almost always a combination of inadequate nutritional intake linked to multiple other factors. Moreover, these factors are intertwined and are highly individualized. Given that good nutrition is the underpinning of good health, it is prudent to measure the multiple barriers influencing dietary practices. Overall, these findings support the need for a comprehensive instrument such as DHS that can be used by

practitioners to identify barriers associated with adult dietary practices in the clinical/community settings. Therefore, to improve the health of adults in the United States identified with or at increased risk of chronic, diet-related diseases, individualized interventions are warranted.

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| Item No. | Items | MAPPING | WEIGHT |
|---|---|---|---|
| 1 | Difficulty these problems have caused | 0 --> No // 1 & 2 & 3 --> Yes | 0.625 |
| 2 | Feeling bad about yourself | 0 --> No // 1 & 2 & 3 --> Yes | 0.625 |
| 3 | Feeling tired or having little energy | 0 --> No // 1 & 2 & 3 --> Yes | 0.625 |
| 4 | Trouble concentrating on things | No --> 0.625, Yes --> 0 | 0.625 |
| 5 | Have little interest in doing things | 0 --> No // 1 & 2 & 3 --> Yes | 0.625 |
| 6 | Feeling down, depressed, or hopeless | 0 --> No // 1 & 2 & 3 --> Yes | 0.625 |
| 7 | Thought you would be better off dead | 0 --> No // 1 & 2 & 3 --> Yes | 0.625 |
| 8 | Poor appetite or overeating | 0 --> No // 1 & 2 & 3 --> Yes | 0.625 |
| 9 | Heard of MyPyramid | Yes to one of the two questions = 7, else 0 | 7 |
| 10 | Heard of Food Pyramid | | |
| 11 | Education level | Education Score | 3 |
| 12 | Perception measures deviate | Score / 3 * 3 | 3 |
| 13 | Perception deviate from average | Score / 3 * 1 | 1 |
| 14 | When perception deviate, how much it deviate | Score / 3 * 1 | 1 |
| 15 | Doctor told you to lose weight | No --> 2.5 // Yes --> 0 | 2.5 |
| 16 | Doctor told you to exercise | No --> 2.5 // Yes --> 0 | 2.5 |
| 17 | Doctor told you to reduce salt in diet | No --> 2.5 // Yes --> 0 | 2.5 |
| 18 | Doctor told you to reduce fat/calories | No --> 2.5 // Yes --> 0 | 2.5 |
| 19 | Ever been told four out of six | No --> 2.0 // Yes --> 0 | 2 |
| 20 | Ever been told three out of six | No --> 2.0 // Yes --> 0 | 2 |
| 21 | Ever been told two out six | No --> 2.0 // Yes --> 0 | 2 |
| 22 | Ever been told one out of six | No --> 2.0 // Yes --> 0 | 2 |
| 23 | Ever told on 2 or more different visits had hypertension | No --> 2.0 // Yes --> 0 | 2 |
| 24 | Ratio of family income to poverty | Score / 3 * 10 | 10 |
| 25 | Food security status | Score / 2 * 5 | 5 |
| 26 | Receive government and community food assistance | 0 --> 0 // 1 --> 5 | 5 |
| 27 | Problems with two or more | No --> 1.25 // Yes --> 0 | 1.25 |
| 28 | Did you have problems with one or more | No --> 1.25 // Yes --> 0 | 1.25 |
| 29 | Physical difficulties for more than 1 wk. in the last 30 days | No --> 1.25 // Yes --> 0 | 1.25 |
| 30 | Experience confusion/memory problems | No --> 1.25 // Yes --> 0 | 1.25 |
| 31 | All drugs or substances and fast food | Score / 3 * 1 | 1 |
| 32 | Hard drugs | Score / 3 * 1 | 1 |
| 33 | Cigarettes and alcohol | Score / 3 * 1 | 1 |
| 34 | Weed and fast food | Score / 3 * 1 | 1 |
| 35 | Cigarettes, alcohol, fast food or weed | Score / 3 * 1 | 1 |
| 36 | Fruits consume | Score / 10 * 2 | 2 |
| 37 | Veggies consume | Score / 10 * 2 | 2 |
| 38 | Proteins consume | Score / 10 * 2 | 2 |
| 39 | Grains consume | Score / 20 * 2 | 3 |
| 40 | Sodium + fats consume | Score / 20 * 2 | 3 |
| 41 | Empty Cal consume | Score / 20 * 2 | 3 |
| 42 | HEI score | Score / 20 * 2 | 5 |
| 43 | Body Mass Index | 0=0 2=2.5 4=0 1=1.25 3=1.25 | 2.5 |
| 44 | Waist Circumference | 0=0 1=2.5 | 2.5 |
| 45 | Average Sagittal Abdominal Diameter | 0=0 1=2.5 | 2.5 |
| 46 | BODY FAT | Score / 4 * 2.5 | 2.5 |

**(M4) Figure 1: DHS 10 subscales; the 46 items and scores of the subscales**

**(M4) Table 8: Comparison of mean clinical characteristics by DHS scores categories using one-way ANOVA**

| | DHS categories | | | | | | Test Statistics |
|---|---|---|---|---|---|---|---|
| | Severe | Poor | Subpar | Adequate | Good | Excellent | p-Value |
| **Hemoglobin AIC** | | | | | | | |
| **Mean(Std.Error)** | **6.7** **(0.12)** | **6.19** **(0.09)** | **5.97** **(0.06)** | **5.66** **(0.03)** | **5.42** **(0.02)** | **5.32** **(0.02)** | **0.001** |
| Lower 95% CI | 6.44 | 6 | 5.84 | 5.59 | 5.37 | 5.27 | |
| Upper 95% CI | 6.96 | 6.38 | 6.09 | 5.73 | 5.47 | 5.37 | |
| | | | | | | | |
| **Total cholesterol** | | | | | | | |
| **Mean** | **201.97** **(4.98)** | **200.15** **(3.65)** | **194.88** **(1.46)** | **192.45** **(2.3)** | **196.96** **(2.2)** | **197.53** **(1.61)** | **0.34** |
| Lower 95% CI | 191.46 | 192.46 | 191.8 | 187.59 | 192.33 | 194.12 | |
| Upper 95% CI | 212.47 | 207.85 | 197.96 | 197.31 | 201.59 | 200.93 | |
| | | | | | | | |
| **Systolic Blood Pressure** | | | | | | | |
| **Mean** | **133.57** **(3.98)** | **124.12** **(1.02)** | **122.78** **(0.73)** | **121.85** **(0.64)** | **119.67** **(0.87)** | **116.66** **(1.05)** | **0.002** |
| Lower 95% CI | 125.16 | 121.97 | 121.23 | 120.5 | 117.83 | 114.45 | |
| Upper 95% CI | 141.97 | 126.27 | 124.33 | 123.2 | 121.5 | 118.88 | |
| **Diastolic Blood Pressure** | | | | | | | |
| **Mean** | **75.86** **(1.98)** | **73.5** **(0.68)** | **72.6** **(0.84)** | **72.78** **(0.79)** | **72.57** **(0.65)** | **72.1** **(0.64)** | **0.322** |
| Lower 95% CI | 71.68 | 72.05 | 70.84 | 71.12 | 71.2 | 70.75 | |
| Upper 95% CI | 80.04 | 74.94 | 74.36 | 74.44 | 73.94 | 73.46 | |

**Summary and Conclusion**

**Brief overview of manuscripts**

This compendium includes four manuscripts: 1) an integrative review "Food Insecurity Interventions for African Americans in the United States: An integrative review of the literature"; 2) a study "Establishing Content Validity for a hypothesized Multidimensional Instrument: A Consensus Approach"; 3) an analysis "Development and Validation of a Multidimensional Instrument to Identify Barriers to Dietary Practices"; and 4) an exploratory secondary analysis "Examining the relationships between Dietary Health Status and selected participants' demographic characteristics and clinical outcomes" Manuscripts 2 to 4 describe studies which are each built upon knowledge gained in the previous study.

**Manuscript 1** builds the foundation for the series of manuscripts that followed. This manuscript supported the need to investigate a multidimensional approach to identify barriers to adult dietary practices in order to guide comprehensive interventions development. Findings revealed that multi-level interventions that address multiple barriers influencing dietary access and choices demonstrated the greatest efficacy in improving access to healthy foods compared to one-dimensional interventions alone.

**Manuscript 2** describes the first steps to develop a conceptualized instrument, DHS, to measure the multidimensional nature of adult dietary practices. This study established the content validity through an expert review process for the items, which were considered as items on the DHS instrument. Expert review feedback was critical to establishing content

validity for 170 variables representing 12 domains identified as potential barriers to dietary practices.

**Manuscript 3** reports the second step in the development of the DHS instrument. An exploratory factor analysis was conducted to assess and validate the DHS. Results revealed adequate construct and internal validity for the DHS as a whole scale, which comprises 10 subscales. Findings affirmed DHS's multidimensionality, thus providing evidence that DHS can measure multiple barriers to adults' dietary practices.

**Manuscript 4** describes the last of the studies involved in developing the DHS instrument. It reports a secondary analysis of the NHANES 2011-2012 datasets to explore relationships between DHS and selected clinical and demographic characteristics among participants. Results indicated that 1) DHS total scores were strongly associated with demographic and clinical characteristics and 2) participants older than 45 years, minorities, (Black, Hispanic or Other race), those living in larger households, those not married, as well as those with abnormal A1c levels or blood pressure were more likely to have lower DHS scores. Additionally, individuals with lower DHS scores were more likely to have hypertension, or diabetes. These findings suggested that these groups may have more barriers to dietary practices compared to their counterparts, therefore, may be at increased risk for chronic diseases.

**Limitations of dissertation research**

The findings of this dissertation affirm DHS's multidimensionality, thus providing evidence that DHS can measure multiple barriers to adults' dietary practices. However, the methods used in this instrument development and validation study have some limitations. The focus of this dissertation was to ensure that the instrument DHS is fully

inclusive of the 14 Theoretical Domains Framework (TDF) domains suggested by Cane, O'Connor, and Michie (1) as necessary to analyze barriers to behavior change, thus ensuring the multidimensionality of the DHS instrument. However, four domains of this version of the TDF could not be represented as no variable considered relevant to these domains existed within the national NHANES 2011-2012 datasets. Reasons for four domains of the TDF not being represented within the NHANES 2011-2012 datasets may be, 1) that this was a pre-existing dataset, not collected for the purpose of this study and therefore available data were not comprehensive or 2) the focus of this study on a particular behavior, dietary practice. This dissertation study was conducted for exploratory purposes; while the instrument DHS is potentially useful as a first step, it does not comprehensively assess all barriers to adult dietary practices in the context of the TDF 14 domains version. Furthermore, the TDF framework was originally developed for implementation research, with a targeted population of health professionals. The TDF framework was adopted for this dissertation with the targeted audience being the general adult population in the United States and not health professionals. Although the TDF framework has been used by various researchers in questionnaire development, most investigators have dealt with identifying factors that may impede the implementation of evidence-based practice. Furthermore, some of the instrument's items were specifically designed to assess a particular construct, therefore making these items not easily adaptable in settings that require quick screening of adults for dietary risks. While this instrument might be impractical as a quick screen in some clinical settings, the DHS could be a useful instrument to assess adults thoroughly for barriers to their dietary practices.

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**Importance of theory, model or framework to guide overall findings**

The Behavioral Change Wheel (BCW), hub COM-B system, and the Theoretical

Domains Framework (TDF) together guided this dissertation (1, 2). Both frameworks

comprise of a variety of behavioral change theories and are used by researchers to

identify barriers to behavior change. As previously noted, researchers have used the

frameworks to develop theory-based questionnaires to identify and understand potential

factors influencing human behavior and to guide the design of effective interventions (3-

5). The frameworks provided support for the conceptualized DHS instrument; justifying

the importance and the significance of this dissertation work and its contribution to new

knowledge in the phenomenon being investigated. Both frameworks, heavily informed

this dissertation methodology. In particular, together they provided a theory-based

systematic approach for identifying variables that are key determinants to adults' dietary

practices from the National Health and Nutrition Examination Surveys (NHANES)

datasets and assigning those variables to their theory-based domains.

**Research trajectory**

This dissertation was exploratory by design, therefore, the following recommendations

are suggested for future refinement of DHS subscales: to include 1) all 14 TDF domains

to ensure the DHS instrument captures the multidimensional nature of adults dietary

practices; 2) geographic information because DHS may vary by different regions 3) more

practical items to increase utilization in other clinical/community settings by revising the

items on DHS; and to 3) pilot test the DHS instrument to establish its

predictive/discriminant validity. While this instrument might be impractical as a quick

screen in some clinical settings, the DHS might be a useful instrument to assess adults

thoroughly for factors influencing their dietary practice, in particular, factors that increase

the risk for diet related diseases. Factors that may influence an individual's dietary

practice could be screened at longer visits, e.g., during health specialty or wellness

clinics, regular primary care annual exams, researchers, or health organization research.

**Contribution of research to nursing, inter-professional sciences**

DHS is a novel instrument designed to be relevant across different contexts to capture the

multidimensional nature of adults' dietary practices. Overall, the results suggest sufficient

construct and internal validity of the DHS instrument and subscales. This exploratory

study is an important first step toward future refinements and pilot testing of the DHS

instrument and its individual subscales which may ultimately establish DHS predictive

validity.

The knowledge gained from this study is to inform the development of a more

comprehensive and simpler instrument that can be used in the clinical/community setting

to screen for barriers to adult's dietary practices. Ultimately, the capacity of DHS to

accurately identify individuals with multiple barriers to dietary practices will have

implications for practice, education, and policy. Regarding practice, practitioners may use

DHS to screen adults thoroughly for barriers to their dietary practice at longer visits, e.g.,

during regular primary care annual exams and health specialty or wellness clinics;

therefore, prompting an individualized intervention plan of care. Regarding education,

the results may lead to training for nutrition and health assistance program developers,

ensuring a multidimensional approach is used in intervention development and

implementation. For example, training seminars/workshops may be developed to

understand the multiple needs of individuals at dietary risk and how to intervene using a

multidimensional approach that is individualized. Regarding policy, the results may help

clinics/communities, administrators in nutrition and health organizations to identify

individuals with multiple barriers to dietary practices, to better understand the multiple

needs of these individuals, and to develop individualized strategies that better address

barriers to dietary practices simultaneously.

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# APPENDICES

## Appendix A: Task instructions for expert reviewers

## <u>OVERVIEW</u>

Dear expert reviewers,

My name is Enia Zigbuo-Wenzler, and I am a Ph.D. candidate in the College of Nursing at the Medical University of South Carolina. My research interest lies in the areas of food security and dietary risks and their association with diet sensitive diseases. My dissertation study is aimed at developing a tool/scale that is capable of assessing multi-dimensions of a person's dietary risk. The study was approved by the Medical University of South Carolina (MUSC) College of Nursing.

You are being asked to participate as part of a panel of reviewers because of your expertise in health and/or nutritional practice. I am seeking your feedback on selected variable items obtained from the National Health and Nutrition Examination Survey (NHANES) 2011-2012 datasets to establish independent review of the variables that have been preliminarily assigned to 13 of the 14 theoretical domains that comprise the Theoretical Domains Framework [(TDF), see Table 1 in Appendix **A**]. This expert review process is being conducted to establish content validity for variables to include as items on the tool/scale that will be developed. The capacity of a tool/scale to accurately identify individuals with multiple dietary risks may have implications for policy, education and practice.

**Background**
The dietary practices of individuals in the United States (U.S.) are influenced by their life situation as well as individual, socio-cultural, and other contextual factors (HHS, 2015 and Darmon & Drewnowski, 2008). The relationship among these factors could affect one's health (Darmon & Drewnowski, 2008), as the link between diet and health is well established. In addition, diet is also a major modifiable risk factor of chronic diseases (Murray et al., 2013; Yoon et al. 2014). Based on my clinical experience as a Family Nurse Practitioner, my central hypothesis is that multiple factors collectively influence one's diet and increase one's risk for diet-sensitive chronic diseases. Those influencing factors need to be identified and addressed collectively. Currently, I am unaware of any multidimensional tool/scale to assess dietary risks. Therefore, *the aim of this study is to develop a multidimensional tool/scale by combining and analyzing the validity of select variables from the 2011-2012 NHANES datasets to determine dietary risk.* It is crucial that evaluations of variable items are based on a theoretical framework that covers a full range of current scientific explanations for human behavior. Therefore, the TDF in conjunction with the hub of the Behavior Change Wheel (BCW) framework, the COM-B model (see (Appendix) Figure 1) were used to guide the systematic identification of variable items from NHANES 2011-2012 datasets.
**Frameworks**

The TDF combines behavioral change theories into one framework that is used to identify barriers relevant to behavior change and to design practical interventions to address them (Michie et al., 2005; Cane et al., 2012). The TDF comprises 14 domains representing barriers, and each domain has a set of theoretical constructs for a total of 84 variables, the following 14 domains are derived from multiple psychological and organizational behavior change theories: knowledge; skills, social/professional role and identity; beliefs about capabilities; optimism; beliefs about consequences; reinforcement; intentions; goals; memory, attention and decision processes; environmental context and resources; social influences; and emotion and behavioral regulation (Cane et al., 2012). Researchers have used the TDF to develop theory-based questionnaires to identify and understand potential factors influencing human behavior and to guide the design of effective interventions to address them (Huijg et al., 2014; Taylor et al., 2013; Beenstock et al., 2012)

The framework was developed by Michie and colleagues over the last decade and was refined in 2012 by Cane and colleagues. The TDF is outlined in **Table 2** in the Appendix **A**.

The BCW was formed by combining 19 behavior change frameworks identified in a systematic literature review to provide a comprehensive, coherent, and universal approach to guide researchers/developers when designing behavior change interventions (Michie et al, 2011). The framework consists of three main layers; however, because the focus of the current study is to identify intrinsic and extrinsic factors that influence a person's dietary choices, only the framework's hub, the COM-B, was used. The hub "behavior system," referred to as the COM-B system, is used to identify behaviors that need to be understood and modified. The COM-B system recognizes that behavior is part of an interacting system involving three components: capability, opportunity, and motivation (Michie et al, 2011). The COM-B proposes that for behavior change to occur, the person performing the behavior needs to 1) have the physical and psychological **capability** to perform the behavior, 2) have the social and physical **opportunity** to perform the behavior, and 3) be **motivated** to perform the behavior. Therefore, the COM-B is used in this study to identify variable items that measure the sources that reflect influences on behavior, which may need to be understood and modified.

As illustrated, the theoretical domains have been mapped to specific behavior change techniques (BCTs) that are the active components of interventions related to each domain (Debono et al., 2017). The COM-B system presents the three conditions that are required for behavior change to occur. Both frameworks are interconnected because each domain of the TDF relates to a COM-B component. Together, the framework provides a theory-based systematic approach for identifying and mapping variable items from NHANES to consider as items on the proposed instrument. The linkage between the TDF and COM-B is illustrated in (Appendix) Figure 2.

## INSTRUCTIONS TO EXPERT PANEL

Your participation in this study is sincerely appreciated. If you decide to participate as a reviewer, please reply to me of your acceptance within one week via email. Once you have agreed to participate, you will need to return the completed review within three weeks via email to zigbuoaw@musc.edu. However, if this timeline does not work for

you, please let me know as soon as possible so we can establish a reasonable completion date. Please contact me, Enia Zigbuo-Wenzler (zigbuoaw@musc.edu), if you have any questions.

**Task Overview:**
Please read through the instructions carefully prior to completing the task. Definitions of terms are presented in **Table 3** in Appendix A to assist you in completing the task. The task will be performed in an Excel spreadsheet, "Zigbuo-wenzler_expert-review_task." The spreadsheet has 9 columns and 14 color coded rows. The last two columns provide the available response options. Please download the file onto your desktop, open it, and save as "Zigbuo-wenzler_expert-review_task_ plus your initials (e.g. Zigbuo-wenzler_expert-review_task_EZ)." The spreadsheet is large and to avoid zooming in and out, please follow the instructions to fit the columns of the spreadsheet exactly to your screen to reduce the width so you can see all the columns. However, you will need to scroll down to see the end. Your task is to provide your expert opinion whether a variable item belongs to the domain it is currently assigned; **"yes" indicates the item** belongs to assigned domain category; **"no" indicates the item** does not belong to assigned domain category. If you select "no", please re-assign the variable item to another domain category.

The last two columns, **H** (Yes/No selection option) and **I** (Domain re-assignment) provide a drop-down list of the available response options.

### SCALE YOUR EXCEL SPREADSHEET TO FIT YOUR SCREEN INSTRUCTIONS
   • Select columns A to I from the top of the spreadsheet.
   • Choose View, Zoom, then select Fit Selection
   • Click OK

**How to determine if the variable item is in the accurate domain category:**

**1. Determine if the variable item is in the accurate domain**
Please review the descriptions provided in columns **B-D** (TDF domain description, TDF theoretical construct) and Study researchers adapted domain description, respectively)**, F** (NHANES variable description), and **G** (NHANES variable item question) to assist you to determine whether the variable item column **E** (NHANES variable item) was appropriately assigned to the accurate domain.

**2. Choose a response option**
Please decide based on your expert opinion and the descriptions provided in columns **B-D, F,** and **G** whether each variable item is a measure of the domain it is currently assigned. Select "yes", the item belongs to the domain category or "no", the item does not belong to the current domain using the dropdown menu response option in column **H**.
   ● Go to column **H** to select your response from a drop-down list of **Yes/No** option for each item.
   ● Click in the variable item cell in column **H,** a down arrow to the right of the cell will appear.
   ● Click on the down arrow, a list of **Yes/No** option will appear.

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- Scroll to your response choice, the one that is highlighted. Click on it to select, it will appear in the cell.
- Once you are happy with your selection, please move to the next variable item.

**How to re-assign the variable item to another domain category:**

If you select "no" that the variable item does not belong to the domain it is currently assigned, please re-assign it to another domain category. You may re-assign a variable item only to one other domain category.

**1**. **Re-assigning a variable item another domain category**
Based on your expert opinion, please indicate another domain category for the variable item you rated "no" by selecting from the dropdown list of 14 domain options provided in column **I**.

**2. Choose a response option**
- Go to column **I** to select your response from a drop-down list of **14 domain** options for each item.
- Click in the variable item cell in column **I, and** a down arrow to the right of the cell will appear.
- Click on the down arrow, and a list of 14 domains will appear.
- Scroll to your response choice, the one that is highlighted. Click on it to select, and it will appear in the cell.
- Once you are satisfied with your selection, please move to the next variable item.

After receiving all completed tasks, the study team will review your responses and address any re-assignment of variable items to another domain. We may have a few follow-up questions and will contact you via email.

Thank you for participating on this expert panel review. Your expertise and time is appreciated through this critical process of my dissertation. My dissertation chair is Dr. Gayenell Magwood (magwoodg@musc.edu), and committee members are Drs. Martina Mueller and Angela Fraser.

Sincerely,

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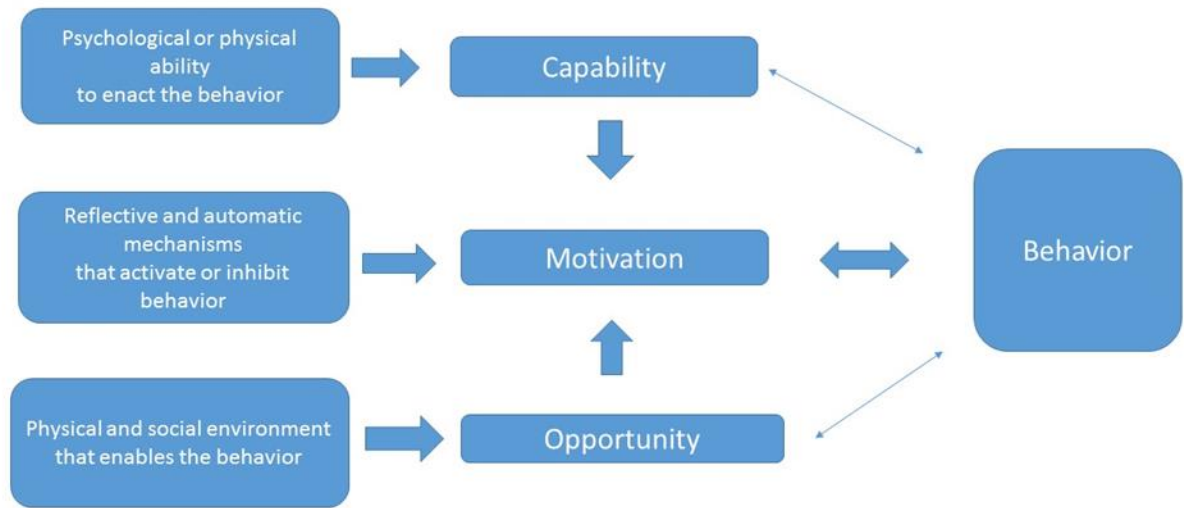
## Appendix A

**(Appendix) Table 1: Theoretical Domains Framework (TDF) 14 theoretical domains, domain description, and the 84 theoretical constructs**

| Theoretical domain | Cane et al. domain description | Theoretical construct |
|---|---|---|
| 1. Knowledge | An awareness of the existence of something | 1. Knowledge (including knowledge of condition /scientific rationale)<br>2. Procedural knowledge<br>3. Knowledge of task environment |
| 2. Skills | An ability or proficiency acquired through practice | 4. Skills<br>5. Skills development<br>6. Competence<br>7. Ability<br>8. Interpersonal skills<br>9. Practice<br>10. Skill assessment |
| 3. Social/professional role and identity | A coherent set of behaviors and displayed personal qualities of an individual in a social or work setting | 11. Professional identity<br>12. Professional role<br>13. Social identity<br>14. Identity<br>15. Professional boundaries<br>16. Professional confidence<br>17. Group identity<br>18. Leadership<br>19. Organizational commitment |
| 4. Beliefs about capabilities | Acceptance of the truth, reality, or validity about an ability, talent | 20. Self-confidence<br>21. Perceived competence<br>22. Self-efficacy<br>23. Perceived behavioral control<br>24. Beliefs<br>25. Self-esteem<br>26. Empowerment<br>27. Professional confidence |
| 5. Optimism | The confidence that things will happen for the best | 28. Optimism<br>29. Pessimism<br>30. Unrealistic optimism<br>31. Identity |
| 6. Beliefs about consequences | Acceptance of the truth, reality, or validity about outcomes of a behavior in a given situation | 32. Beliefs<br>33. Outcome expectancies<br>34. Characteristics of outcome expectancies<br>35. Anticipated regret<br>36. Consequents |
| 7. Reinforcement | Increasing the probability of a response by arranging a dependent relationship, or contingency | 37. Rewards (proximal/distal, valued/not valued, probable/improbable)<br>38. Incentives<br>39. Punishment<br>40. Consequents<br>41. Reinforcement |

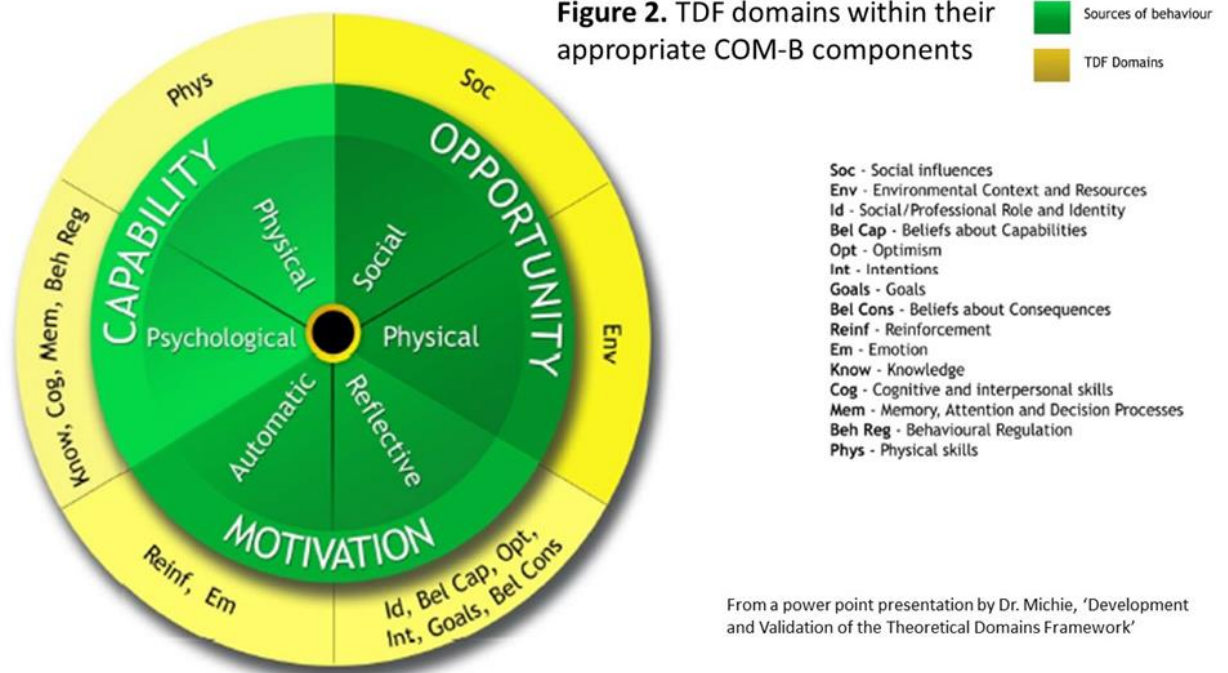| | | 42. Contingencies<br>43. Sanctions |
|---|---|---|
| 8. Intentions | A conscious decision to perform a behavior or a resolve to act in a certain way | 44. Stability of intentions<br>45. Stages of change model<br>46. Trans theoretical model and stages of change |
| 9. Goals | Mental representation of outcomes or end states | 47. Goals (distal/proximal)<br>48. Goal priority<br>49. Goal/target setting<br>50. Goals (autonomous/controlled)<br>51. Action planning<br>52. Implementation intention |
| 10. Memory, attention and decision processes | The ability to retain information, focus selectively on aspects of the environment, and choose between two or more alternatives | 53. Memory<br>54. Attention<br>55. Attention control<br>56. Decision making<br>57. Cognitive overload/tiredness |
| 11. Environmental context and resources | Any circumstance of a person's situation or environment that discourages or encourages the development of skills and abilities, independence, social competence | 58. Environmental stressors<br>59. Resources/material resources<br>60. Organizational culture /climate<br>61. Salient events/critical incidents<br>62. Person x environment interaction<br>63. Barriers and facilitators |
| 12. Social influences | Those interpersonal processes that can cause an individual to change their thoughts, feelings, or behaviors | 64. Social pressure<br>65. Social norms<br>66. Group conformity<br>67. Social comparisons<br>68. Group norms<br>69. Social support<br>70. Power<br>71. Intergroup conflict<br>72. Alienation<br>73. Group identity<br>74. Modelling |
| 13. Emotion | A complex reaction pattern, involving experiential, behavioral, and physiological elements, by which the individual attempts to deal with a personally significant matter or event | 75. Fear<br>76. Anxiety<br>77. Affect<br>78. Stress<br>79. Depression<br>80. Positive/negative affect<br>81. Burn-out |
| 14. Behavioral regulation | Anything aimed at managing or changing objectively observed or measured actions | 82. Self-monitoring<br>83. Breaking habit<br>84. Action planning |

Figure 1. The COM-B system: Behavior occurs as an interaction between three necessary conditions

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**(Appendix) Figure 1: The COM-B system: Behavior occurs as an interaction between three necessary conditions**



Figure 2. TDF domains within their appropriate COM-B components

Sources of behaviour
TDF Domains

Soc - Social influences
Env - Environmental Context and Resources
Id - Social/Professional Role and Identity
Bel Cap - Beliefs about Capabilities
Opt - Optimism
Int - Intentions
Goals - Goals
Bel Cons - Beliefs about Consequences
Reinf - Reinforcement
Em - Emotion
Know - Knowledge
Cog - Cognitive and interpersonal skills
Mem - Memory, Attention and Decision Processes
Beh Reg - Behavioural Regulation
Phys - Physical skills

From a power point presentation by Dr. Michie, 'Development and Validation of the Theoretical Domains Framework'

**(Appendix) Figure 2: TDF domains within their appropriate COM-B components**

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**(Appendix) Table 2: 14 TDF domains, their TDF description and study researchers' operational description**

| TDF Theoretical Domain | TDF Domain Description | Study Researchers Operational Description |
|---|---|---|
| Knowledge | An awareness of the existence of something | An awareness of the dietary guidelines, their general health and health risks factors and the benefits of sports and recreational activities |
| Beliefs about capabilities | Acceptance of the truth, reality, or validity about an ability, talent, or facility that a person can put to constructive use | A person's belief concerning their confidence, control, or performance concerning making appropriate dietary choices, staying healthy and engaging in sports and recreational activities |
| Beliefs about consequences | Acceptance of the truth, reality, or validity about outcomes of a behavior in a given situation | A person's subjective rating of his/her general health, diet, and weight and his/her belief about the outcomes of making appropriate dietary choices, staying healthy and engaging in sports and recreational activities |
| Reinforcement | Increasing the probability of a response by arranging a dependent relationship, or contingency, between the response and a given stimulus | Internal or external responses to a person's behavior that affect the likelihood of making appropriate dietary choices, staying healthy and engaging in sports, fitness and recreational activities [Social Cognitive Theory (SCT)] |
| Memory, attention and decision processes | The ability to retain information, focus selectively on aspects of the environment, and choose between two or more alternatives | The ability to retain information concerning diet and health and to be able to focus on making appropriate dietary and health choices |
| Environmental context and resources | Any circumstance of a person's situation or environment that discourages or encourages the development of skills and abilities, independence, social competence, and adaptive behavior | Any characteristics of the socio-political context, organization, and the person that discourages or encourages a person to make appropriate dietary choices, stay healthy and engage in sports and recreational activities |
| Social influences | Those interpersonal processes that can cause an individual to change their thoughts, feelings, or behaviors | A person's association with people and situations in society that dictates the way he/she thinks about things that might affect his/her diet, health, and sports and recreational activity level |
| Behavioral regulation | Anything aimed at managing or changing objectively observed or measured actions | All the things a person does concerning their diet, health and sports and recreational activities |
| Optimism | The confidence that things will happen for the best, or that desired goals will be attained | A person's confidence that things will happen for the best; never give up hope or look at the bright side of life |
| Emotion | A complex reaction pattern, involving experiential, behavioral, and physiological elements, by which the individual attempts to deal with a personally significant matter or event | A subjective psychophysiological experience that might affect a person's likelihood of making appropriate dietary and health choices, and engaging in sports and recreational activities |
| Skills | An ability or proficiency acquired | The competence or capacity that help a |

| | | |
|---|---|---|
| | through practice | person routinely manage their diet and health in a productive manner; making appropriate dietary choices, staying healthy, and engaging in sports and recreational activities |
| Social/professional role and identity | A coherent set of behaviors and displayed personal qualities of an individual in a social or work setting | A coherent set of dietary and health promotion behaviors and displayed personal qualities of an individual in a social setting |
| Intentions | A conscious decision to perform a behavior or a resolve to act in a certain way | Readiness/commitment to make healthy dietary choices, stay healthy and engage in sports and recreational activities |
| Goals | Mental representation of outcomes or end states that an individual wants to achieve | An aim or an objective a person wants to achieve concerning their diet and health |

**(Appendix) Table 3: Definitions/terms that may assist you during task completion**

| Term | Definition |
|---|---|
| Theoretical Domains Framework (TDF) | A combination of behavioral change theories into one framework that may use to identify the sources relevant to behavior change. The TDF comprises of 14 domains and 84 constructs (Cane et al., 2012). Revision version 2012. |
| Theoretical domains (domain) | A group of related theoretical constructs (Michie et al., 2005 and Cane et al., 2012). |
| Theoretical construct (construct) | A concept specially devised to be part of a theory (Michie et al., 2005 and Cane et al., 2012). |
| TDF domain description. | Each domain as defined by the TDF researchers. |
| Authors' domain description | Each domain as defined by this study's authors based on the TDF researchers' definition of theoretical domains and construct and as applicable to this study. |
| National Health and Nutrition Examination Survey (NHANES) variable item | Variable items obtained from the 2011-2012 NHANES datasets based on the TDF domain and constructs and the COM-B model. |
| NHANES variable item question | The exact questions used my NHANES's interviewers for each variable item. |