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Relationships among Vitamin D Deficiency, Metabolic Syndrome, Smoking Behavior, and Physical Activity

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Abstract

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MBA, Bay Path University, 2011

BS, American International College, 2004

Dissertation Submitted in Partial Fulfilment

of the Requirements for the Degree of

Doctor of Philosophy

School of Public Health Sciences-Epidemiology

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Abstract

Aging increases the risk of both vitamin D deficiency and metabolic syndrome. Vitamin D deficiency and metabolic syndrome may be related, although there are mixed findings. Furthermore, literature suggests other factors such as physical fitness activity and smoking behavior are associated with Vitamin D deficiency and the development of metabolic syndrome. A number of studies have documented associations between Vitamin D levels and physical fitness activities, while other studies found correlations between Vitamin D levels, metabolic syndrome, and smoking behavior. However, no previous study has examined the links between physical fitness activity, smoking behavior, Vitamin D levels, and the risks for metabolic syndrome. The purpose of this study was to examine if smoking behavior and physical fitness activity moderated the relationship between Vitamin D deficiency and metabolic syndrome among older individuals. The research problem was addressed through the use of retrospective data collected from the National Health and Nutrition Examination Survey (NHANES) 2005-2006. This study utilized a quantitative, retrospective, cross-sectional design employing regression and correlational analysis to determine that Vitamin D deficiency ($p = 0.02$) predicts metabolic syndrome ($n = 1570$). However, neither physical activity ($p = 0.99$) nor smoking behavior ($p = 0.23$) moderated the relationship between Vitamin D deficiency and metabolic syndrome ($n = 1570$). The results of the study could give practitioners a better understanding and insights into the different risk factors to metabolic syndrome among older individuals, which can eventually enable primary and secondary prevention interventions.

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Dedication

I would like to dedicate this dissertation to my grandfather Nguyen Van Chut. Our time together was brief, yet your contribution and inspiration are engraved forever in my heart.

To my children Sophia Nhi Pham, Fiona Vi Pham and Bella An Pham, never give up on your dreams. So long as you have the desire, the dedication, and the commitment, your dreams can become real.

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Chapter 1: Introduction to the Study

This study examined the relationships between Vitamin D deficiency, metabolic syndrome, smoking behavior and physical fitness activities in elderly individuals. The study sought to determine the type of relationships that these factors have on people's health. Zambon (et al., 2009) found that the prevalence of metabolic syndrome increases with age. Due to the progressive growth of elderly populations worldwide, studies showing empirical evidence of the effect of behavioral factors that affect metabolic syndrome are valuable tools in improving healthcare and decreasing morbidity. This affects not only the elderly but also all age groups. Vitamin D can be obtained through food sources (Chen et al., 2007) and skin exposure to sunlight (UVB; MacLaughlin, Anderson, & Holick, 1982). The main food sources of Vitamin D are milk fortified with Vitamin D, cereal and margarine. Fish, liver and egg yolks are also good albeit lesser sources of Vitamin D. Exposure to UVB light is the primary source of Vitamin D via photo-conversion of Vitamin D pre-cursors to pre-vitamin D3 in skin (Chen et al., 2007). An elderly person over the age of 70 produces less than half of the vitamin D of a young person with the same amount of sun exposure (MacLaughlin & Holick, 1985). The less efficient production of Vitamin D in combination with lower Vitamin D absorption in the intestines makes the elderly patient particularly susceptible to vitamin D deficiency (MacLaughlin & Holick, 1985).

Aguilar, Bhuket, Torres, Liu, and Wong (2015) found that from 2003 to 2012, 33% of the U.S. population is afflicted with metabolic syndrome, with significantly higher prevalence in women versus men (35.6% vs 30.3%, respectively, $p < .001$).-It was also found that metabolic syndrome prevalence increased-across all age groups. Among those aged 20 to 39 years, 18.3% were affected by metabolic syndrome while 46.7% of those aged 60 or older had metabolic syndrome. For participants aged 60 or older, more than 50% of women and Hispanics had metabolic syndrome.

Ford, Ajani, McGuire, and Liu (2005) reported an inverse relationship between serum concentrations of vitamin D and the prevalence of metabolic syndrome, which indicates that there is a relationship between Vitamin D deficiency and the prevalence of metabolic syndrome. Metabolic syndrome has also been found to be associated with Vitamin D deficiency among older individuals (Vitezova et al., 2015). However, the results of studies regarding the relationship between Vitamin D deficiency and metabolic syndrome among older adults are inconsistent, with some studies showing that Vitamin D deficiency and metabolic syndrome are related (Kim, 2015; Vitezova et al., 2015) and other research finding no such association (Veronese et al., 2014).

Other factors such as physical fitness activity and smoking behavior have been found to be associated with Vitamin D deficiency and the development of metabolic syndrome. A number of studies have documented associations between Vitamin D levels and physical fitness activities (Valtuena et al., 2013; Al-Othman et al., 2012; Klenk et al., 2015; Romme et al., 2012; and Grimaldi et al., 2013) while other studies have found correlations between Vitamin D levels, metabolic syndrome and smoking behavior (Lange, Sparrow, Vakonas & Litonjua, 2012; Slagter et al., 2013). However, no previous study has examined the links between physical fitness activity, smoking behavior, Vitamin D levels, and the risks for metabolic syndrome. Thus, this study assessed the relationships between Vitamin D deficiency, metabolic syndrome, physical fitness activity, and smoking behavior in elderly individuals.

This study aimed to enhance knowledge on the possible risk factors that affect the development of metabolic syndrome among older individuals. It is hoped that the results of the study could give healthcare practitioners a better understanding and insights into the relationships between Vitamin D deficiency, metabolic syndrome, physical fitness activity, and smoking behaviour. Additionally, the results of this study can also provide assistance to healthcare practitioners by eventually enabling primary and secondary prevention interventions.

This chapter discusses the background of the problem statement and purpose of the study. The research questions and hypotheses are presented and the theoretical framework of the study. The nature of the study, definitions, assumptions, scope and delimitations, limitations and significance are addressed.

Background

According to extensive review conducted by Palacios and Gonzalez (2014), Vitamin D deficiency is a significant health issue that afflicts many individuals from different age groups worldwide. It is estimated that over a billion people worldwide are Vitamin D deficient or insufficient (Lips, 2010). During the past 20 years, significant attention to the health impacts of Vitamin D deficiency has been drawn (Ginde, Liu, & Camargo, 2009; Lange et al., 2012; Valtuena et al., 2013). The recommended Vitamin D intake for adults aged from 50–70 years is 600–800 IU/day, which is the amount needed to maintain a serum level of 25OH (Falasca et al., 2014). However, a number of issues have posed significant hurdles in testing and treatment for Vitamin D deficiencies. In 2010, Isenor and Ensom noted that one of the problems in measuring Vitamin D deficiency through serum is the unreliability of instruments due to the lack of standardization. Another challenge was the insufficient evidence regarding the benefits of testing and early intervention with regard to Vitamin D deficiency which was the findings of the U.S. Preventive Services Task Force (USPSTF; LeBlanc, Chou, Zakher, Daeges, & Pappas, 2014).

Other studies have found that Vitamin D deficiency has interactions with other factors and that these interactions pose more serious health risks. Lange et al. (2012) and Slater et al. (2013) found that smoking practices of individuals are significantly related with both Vitamin D deficiency and metabolic syndrome. Valtuena et al. (2013) found that the level of physical fitness activity of individuals is related to deficiency in Vitamin D and risks for developing metabolic syndrome. Kostoglou-Athanassiou, Athanassiou, Gkountouvas, and Kaldrymides (2013) found that an increase in Vitamin D through supplements can lead to improvements in glycemic control among individuals with type 2 diabetes, thereby suggesting that there is a relationship between Vitamin D and metabolic syndrome. While Vitezova et al. (2015) found that the relationship between Vitamin D deficiency and metabolic syndrome among older adults is inconclusive because some researchers (Oosterwerff, Eekhoff, Heymans, Lips, & van Schoor (2011) found a significant relationship between the two variables (odds ratio (OR) = 1.54; 95% CI [1.23-1.94]), but results from a separate study (Reis, von Muhlen, Kritz-Silverstein, Wingard, & Barrett-Connor, 2007) found that Vitamin D concentration levels did not affect the risks for metabolic syndrome.

Due to the mixed findings of previous studies, the aim of this dissertation was to determine whether Vitamin D deficiency and metabolic syndrome are statistically significantly associated. Furthermore, this study examined how smoking and physical fitness activities are associated with Vitamin D deficiency and metabolic syndrome.

Problem Statement

In the United States, Vitamin D deficiency, a condition used to describe serum levels below 20 ng/mL (Forrest & Stuhldreher, 2011) afflicts approximately 40% of American adults. A separate study that grouped patients based on the severity of their Vitamin D deficiency namely, severe (less than 13 ng/mL), moderate (14 to 26 ng/mL) and mild (27 to 39 ng/mL), found that 53.5% of patients were severely Vitamin D deficient (Matthews, Ahmed, Wilson, Griggs, & Danner, 2012). The scale used by Matthews et al. (2012) differs from the Institute of Medicine's (IOM) cutoff of <20 ng/mL for vitamin D3 deficiency (IOM, 2011). Among elderly and older adults, deficiency in Vitamin D is associated with various health problems such as inflammatory diseases (Laird et al., 2014), hip and knee pains (Laslett et al., 2014), and osteoporosis (Zhen, Liu, Guan, Zhao, & Tang, 2015). Metabolic syndrome, which pertains to risk factors associated with heart problems and diabetes, has also been found to be associated with Vitamin D deficiency among older individuals (Vitezova et al., 2015). However, the results of studies regarding the relationship between Vitamin D deficiency and metabolic syndrome among older adults are inconsistent, with some studies showing that Vitamin D deficiency and metabolic syndrome are related (Kim, 2015; Vitezova et al., 2015) and other research finding no such association (Veronese et al., 2014).

In addition to mixed results of past studies, the relationship between Vitamin D deficiency and metabolic syndrome is complex, given that other factors also play a role in people's health. Past research has shown that smoking behaviors (Lange et al., 2012;

Slater et al., 2013) and physical fitness activity (Valtuena et al., 2013) are related to both Vitamin D deficiency and metabolic syndrome. The gap in the literature is that it is not known how smoking behaviors and physical fitness activity affect the relationship between Vitamin D deficiency and metabolic syndrome. This study addressed the gap in the literature by conducting a moderation analysis to determine how smoking behaviors and physical fitness activity moderate the relationship between Vitamin D deficiency and metabolic syndrome.

Purpose of the Study

The purpose of this quantitative, retrospective, cross-sectional study was to examine if smoking behavior and physical fitness activity moderated the relationship between Vitamin D deficiency and metabolic syndrome among older individuals. This study also aimed to provide empirical proof to support or contradict previous studies if Vitamin D deficiency is related to metabolic syndrome, physical fitness activity and smoking behavior in older individuals. To address the issues presented in this dissertation, this study's approach used the quantitative paradigm using post positivist perspective and statistical tools. The research problem was addressed through the use of retrospective data collected from the National Health and Nutrition Examination Survey (NHANES) 2005-2006 (United States Department of Health and Human Services, 2012), which can be publicly accessed online.

Research Questions and Hypotheses

Based on the problem and purpose, this study was guided by the following research questions:

RQ1: Is Vitamin D deficiency associated with metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older?

H_o1: Vitamin D deficiency is not statistically significantly associated with metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older.

H_a1: Vitamin D deficiency is statistically significantly associated with metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older.

RQ2: Does smoking behavior moderate the relationship between Vitamin D deficiency and metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older?

H_o2: Smoking behavior does not moderate the relationship between Vitamin D deficiency and metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older.

H_a2: Smoking behavior moderates the relationship between Vitamin D deficiency and metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older.

RQ3: Does physical fitness activity moderate the relationship between Vitamin D deficiency and metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older?

In response to the three research questions, the following hypotheses were formulated:

H_o3: Physical fitness activity does not moderate the relationship between Vitamin D deficiency and metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older.

H_a3: Physical fitness activity moderates the relationship between Vitamin D deficiency and metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older.

Theoretical Framework for the Study

According to Greene (2010), Bronfenbrenner (1994), who contributed notably to the development of ecological theory, applied this theory to the study of human behavior by defining processes of mutual interaction and shaping between the person and the surrounding environment. These processes of mutual accommodation were also framed in terms of life course development, occurring continually to shape the person's growth over time (Greene, 2010). The main assumption of the model when used in health context is that the environment and behavior of individuals, along with psychological and social factors, can influence their well-being (Sallis, Owen, & Fisher, 2015). Based on this theoretical assumption, the social ecological model is connected to the purpose of the study because of the recognition that metabolic syndrome is influenced by a combination of factors such as nutrition, physical fitness activity, and smoking behaviors.

For the purposes of this study, the social-ecological model by the CenCDC) ("The Social Ecological Model," n.d.) was adapted to examine the influence of smoking behavior and physical fitness activity on the relationship between vitamin D deficiency and metabolic syndrome. The social-ecological model is composed of multiple environments that influence the subject. These environments are represented by five bands. In the center lies the microsystem which is enveloped by four bands of influence namely, the mesosytem, exosystem, macrosystem and chronosystem. This study focused on the three bands that advance research on the development of metabolic syndrome on elderly people- the micro, meso and macrosystems.

In support of the social-ecological model, smoking behaviors are influenced by social variables such as peer pressures and environmental factors such as regulations and tax policy (Sallis et al., 2015). In addition, smoking behavior is subject to significant psychological influence. Similarly, physical fitness activities of individuals are affected by variables as varied as the presence of sidewalks, perceived crime, and the attractiveness of the environment; some of these factors and others, then, directly and indirectly influence individuals' risk for developing cardiovascular diseases and diabetes (Riley, Mark, Kristjansson, Sawada, & Reid, 2013; Sallis et al., 2015). As such, the social ecology model can also serve as a preventive model based on the recognition of personal, environmental, social, and psychological factors that can facilitate the development of diseases or health problems. The succeeding chapter discusses the social-ecological model in greater detail.

Nature of the Study

The purpose of this research was to determine if metabolic syndrome disease could be predicted by Vitamin D deficiency and to ascertain if varied levels of smoking behavior and physical fitness activity affect this association. Furthermore, the social ecology model can also serve as a preventive model based on the recognition of personal, environmental, social, and psychological factors that can facilitate the development of diseases or health problems. This study also endeavoured to provide empirical evidence to determine the relationships and approximate the risks in the form of odds ratios between Vitamin D deficiency, metabolic syndrome, smoking behaviour, and physical fitness activity.

To examine the correlations of these variables, the risks associated with smoking behavior, physical fitness activity and Vitamin D deficiency were tested on the dependent variable metabolic syndrome. This study utilized a quantitative, retrospective, cross-sectional design employing regression and correlational analysis. Correlation analysis was also conducted on the study variables to test if they have a significant relationship; however, correlational research may not lead to causal inferences, but variables can be measured and quantified to gain information about possible associations (Thompson, Diamond, McWilliam, Snyder, & Snyder, 2005).

The study used a secondary analyses of an existing data set from the 2005-2006 NHANES to measure metabolic syndrome, Vitamin D deficiency, physical fitness activity and smoking behaviors. The NHANES data can be publicly accessed online and did not require permission to be used in a research study. Data from NHANES contains a wide range of information about individuals' health practices and conditions, including the level of Vitamin D deficiency, smoking behavior such as the number of cigarettes consumed in a day, and physical fitness activity. Data from the NHANES also includes demographic data such as gender, age, and weight.

Definitions

Following are definitions of key terms used in this study:

Inflammatory diseases. This term refers to "a biological response to stimuli interpreted by the body to have a potentially harmful effect. While after injury or in certain conditions inflammation is a normal, healthy response, inflammatory disorders that result in the immune system attacking the body's own cells or tissues may cause abnormal inflammation, which results in chronic pain, redness, swelling, stiffness, and damage to normal tissues," (The Hospital for Special Surgery, n.d., para. 1).

Metabolic Syndrome. Diagnosis of metabolic syndrome requires presence of at least three of the following five criteria: high waist circumference, high triglycerides, low HDL cholesterol, high blood pressure, and high blood glucose levels (Grundy, Brewer, Cleeman, Smith, & Lenfant, 2004).

Osteoporosis. This refers to a bone disease characterized by loss of bone, lower bone production, or a combination of these factors (National Osteoporosis Foundation, n.d.).

Physical fitness activity. Bodily movement created through muscular contraction, which results in higher levels of energy expenditure compared with baseline activity (The Centers for Disease Control and Prevention, n.d.).

Smoking behaviors. This is defined as the number of tobacco cigarettes smoked per day (CDC, 2008c).

Vitamin D Deficiency. This is a condition indicated by serum levels below 20 ng/mL (Gallagher & Sai, 2010).

Assumptions

Since the study used a secondary analysis from an existing external data source, it is assumed that the data collected from this database is valid. It is assumed that all data downloaded from the NHANES database is accurate. It is also assumed that the respondents answered questions truthfully and to the best of their knowledge. Next, it is also assumed that the data was correctly encoded before it was uploaded into the website for public use. Finally, it is assumed that the retrospective data collected and organized for the purposes of the study continues as a truthful representation of the current population.

Scope and Delimitations

This study focused on the effects of metabolic syndrome in elderly individuals because the growth of elderly populations has been progressively increasing worldwide and the prevalence of metabolic syndrome increases with age (Zambon et al., 2009). The study also focused on the effect of certain lifestyle behaviors such as smoking and physical fitness activities that could mitigate or progress the development of metabolic syndrome.

This study employed the social-ecological model to examine the relationships between Vitamin D deficiency, metabolic syndrome, smoking behavior and physical fitness activities. In line with this theoretical framework, the study excluded factors endemic to the respondents' person. These factors are genetics, ethnicity, personal abilities and gender.

The study utilized secondary analyses of an existing, retrospective data downloaded from the NHANES database for 2005-2006 (United States Department of Health and Human Services, 2012) to measure the variables -metabolic syndrome, Vitamin D deficiency, physical fitness activity and smoking behavior. The NHANES data can be accessed online and did not require permission to be used in a research study.

Limitations

To manage time and funding efficiently, the researcher utilized data from a publicly available external database. Although the database originated from a credible source, the data used in the study may not reflect current trends and practices since it has been ten years since the data was collected. This study focused on the elderly population and may also have been limited by the number of elderly respondents who participated in the study. However, this concern may have been balanced by the large sample size obtained by the NHANES. Given that a person's health is attributed to multiple components, this study excluded those other factors and focused on the analysis of the relationships between Vitamin D deficiency, metabolic syndrome, smoking behavior and physical fitness activities.

Significance

Vitamin D deficiency is a condition that has been suggested to lead to health problems such as metabolic syndrome that affects all age groups worldwide, underscoring the importance of further examining how poor nutrition affects the well-being of individuals (Palacios & Gonzalez, 2014). While there have been prior studies that examined the relationship between Vitamin D deficiency and metabolic syndrome, the findings from these studies are inconsistent (Vitezova et al., 2015). A study conducted by Looker (et al., 2015) found that the prevalence of Vitamin D deficiency was lowest among children aged from 1-8 years. Risks for Vitamin D deficiency for males and females were found to peak between the ages of 19 to 30 and 51 to 70, respectively. Nevertheless, the results indicate that the risks for Vitamin D deficiency for the elderly were 24% for males and 27% for females. Another study by Zhen (et al., 2015) concluded that elderly people are at a higher risk of having Vitamin D deficiency. Vitamin D deficiency is particularly critical among elderly individuals because of its association with various negative health outcomes, including metabolic syndrome (Zhen et al., 2015).

This study has practical significance because it enhanced the understanding of possible risk factors that may play a role in the development of metabolic syndrome among older individuals. The results of the study may give practitioners better understanding and insights into the different risk factors to metabolic syndrome among older individuals, which can eventually enable primary and secondary prevention interventions. This study is also significant because it addressed the gaps in the literature in terms of the following issues: (a) mixed findings about the relationship between Vitamin D deficiency and metabolic syndrome among older adults (b) lack of information about the role of physical fitness activity and smoking behaviors in the relationship between Vitamin D deficiency and metabolic syndrome among older adults.

Summary

In light of the recent progressive growth of the elderly population worldwide, this study delved into the factors that predict and affect the development of metabolic syndrome in the elderly. Utilizing Bronfenbrenner's (1994) social ecological model as the basis for the hypotheses that guided this study, a retrospective quantitative research design was used to analyze the variables that were the subjects of this study. Statistical analyses used data from the 2005-2006 NHANES to measure the dependent (metabolic syndrome), independent (Vitamin D deficiency, physical fitness activity and smoking behaviors). The study hoped to contribute valuable insights in the diagnosis, management and treatment of metabolic disease in elderly individuals.

The next chapter is dedicated to a review of the literature on metabolic syndrome, Vitamin D deficiency, smoking behavior and physical fitness activities. The chapter also studies the origin, development of current understanding of the causes of metabolic syndrome and Vitamin D deficiency. The chapter also elaborates on the current state of empirical evidence regarding the relationship between Vitamin D deficiency and metabolic syndrome.

Chapter 2: Literature Review

The problem of Vitamin D deficiency is becoming an increasingly urgent public health concern. Even with some disagreement about the correct definition, health professionals agree that the prevalence of Vitamin D deficiency is increasing worldwide (Binkley, Ramamurthy & Krueger, 2012). In the United States, Vitamin D deficiency afflicts approximately 41.6% of American adults (Forrest & Stuhldreher, 2011; Matthews et al., 2012).

Some disagreement exists among health professionals about how to define and Vitamin D deficiency. Binkley (et al., 2012) performed a systematic review of the literature and found consensus on the classification of "deficient" Vitamin D status (a 25[OH]D serum level below approximately 10 ng/ml) and "insufficient" Vitamin D status (a serum level of below 30 ng/ml). They note, however, that the cutpoint values and the verbiage used to describe low vitamin D status are used inconsistently. Researchers and health providers tend to use the terms deficiency, insufficiency, inadequacy and hypovitaminosis interchangeably to describe low vitamin D status. The current study investigated whether Vitamin D deficiency predicts metabolic syndrome in older adults. Therefore, a conclusive definition of Vitamin D deficiency was required.

Because of the role of Vitamin D in calcium absorption, Vitamin D deficiency has long been associated with disorders of the bone, including rickets in children and osteoporosis in adults. However, research has uncovered additional adverse consequences to low Vitamin D status. Muscle function is related to levels of Vitamin D in the body, and those with low Vitamin D status experience muscle pain and weakness and are more susceptible to falls (Binkley et al., 2012). In addition, it is associated with many health problems in the elderly, including inflammatory diseases (Laird et al., 2014), hip and knee pains (Laslett et al., 2014), and osteoporosis (Zhen, Liu, Guan, Zhao, & Tang, 2015). Since Vitamin D has anti-carcinogenic properties, such as anti-proliferative and pro-differentiating effects on cells, Vitamin D deficiency may contribute to the development of some cancers (Binkley et al., 2012). Finally, Vitamin D deficiency has been associated with metabolic syndrome (MetS), which is an underlying factor in some of the leading causes of death in the United States, including diabetes and cardiovascular disease (Forrest & Stuhldreher, 2011; Binkley et al., 2012). This is because low Vitamin D status may contribute to the development of some of the symptoms of MetS (Awad, Alappat & Valerio, 2012).

MetS is a collection of symptoms that include pre-diabetes, abdominal obesity, elevated blood pressure and dyslipidemia (lipid levels that are too high or too low) (Prasad, Ryan, Celzo & Stapleton, 2012). The insulin resistance and systemic inflammation associated with MetS are underlying factors of cardiovascular disease and diabetes (Grundy, 2012). Therefore, MetS can lead to increased risk for cardiovascular disease and diabetes (Prasad et al., 2012; Vitezova et al., 2015).

Research on the relationship between Vitamin D deficiency and metabolic syndrome has yielded inconsistent results. Some studies find a relationship between Vitamin D deficiency and metabolic syndrome. For instance, Kim (2015) and Vitezova et al. (2015) found that Vitamin D levels were significantly lower in people with MetS than in those without it. Veronese et al. (2014), however, found no such association. This is why there have been major reviews of the issue. Theodoratou, Tzoulaki, Zgaga and Ioannidis (2014) conducted an umbrella review of the evidence across systematic reviews and meta-analyses of observational studies of plasma 25-hydroxyvitamin D or 1,25-dihydroxyvitamin D concentrations and randomised controlled trials of vitamin D supplementation in an effort to evaluate the breadth, validity, and presence of biases of the associations of vitamin D with diverse outcomes. They found that suggestive evidence exists for a correlation between high vitamin D concentrations and low risk of metabolic syndrome. Because the relationship between vitamin D concentrations and MetS was only discovered in observational studies, however, the causal relationship between these variables could not be asserted by Theodoratou (et al., 2014). Since Vitamin D deficiency is so prevalent, these studies underscore a need to further understand its causes and for standardization of the definitions and diagnostic criteria of vitamin D deficiency.

Research has begun to explore some of the relationships between Vitamin D deficiency and smoking. Vitamin D deficiency is more frequently experienced by smokers than non-smokers (Kim & Kim, 2016; Streinu-Cercel et al., 2016; Tønnesen, Hovind, Jensen & Schwarz, 2016). Also, cigarette smoke inhibits the immunomodulatory and anti-inflammatory effects of Vitamin D, reducing organ function in Vitamin-D deficient smokers who are already sick (Sparrow et al., 2012; Radcliffe et al., 2016; Streinu-Cercel et al., 2016) and increasing the likelihood of cancer and other diseases in Vitamin D deficient smokers (Anaya, Ramirez-Santana, Alzate, Molano-Gonzalez & Rojas-Villarraga, 2016).

A relationship between Vitamin D deficiency and physical activity has also been documented. Fitness levels are positively associated with serum 25(OH)D concentrations in the body (Al-Othman et al., 2012; Klenk et al., 2015; Valtuena et al., 2013).

Furthermore, Vitamin D deficiency leads to loss of bone density and muscle strength, which adversely affects levels of physical activity (Grimaldi et al., 2013; Romme et al., 2013).

The gap in the literature is that it is not clear how smoking behaviors and levels of physical activity might moderate the interactions between Vitamin D deficiency and metabolic syndrome. Smoking and physical inactivity have been shown to have an impact on Vitamin D deficiency. Vitamin D deficiency may be associated with risk for development of metabolic syndrome. However, the modifying effect of smoking and inactivity on Vitamin D deficiency and the risk for metabolic syndrome has not been addressed.

The purpose of this study was to examine if smoking behaviors and physical fitness activity moderate the relationship between Vitamin D deficiency and metabolic syndrome. This study also aimed to provide empirical proof to support or contradict previous studies if Vitamin D deficiency is related to metabolic syndrome, physical fitness activity and smoking behavior in older individuals. To address this gap in the knowledge, the approach used a quantitative retrospective cross-sectional design using regression and moderation analysis, which are post positivist perspective and statistical tools. While correlational research cannot explain causes, it allows for assessment of associations (Thompson, Diamond, McWilliam, Snyder, & Snyder, 2005). The quantitative study answered two questions: (a) whether Vitamin D deficiency is associated with MetS in the elderly and (b) whether the relationship between Vitamin D and metabolic syndrome differs by smoking status and/or levels or physical activity. The research problem was addressed by using retrospective data collected from the National

Health and Nutrition Examination Survey (NHANES, n.d.), which is publicly accessible online.

In this literature review, the researcher expanded upon the background to the research question described earlier in this chapter. The first section explains the search strategy used in the literature review. The second section describes the theoretical framework, which is the social ecological model. The third section examines relationships among seemingly disparate variables in health outcomes. The fourth section discusses Vitamin D deficiency, including a practical definition, a discussion of the prevalence of Vitamin D deficiency, theories about the causes, its effect on health status of individuals and corrective practices. The fifth section deals with metabolic syndrome, including the prevalence of this medical condition and its relationship with Vitamin D deficiency. The sixth and seventh sections explore the documented associations between Vitamin D deficiency, metabolic syndrome and smoking and physical activity. The chapter ends with a summary and conclusions of the literature review.

Literature Search Strategy

To identify sources for the literature review, the following online databases were used: Educational Resource Information Center (ERIC), PubMed and Google Scholar. The key search terms and combinations of terms that were input into the online databases included the following: *ecological models health promotion, (ecological model) and (smoking), (ecological model) and (physical activity OR exercise), vitamin D deficiency, vitamin D insufficiency, vitamin D inadequacy, vitamin D hypovitaminosis, metabolic syndrome, (metabolic syndrome) and (vitamin D deficiency), (vitamin D deficiency) and* *(smoking), (vitamin D deficiency) and (physical activity).* Limits included articles written in English, peer-reviewed sources, full text available, published since 2012. All key terms yielded studies that were relevant to the purpose of the study and the research question. The search resulted in a total of 106 sources for inclusion in this chapter. Most of the literature reviewed (77%) was published between 2012 and 2016. Older articles were also used to explain the social ecological model in the theoretical framework and to provide definitions of key terms such as Vitamin D deficiency and metabolic syndrome.

Theoretical Framework

The theoretical framework for this study was based on the social ecological model. In the context of healthcare, this model describes the interaction between environment and behaviors of individuals, along with psychological and social factors, in predicting health outcomes (Sallis, Owen, & Fisher, 2008). This theoretical assumption supports the hypothesis that metabolic syndrome is influenced by a combination of factors such as nutrition, physical fitness activity, and smoking behaviors. The social-ecological model is composed of multiple environments that influence the subject. Five bands represent these environments. In the center lay the microsystem, which is enveloped by four bands of influence namely, the mesosytem, exosystem, macrosystem and chronosystem. This study focused on the three bands that advance research on the development of metabolic syndrome on elderly people- the micro, meso and macrosystems. Although all of the variables measured in the present study were individual level factors, they can be reasonably associated with influences that occur beyond this level. For example, smoking and physical activity levels may be associated with normative influences of one's social network, and Vitamin D may be associated with behavioral and environmental factors (Sallis et al., 2008).

Historical and Conceptual Background of the Social Ecology Model

The social ecological model is derived from ecology and emphasizes the complex interactions between people, groups and their environments (Bronfenbrenner, 1994). Ecological models are based on concepts from behavioral and social sciences. Sallis (et al., 2008) stated that categories and hierarchies of behavior have been explained in many ways. Some conceptual models explain behavior, while others offer recommendations for behavior interventions. They noted that many of the earlier models refer to behavior in the broad sense. But since the research of McLeroy in 1988, models have been developed that relate to health behaviors and health promotion.

McLeroy, Bibeau, Steckler and Glanz (1988) suggested an ecological model for understanding and promoting health behaviors. Individual and social environmental factors should be addressed in health interventions. Interventions should be directed at changing interpersonal, organizational, community, and public policy; changes in the social environment will promote changes in individuals. Rayner and Lang (2012) explored the interdependence of humans and ecosystems. Humans can no longer ignore the health of ecosystems. Also, they cannot continue believing that individual needs, behaviors and health patterns can be disconnected from the health of other people and of the Earth's environment. Simons-Morton (2013) said that health is best defined within an ecological context, and health promotion initiatives should promote supportive environments and healthful behavior. Thus, effective health behavior interventions are typically multilevel, focusing not only on the individuals exhibiting the target behavior, but also on the environmental conditions that contribute to health and health behavior.

Sallis (et al., 2008) stated that ecological models differ from other behavioral models that focus on individual characteristics and social influences, but ignore broader community, organizational and policy influences on health behaviors. Ecological models comprehensively incorporate psychological, social and organizational levels of influence on health behaviors, along with broader environmental and community factors. Furthermore, healthy behaviors are maximized when individuals are motivated to make healthy choices because environments and policies support healthy choices.

Applications of the Social Ecological Model in Health Research

Previous researchers have similarly used the social ecological model to investigate multiple risk factors for health behaviors and conditions (Baral, Logie, Grosso, Wirtz, & Beyrer, 2013; Gruenewald, Remer, & LaScala, 2014; Mudd-Martin et al., 2014). For example, Gruenwald (et al., 2014) examined the relationships between psychosocial and environmental characteristics and patterns of alcohol consumption behavior, and found that individuals who were more impulsive and risk-taking were more likely to consume alcohol more frequently and in greater quantities. Also, greater on-site availability of alcoholic beverages, indicated by higher environmental densities of such establishments, was associated with more frequent drinking (Gruenewald et al., 2014). Similarly using multiple ecological levels to examine health risk factors, Baral et al. (2013) proposed a model for risk assessment for contracting HIV that included individual behaviors (i.e., unsafe sexual practices, sharing needles) as well as social network characteristics and community care and prevention resources. Finally, Mudd-Martin (et al., 2014) used the social ecological model to identify risk factors for cardiovascular disease among residents of six Appalachian counties that included individual behavior, interpersonal normative contexts, and environmental features that promoted or prevented health-promoting behavior (i.e., physical exercise). As in the present study, these studies included examination of multiple factors that were associated with health-related behaviors and risk factors for health conditions.

Logistical Challenges of Research and Interventions

Research based on the social-ecological framework is arduous, but the strength of the social-ecological framework as it applies to health behavior is that it broadens the options for effective interventions because it focuses on multiple levels of influence. The tasks of creating and amassing measures of variables at multiple levels, working collaboratively with multidisciplinary teams, developing interventions at multiple levels and analyzing complex statistics places sizeable expectations on researchers and public health policy makers (Sallis et al., 2008). Furthermore, while there is an understanding about how the social-ecological model can improve public health practice, it is difficult to determine how well these recommendations are put into effect by health promotion programs (Golden & Earp, 2012). Golden and Earp (2012) found that health intervention programs that have been implemented over the last 20 years have focused more on individual and interpersonal characteristics instead of institutional, community or policy variables.

This study examined the moderating effects of smoking behaviors and physical activity levels on Vitamin D deficiency and metabolic syndrome. The social-ecological model provides a framework for investigating the multi-level influence of these behaviors on Vitamin D deficiency and metabolic syndrome. As in previous research that used the social ecological model to examine multiple factors that influenced risk for health conditions, it was anticipated that this model would be useful in framing examination of Vitamin D status, physical activity, smoking behavior, and metabolic syndrome in older adults in the present study.

Review of the Literature

Vitamin D Deficiency

Vitamin D deficiency is a condition that affects people of all ages and health statuses all over the world (Autier, Boniol, Pizot & Mullie, 2014). As diagnostic procedures become more automated and standardized, the prevalence of Vitamin D deficiency is becoming well-documented (Autier et al, 2014). Of increasing concern is that Vitamin D deficiency has been identified as a risk factor for several significant health problems, including bone and muscle disorders (Binkley et al., 2012), inflammatory diseases (Laird et al., 2014) and some kinds of cancer (Binkley et al., 2012). Vitamin D deficiency has also been linked with risk factors for metabolic syndrome and underlying causes of cardiovascular disease and diabetes, such as high blood pressure, high triglycerides, low HDL cholesterol and high fasting blood sugar (Forrest & Stuhldreher, 2011; Binkley et al., 2012; Fung et al., 2012).

Vitamin D is a fat-soluble vitamin that aids in the absorption of calcium and phosphates. It exists in two forms, Vitamin D3 and Vitamin D2 (Chowdhury et al., 2014). It enters the system either through the skin or by ingestion of food. When skin is exposed to ultraviolet radiation from the sun, a chemical in the skin called 7-dehydrocholesterol is converted into Vitamin D3 (Binkley et al., 2012). Current human indoor lifestyles and sun-avoiding behaviors such as sunscreen use reduce the amount of Vitamin D in the body (Hirani et al., 2013). Food may also be a source of either Vitamin D3 or Vitamin D2, but few foods contain enough to significantly affect Vitamin D levels in the body. It is therefore understandable how low Vitamin D status is so prevalent. Since Vitamin D affects the absorption of calcium, the effect of Vitamin D deficiency on the bones has long been understood. In recent years, research has uncovered links between Vitamin D deficiency and other health problems such as muscle weakness (Binkley et al., 2012), cancer (Garland et al., 2006), cardiovascular disease and diabetes (Binkley et al., 2012; Ginde (et al., 2009; Khan, Kunutsor, Franco, & Chowdhury, 2013).

Definition of Vitamin D deficiency. Before it can become active in the body, Vitamin D must be metabolized by the liver and kidneys. First, Vitamin D is converted to 25 hydroxyvitamin D (25(OH)D) serum in the liver. Then the kidneys convert it into the hormone 1, 25-dihydroxyvitamin D (1, 25(OH)2D) (Binkley et al., 2012). The amount of 25(OH)D serum in the body is the accepted measure of vitamin D status. A result of at least 40 ng/mL of 25(OH)D is considered a normal level. Vitamin D deficiency ranges from mild (27 to 39 ng/mL) to moderate (14 to 26 ng/mL) to severe (less than 13 ng/mL; Matthews et al., 2012).

The accuracy of measurement of Vitamin D levels has been problematic. One of the problems has been the unreliability of instruments due to lack of standardization, which has resulted in significant variability in results between laboratories (Isenor & Ensom, 2010). This has made it difficult to accurately diagnose and treat Vitamin D deficiency (Binkley, 2006). However, recent recognition of the significant adverse health effects of Vitamin D deficiency have led to automated systems and improved calibration of equipment (Binkley, 2006).

Prevalence of Vitamin D deficiency. Advances in the technology for the measurement of 25(OH)D serum levels in the body have allowed researchers to accurately gauge the prevalence of Vitamin D deficiency. Since even those with a serum level of 30 ng/mL are considered deficient, it is not surprising that diagnoses of Vitamin D deficiency are so common all over the world (Binkley et al., 2012). Around the world, large portions of the population are reportedly Vitamin D deficient. This is true even in countries at a low latitude, where it was assumed that UV radiation levels were high enough to prevent it, and in industrialized countries where Vitamin D supplements are widely available. Some studies find that girls and women from the Middle East are at the highest risk (Palacios & Gonzalez, 2014). In Australia, it afflicts nearly one-third of the adult population (Daly et al., 2012). In the United States, the National Health and Nutrition Examination Survey (NHANES) found a decrease in Vitamin D levels between the 1988 – 1994 data collection period and the 2000 – 2004 data collection period (Binkley, et al., 2012). Nearly 70% of the total U.S. population has some level of Vitamin D deficiency (Forrest & Stuhldreher, 2011; Matthews et al., 2012). Similarly, G and Gupta (2014) found a prevalence of at least 70% of India's population. In a review of studies of Vitamin D levels in regions around the world, Mithal et al. (2009) found that the prevalence of Vitamin D deficiency was highest in the Middle East and South Asia. Elderly people are at a higher risk of having deficiency in Vitamin D, and this is particularly concerning because of its association with serious health problems (Zhen et al., 2015). Wahl et al. (2012) found that large gaps exist worldwide in data about children and adolescents, and some gaps exist in information about adults. Since Vitamin D is so important for good health and growth and development of children, further research is warranted to define vitamin D deficiency prevalence around the world.

Causes of Vitamin D deficiency. One important cause of Vitamin D deficiency is lack of sun exposure. Specifically, UV rays are needed to convert the skin chemical 7-dehydrocholesterol into Vitamin D3. In the modern age, humans have an indoor lifestyle. Furthermore, they engage in sun avoidance behaviors, such as applying sunscreen and wearing protective clothing, which block UV rays (Binkley et al., 2012). In a cross-sectional study, Hirani et al. (2013) also found that Vitamin D levels are lower in the winter, which suggests an association between lower levels of sun exposure and Vitamin D deficiency. Although sun exposure has been associated with Vitamin D levels, individual differences appear to affect serum levels as well. Lighter-skinned individuals have been found to produce higher levels of Vitamin D with the same amount of sun exposure compared with darker-skinned individuals (Clemens, Adams, Henderson, & Holick, 1982; Matsuoka, Wortsman, Haddad, Kolm, & Hollis, 1991). Other individual differences appear to affect Vitamin D production resulting from sun exposure. For example, in a sample of 93 adults living in Hawaii, all of whom routinely obtained high levels of sun exposure, 51% were found to have low Vitamin D levels (less than 30 ng/ml; Binkley et al., 2007). Binkley et al. (2007) suggested that this indicated variability in individual responsiveness to sun exposure with regard to Vitamin D levels. This was a cross-sectional study that did not include control variables related to dietary or other relevant behavioral influences on Vitamin D levels, however, which prevented direct examination of explanatory factors for individual differences. Binkley et al. (2012)

suggested that additional research would be helpful in exploring the underlying reasons for individual variability in Vitamin D levels in spite of ample sun exposure. A challenge encountered in reviewing the literature related to sun exposure and Vitamin D levels was the lack of prospective studies. Although researchers (i.e., Binkley et al., 2012) have posited with confidence that sun exposure affects Vitamin D levels, the research obtained for this chapter could only support correlations between sun exposure and Vitamin D levels.

Nutrition also affects levels of Vitamin D. Vitamin D occurs naturally in some foods, such as fatty fish, like tuna, mackerel, and salmon, beef liver, cheese and egg yolks. Other foods are fortified with Vitamin D, such as some dairy products, orange juice, soymilk, and cereals (Chowdhury et al., 2014). Because meat and dairy contain the highest levels of Vitamin D compared with other types of foods, individuals who consume a vegan or vegetarian diet are likely to obtain lower levels of Vitamin D through diet compared with persons who eat meat and dairy (G & Gupta, 2014). Because Vitamin D degrades at temperatures exceeding 200 degrees Fahrenheit, cooking practices may impact its levels in food (Natri et al., 2006). In particular, frying foods results in degradation of Vitamin D and also causes it to leach out of the food and into the frying oils (Lu et al., 2007). Finally, poverty may also reduce some individuals' access to foods rich in Vitamin D, as meat and dairy are often more expensive than processed foods (G & Gupta, 2014). Although dietary sources do contribute to Vitamin D levels, consumption of these foods alone is not enough to significantly raise levels of Vitamin D in the system (Binkley et al., 2012).

Aging is associated with vitamin D deficiency. In a sample of 11,247 Australian adults, Daly et al. (2012) found that the prevalence of Vitamin D deficiency increased significantly with age, but only for female participants. Specifically, female participants over the age of 75 had a Vitamin D deficiency prevalence of 12.5%, compared with a rate of 3.9% for women between 25 and 34 years (Daly et al., 2012). Similarly, in a sample of 10,038 Chinese adults between the ages of 40 and 75, Zhou et al. (2015) found that older age was a significant risk factor for Vitamin D deficiency. Among participants who were 70-75 years of age, the prevalence of Vitamin D deficiency was 79.6%, compared with 74.2% among participants aged 40-49 (Zhou et al., 2015). Daly et al. (2012) found that older age was a consistent risk factor for Vitamin D deficiency in a review of studies from around the globe. Although these cross-sectional studies could not provide evidence that aging causes decreased Vitamin D levels, the higher prevalence of Vitamin D deficiency in older adults might be partially related to decreases in the skin's capacity to produce Vitamin D3 as one ages (MacLaughlin & Hollick, 1985). Confinement to care facilities may also create additional risk for Vitamin D deficiency in elderly persons (Lips, 2001). Studies have shown a link between physical activity levels, elevated body weight and Vitamin D status (Hirani et al., 2013; Turer, Lin & Flores, 2013). Lifestyle changes induced by ill health, including decreased activity levels and weight gain, lead to vitamin D deficiencies in elderly adults (Autier, Boniol, Pizot & Mullie, 2014).

Effects of Vitamin D deficiency. Vitamin D deficiency has long been associated with loss of bone density and bone fragility. Vitamin D aids in absorption of calcium and phosphates. Therefore, Vitamin D deficiency can lead to bone disorders such as rickets, osteoporosis and increased risk for fractures (Theodoratou et al., 2014; Binkley et al., 2012).

Recent research has revealed other serious adverse health effects associated with Vitamin D deficiency. Some research links Vitamin D deficiency and depression (Anglin, Samaan, Walter & McDonald, 2013). Muscle pain and weakness is a common symptom, along with an increased risk of falls (Binkley et al., 2012). For the elderly, Vitamin D deficiency leads to health problems like inflammatory diseases (Laird et al., 2014), hip and knee pains (Laslett et al., 2014), and osteoporosis (Zhen et al., 2015). Since Vitamin D has an anti-inflammatory effect on cells and inhibits cell reproduction, Vitamin D deficiency may contribute to the development of some cancers, such as colon, prostate, breast and ovarian cancer (Binkley et al., 2015; Garland et al., 2006). In addition, Vitamin D deficiency has been linked to metabolic syndrome, which is trigger for some of the leading causes of death in the United States, including diabetes, cardiovascular disease (Forrest & Stuhldreher, 2011; Binkley et al., 2012; Fung et al., 2012).

Because of the serious adverse effects associated with Vitamin D deficiency, it has been linked with increased mortality rates. The high risk of cardiovascular disease, cancer and other health problems increased mortality rates in people with Vitamin D deficiency (Chowdhury et al., 2014; Zitterman et al., 2012). Both studies suggest the need for Vitamin D supplementation to correct the deficiency. The optimal dose of vitamin D supplementation needs to be investigated (Autier & Gandini, 2007). Baggerly et al. (2015) suggested that the best way to get additional vitamin D is through sun exposure. Vitamin D supplementation is also available, either by capsules, chewable tablets, liquids or drops. Over-the-counter multivitamins usually contain about 400 IU of vitamin D. Many, however contain as much as 800 to 1000 IU.

Correction of Vitamin D deficiency. Effective methods of correcting Vitamin D deficiency include increased sunlight exposure and supplementation. Increased sunlight exposure raises levels of Vitamin D in otherwise healthy adults and children, and this method is even more effective if the individuals are physically active (Al-Othman et al. 2012). Taking Vitamin D supplements also improves Vitamin D status. In the elderly, vitamin D supplements have been found to correct Vitamin D status and improve overall health (Autier et al., 2014). While supplements do improve Vitamin D levels, they do not seem to affect overall physical activity levels (Close et al., 2013). Encouraged by the positive results of supplementation, Holick et al. (2012) stated that the benefits outweigh any potential risks. According to Falasca et al. (2014), the recommended Vitamin D intake for adults over 50 years old (age 50-70) is 600-800 IU/day, which is the amount needed to maintain a serum level of 25OH. However, because of inconsistencies in diagnostic procedures and disagreements about optimal levels of Vitamin D, there is lack of consensus about optimal dosage of Vitamin D supplementation and how long the supplements should be taken (Zittermann et al., 2012).

Metabolic Syndrome

Metabolic Syndrome (MetS) is an array of risk factors underlying the development of cardiovascular disease and diabetes. Since it was first determined that these symptoms tend to cluster together (Reaven, 1988), research has sought to identify the components of MetS and define its clinical outcomes. An emerging area of study involves the relationship of Vitamin D status to the development ofMetS. Vitamin D status is increasingly linked to the development of the risk factors associated with MetS (Kim, 2015; Vitezova et al., 2015). Further research is warranted to determine if the correlation between Vitamin D levels and MetS implies causation, and whether correction of Vitamin D status reverses symptoms ofMetS.

Definition and prevalence. Reaven (1988) first noted that several risk factors for cardiovascular disease, including dyslipidemia, hypertension and hyperglycemia, tend to occur together. He referred to this cluster of symptoms as Syndrome X, and it later came to be known as insulin resistance or metabolic syndrome (Grundy et al., 2005). Metabolic syndrome is also associated with increased risk for developing type 2 diabetes mellitus (Grundy et al., 2005). Rather than a discrete disease with a single cause, metabolic syndrome should be seen as a syndrome, a grouping of risk factors for cardiovascular disease and diabetes. It likely has more than one cause (Grundy et al., 2005).

Metabolic Syndrome is characterized by several components including and can include abdominal obesity (increased waist circumference), atherogenic dyslipidemia (raised triglycerides; elevated LDL, low HDL cholesterol and other lipoprotein abnormalities such as small LDL and HDL particles), hypertension, glucose intolerance (prediabetes-level hyperglycemia), a proinflammatory state (elevations of C-reactive proteins), and a prothrombotic state (an abnormality of blood coagulation that increases the risk of blood clots) (Grundy et al., 2005). The Third Report of the National Cholesterol Education Program Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (ATP III) defines MetS as the presence of three or more of these abnormalities (Ford, Giles, & Dietz, 2002). Furthermore, risk factors associated with MetS have been categorized according to their significance in causing cardiovascular disease and diabetes. Symptoms classified at *underlying* include obesity, physical inactivity and a high-fat diet. Those classified as *major* risk factors are cigarette smoking, hypertension, elevated LDL cholesterol, low HDL cholesterol, family history of premature coronary heart disease and aging. Finally, the classification of *emerging* risk factors (also defined as *metabolic* risk factors) is attributed to elevated triglycerides, small LDL particles, insulin resistance, glucose intolerance, proinflammatory state, and prothrombotic state (Grundy et al., 2005).

The recognition of the significance of MetS as a predictor of cardiovascular disease and diabetes has led to increasing urgency to investigate the prevalence of this syndrome. Ford et al. (2002) performed an analysis of data from the ATP III (1988 – 1994) in order to determine the prevalence of MetSin the United States. In the aggregate, 22% of US adults were found to have metabolic syndrome. Using the 2000 census data, this translates into approximately 47 million Americans. Disaggregated data revealed large variances in prevalence among age groups, gender and race. Only 6.7% of participants aged 20 through 29 years hadMetS. Prevalence increased to 43.5% for those aged 60 to 69 years and to 42% for those aged at least 70 years. The highest prevalence was found among Mexican Americans, for whom 31.9% had MetS, and Mexican American women were 26% more likely to have it. Among African Americans, women were 57% more likely than men to have MetS

The high prevalence of MetS has serious implications. Since the root causes of MetS for many people are poor dietary habits and low activity levels that lead to obesity, further research is warranted to identify the individual, social and environmental factors that impact these behaviors. Furthermore, research needs to identify moderating factors that affect people's ability to get proper nutrition from their food, including Vitamin D deficiency.

Association of Vitamin D deficiency and metabolic syndrome. Researchers have come to conflicting conclusions about the relationship between Vitamin D deficiency and metabolic syndrome. Some studies find a relationship between Vitamin D deficiency and metabolic syndrome. For instance, Kim (2015) and Vitezova et al. (2015) found that Vitamin D levels were significantly lower in people with MetS than in those without it. Veronese et al. (2014), however, found no such association. To investigate the relationship between Vitamin D deficiency and metabolic syndrome, researchers have used quantitative research methods, such as cohort studies, interventional studies and cross-sectional surveys.

Population-based cohort studies. Cohort studies that have analyzed the relationship between Vitamin D deficiency and MetS have been performed with populations of people from all over the world. For example, Vitezova et al. (2015), Brenner et al. (2011) and Gagnon et al. (2012) all looked at the effect of Vitamin D levels in the Netherlands, Canada and Australia, respectively. All three of these studies identified an inverse relationship between Vitamin D levels and the development of metabolic syndrome. Furthermore, the researchers all used regression analyses to examine the relationship between Vitamin D status and the different components of MetS. Brenner et al. (2011) found a positive relationship between levels of Vitamin D and the number of MetScomponents. Vitezova et al. (2015) and Gagnon et al. (2012) determined that the association was mainly driven by abdominal obesity, reduced HDL and elevated glucose levels; elevated blood pressure was not associated with vitamin D levels. The similarity of all of these studies is that the researchers used data gathered from national surveys of randomly-selected participants meant to represent larger populations. Whereas Brenner et al. (2011) gathered data on approximately 1,800 individuals, ranging in age from 6 to 79 years, Vitezova et al. (2015) and Gagnon et al. (2012) focused on elderly participants (sample size 3,240 and 4,164, respectively; mean age 71.2 years and 50 years, respectively). The results of the two latter studies speak to the purpose of this study.

Other cohort studies did not find a relationship between Vitamin D deficiency and metabolic syndrome. Veronese et al. (2014) studied 2,227 participants over the age of 65 from northern Italy for 4.4 years. They found no link between Vitamin D deficiency and diabetes, which implies that Vitamin D deficiency did not contribute to the risk factors for diabetes associated with MetS. However, this study was performed in northern Italy, where the dietary, activity and smoking habits are very different from those in the United States. Not only did this study not address these moderating factors, but also it is questionable whether these results could be generalized to groups outside of Italy.

The limitation of these studies, as with any population-based cohort study, is the problem with external validity. The inclusion criteria for participation in the study may not be random. Because the studies examine such a specific, non-randomized group, it is difficult to generalize the results beyond the study population.

Interventional studies. These studies investigated the effect of exposure to sunlight, eating Vitamin D-rich foods and taking Vitamin D supplements on metabolic syndrome. Al-Daghri et al. (2012) investigated whether correction of vitamin D deficiency can reverse symptoms of metabolic syndrome with a one-year interventional study. Participants were 59 adult non-diabetic, overweight, and obese Saudis (31 male, 28 female). They attempted to correct vitamin D status by regularly exposing themselves to sunlight and increasing their intake of vitamin D-rich foods. After one year, participants had an improved cardio-metabolic profile. They reported a decrease in the prevalence of MetS symptoms, including low HDL cholesterol, reduced triglycerides, and lower blood pressure. Prevalence of MetS, as defined by the ATP III, was reduced from 25.2% to 13.0%. The findings of this study were limited, however, by its simple pre-post design and lack of control group.

Similarly, Chacko et al. (2011) studied the impact of taking Vitamin D supplementation on symptoms of MetS that are linked with cardiovascular disease. They looked at data about Vitamin D levels for 292 post-menopausal women from nested case-control studies within the Women's Health Initiative Calcium-Vitamin D (WHI-CaD) trial, which was designed to test the effect of calcium and vitamin D supplementation on bone fracture and colorectal cancer in postmenopausal women. In the original study, which included 36,282 postmenopausal women, participants were randomly assigned to take either 400 IU of vitamin D or placebo. Findings of this study indicated that subjects who took Vitamin D supplements achieved higher Vitamin D serum levels, lower levels of body fat and triglycerides and an improved triglyceride:HDL-cholesterol ratio. While subjects did not demonstrate improvement in levels of LDL and HDL cholesterol, insulin, glucose, HOMA-IR, or HOMA-β, this study supports the hypothesis that vitamin D deficiency is a predictor of some components of metabolic syndrome in older adults. In contrast, Kostoglou-Athanassiou, Athanassiou, Gkountouvas, and Kaldrymides (2013) found that an increase in Vitamin D through supplements can lead to improvements in glycemic control among individuals with type 2 diabetes, highlighting the relationship between Vitamin D and metabolic syndrome. They performed medical tests measuring Vitamin D levels in 120 patients with type 2 diabetes. T-tests were used to compare the patient and control groups, and regression analysis analyzed relationships among variables.

These studies contribute valuable information about the link between vitamin D deficiency and metabolic syndrome. Although increased sun exposure and consumption of vitamin D rich foods were associated with subsequent decreases in MetS symptoms, these findings were not contextualized against control group results (Al-Daghri et al., 2012). Findings across these three studies were contradictory, with set of findings indicating no effect of vitamin D supplementation on HDL cholesterol (Chako et al., 2011) and another finding that there was a relationship between these variables (Al-Daghri et al., 2012). Also, the sample sizes in these studies were small, which brings into question the generalizability of these studies. Also, they did not examine the impact of other health behaviors, such as smoking and physical activity, on the relationship between Vitamin D status and metabolic syndrome.

Cross-sectional research methods. Cross-sectional studies have been used to examine the associations between Vitamin D deficiency and blood pressure, low HDL cholesterol and high triglycerides, which are components of MetS associated with cardiovascular disease. Studies have found that people with low levels of Vitamin D are significantly more likely to have elevated blood pressure, low HDL cholesterol and high triglycerides (Kim, 2015; Baker et al., 2012). Kim (2015) studied 2,624 Korean adults (aged 50 years or older) who participated in the fifth Korean National Health and Nutrition Examination Surveys, and Baker et al. (2012) studied 499 patients with rheumatoid arthritis. The studies were similar in that they found an associated between Vitamin D deficiency and certain components of MetS. However, the potential generalizability of these studies is problematic because of the specific characteristics of the participants. The subjects of the Kim (2015) study were all of the same ethnic background, and those from the Baker et al. (2012) study all had rheumatoid arthritis, a significant health factor that may have confounded the results.

Cross-sectional studies have also documented links between Vitamin D status and other components of MetS. Kim et al. (2013) found an association between Vitamin D deficiency, insulin resistance, low-grade inflammation and obesity in a cross-sectional study of 493 obese subjects in Korea. Rhee et al. (2013) studied 6,567 Korean men who participated in a national health survey. This study documented an association between Vitamin D levels and non-alcoholic fatty liver disease, which has been associated with risk factors of MetS. Both of these studies documented a correlation between Vitamin D deficiency and components of MetS, but they did not sufficiently examine other moderating factors of the subjects' health to establish causation.

Navarro et al. (2013) conducted a cross-sectional study that looked at not only individual health issues, but also socio-economic factors that impact the link between Vitamin D deficiency and MetS. The purpose of this study was to investigate the links among poverty, bone density, fragility fractures and metabolic syndrome in 1,250 postmenopausal Caucasian Spanish women. In addition, the modifying influence of vitamin D and parathyroid hormone (PTH) levels was investigated. In conclusion, this study found that poverty was associated with higher levels of risk factors for metabolic syndrome, including higher BMI, increased PTH levels and vitamin D deficiency. The significance of this study is that it supported the hypothesis that vitamin D deficiency is associated with metabolic syndrome in the context of social economic theory. Social factors were responsible for the higher prevalence of risk factors for metabolic syndrome, including vitamin D deficiency.

Similar to the studies cited previously, the nature of this study was quantitative retrospective cross-sectional. A criticism of correlational research is that it may not lead to causal inferences. However, this kind of research is effective at measuring and quantifying variables in order to gain information about possible associations (Thompson et al., 2005).

The research on Vitamin D deficiency and metabolic syndrome fails to adequately examine the effect of health behaviors on the link between them. If Vitamin D levels are affected by healthy choices, such as adequate nutrition, then how are unhealthy choices, such as smoking and physical inactivity, linked to a person's Vitamin D levels? If a link between unhealthy behaviors and Vitamin D levels can be established, how then, do these behaviors impact risk of development of metabolic syndrome? Finally, how do individual, social and environmental factors determine a person's health choices? Some studies have begun to explore these associations, but further research is warranted.

Vitamin D Deficiency, Metabolic Syndrome, Smoking and Second-Hand Smoke

As the negative health impacts of smoking continue to be explored, a developing area of research examines the link between smoking behaviors and Vitamin D deficiency. Since Vitamin D has such powerful anti-inflammatory, anti-carcinogenic and immunomodulatory effects, it makes sense that it might protect the body against the damaging effects of smoking. However, does exposure to cigarette smoke reverse the positive health benefits of Vitamin D? If so, how does this impact the link between Vitamin D levels and metabolic syndrome?

Researchers have determined that Vitamin D may protect the lungs against the damaging effects of smoking. Lange et al. (2012) studied the effect of Vitamin D deficiency on lung function and decline in lung function among smokers. The participants were 626 men from the *Noramative Aging Study*, an ongoing longitudinal study of aging sponsored by the Veterans Administration. All of the participants were Caucasian men from the Boston, Massachusetts area. Vitamin D levels and lung function were measured three times between the years 1984 and 2003. The study confirmed the negative effect of smoking on lung function over time. Vitamin D levels had no correlation with lung function in non-smokers. However, among smokers, those with Vitamin D deficiency had worse lung function than those with optimal Vitamin D levels. Furthermore, the Vitamin D-deficiency smokers experienced more rapid decline in lung function over time than did the smokers with adequate Vitamin D levels. This research suggests that the health benefits of Vitamin D may protect the body from the damaging effects of smoking. This study combined a cross-sectional research design (to measure lung function and Vitamin D levels at specific points in time) with a longitudinal model (to measure change in lung function over time). This allowed for an analysis of the interplay of multiple health factors over time. However, the participants of this study were from a very specific demographic group, calling into question the generalizability of these results.

While Vitamin D levels may protect the body from damage due to smoking, it is possible that exposure to cigarette smoke interferes with the positive effects of Vitamin D. Mulligan et al. (2014) and Afzal, Bojesen and Nordestgaard (2013) studied the effect of cigarette smoke exposure on the body's ability to metabolize Vitamin D. Exposure to cigarette smoke impacted the skin's ability to convert 7-dehydrocholesterol into Vitamin D3 (Mulligan et al., 2014). Since the anti-inflammatory properties of Vitamin D protect the body from cancer, an impaired ability to metabolize Vitamin D may lead to an increased risk for development of cancer (Afzal et al., 2013). Moreover, exposure to cigarette smoke signals the development of pro-inflammatory proteins in the skin, further enhancing the risk for development of cancer cells (Mulligan et al., 2014). Taking Vitamin D supplements, however, blocked the inflammatory response of exposure to cigarette smoke (Mulligan et al., 2014). While these studies clearly demonstrated the link between Vitamin D levels and cancer risk in smokers and others exposed to cigarette smoke, they did not examine the relationship between smoking, Vitamin D levels and metabolic syndrome.

Slagter et al. (2013) attempted to address the link between smoking and metabolic syndrome. In their population-based cohort study of 24,389 men and 35,078 women from the northeast of the Netherlands aged between 18 and 80 years who participated in the LifeLines Cohort Study between December 2006 and January 2012, Slagter et al. (2013) documented a link between smoking and some components of metabolic syndrome. MetS was more prevalent among smokers than non-smokers, independent of sex or weight. Compared to non-smokers, smokers had an increased occurrence of reduced HDL cholesterol levels, elevated triglycerides and abdominal obesity. While this study had a large, random sample of subjects, all of the participants were from a very small geographic area. Furthermore, this study did not address the association that Vitamin D levels might have with smoking behaviors and risk for MetS.

Smoking is linked to Vitamin D deficiency, then, in two ways. First, if the anti-inflammatory and anti-carcinogenic properties of Vitamin D protect the body from the harmful effects of smoking, then those with Vitamin D deficiency cannot benefit from these protections (Afzal et al., 2013; Mulligan et al., 2014). Also, smoking inhibits the body's ability to metabolize Vitamin D (Mulligan et al., 2014). Further research is needed on the moderating effect of smoking on the association between Vitamin D deficiency and metabolic syndrome.

Vitamin D Deficiency, Metabolic Syndrome and Physical Activity

The relationship between physical activity and Vitamin D status has been documented in populations of people from all over the world. Among other factors that affect levels of Vitamin D, such as sun exposure, diet and genetics, level of physical activity has been found to be positively associated with Vitamin D levels (Valtuena et al., 2013). Valtuena et al. (2013) and Al-Othman et al. (2012) both documented the positive effect of increased physical activity on Vitamin D levels in children and adolescents in Europe and Saudi Arabia, respectively. Al-Othman et al. (2012) found that for Saudi children and adolescents with the same amount of sun exposure, those with higher physical activity levels had higher Vitamin D serum levels. Similar results have been documented in studies on older people. Klenk et al. (2015) studied 1,193 individuals from Germany aged 65 or older for one week in each of the four seasons. Participants wore a thigh-worn accelerometer to measure their physical activity. Those who engaged in regular outdoor walking had significantly higher 25(OH)D serum levels in all seasons except summer. The 25(OH)D serum levels were positively associated with duration of walking. However, vitamin D insufficiency was still very prevalent even in high-active persons during all seasons. The time frame for this study was short, it focused on individuals from one specific geographic area and the author did not address the effect of sun exposure on vitamin D levels (since outdoor walking was measured). However, it did highlight the link between activity levels and Vitamin D status. Some studies have documented that higher levels of Vitamin D affect muscle strength and bone density, which improves physical activity levels. Romme et al. (2013) found a link between Vitamin D deficiency, bone density, muscle strength and exercise capacity in patients with COPD. Similarly, in a study of 419 men and women aged 20 to 76, Grimaldi et al. (2013) documented that upper body strength was greater in participants with higher Vitamin D levels. Since they documented the effect of Vitamin D on bone and muscle health, the latter two studies highlighted the link between Vitamin D status and exercise capacity. But they did not address the opposite question, whether increased physical activity impacts Vitamin D levels. None of the studies discussed the link between physical activity, Vitamin D and metabolic syndrome.

Effects of Multiple Levels of Variables that Promote High-Risk Behaviors

Sallis et al. (2008) identified multiple levels of variables that promote high-risk behaviors. These included: intrapersonal, interpersonal, organizational, community, and public policy. Variables interact across levels – there are likely to be multiple variables at each level that lead people to engage in unhealthy behaviors.

Variables affecting levels of physical activity. Physical activity is a significant health challenge because it affects risk of disease, mental health, quality of life and mortality. In fact, Kohl et al. (2012) described physical inactivity as a global pandemic that is now the fourth leading cause of death worldwide. The ecological model of physical activity synthesizes findings and concepts from multiple disciplines, including the fields of health, behavioral science, transportation and city planning, policy studies and economics, and leisure sciences. For example, physical fitness activities of individuals are affected by variables as varied as the presence of sidewalks, perceived crime, and the attractiveness of the environment (Riley, Mark, Kristjansson, Sawada, & Reid, 2013; Sallis et al., 2008).

Identifying reasons why individuals are inactive or active can lead to evidence-based, social-ecological planning of public health interventions (Bauman et al., 2012). Researchers have identified intrapersonal factors that affect an individual's level of physical activity, including perceived behavioral control (such as questions like, "Am I able?" or "Is it worth it?"), physical activity identity (one's believe that physical activity is a part of who they are) (Bauman et al., 2012), time constraints due to other family commitments (Hansen, Ommundsen, Holme, Kolle & Anderssen, 2014), and demographic features (differences exist in levels of physical activity according to gender, age and race) (Yan, & Cardinal, 2013). Environmental and social factors, such as perceived safety levels, accessibility and degree of community support for active lifestyles have been found to have an impact on levels of physical activity (Yan, & Cardinal, 2013; Hansen et al., 2014; Trapp et al., 2012). Health programs aimed at promoting healthy lifestyles by increasing levels of physical activity should be based on research that provides evidence of the causes of physical inactivity. The interventions designed within the social-ecological model should be multi-level and address the psychological, social and environmental causes of inactivity.

Interventions to increase physical activity. Cross-level interventions that address environmental elements, community elements and psychosocial characteristics have been effective in increasing levels of physical activity in adults (Balcázar, 2012; Carlson et al., 2012; Dunton, Kawabata, Intille, Wolch & Pentz, 2012). In order to achieve higher levels of physical activity in individuals, a social ecological framework that incorporates the complex interactions among the correlates of physical inactivity would be more effective than behavioral science approaches focusing on individuals (Kohl et al., 2012; Satariano et al., 2012; Sallis, Floyd, Rodríguez and Saelens, 2012). Prevention approaches that targeted mainly individuals with educational and motivational programs have been ineffective (Kohl et al., 2012; Satariano et al., 2012). Interventions would be more effective if they changed the person, the social environment, as well as built environments and policies that motivated individuals to change their behaviors (Sallis et al., 2012).

Interventions designed within the social-ecological model have been effective in increasing levels of physical activity. Multi-level programs that have successfully reduced physical inactivity addressed multiple domains of active living. Programs that addressed factors in the intrapersonal domain focused on self-efficacy, family support and predisposition to be active (Kegler, Swan, Alcantara, Feldman, & Glanz, 2014; McNaughton, Crawford, Ball & Salmon, 2012; Ding et al., 2012; Wilson et al., 2015). Programs that focused on the perceived environment and access issues concentrated on access to physical activity equipment and neighborhood walkability (Kegler et al., 2014; McNaughton, Crawford, Ball & Salmon, 2012). For children, interventions that involved the school community were effective (Rivard & Deslandes, 2014). Finally, successful interventions involved action at the policy environment level. For example, when communities focused on creating built environments (which are manmade surroundings that provide the setting for physical activity, such as parks or green space) or implementing social marketing campaigns aimed at educating people about positive changes in their levels of physical activity (Ding et al., 2012; Wilson et al., 2015). These studies support a social ecological approach to obesity prevention. However, before effectual policy changes and community programs can be implemented, public health policy makers must understand the reasons why people are inactive.

Variables affecting smoking behaviors. With an understanding of the interplay of factors from multiple domains, research has been conducted to identify the individual, social and environmental factors that influence smoking behavior. Individual and psychological factors that affect prevalence of cigarette use include the brain physiology of nicotine addiction (Sallis et al., 2008), a sense of invincibility or denial of consequences of smoking (Huh, Sami, Abramova, Spruijt-Metz, & Pentz, 2013) and demographic characteristics, such as gender and race (Lewis, Wang, & Berg, 2014; Lanza, Piper & Schiffman, 2014; Pike et al., 2016). Social influences on smoking behavior include being with other friends who smoke (Sallis et al., 2008; Shiffman et al., 2002), identification with a culture in which smoking is prevalent (Huh et al., 2013; Lewis et al., 2014) and lack of role models or pressure to quit (Huh et al., 2013).

Community-level factors that impact smoking include cessation program funding, counter-advertising, and restrictions on tobacco marketing, public smoking restrictions and tobacco taxation policy (Sallis et al., 2008; Morley & Pratte, 2013). Huh et al. (2013) questioned the efficacy of community and national policy programs for tobacco control. In fact, state compliance with national tobacco control measures is often suboptimal (Morley & Pratte, 2013). Morley and Pratte (2013) assessed the effect of tobacco control measures and investigated associations between environmental factors and states' compliance with implementation of these measures. They looked at the impact of cigarette excise taxes, state-level tobacco control expenditures relative to Center for Disease Control and Prevention recommendations, smoking restrictions, and support for smoking cessation by state Medicaid programs on adult smoking levels. They found that taxation and smoking restrictions had the most influence on smoking rates. Variables that affected the level of implementation of tobacco control measures were pro-business or anti-tax policies and the presence of local tobacco manufacturing. These results underscore the influence of interventions at the policy level, not only on the health behaviors of individuals, but also on the ability of the government to enact these policies.

Variables that affect other health outcomes. While this study focused specifically on smoking and physical inactivity and the influence of these behaviors on Vitamin D deficiency and metabolic syndrome, it is significant to note that the social-ecological model has influenced health promotion interventions in other areas. Programs that address individual, social and environmental factors at the intrapersonal, social and organizational policy levels have affected health outcomes related to communicable diseases, women's health issues, dietary habits and asthma.

Communicable diseases. Multi-level interventions affect community behavior and the prevention or treatment of communicable diseases (Dirawan, Yahya & Taiyeb, 2015). For example, during the H1N1 outbreak in 2009, influences at each level of the social-ecological model impacted the likelihood of individuals getting a flu vaccine. The study found that intrapersonal variables (attitudes about susceptibility to the flu and belief in the effectiveness of the vaccine), interpersonal variables (social influence) and institutional variables (information received from healthcare providers) were equally effective in encouraging people to get the flu vaccine. Policy-level factors (such as access to health insurance) also had a small influence on whether people got the vaccine. (Kumar et al., 2012).

HIV/AIDS treatment and prevention is another health outcome that has benefitted from multi-level interventions aimed at changing people's behavior. The abundance of research on high-risk behaviors that lead to HIV infection has uncovered a growing number of individual and environmental variables that shape these behaviors. Social-ecological models help public policy makers respond to this complexity. Data from influential research and interdisciplinary partnerships has allowed public health officials to create evidence-based interventions at the individual, social, community, organizational and policy levels (Kaufman, Cornish, Zimmerman & Johnson, 2014; Baral, Logie, Grosso, Wirtz, & Beyrer, 2013).

Women's health issues. Women have distinctive health issues. Also, the health concerns that affect both women and men often affect women differently. Furthermore, women have different psychological and social experiences than men, and they have a unique relationship with their local and global communities. Therefore, programs that address women's health behaviors need to address the special concerns of women across psychological, social and environmental levels if they are to be effective (Brodmann, Devoto, & Galasso, 2015).

Intrapersonal variables that affect women's health behaviors include personal beliefs or perceptions. For example, women have specific beliefs and attitudes about their role in the household, whether and how much they should work, how family money should be allocated to them and how they should spend it (M'cormack & Drolet, 2012). These attitudes and beliefs are often modified by cultural identity, education level, past experiences, motivation and perceptions about the seriousness or effectiveness of medical care (Tolma, Batterton, Hamm, Thompson & Engelman, 2012). These intrapersonal factors affect how women spend money on healthcare and their access to healthcare (M'cormack & Drolet, 2012). This must be taken into consideration when designing health interventions aimed at increasing women's compliance with healthcare programs like adequate prenatal care, regular mammography screenings, quality nutrition for children and child care practices (Brodmann et al., 2015; M'cormack & Drolet, 2012; Tolma et al., 2012).

Community-level variables that affect women's health choices include experience with events, people or information that motivates them to make changes to their behavior. For example, women from a socio-economically depressed neighborhood were motivated to participate in a nutrition program when they saw other women from the same neighborhood finding ways to adequately nourish their children (Brodmann et al., 2015). Other examples of community variables that motivate women to comply with healthcare recommendations include media reports, mass media campaigns, warning labels on products and even reminder postcards from their healthcare providers (M'cormack & Drolet, 2012; Tolma et al., 2012).

Dietary habits. Chronic diseases such as type 2 diabetes, certain cancers and cardiovascular diseases, are associated with poor dietary and lifestyle behaviors. These multifaceted healthcare concerns require multi-level and multidisciplinary interventions. Initiatives aimed at improving dietary habits must address the individual, social and macro-policy influences on behavior (Slawson, Fitzgerald, & Morgan, 2013). Interpersonal factors that influence dietary habits include taste and food preferences, weight concerns, physiology and knowledge about healthy food choices (Freeland-Graves & Nitzke, 2013). In addition, demographic factors like age, gender, education level and income level also impact nutritional behavior. Furthermore, perceptions about product safety influence food choices (Freeland-Graves & Nitzke, 2013; Townsend & Foster, 2013; Fitzgerald, Morgan & Slawson, 2013).

Community-level influences on dietary behavior have to do with dissemination of information. For example, media stories and marketing campaigns educate people about the effects of unhealthy food choices and ideas for healthier options (Freedland-Graves & Nitzke, 2013). School policies and rules can influence children’s food choices, at least while they are in school (Townsend & Foster, 2013; Moore, de Silva-Sanigorski & Moore, 2013). Placement of promotional labels and educational posters at the point-of-purchase influenced customers to make healthier food purchases at the grocery store (Gittelsohn, 2012).

Policy-level programs that help people improve dietary choices address access to healthy food (Rubio-Valera et al., 2014). Abundance of healthy food choices affects people's nutritional behavior (Freeland-Graves & Nitzke, 2013). Furthermore, business training help organizations improve access to healthier foods (Gittelsohn, 2012).

Asthma. Socio-ecological models provide a framework for the management of chronic diseases such as asthma. Asthma is the result of the interaction between a number of biological, environmental and social factors. In addition to managing their asthma medically, those with asthma must be enabled to avoid asthma triggers and manage their asthma on a daily basis with recommended practices. Communities, schools and other organizations and social networks can collaborate to develop multi-level interventions, such as improved access to healthcare and education about trigger avoidance and medical management (Nuss et al., 2016).

The social-ecological model, then, provides an effective framework for categorizing the seemingly disparate factors that interact to affect health behaviors. While the model explains the interplay of variables underlying health problems, further research is warranted to gain a deeper understanding of modifiers to relationships among variables. In order to investigate the relationship between smoking, physical activity, Vitamin D levels and metabolic syndrome, it is important to first gain an understanding of the definition of Vitamin D deficiency and how it affects people's health.

Conclusion

Vitamin D deficiency is a condition that is prevalent all over the world (Palacios & Gonzalez, 2014). Vitamin D is essential for the healthy development of bone and muscle in children (Binkley et al., 2012). For adults, Vitamin D has health-promoting properties, such as reducing inflammation, inhibiting growth of cancer cells and boosting the immune system (Laird et al., 2014). Those with Vitamin D deficiencies are at greater risk for a host of health problems, such as bone and muscle disorders (Binkley et al., 2012), inflammatory diseases (Laird et al., 2014) and some kinds of cancer (Binkley et al., 2012). In addition, Vitamin D deficiency has been linked with metabolic syndrome, which includes abnormal cholesterol and triglyceride levels, elevated blood pressure, insulin resistance and obesity (Forrest & Stuhldreher, 2011; Binkley et al., 2012; Fung et al., 2012).

Health behaviors, such as smoking and physical activity, impact Vitamin D levels. Exposure to cigarette smoke inhibits the skin's ability to metabolize Vitamin D (Mulligan et al., 2014). Therefore, smokers tend to have lower Vitamin D levels. Also, increased activity has been linked to increased levels of Vitamin D in the body (Valtuena et al., 2013; Al-Othman et al., 2012; Klenk et al., 2015; Romme et al., 2013; Grimaldi et al., 2013). While it is recognized that these health choices affect Vitamin D levels in individuals, a large gap in the research exists. The link between smoking, physical activity, Vitamin D levels and metabolic syndrome must be further explored. Chapter 3 provides a description of the methods used to address this study's purpose.

Chapter 3: Research Method

Introduction

The purpose of this quantitative, retrospective, cross-sectional study was to examine if smoking behavior and physical fitness activity moderated the relationship between Vitamin D deficiency and metabolic syndrome among older individuals. To address the issues presented in this research, the researcher used the quantitative paradigm using post positivist perspective and statistical tools. The research problems were addressed through the use of retrospective data from the National Health and Nutrition Examination Survey (NHANES), which can be publicly accessed online from the United States Department of Health and Human Services (2012) website.

This chapter details the research design and its rationale. The sampling procedures will be explained followed by a discussion of the variables in this study and how they were operationalized. Threats to internal and external validity are discussed and finally, ethical considerations are also described.

Research Design and Rationale

To examine the effect of the moderating variables of physical fitness activity and smoking behavior on the association between the Vitamin D deficiency (independent variable) and metabolic syndrome (dependent variable), a quantitative, retrospective, cross-sectional study was used. The study was is structured to not only determine the correlations between the variables but to determine the direction and magnitude of the relation among the different study variables. The data used to analyze the study variables was collected from the 2005-2006 NHANES which was publicly accessed without the need for the researcher to gain written consent. However, during its data collection phase the NHANES survey personnel collected informed consent forms from the study participants and no names were collected in during the data collection process.

The researcher used data from the NHANES that measured the five conditions used to detect the presence of metabolic syndrome namely, waist circumference, blood pressure, triglycerides, high density lipoprotein (HDL) cholesterol levels, and blood sugar. Respondents were determined as having metabolic syndrome if they met at least three of the NCEP ATP III diagnostic criteria: "waist circumference over 40 inches (men) or 35 inches (women), blood pressure over 130/85 mmHg, fasting triglyceride (TG) level over 150 mg/dl, fasting HDL cholesterol level less than 40 mg/dl (men) or 50 mg/dl (women) and fasting blood sugar over 100 mg/dl" (Huang, 2009, Current Definitions section, para. 4).

A quantitative research design was conceived to provide empirical evidence to assess whether the Vitamin D deficiency, metabolic syndrome, physical fitness activity and smoking behaviour are related. Using statistical evidence through the use of replicable analyses, the study hoped to contribute to the healthcare field by providing valuable insights into the relationships between Vitamin D deficiency, metabolic syndrome physical fitness activity and smoking behavior.

Methodology

Population

This study aimed to examine the relationships of the study variables on elderly individuals. Thus, the target population of this study consisted of elderly individuals, aged at least 60 years and above and residing within the United States of America. According to the World Bank (n.d.), there were roughly 35.5 million U.S. residents over the age of 65 in 2005. It has also been projected that between 2012 to 2050, the United States will experience significant growth in its elderly population and that by 2050, the number of individuals aged 65 and over is projected to be 83.7 million, almost double its estimated population of 43.1 million in 2012 (Ortman, Velkoff &Hogan, 2014). These projections underscore the need for studies that improve quality of life for the elderly.

Sampling and Sampling Procedures

The NHANES data was not obtained using a simple random sample. Instead, a complex, multistage probability sampling design was used to select a sample representative of the civilian, non-institutionalized resident population of the United States. A four-stage sample design was used in the NHANES 2002–2006 with 5,000 participants in 15 locations (Centers for Disease Control and Prevention [CDC], 2015a). The details of the sampling design can be found on the CDC's website (Curtin, Mohadjer, Dohrmann, et al., 2012).

The G*power software tool was used to determine the sample size for analysis in this study. A small effect size of .10 (Cohen, 1969) was used since the NHANES 2005-2006 data had a large sample size. An *a priori* power analysis was carried out considering a correlational analysis using .10 as the effect size, 80% power and an alpha of .05. These parameters were selected due to the large sample size that participated in the NHANES. However, this study focused on elder persons and this was considered since the NHANES includes participants from all age groups within the United States. The results from the G*power analysis yielded a minimum sample size of 3,146 participants given the parameters of this study. A copy of the calculation is shown on Appendix A.

Procedures for Recruitment, Participation, and Data Collection

This study tapped an existing nationally representative sample collected by the CDC through the NHANES program. The NHANES population sample was selected through a random statistical process based on U.S. Census information. The NHANES combines health interviews and physical examinations to evaluate the health and nutritional status of the non-institutionalized civilian U.S. population. Local health and government officials in each survey location were notified prior to the actual survey. Potential participants received letters from the NCHS Director introducing the survey. Health interviews were conducted in the participants' homes while the physical examinations were conducted inside mobile examination centers (MECs).

Advanced computer systems were used to collect and process the NHANES data. This enabled the NHANES staff to access the NHANES data within 24 hours after collection and also ensured the respondents' privacy. The participants were provided transportation to and from the exam center and were also given compensation for their participation. Additionally, participants were also given reports of the medical findings. No names were collected during the survey process and participant information was kept strictly confidential. Privacy is protected by public laws (CDC, 2015a).

Data collected from the NHANES is used to develop public health and safety policies, create health programs and services and deepen the understanding of health for the Nation. National standards for height, weight and blood pressure are benchmarked on the data collected by the NHANES. The data is also used to assess the incidences of major diseases and the risk factors for diseases. Lastly, the NHANES data is also used to establish US residents' nutritional status and its effect on promoting health and mitigating the development of diseases (CDC, 2015a). More information about the NHANES can be accessed at http://www.cdc.gov/nchs/nhanes/about_nhanes.htm.

In order to gain access to continuous data from the NHANES years 2005-2006, the researcher accessed the CDC's website and was brought to the subsection on the NHANES where the datasets were available for download. To access the datasets, the "Questionnaires, Datasets and Related Information" tab was selected to reveal all continuous NHANES for 2005-2006. Some of the data used in this study was extracted from different surveys collected by the NHANES. The data for smoking behaviors was downloaded from the section on Questionnaire Data. The data for Vitamin D, blood sugar (Oral Glucose Tolerance Test), HDL (Cholesterol - HDL), triglyceride (Cholesterol – LDL, triglyceride and a poliprotein) was accessed under the Laboratory Data section while blood pressure, waist circumference (Body Measure), physical fitness activity (Physical Activity Monitor) was retrieved from the section on Examination Data. The researcher did not need to seek for permission to download the data as it is available for public use. A copy of the NHANES Data Release and Access Policy is attached as Appendix B.

Instrumentation and Operationalization of Variables

Vitamin D. Measurements of serum concentrations of 25(OH)D were performed as part of the nutrition biomarker component in NHANES 2001-2006.1 Serum 25(OH)D concentrations were measured at the National Center for Environmental Health, CDC, Atlanta, GA using the DiaSorin RIA kit (Stillwater, MN). The detailed procedure for the 2005-2006 Vitamin D description of the laboratory methodology is available online from the CDC website (CDC, 2015d). Vitamin D deficiency is a continuous independent variable measured in nanograms/milliliter and a result of less than 20 ng/Ml indicates Vitamin D deficiency.

Smoking behavior. The data for smoking behavior was extracted from a survey questionnaire inquiring about the respondents' cigarette use. The procedure and protocol for collecting data on smoking behaviour is published on the CDC website (CDC, 2008c). Only respondents aged 60 years and above were included in the analyses of this study. For the purposes of this research, smoking behavior was represented by the number of cigarette sticks that the respondents consumed in a day. A copy of the survey questionnaire is attached in Appendix C (CDC, 2015e).

Physical fitness activity. To address accuracy and reliability issues, the NHANES used physical activity monitors that objectively collected continuous data. It is believed that the device provided accuracy and reliability in reporting activities that require mobility like walking or jogging. The device used in NHANES was the ActiGraph AM-7164, which was manufactured by ActiGraph of Ft. Walton Beach, FL. Physical fitness activity was operationalized as a continuous variable using the step counts of the participants at least 60 years of age. The protocol and procedure for the collection of physical fitness activity is published on the CDC website (CDC, 2008d).

Participants were identified as having metabolic syndrome based on diagnostic criteria from the National Cholesterol Education Criteria III. Hence, if the participants fulfilled at least three of the five criteria set forth in the following discussion, then they would be considered as having metabolic syndrome. After evaluation of the risk factors, participants would be coded as either having metabolic syndrome or not having metabolic syndrome.

HDL cholesterol. In the MEC laboratory, blood specimens were properly labelled, processed and stored at -20° Centigrade and then sent to the Johns Hopkins University Lipoprotein Analytical Laboratory for analysis. The procedure for laboratory methodology for HDL cholesterol is available from the CDC website (CDC, 2010). In this study, HDL cholesterol was operationalized as a continuous variable measured in mg/dL. Participants were considered at risk if their fasting HDL level was less than 40 mg/dl (men) or 50 mg/dl (women)

Triglycerides. The participants' triglycerides were measured enzymatically in serum using a series of coupled reactions. The triglycerides were only measured from participants in the morning session. The laboratory methodology for triglycerides is available from the CDC website (CDC, 2008b). Only data from participants aged at least 60 years old was considered in this study. In this dissertation, triglycerides were operationalized as a continuous dependent variable and were measured in mg/dL. Participants were considered at risk for metabolic syndrome if their fasting triglyceride level was over 150 mg/dl.

Blood pressure. During the physical examination inside the MEC, the participants were requested to quietly rest in a sitting position for five minutes. After determining the maximum inflation level (MIL), a series of three blood pressure readings were taken. If any of the BP readings were incomplete or interrupted, then a fourth reading was performed. The protocol and procedure for blood pressure is published on the CDC website (CDC, 2007a). Blood pressure was operationalized as the average of the series of blood pressure readings and was measured in mmHg. Participants were considered at risk for metabolic syndrome if their blood pressure was over 130/85 mmHg.

Waist circumference. The NHANES Body Measurement component gauged the participants' body measurements. Some of the data included were head circumference, maximal calf circumference, mid-thigh circumference and waist circumference. The protocol and procedure for the collection of body measures is published on the CDC website (CDC, 2007b). The measurements for waist circumference were extracted from the NHANES Body Measurement component for participants aged at least 60 years old. Waist circumference was measured in centimeters and was operationalized as one of the factors for metabolic syndrome as a continuous dependent variable. Participants were considered at risk for metabolic syndrome if their waist circumference was over 100 centimeters (40 inches) for men and 87.50 centimeters (35 inches) for women.

Blood sugar. Blood specimens were analysed in the Fairview Medical Center Laboratory at the University of Minnesota (Minneapolis) for analysis using a Roche/Hitachi 911. Glucose concentration was determined by a hexokinase method. A detailed description of the laboratory methodology for processing the results for blood sugar is available from the CDC website (CDC, 2008a). Blood sugar was operationalized in this study as a continuous dependent variable measured in mg/dL and participants were considered at risk for metabolic syndrome if their fasting blood sugar was over 100 mg/dl.

The above variables were used to answer the research questions that guided this study:

RQ1: Is there a statically significant association between Vitamin D deficiency and metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older?

H_o1: There is no statically significant association between Vitamin D deficiency and metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older.

H_a1: Vitamin D deficiency is significantly associated with metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older.

RQ2: Does smoking behavior moderate the relationship between Vitamin D deficiency and metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older?

H_o2: Smoking behavior does not moderate the relationship between Vitamin D deficiency and metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older.

H_a2: Smoking behavior moderates the relationship between Vitamin D deficiency and metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older.

RQ3: Does physical fitness activity moderate the relationship between Vitamin D deficiency and metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older?

In response to the three research questions, the following hypotheses were formulated:

H_o3: Physical fitness activity does not moderate the relationship between Vitamin D deficiency and metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older.

H_a3: Physical fitness activity moderates the relationship between Vitamin D deficiency and metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older.

A correlational and moderation analysis was carried out using SPSS (v.23) software that required data collection and organization in addition to statistical analysis. Thus, SPSS software supported the researcher in case selection and file reshaping. Missing data and questions where the participants refused to respond were excluded from the analysis. Prior to conducting the correlation analysis, a Kolmogorov-Smirnov test was performed on the study variables to determine parametric or non-parametric testing. Finally, all statistical analyses were considered significant if $p < 0.05$. Descriptive statistical processing were also used to define gender and ethnicity profiles of the participants.

Threats to Validity

The data collected from the NHANES 2005-2006 consisted of laboratory, examination and survey questionnaire components. It has been argued that the reliability of the different laboratory and examinations could possibly vary according to the type of test used to determine the results. The brand, make and model of the machines used to collect and analyze the specimens could have also varied the results. Laboratory results could have also varied depending on the third-party contracted laboratories who performed the tests on the specimen samples. In addition to these concerns, environmental factors during extraction such as the location, time, lighting, noise level, among others had the potential to affect the results conducted by the NHANES. Finally, recall bias on the part of participants in the study, especially with regard to self-reported smoking and physical activity, constituted a threat to the validity of the NHANES data.

In order to address these concerns, the NHANES employed automated data collection procedures. All laboratory and examination procedures were conducted inside MECs that were specially designed and equipped for the NHANES. The data collected inside the MEC was recorded directly into an electronic database and survey forms were also computerized. All laboratory staff who were medical technologists or phlebotomists were required to complete comprehensive training in standardized laboratory procedures prior to specimen collection. Also, all laboratory staff were required to complete safety training, subject privacy and confidentiality. All staff were also trained in cardio-pulmonary resuscitation (CPR). The staff also underwent formal retraining sessions yearly (CDC, 2015a).

To ensure the quality of the laboratory team's performance, unscheduled site visits were conducted by the NCHS and contracted consultants to evaluate and observe the laboratory staff in relation to how they handled equipment operation, specimen collection and preparation, interaction with the survey participants, and implementation of the survey protocol.

To ensure the accuracy of the test results, all collection materials and storage containers were examined by the CDC and NCEH Environmental Health Laboratory Sciences Laboratory for lead, cadmium, total and speciated mercury background contamination levels. In the MEC, quality control was upheld by analyzing "blind" split samples collected during practice sessions. All contract laboratories were also required to perform random repeat testing on two percent of all samples. The contract laboratories also submitted progress reports that documented the problems encountered during shipping or receipt of the specimen samples. These reports were evaluated every quarter for any changes in the data; In case there were any concerns, the contract laboratories were then asked to explain these changes (CDC, 2015a).

The implementation of the NHANES required extensive organizational, financial, time, technological and manpower resources. Thus, the researcher utilized the data collected from the NHANES 2005-2006 and it is believed that succeeding studies can confirm or contradict the findings of this study after following the statistical analytical methods outlined in this dissertation.

Ethical Procedures

The NHANES, 2005-2006 Examination Consent Brochure provides participants with background information and the purpose. It also explains why the participants were selected to participate in the survey. Participants were informed that they and their child had the option to take part in the survey. Moreover, they were also informed that no repercussions would arise from refusal to participate in the survey. Participants could have refused any part of the exam and were free to drop out of the survey anytime. During interviews, participants also had the option to not answer any question. The respondents were given some of the health test results for free and monetary compensation was also given to the respondents for their time and effort (CDC, 2004a).

To ensure privacy and confidentiality the NHANES assigned numerical codes in place of the participants' names and was bound by federal law to never reveal any information about the participants. However, if signs of child abuse were found during an exam, personnel reported it to the department of social services or the pertinent government agency. The type of tests and measurements were selected because they are harmless although some of the procedures could have caused the participants slight discomfort. Participants with certain circumstances (i.e. pregnant, minors, etc.) were excluded from tests that could upset their condition. When certain government collaborators were allowed access to the data, the information was handled with strict requirements to protect participant confidentiality and privacy as guaranteed by NCHS (CDC, 2004a).

Specimen samples from participants who had given their consent and/or parental assent were stored for use in future studies. Researchers from Federal agencies, universities, and other scientific centers required to submit proposals to use the stored specimens could use them. Approval to use the samples was based on the study's scientific merit and by a board who determines if the study is ethical. All NHANES data was kept strictly private, including all health data and samples. The staff was not allowed to discuss any person that was part of the survey under penalty of Federal laws: Section 308(d) of the Public Health Service Act (42 USC 242m) and the Privacy Act of 1974 (5 USC 552A) (CDC, 2004a). Participants could also ask for the removal of their specimens from the specimen bank by calling a toll free number that was given to them. A copy of the examination consent form (CDC, 2004a) is attached in appendix D while a copy of the specimen storage consent form (CDC, 2004b) is attached as appendix E. The procedures outlined in this chapter were approved by the NCHS Research Ethics Review Board (ERB) Protocol #2005-06 for NHANES 2005-2006 (CDC, 2015c).

In the present study, NHANES data were publicly available and were accessed online. Because participant data was not identifiable, no additional ethical considerations were necessary to safeguard participant confidentiality and anonymity; however, Walden IRB approval was obtained prior to conducting the study. The downloaded NHANES dataset was stored on a password-protected laptop and will be deleted after five years.

Summary

The purpose of this quantitative, retrospective, cross-sectional study was to examine the correlations between Vitamin D deficiency, metabolic syndrome, physical fitness activities, and smoking behavior among older individuals. The study utilized retrospective data from the NHANES from the years 2005-2006 wherein the participants were selected based on a complex, multistage probability sampling design. A correlational analysis was identified as the appropriate analytical test in response to the research questions that guided this study. Discussion addresses the results based on the methodologies outlined in this chapter.

Chapter 4: Results

Introduction

The purpose of this quantitative, retrospective, cross-sectional study was to examine if smoking behavior and physical fitness activity moderated the relationship between Vitamin D deficiency and metabolic syndrome among older individuals. This study also aimed to provide empirical evidence to support or contradict previous studies if Vitamin D deficiency is related to metabolic syndrome, physical fitness activity, and smoking behavior in older individuals. Chapter 4 is comprised of the results of the descriptive data, data analysis using logistic regression analysis and data findings structured by the study question. The purpose of this chapter was to provide the results of the analysis using descriptive statistics and logistic regression to address the purpose of the study. IBM©SPSS® Statistics Version 22 was utilized to conduct the data analysis.

Data Collection

The source of data was the data on the NHANES from the year 2005 to 2016. The data was available in the database of the Centers for Disease Control and Prevention (CDC) website. Data were obtained in the examination and laboratory sections under the "Data, Documentation, Codebooks, SAS Code". Each of the data of the study variables of actual levels of Vitamin D, and the metabolic syndrome related data of smoking behavior, physical fitness activity, HDL cholesterol, triglyceride, blood pressure, waist circumference, and blood pressure were obtained one by one in the different sections. Then, data merging of the consolidated data was conducted. Data was collected from 1,570 individuals aged 60 years old and older and residing within the United States of America. The minimum sample required in the power analysis was 3,146 participants.

There was a discrepancy of the actual number of study subjects enrolled and the planned number. The sample size was not met since the 1,570 sample was the only available data for each of the study variables in the CDC website on the NHANES.

Tables 1 and 2 summarize the demographic characteristics of the 1,570 study subjects. The mean age of the samples of study subjects was 71.98 years old (SD = 8.18 years). Mean age of the male samples was lower than the female samples. However, there was no significant difference in age between the two gender groups ($t(11552.16) = -0.98$, $p = 0.33$). The oldest study subject was 85 years old and the youngest was 60 years old. There were almost equal percentages of male (801; 51%) and female subjects (769; 49%). For race, majority of the subjects-were Non-Hispanic White (955; 60.8%) or Non-Hispanic Black (321; 20.4%). A significant number of Mexican American subjects (235; 15%) were also included.

Prior to conducting inferential statistics to address the research questions of the study, descriptive statistics were first obtained to summarize the data of the study variables. The study variables included the actual levels of Vitamin D, and the metabolic syndrome related data of smoking behavior, physical fitness activity, HDL cholesterol, triglyceride, blood sugar, waist circumference, and blood pressure. Descriptive statistics included the mean, standard deviation, and minimum and maximum values. These are summarized in Table 3.

Table 1

Frequency and Percentage Summaries of Age

		N	Minimum	Maximum	Mean	Std. Deviation
Age of Study Subjects at Screening	Male	801	60	85	71.79	7.93
	Female	769	60	85	72.19	8.42
	Total	1,570	60	85	71.98	8.18

Note: Age is not significantly different by gender ($t(1568) = -0.98$, $p = 0.33$),

Table 2

Frequency and Percentage Summaries of Demographic Information of Study Subjects

	Frequency	Percent
Gender		
Male	801	51
Female	769	49
Race/Ethnicity		
Mexican American	235	15
Other Hispanic	20	1.3
Non-Hispanic White	955	60.8
Non-Hispanic Black	321	20.4
Other Race - Including Multi-Racial	39	2.5

For the levels of Vitamin D, the mean level was 57.95 ng/Ml (SD = 20.57 nmol/L) wherein the mean Vitamin D was greater than the 20 ng/Ml for the Vitamin D deficiency level. For smoking behavior, the mean number of cigarettes smoked per day by the older samples was 16.55 (SD = 13.48). For physical fitness activity, the mean number of steps taken by the older on a week period was 186748.87 steps (SD = 4381775.14). For HDL cholesterol levels, the mean level was 54.84 mg/dl (SD = 15.58 mg/dl) wherein the mean HDL cholesterol level was greater than the 40 mg/dl border line for the male criteria but less than the 50 mg/dl border line for the female criteria for at risk of having metabolic syndrome. For triglycerides levels, the mean level was 126.90

mg/dl (SD = 98.51 mg/dl) wherein the mean triglycerides level was less than the 150 mg/dl border line for the criteria of at risk of having metabolic syndrome. For blood pressure, the mean level was 118.21/65.48 mm/Hg (SD = 17.72/13.39 mm/Hg) wherein the mean blood pressure was less than the 130/85 mm/Hg border line for the criteria of at risk of having metabolic syndrome. For waist circumferences, the mean level was 84.28 cm (SD = 21.38 cm) wherein the mean waist circumference was less than the 40 inches and 30 inches border line for at risk of having metabolic syndrome for the male and female criteria, respectively. For blood sugar, the mean level was 101.73 mg/dl (SD = 28.97 mg/dl) wherein the mean blood sugar level was greater than the 100 mg/dl border line for the criteria of at risk of having metabolic syndrome. Table 4 shows the results of the independent sample t-test of the difference of actual levels of Vitamin D, and the metabolic syndrome related data of smoking behavior ($t(1533.08) = 0.11$, $p = 0.91$), physical fitness activity ($t(1568) = -0.64$, $p = 0.52$), physical fitness step ($t(768.83) = -1.03$, $p = 0.30$), HDL cholesterol ($t(1568) = 0.43$, $p = 0.67$), triglyceride ($t(1568) = 0.72$, $p = 0.47$), blood sugar ($t(1467.83) = 1.49$, $p = 0.14$), waist circumference ($t(1568) = -0.06$, $p = 0.95$), systolic blood pressure ($t(1568) = 1.05$, $p = 0.29$), and diastolic blood

Table 3

Descriptive Statistics Summaries of Study Variables

	Gender	Minimum	Maximum	Mean	Std. Deviation	Std. Error Mean
Vitamin D (nmol/L)	Male			58.01	19.43	0.69
	Female			57.89	21.71	0.78
	Total	15.60	151.00	57.95	20.57	
Smoking behavior (# cigarettes smoked per day)	Male			16.34	13.52	0.48
	Female			16.78	13.45	0.49
	Total	1.00	95.00	16.55	13.48	
Physical fitness activity (10, 000 step counts)	Male			7.28	14.82	0.523
	Female			30.55	625.89	22.57
	Total	0.00	17338.86	18.67	438.18	
Direct HDL-Cholesterol (mg/dL)	Male			55.00	15.86	0.56
	Female			54.66	15.30	0.55
	Total	26.00	151.00	54.84	15.58	
Triglyceride (mg/dL)	Male			128.67	100.65	3.56
	Female			125.06	96.89	3.49
	Total	19.00	1340.00	126.9	98.81	
Waist Circumference (cm)	Male			84.24	21.26	0.75
	Female			84.31	21.52	0.78
	Total	42.50	163.10	84.28	21.38	
Blood Sugar Fasting Glucose (mg/dL)	Male			102.79	32.92	1.16
	Female			100.63	24.15	0.87
	Total	54.00	384.00	101.73	28.97	

(continued)

Table 3 (cont'd)

Descriptive Statistics Summaries of Study Variables

	Gender	Minimum	Maximum	Mean	Std. Deviation	Std. Error Mean
Systolic: Blood pres (mm Hg)	Male			118.67	18.25	0.64
	Female			117.73	17.15	0.62
	Total	82.00	215.00	118.21	17.72	
Diastolic: Blood pres (mm Hg)	Male			65.66	14.13	0.50
	Female			65.30	12.59	0.45
	Total	0.00	118.67	65.48	13.39	

Table 4

Independent Sample t-test Results of Difference of Data of Study Variables by Gender

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Vitamin D (nmol/L)	Equal variances assumed	5.05	0.03	0.11	1533.08	0.91	0.12	1.04	-1.92	2.16

(continued)

Table 4 (cont'd)

Independent Sample t-test Results of Difference of Data of Study Variables by Gender

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Smoking behavior (# cigarettes smoked per day)	Equal variances assumed	0.25	0.62	-0.64	1568	0.52	-0.44	0.68	-1.77	0.90
Physical fitness activity (10,000 step counts)	Equal variances not assumed	4.08	0.04	-1.03	768.83	0.30	-23.27	22.58	-67.59	21.05
Direct HDL-Cholesterol (mg/dL)	Equal variances assumed	0.69	0.41	0.43	1568	0.67	0.34	0.79	-1.20	1.88
Triglyceride (mg/dL)	Equal variances assumed	2.86	0.09	0.72	1568	0.47	3.61	4.99	-6.18	13.39
Waist Circumference (cm)	Equal variances assumed	0.05	0.82	-0.06	1568	0.95	-0.06	1.08	-2.18	2.05
Blood Sugar Fasting Glucose (mg/dL)	Equal variances not assumed	5.92	0.02	1.49	1467.83	0.14	2.16	1.45	-0.69	5.01
Systolic: Blood pres (average) mm Hg	Equal variances assumed	0.98	0.32	1.05	1568	0.29	0.94	0.89	-0.82	2.69
Diastolic: Blood pres (average) mm Hg	Equal variances not assumed	4.74	0.03	0.54	1559.37	0.59	0.36	0.67	-0.96	1.69

pressure ($t(1559.37) = 0,54$, $p = 0.59$) between the two gender groups. The results showed that the actual levels of Vitamin D, and the metabolic syndrome related data of smoking behavior, physical fitness activity, HDL cholesterol, triglyceride, blood pressure, waist circumference, and blood pressure between the male and female samples were not significantly different since the *p*-values of the *t* statistics were all greater than the level of significance value of 0.05.

Table 5 summarizes the number of study subjects that have vitamin D deficiency, at risk of having metabolic syndrome, and having metabolic syndrome. There were only 8 (0.5%) out of the 1,570 of study subjects that were experiencing vitamin D deficiency. There were 425 (27.1%) out of the 1,570 of study subjects at risk of metabolic syndrome based on the criteria of cholesterol levels. There were 403 (25.7%) out of the 1,570 of study subjects at risk of metabolic syndrome based on the criteria of triglyceride levels. There were 539 (34.3%) out of the 1,570 of study subjects at risk of metabolic syndrome based on the criteria of waist circumference. There were 514 (32.7%) out of the 1,570 of study subjects at risk of metabolic syndrome based on the criteria of blood sugar. There were only 65 (4.1%) out of the 1,570 of study subjects at risk of metabolic syndrome based on the criteria of blood pressure. In terms of the number of NCEP ATP III diagnostic criteria the respondents have met in order to have metabolic syndrome, there were 615 (39.2%) that met one of the criteria, 415 (26.4%) that met two of the criteria, and 380 (24.2%) that did not meet any of the five criteria. As stated, they met at least three of the NCEP ATP III diagnostic criteria. There were only 160 (10.2%) study subjects that have met at least three of the NCEP ATP III diagnostic criteria and these were the only study subjects that have metabolic syndrome.

Table 5

Frequency and Percentage Summaries of Study Subjects with Vitamin D Deficiency and Metabolic Syndrome Related Variables

	Male		Female		Total	
	n	%	n	%	n	%
Vitamin D Deficiency						
Not Vitamin D deficient	797	99.5	765	99.5	1562	99.5
Vitamin D deficient	4	0.5	4	0.5	8	0.5
Direct HDL-Cholesterol (metabolic syndrome)						
Not at risk for metabolic syndrome	584	72.9	561	73.0	1145	72.9
At risk for metabolic syndrome	217	27.1	208	27.0	425	27.1
Triglyceride (metabolic syndrome)						
Not at risk for metabolic syndrome	595	74.3	572	74.4	1167	74.3
At risk for metabolic syndrome	206	25.7	197	25.6	403	25.7
Waist Circumference (metabolic syndrome)						
Not at risk for metabolic syndrome	523	65.3	508	66.1	1031	65.7
At risk for metabolic syndrome	278	34.7	261	33.9	539	34.3
Blood Sugar Fasting Glucose (metabolic syndrome)						
Not at risk for metabolic syndrome	551	68.8	505	65.7	1056	67.3
At risk for metabolic syndrome	250	31.2	264	34.3	514	32.7
Blood Pressure (metabolic syndrome, coded)						
Not at risk for metabolic syndrome	654	81.6	609	79.2	1263	95.9
At risk for metabolic syndrome	147	18.4	160	20.8	307	4.1
Number that met criteria						
0	192	24.0	188	24.4	380	24.2
1	323	40.3	292	38.0	615	39.2
2	207	25.8	208	27.0	415	26.4
3	69	8.6	71	9.2	140	8.9
4	9	1.1	10	1.3	19	1.2
5	1	0.1	0	0.0	1	0.1
Metabolic syndrome						
Not having metabolic syndrome	722	90.1	688	89.5	1410	89.8
Having metabolic syndrome	79	9.9	81	10.5	160	10.2

Table 6 shows the results of the chi-square test of the difference of number of samples that have vitamin D deficiency, at risk of having metabolic syndrome, and having metabolic syndrome across different gender groups. The results showed that the vitamin D deficiency, at risk of having metabolic syndrome, and having metabolic syndrome between the male and female samples were not significantly different since the *p*-values of the X^2 statistics were all greater than the level of significance value of 0.05.

Table 6

Independent Sample t-test Results of Difference of Data of Vitamin D Deficiency and Metabolic Syndrome Related Variables by Gender

Dependent Variable	Pearson Chi-Square Value	df	Asymp. Sig. (2-sided)
Vitamin D Deficiency	0.00	1	0.95
Direct HDL-Cholesterol (metabolic syndrome)	0.00	1	0.99
Triglyceride (metabolic syndrome)	0.00	1	0.96
Waist Circumference (metabolic syndrome)	0.10	1	0.75
Blood Sugar Fasting Glucose (metabolic syndrome)	1.73	1	0.19
Blood Pressure (metabolic syndrome, coded)			
Number that met criteria	2.04	5	0.84
Metabolic syndrome	0.19	1	0.66

Results

Logistic regression analysis was conducted to determine if Vitamin D deficiency is associated with metabolic syndrome among adults 60 years and older. The logistic regression analysis also investigated if smoking behavior and physical fitness activity moderate the relationship between Vitamin D deficiency and metabolic syndrome among adults 60 years and older. A logistic regression was conducted since the dependent variable of metabolic syndrome is a dichotomous variable with two possible events. On the other hand, the moderating effects of smoking behavior and physical fitness activity were represented using interaction terms between the moderators and independent variables. These included the interaction terms of Vitamin D Deficiency x Smoking Behavior and Vitamin D Deficiency x Physical Fitness Activity. Logistic regression results are summarized in Table 7 There was a significant relationship and moderation effect if the p-value in the logistic regression was less than or equal to the level of significance value of 0.05.

Table 7

Logistic Regression Results of Effect of Vitamin D Deficiency on Metabolic Syndrome and Moderating Effects of Smoking Behavior and Physical Fitness Activity on Relationship of Vitamin D Deficiency and Metabolic Syndrome

		B	S.E.	Wald	df	Sig.	Exp(B)
Model 1	Vitamin D Deficiency	1.72	0.74	5.45	1	0.02	5.59
	Smoking behavior	0.01	0.01	4.36	1	0.04	1.01
	Physical fitness activity	0.00	0.00	1.84	1	0.18	1.00
	Constant	-2.27	0.16	195.98	1	0.00	0.10
Model 2	Vitamin D Deficiency	-1.49	2.79	0.29	1	0.59	0.23
	Smoking behavior	0.01	0.01	4.13	1	0.04	1.01
	Physical fitness activity	0.00	0.00	1.80	1	0.18	1.00
	Vitamin D Deficiency x Smoking Behavior	0.29	0.24	1.47	1	0.23	1.34
	Constant	-2.27	0.16	197.21	1	0.00	0.10
Model 3	Vitamin D Deficiency	-1115.19	135238.73	0.00	1	0.99	0.00
	Smoking behavior	0.01	0.01	4.12	1	0.04	1.01
	Physical fitness activity	0.00	0.00	1.86	1	0.17	1.00

(continued)

Table 7 (cont'd)

Logistic Regression Results of Effect of Vitamin D Deficiency on Metabolic Syndrome and Moderating Effects of Smoking Behavior and Physical Fitness Activity on Relationship of Vitamin D Deficiency and Metabolic Syndrome

		B	S.E.	Wald	df	Sig.	Exp(B)
Model 3	Vitamin D Deficiency x Smoking Behavior	56.39	6941.62	0.00	1	0.99	3.09 E+24
	Vitamin D Deficiency x Physical Fitness Activity	0.01	1.22	0.00	1	0.99	1.01
	Constant	-2.26	0.16	193.90	1	0.00	0.10

Model 1
Note. Nagelkerke R Square = 0.02, Correct classified cases = 89.8%
a. Variable(s) entered on model 1: Vitamin D Deficiency, Smoking behavior, Physical fitness activity.
Model 2
Note. Nagelkerke R Square = 0.02, Correct classified cases = 89.9%
a. Variable(s) entered on model 2: Vitamin D Deficiency x Smoking Behavior.
Model 3
Note. Nagelkerke R Square = 0.03, Correct classified cases = 90.0%
a. Variable(s) entered on model 2: Vitamin D Deficiency x Smoking Behavior.

Results for Research Question One. Research Question one stated "Is Vitamin D deficiency associated with metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older?"

H_o1: Vitamin D deficiency is not significantly associated with metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older.

H_a1: Vitamin D deficiency is significantly associated with metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older.

The first model in the logistic regression investigated the individual effects of the independent variable of Vitamin D deficiency and the moderators of smoking behavior and physical fitness activity on metabolic syndrome. The model containing the individual effects of the independent variable and moderators explained only 2% (Nagelkerke R^2) of the variance in metabolic syndrome and correctly classified 89.8% of cases. Logistic regression result showed that the independent variable of Vitamin D deficiency (Wald(1) = 5.45, p = 0.02) and the moderator of smoking behavior (Wald(1) = 4.36, p = 0.04) had significant effects or are significantly related with the metabolic syndrome.

The coefficient of the odd ratio statistics of Exp(B) of the significant independent variable and moderator was investigated to determine change in the log odds of the dependent variable of metabolic syndrome for a one unit increase in the values independent variables. This determined the odds that the study subjects had metabolic syndrome. Looking at the log odds of Exp(B), having Vitamin D deficiency resulted to an increase in the odds of having metabolic syndrome by 5.59% than not having metabolic syndrome. Also, having greater smoking behavior or an increase of using one stick of cigarette per day resulted to an increase in the odds of having metabolic syndrome by 1.01 than not having metabolic syndrome. With this result, the null hypothesis for research question one that "Vitamin D deficiency is not significantly associated with metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older" was rejected. The logistic regression result supported the alternative hypothesis that "Vitamin D deficiency is significantly associated with metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older".

Results for Research Question Two. Research Question two states "Does smoking behavior moderate the relationship between Vitamin D deficiency and metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older?"

H_o2: Smoking behavior does not moderate the relationship between Vitamin D deficiency and metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older.

H_a2: Smoking behavior moderates the relationship between Vitamin D deficiency and metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older.

The second model in the logistic regression investigated if smoking behavior moderated the relationship between Vitamin D deficiency and metabolic syndrome among adults 60 years and older. The model containing the individual effects of the independent variable and moderators and the moderating effect of smoking behavior explained only 2% (Nagelkerke R^2) of the variance in metabolic syndrome and correctly classified 89.9% of cases. Logistic regression result showed that the smoking behavior did not significantly moderate the relationship between Vitamin D deficiency and metabolic syndrome (Wald(1) = 1.47, p = 0.23). With this result, the null hypothesis for research question two that "Smoking behavior does not moderate the relationship between Vitamin D deficiency and metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older" was not rejected.

Results for Research Question Three. Research Question three states "Does physical fitness activity moderate the relationship between Vitamin D deficiency and metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older?"

H_o3: Physical fitness activity does not moderate the relationship between Vitamin D deficiency and metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older.

H_a3: Physical fitness activity moderates the relationship between Vitamin D deficiency and metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older.

The third model in the logistic regression investigated if physical fitness activity moderated the relationship between Vitamin D deficiency and metabolic syndrome among adults 60 years and older. The model containing the individual effects of the independent variable and moderators and the moderating effect of physical fitness activity explained only 3% (Nagelkerke R^2) of the variance in metabolic syndrome and correctly classified 90% of cases. Logistic regression result showed that the physical fitness activity did not significantly moderate the relationship between Vitamin D deficiency and metabolic syndrome (Wald(1) = 0.00, p = 0.99). With this result, the null hypothesis for research question three that "Physical fitness activity does not moderate the relationship between Vitamin D deficiency and metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older" was not rejected.

Summary

The purpose of this quantitative, retrospective, cross-sectional study was to examine if smoking behavior and physical fitness activity moderated the relationship between Vitamin D deficiency and metabolic syndrome among older individuals. Logistic regression analysis was conducted to address the three research questions of the study. The results of the logistic regression analysis showed that Vitamin D deficiency was significantly associated with metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older. It also showed that both smoking behavior and physical fitness activity did not moderate the relationship between Vitamin D deficiency and metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older. Chapter Five concludes this study with findings from the study, findings as they relate to literature, implications for action, and recommendations for future research.

Chapter 5: Results, Conclusions, and Recommendations

Introduction

Since the late 1990s, significant attention to the health impacts of Vitamin D deficiency has been drawn (Ginde, Liu, & Camargo, 2009; Lange, Sparrow, Vokonas & Litonjua, 2012; Valtuena et al., 2013). The recommended Vitamin D intake for adults aged from 50–70 years is 600–800 IU/day, which is the amount needed to maintain a serum level of 25OH (Falasca et al., 2014). However, a number of issues have posed significant hurdles in testing and treatment for Vitamin D deficiencies including that other factors also play a role in people's health.

The main goal of this study was to examine whether smoking behavior and physical fitness activity moderated the relationship between Vitamin D deficiency and metabolic syndrome among older individuals. This study's approach utilized the quantitative paradigm and statistical tools. The research used retrospective data collected by the National Health and Nutrition Examination Survey (NHANES) 2005-2006 (Centers for Disease Control and Prevention, 2012). This data was chosen because it was already available and included 5,000 participants in 15 locations across the United States. The 2005-2006 data set was chosen because it was the year where there was a detailed procedure of Vitamin D laboratory methodology. Both smoking behavior and physical fitness activity did not moderate the relationship between Vitamin D deficiency and metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older.

This chapter evaluates the results obtained in this study vis-à-vis the findings of relevant studies previously conducted and makes recommendations for future research. The researcher presents limitations of the and how they might relate to future research in the field. Finally, this chapter offers a concise conclusion of the entire dissertation.

Interpretation of Findings

Research Question 1

Is Vitamin D deficiency associated with metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older?

Vitamin D deficiency was found to be significantly associated with metabolic syndrome (Wald(1) = 5.45, $p = 0.02$). This finding is similar to other findings of previous studies. For example, Ford, Ajani, McGuire, and Liu (2005) reported an inverse relationship between serum concentrations of vitamin D and the prevalence of metabolic syndrome, which indicates that there is a relationship between Vitamin D deficiency and the prevalence of metabolic syndrome. Metabolic syndrome has also been found to be associated with Vitamin D deficiency among older individuals (Vitezova et al., 2015). Other studies found correlations between Vitamin D levels, metabolic syndrome and smoking behavior (Lange et al., 2012; Slagter et al., 2013). This finding contradicts the findings of other studies which found no such association (Veronese et al., 2014).

The finding of the study that there is an association between Vitamin D deficiency and metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) is similar to the findings of previous researchers. Previous studies have suggested significant statistical associations between Vitamin D levels, metabolic syndrome and smoking behavior (Lange et al., 2012; Slagter et al., 2013). Lange et al. (2013) focused on men and the effect of Vitamin D and smoking on lung function and lung function decline. Compared to this study that used information from the 2005-2006 NHANES, Lange et al. used data from the Normative Aging Study that had 25-hydroxyvitamin D levels measured at three different times between 1984 and 2003 with concurrent spirometry. In relation to Lange et al.'s study, Slagter et al. (2013) also examined the association between smoking and metabolic syndrome. Slagter et al. included 24,389 men and 35,078 women aged between 18 and 80 years who participated in the LifeLines Cohort Study between December 2006 and January 2012. Similar to this study, Lange et al.'s (2013) and Slagter et al.'s (2013) studies also used secondary data from another study. However, both Lange et al.'s (2013) and Slagter et al.'s (2013) studies used longitudinal data collection compared with this study's cross-sectional data collection. The interpretation of data in this study allowed for the observation and measure of changes over time, as opposed to a one-time data point producing a single set of results, thus allowing for examination of how variables of association my change over time within the population.

Vitamin D deficiency was associated with metabolic syndrome specifically Type 2 diabetes. This is similar to the finding of Kostoglou-Athanassiou, Athanassiou, Gkountouvas, and Kaldrymides (2013) that an increase in Vitamin D^3 through supplements may lead to improved glycemic control among individuals with type 2 diabetes. These studies results have shaped current study and support the finding that there exists evidence of association between Vitamin D deficiency, metabolic syndrome, and smoking behaviour.

In the population of older individuals, previous researchers have produced inconclusive findings about the relationship of Vitamin D deficiency and metabolic syndrome (Vitezova et al., 2015). One recent study found a significant relationship between the Vitamin D deficiency and metabolic syndrome [odds ratio (OR) = 1: 54; 95% CI [1.23-1.94]] (Oosterwerff, Eekhoff, Heymans, Lips, & van Schoor, 2011). However, another study found that Vitamin D concentration levels did not affect the risks for metabolic syndrome (Reis, von Muhlen, Kritz-Silverstein, Wingard, & Barrett-Connor, 2007). One possible explanation for the varied findings were the different variables used to measure exposure and outcome. Oosterwerff et al. (2011) specifically studied serum 25-hydroxyvitamin D levels and focused on the elderly population. Reis et al. (2007) studied cardiometabolic risk factors and focused on the adolescent population. Finally, Kim (2015) and Vitezova et al. (2015) found that Vitamin D levels were significantly lower in people with MetS than in those without it.

The finding that Vitamin D deficiency and metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) is associated with one another is compatible with the premises of social ecological model. The model asserts that there is an interaction between an individual and his or her environment that leads to health outcomes. Vitamin D deficiency of an individual is connected to the metabolic syndrome of an individual. Vitamin D deficiency and nutrition might have influence metabolic syndrome of adults 60 years and older.

Research Question 2

Does smoking behavior moderate the relationship between Vitamin D deficiency and metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older?

For this research question, it was found that smoking behavior did not significantly moderate the relationship between Vitamin D deficiency and metabolic syndrome (Wald(1) = 1.47, $p = 0.23$). To our knowledge, there has been no previous study that investigated whether smoking behaviour moderated the relationship between Vitamin D deficiency and metabolic syndrome. Previous researchers directly examined whether smoking behaviour is associated to Vitamin D deficiency and metabolic syndrome. Both Lange et al. (2012) and Slagter et al. (2013) found that smoking practices of individuals are significantly related with both Vitamin D deficiency and metabolic syndrome. Moreover, smokers more frequently experience Vitamin D deficiency than non-smokers (Kim & Kim, 2016; Streinu-Cercel et al., 2016; Tønnesen, Hovind, Jensen & Schwarz, 2016). Also, cigarette smoke inhibits the immunomodulatory and anti-inflammatory effects of Vitamin D, reducing organ function in Vitamin-D deficient smokers who are already sick (Lange et al., 2012; Radcliffe et al., 2016; Streinu-Cercel et al., 2016) and, increases the likelihood of cancer and other diseases in Vitamin D deficient smokers (Anaya, Ramirez-Santana, Alzate, Molano-Gonzalez & Rojas-Villarraga, 2016). Therefore, the findings of this study were unique as smoking behavior is associated to Vitamin D deficiency, but it was found that smoking behaviour does not moderate the relationship between Vitamin D deficiency and metabolic syndrome.

Using social ecological model as a lens, metabolic syndrome is influenced by a combination of factors such as nutrition, physical fitness activity, and smoking behaviors. However, it was found that smoking behaviour does not moderate the relationship between Vitamin D deficiency and metabolic syndrome. There might be other factors that influence metabolic syndrome of an individual.

Research Question 3

Does physical fitness activity moderate the relationship between Vitamin D deficiency and metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older?

It was found that physical fitness activity did not significantly moderate the relationship between Vitamin D deficiency and metabolic syndrome ($Wald(1) = 0.00$, $p = 0.99$). This is another unique finding as to our knowledge, there has been no previous study that explored whether physical fitness activity moderated the relationship between Vitamin D deficiency and metabolic syndrome. Previous researchers investigated the association among Vitamin D deficiency, physical fitness, and metabolic syndrome. For instance, Valtuena et al. (2013) found that the level of physical fitness activity of individuals is related to deficiency in Vitamin D and risks for developing metabolic syndrome. Al-Othman et al. (2012), Klenk et al. (2015), and Valtuena et al. (2013) found fitness levels positively associated with serum 25(OH) D concentrations in the body. Furthermore, Vitamin D deficiency leads to loss of bone density and muscle strength, which adversely affects levels of physical activity (Grimaldi et al., 2013; Romme et al., 2013). This finding is a new contribution to the field of Vitamin D deficiency.

The finding that physical fitness activity did not significantly moderate the relationship between Vitamin D deficiency and metabolic syndrome is not consistent with the social ecological model. It is recognized that a combination of factors such as nutrition, physical fitness activity, and smoking behaviors might influence metabolic syndrome of an individual. There might be other factors that influences the metabolic syndromes of people.

Limitations

One limitation of this study pertains to the source of data this study. Although the database originated from a credible source, the data may not reflect current trends and practices since it has been ten years since the data was collected (Stamatelou et al., 2003). Two of the recent studies reviewed concluded that Vitamin D, metabolic syndrome, and smoking behavior are all correlated (Lange et al., 2012; Slagter et al., 2013) This might be one of the factors why the null hypothesis for research question one was not affirmed.

The sample size might not have been enough to determine the relationship between Vitamin D deficiency and metabolic syndrome among adults 60 years and older. Other studies have more than 3,000 participants (Reis et al., 2007. The actual sample size of the study was only 1,570 individuals aged 60 years old and older and residing within the United States of America. There was 99.72% power achieved based on the 1,570 participants. A post-hoc power analysis was conducted to check if the actual sample number of 1,570 individuals was enough to reach a minimum of 80% power. The post-hoc power analysis conducted used the actual statistical analysis used in the study which was a logistic regression analysis. According to a post-hoc power analysis with a total sample size of 1,570, a medium effect size of 0.30 for a logistic regression analysis, a level of significance of 0.05, odds ratio of 1.3, two-tailed test, and considering a normal distribution resulted in a computation power of 99.72% (See Appendix F). The post-hoc power analysis showed that the power was more than sufficient.

Finally, excluding other health-related variables (only Vitamin D deficiency, metabolic syndrome, smoking behavior and physical fitness activities were included) was also a limitation to this study. A person's health is attributed to multiple components, this study focused on the analysis of the relationships between Vitamin D deficiency, metabolic syndrome, smoking behavior and physical fitness activities. The health-related variables mentioned were included in the study because they were the data available in the NHANES dataset.

Recommendations

Since the findings of this study failed to support the initial hypotheses, this section will only discuss recommendations for further study derived from methodological, research design, and other limitations as enumerated in the previous section. In particular, only the suitability of the method used, the data collection procedures which include the inclusion criteria, and the sampling limitation.

1. One recommendation is to increase the number of respondents similar to previous studies that have more than 3,000 participants and to increase the effect size.
2. NHANES data could be combined to get the necessary number of participants.

3. Another recommendation would be to expand the sources of data for a similar study design. Future researchers could have used current or recent data from NHANES or from another institution.

Conclusion

The purpose of this study was to examine whether smoking behavior and physical fitness activity moderated the relationship between Vitamin D deficiency and metabolic syndrome among older individuals. This study partially addressed the gap as to the mixed findings of previous studies. Previous studies have provided inconsistent findings about the link between smoking, physical activity, Vitamin D levels and metabolic syndrome.

Vitamin D deficiency was found to be significantly associated with metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older. Smoking behavior did not moderate the relationship between Vitamin D deficiency and metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older. Physical fitness activity did not moderate the relationship between Vitamin D deficiency and metabolic syndrome (hypertension and cardiovascular diseases and Type 2 diabetes) among adults 60 years and older.

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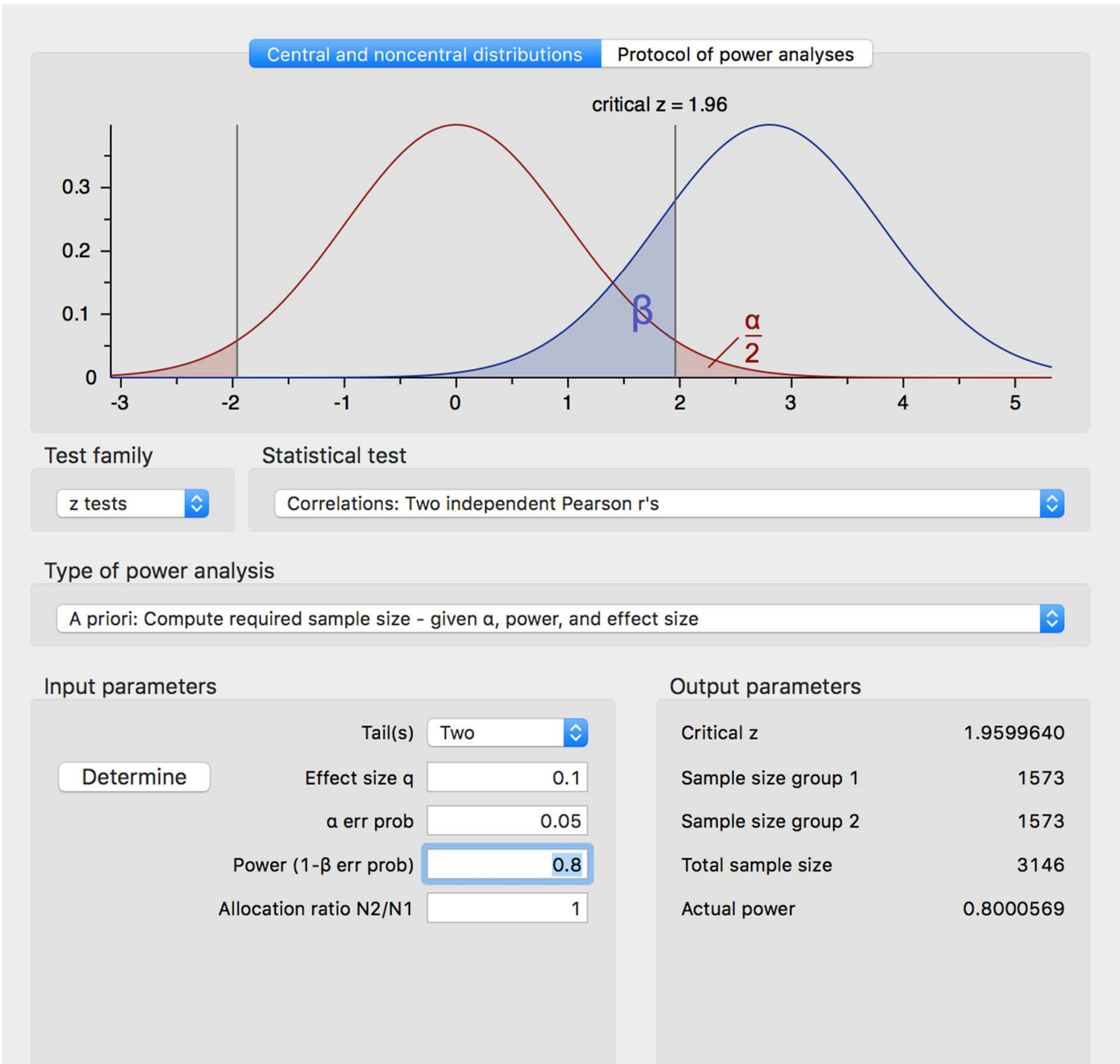
Appendix A: G*Power Computation for Sample Size



Appendix B: NHANES Data Release and Access Policy

NHANES DATA RELEASE and ACCESS POLICY

This policy addresses when, to whom, and in what form the Division of Health Examination Statistics (DHANES) disseminates National Health and Nutrition Examination Survey (NHANES) data and also outlines dissemination procedures. This DHANES policy is consistent with the CDC and NCHS policies, including the guiding principles of making high quality data available

- as widely as practicable
- as soon as possible after data collection
- in as much detail as possible

while maintaining survey participant confidentiality.
Various mechanisms of data release and access will be used to meet the requirements of these principles including public data release as well as limited data access arrangements.

DHANES Policy on Public Release Data:

A. Beginning with NHANES 1999-2000, public use data releases will be made on a biannual basis. Due to the voluminous nature of NHANES and the large amount of post data-collection processing, release of all data from two years of data collection will not occur at one point in time. It is anticipated that release will occur twice a year until all releasable data are available for public use. More frequent releases may occur if needed. See Appendix.

B. Public use data releases from prior NHANES (through NHANES III) will consist predominantly of additional datasets derived from surplus sera projects or special use agreements and will be released on an ad hoc basis. Data release will occur after data cleaning, editing, documentation and DRB review, estimated to be within three months of receipt of the data, subject to manpower limitations.

C. 'Need to Know Release': Urgent policy or legislative-related requests on estimates developed from targeted analyses of data not yet publicly released

a. Recipients: CDC, HHS, OMB, OIG, GAO, or the Office of the Surgeon General
b. How: Analyses will be conducted by staff in DHANES and approved for release by the Director, DHANES or his/her designee
c. Process: Submission of a data analysis request in writing to the Director, DHANES

DHANES Policy on Obtaining Access to Data that will not be Publicly Released:
Several mechanisms will be used for access to non-public data. Each mechanism has specific access criteria and associated procedures.

1. NHANES Data Support Agreements:

a. Recipients: Identified experts under signed agreement to assist in data collection or processing.
b. When: During survey planning, data collection or editing.
c. Process: These agreements are initiated by the NHANES program.

2. NHANES QA/QC Collaborator datasets:
   a. Recipients: Current NHANES Collaborators, as outlined in inter-agency agreements (IAAs) instituted during component planning or funding process.
   b. When: approximately three months prior to public release.
   c. Process: Inter-agency QA/QC dataset agreement (*see appendix)* noting restrictions on QA/QC dataset sharing, analysis and publication prior to public release.

3. NHANES Special Use Data Agreements: Under special circumstances NCHS enters into an agreement to provide a limited non-public special dataset that cannot be released publicly. The user must agree to all conditions of data use for this data.
   a. Recipients:
      i. NHANES current Collaborators – e.g. odd year datasets
      ii. CDC employees on-site at NCHS – e.g. non-DHANES employees
      iii. Any researcher – physical samples from an NHANES survey such as surplus sera projects, DNA, imaging studies, or data that has been approved for release by the DRB under a special use agreement
   b. When: (ongoing) Timing of access may be limited by manpower resources to prepare a dataset; agreements to access the data cannot exceed a two year period.
   d. Process: Requestors must submit a request for a Special Use Data Agreement to the Director, DHANES. These agreements shall be reviewed for approval by the Director, DHANES or his/her designate, and the NCHS Confidentiality Officer.

4. NCHS RDC applications: Requests to match NHANES data to external data sources; to analyze lower level geography or indirect identifiers; for access to non-public release data which are the basis of published analyses (e.g. published analyses based on one year of data).
   a. Recipients: Any researcher
   b. When: (ongoing) RDC proposals are reviewed and approved by the Director, DHANES or his/her designee; timing of access may be limited by manpower resources to prepare a dataset
   c. Process: Submission of a research proposal to the RDC

DHANES Policy on Release of New Data Items Derived from NHANES Physical Samples:
Whenever new data items are developed using physical samples from an NHANES survey such as surplus sera projects, DNA, imaging studies, these new data items will be

made publicly accessible under either public use; special use agreement, or RDC access, depending on the nature of the derived data item and disclosure risk. If requested data are not currently collected or available in NHANES, a proposal to obtain (and fund) the new data items can be made to the Director, DHANES. The proposal will be reviewed by the Director, DHANES or his/her designee. Any data developed under this mechanism will be made accessible under either public use; special use agreement, or RDC access to appropriate recipients as noted above.

APPENDIX.

1. NHANES Public Use Data Release schedule

2. DHANES Collaborator Agreement for Access to QA/QC Datasets:

THE DEPARTMENT OF HEALTH AND HUMAN SERVICES
The Public Health Service
The Centers for Disease Control and Prevention (CDC)
The National Center for Health Statistics (NCHS)
And
Agency Name

AGREEMENT BETWEEN NCHS AND **Agency Initials**
REGARDING PROVISION OF ACCESS TO **Year** NHANES DATA FILE.

Pursuant to its authority to support statistical and epidemiological activities to improve the effectiveness, efficiency, and quality of health services in the United States, (42 U.S.C. 242k(a)), the National Center for Health Statistics (NCHS) agrees to provide to **Agency Name**, (**AGENCY INITIALS**), a data file from the National Health and Nutrition Examination Survey (NHANES) containing **Year** NHANES data. This will enable the **AGENCY INITIALS** to review for quality purposes the **Year** NHANES data before general release. Prior to being granted access to the data, an individual with organizational oversight over the persons (staff and contractors) accessing the data will sign this agreement.

AGENCY INITIALS agrees that no abstracts or manuscripts will be submitted or public presentations occur using the data in this data set prior to the general release. The general release is planned to occur on the NCHS Internet in **Date**.

The individual signing this agreement assures that appropriate administrative, technical, procedural, and physical safeguards shall be established by **AGENCY INITIALS** to prevent unauthorized access to or publication or presentation of the data. If these responsibilities are transferred within **AGENCY INITIALS**, NCHS will be notified promptly and before such official transfer is made.

NHANE

At the time of general release **AGENCY INITIALS** will return to NCHS this data file (including any copies or backup files) or document that the file has been destroyed.

Project Officer, AGENCY INITIALS **E-mail address**	**Name** Director, DHANES, NCHS
DATE	DATE

Appendix C: Smoking Behavior Survey Questionnaire

2005-06 Questionnaire

SMOKING AND TOBACCO USE – SMQ
Target Group: SPs 20+

These next questions are about cigarette smoking.

SMQ.020 {Have you/Has SP} smoked at least 100 **cigarettes** in {your/his/her} entire life?

YES	1	
NO	2	(END OF SECTION)
REFUSED	7	(END OF SECTION)
DON'T KNOW	9	(END OF SECTION)

SMQ.030 G/Q How old {were you/was SP} when {you/s/he} first started to smoke cigarettes fairly regularly?

|___|___|___|
ENTER AGE IN YEARS

NEVER SMOKED CIGARETTES REGULARLY	666
REFUSED	77777
DON'T KNOW	99999

SMQ.040 {Do you/Does SP} **now** smoke cigarettes . . .

every day, ...	1	(SMQ.070)
some days, or	2	(SMQ.641)
not at all?	3	(SMQ.050Q/U)
REFUSED	7	(END OF SECTION)
DON'T KNOW	9	(END OF SECTION)

SMQ.050 Q/U How long has it been since {you/SP} quit smoking cigarettes?

|___|___|___|
ENTER NUMBER (OF DAYS, WEEKS, MONTHS OR YEARS)

REFUSED	77777
DON'T KNOW	99999

ENTER UNIT

DAYS	1
WEEKS	2
MONTHS	3
YEARS	4
REFUSED	7
DON'T KNOW	9

BOX 1A

CHECK ITEM SMQ.053:
IF SMQ.050Q/U >= 1 YEAR (365 DAYS, 52 WEEKS, 12 MONTHS, OR 1 YEAR), CONTINUE.
OTHERWISE, GO TO END.

SMQ.055 How old {were you/was SP} when {you/s/he} **last** smoked cigarettes {fairly regularly}?

CAPI INSTRUCTION:
DISPLAY "FAIRLY REGULARLY" EXCEPT WHEN SMQ.030G/Q = 666 (NEVER SMOKED CIGARETTES REGULARLY).

|___|___|___|
ENTER AGE IN YEARS

REFUSED 77777
DON'T KNOW 99999

SMQ.057 At that time, about how many cigarettes did {you/SP} **usually** smoke per day?

1 PACK EQUALS 20 CIGARETTES
IF LESS THAN 1 PER DAY, ENTER 1
IF 95 OR MORE PER DAY, ENTER 95

|___|___|___|
ENTER NUMBER OF CIGARETTES (PER DAY)

REFUSED 7777
DON'T KNOW 9999

BOX 1B

CHECK ITEM SMQ.060:
GO TO END.

SMQ.070 On average, how many cigarettes {do you/does SP} **now** smoke per day?

1 PACK EQUALS 20 CIGARETTES
IF LESS THAN 1 PER DAY, ENTER 1
IF 95 OR MORE PER DAY, ENTER 95

|___|___|___|
ENTER NUMBER OF CIGARETTES (PER DAY)

REFUSED 7777
DON'T KNOW 9999

SMQ.075 For about how many years {have you/has SP} smoked this amount?

IF LESS THAN 1 YEAR, ENTER 1

|___|___|
ENTER NUMBER OF YEARS

REFUSED 77777
DON'T KNOW 99999

SMQ.077 How soon after {you/SP} wake{s} up {do you/does s/he} smoke? Would you say . . .

within 5 minutes, ...	1
from 6 to 30 minutes, ...	2
from more than 30 minutes to 1 hour, or........	3
more than 1 hour?	4
REFUSED	7
DON'T KNOW	9

SMQ.641 During the past **30 days**, on how many days did {you/SP} smoke cigarettes?

|___|___|
ENTER NUMBER OF DAYS

REFUSED 7777
DON'T KNOW 9999

CAPI INSTRUCTION:
ALLOW '0' AS AN ENTRY. IF '0' DK OR RF ENTERED, SKIP TO QUESTION SMQ.093.

SMQ.650 During the **past 30 days**, on the days that {you/SP} smoked, how many cigarettes did {you/s/he} smoke per day?

1 PACK EQUALS 20 CIGARETTES
IF LESS THAN 1 PER DAY, ENTER 1
IF 95 OR MORE PER DAY, ENTER 95

|___|___|___|
ENTER NUMBER OF CIGARETTES (PER DAY)

REFUSED 7777
DON'T KNOW 9999

SMQ.093 May I please see the pack for the brand of cigarettes {you **usually** smoke/SP **usually** smokes}.

TO OBTAIN ACCURATE PRODUCT INFORMATION, IT IS IMPORTANT THAT YOU SEE THE CIGARETTE PACK.

PACK SEEN 1
PACK NOT SEEN 2 (SMQ.100k)
REFUSED 7 (SMQ.100k)

SMQ.310 ENTER THE UNIVERSAL PRODUCT CODE FROM THE CIGARETTE PACK. UPC MUST CONTAIN **8 OR 12** DIGITS.

SELECT ONE OPTION.

ENTERING 8 DIGIT UPC 1
ENTERING 12 DIGIT UPC 2 (SMQ.330)
UNABLE TO READ CODE-PACK DAMAGED 3 (SMQ.100k)

SMQ.320 ENTER THE 8 DIGIT UPC CODE.

|___|___|___|___|___|___|___|___|

CAPI INSTRUCTION:

DOUBLE ENTRY IS REQUIRED. IF ENTRIES DO NOT MATCH, DISPLAY THE FOLLOWING MESSAGE: ENTRIES DO NOT MATCH. HIGHLIGHT THE ENTRY THAT SHOULD BE CORRECTED AND PRESS 'ENTER' TO CHANGE.

BOX 2B
CHECK ITEM SMQ.329: GO TO END.

SMQ.330 ENTER THE 12 DIGIT UPC CODE.

|___|___|___|___|___|___|___|___|___|___|___|___|

CAPI INSTRUCTION:

DOUBLE ENTRY IS REQUIRED. IF ENTRIES DO NOT MATCH, DISPLAY THE FOLLOWING MESSAGE: ENTRIES DO NOT MATCH. HIGHLIGHT THE ENTRY THAT SHOULD BE CORRECTED AND PRESS 'ENTER' TO CHANGE.

BOX 3

CHECK ITEM SMQ.096A:
IF INVALID CODE OR CODE NOT ON FILE, GO TO SMQ.099.
OTHERWISE, CONTINUE.

SMQ.098 YOU HAVE SELECTED

{DISPLAY BRAND ASSOCIATED WITH CODE}

CORRECT .... 1 (END OF SECTION)
NOT CORRECT 2 (SMQ.100k)

CAPI INSTRUCTION:
DISPLAY BRAND NAME WITH ALL QUALIFIERS – NAME, SIZE (REGULAR, KING, 100, 120), FILTERED/NONFILTERED, MENTHOLATED/NONMENTHOLATED, OTHER QUALIFIERS (DELUXE, HARD PACK, LIGHTS, ETC.)

SMQ.099 CODE NOT ON FILE – PRESS 'ENTER' TO CONTINUE

SMQ.100k What brand of cigarettes {do you/does SP} **usually** smoke?

CAPI INSTRUCTION:
FOLLOW THE BASIC FORMAT FOR DIETARY SUPPLEMENT LOOKUP. ONLY ALLOW INTERVIEWER TO ENTER 1 BRAND OF CIGARETTES OR 'NO USUAL BRAND'. ALLOW ENTRY OF DON'T KNOW AND REFUSED.

REFER TO PRODUCT LABEL IF AVAILABLE.

ENTER **BRAND** NAME OF CIGARETTE.

IF NO USUAL BRAND, TYPE 'NO USUAL BRAND'.

SMQ.111 PRESS BS TO START THE LOOKUP.

SELECT PRODUCT FROM
LIST OR TYPE
'NO USUAL BRAND.'

IF PRODUCT **NOT** ON LIST.
PRESS BS TO
DELETE ENTRY.

TYPE '**'.

PRESS ENTER TO SELECT.

CAPI INSTRUCTION:
DISPLAY CAPI CIGARETTE PRODUCT LIST. INTERVIEWER SHOULD BE ABLE TO SELECT ONE PRODUCT NAME FROM LIST OR 'NO USUAL BRAND'. IN ADDITION, INTERVIEWER SHOULD BE ABLE TO ACCEPT THE PRODUCT NAME AS IT WAS KEYED IN SMQ.100K BY TYPING IN '**'.

BOX 4A

CHECK ITEM SMQ.112:
IF '** PRODUCT NOT ON LIST' SELECTED AT SMQ.111, CONTINUE.
OTHERWISE, GO TO END OF SECTION.

SMQ.110a ASK IF NECESSARY:

IS THE CIGARETTE PRODUCT FILTERED OR NON-FILTERED?

ENTER '1' FOR **FILTERED**
ENTER '0' FOR **NON-FILTERED**

CAPI INSTRUCTION:
'1' AND '0' SHOULD BE THE ONLY CODES ACCEPTED BY CAPI.

FILTERED	1
NON-FILTERED	0

SMQ.110b ASK IF NECESSARY:

IS THE CIGARETTE PRODUCT MENTHOLATED OR NON-MENTHOLATED?

ENTER '1' FOR **MENTHOLATED**
ENTER '0' FOR **NON-MENTHOLATED**

CAPI INSTRUCTION:
'1' AND '0' SHOULD BE THE ONLY CODES ACCEPTED BY CAPI.

MENTHOLATED	1
NON-MENTHOLATED	0
REFUSED	7
DON'T KNOW	9

SMQ.110h ASK IF NECESSARY:

WHAT IS THE CIGARETTE PRODUCT SIZE?

CAPI INSTRUCTION:
THIS ITEM IS STORED IN SMQ.110f IN THE DATA BASE.

REGULARS	1
KINGS	2
100S	3
120S	4
REFUSED	77
DON'T KNOW	99

SMQ.110g REFER TO PRODUCT LABEL, IF AVAILABLE – ASK IF NECESSARY.

WHAT ARE THE OTHER NAME BRAND QUALIFIERS FOR THE CIGARETTE PRODUCT?

CAPI INSTRUCTION:
SHOULD BE A 'CODE ALL THAT APPLY' EXCEPT IF "REF", "DK" OR "NONE" SELECTED. NO OTHER RESPONSE OPTION SHOULD BE ALLOWED. THE "OTHER SPECIFY" RESPONSE SHOULD REQUIRE A TEXT ENTRY.

DELUXE	10
HARD PACK	11
LIGHTS	12
MILDS	13
SLIMS	14
SPECIALS	15
SUPER	16
ULTRA LIGHTS	17
OTHER (SPECIFY)	18
NONE	19
REF	77
DK	99

Appendix D: Examination Consent Form

NATIONAL HEALTH AND NUTRITION EXAMINATION SURVEY

CONSENT/ASSENT AND PARENTAL PERMISSION FOR EXAMINATION AT THE MOBILE EXAMINATION CENTER

Print name of participant ____________________ ____________________

___________________________________ First Middle Last

The attached brochure gives the details about National Health and Nutrition Examination Survey (NHANES). After reading the information provided, please complete the form below.

For the Parent or Guardian of the Survey Participant who is Under 18 Years Old: (unless the participant is an emancipated minor):

I have read the information in the attached NHANES brochure, which explains the nature and purpose of the survey. I freely choose to let my child take part in the survey.

____

____________________ Signature of parent/guardian of participant Date

If you **do not want a written report** of your child’s exam results, check here .

For the Survey Participant who is 12 Years Old or Older:

I have read the information in the attached NHANES brochure, which explains the nature and purpose of the survey. I freely choose to take part in the survey.

____

____________________ Signature of participant Date

If you **do not want a written report** of your exam results, check here .

______________________________ _________ ______________________________

____

Signature of staff member Date Witness (if required) Date

___ ___ ___ ___ ___ ___ SP ID

04-0561 (10/04)

Appendix E: Specimen Storage Consent

5

NATIONAL HEALTH AND NUTRITION EXAMINATION SURVEY (NHANES)
Consent/Assent and Parental Permission for Specimen Storage and Continuing Studies

Print name of participant ____________________ _______________ __________________________
First Middle Last

Q **Why will a sample of blood and urine be kept for future health studies?**

A We would like to store some of the urine and blood from persons who are examined in NHANES for future health studies. These samples will be frozen and kept in a specimen bank for as long as they last.

Q **What studies will be done with the samples?**

A At this time, no specific studies are planned besides the tests included in the NHANES exam. As scientists learn more about health and diseases, other studies will be conducted that may include stored samples. People conducting these studies will not contact NHANES participants for any additional information.

We will keep strictly private all health data and samples that we collect in NHANES. Our staff is not allowed to discuss that any person is part of this survey under penalty of Federal laws: Section 308(d) of the Public Health Service Act (42 USC 242m) and the Privacy Act of 1974 (5 USC 552A).

Q **Who can use the stored samples for further study?**

A Researchers from Federal agencies, universities, and other scientific centers can submit proposals to use the stored specimens. These proposals will be reviewed for scientific merit and by a board that determines if the study proposed is ethical. The NHANES program will always know which samples belong to you or your child, but we will not give other researchers any information that could identify you or your child.

Q **Will I receive results from any future testing of my specimens?**

A Most studies will simply add to our knowledge of health and disease. Therefore, we do not plan to contact you or your family with individual results from these studies. Periodically we will send a newsletter telling all NHANES participants about the studies being conducted. To get more general information about a particular study, you can call our toll-free number, 1-800 452-6115.

Q **How can I remove blood or urine samples from the specimen bank?**

A In the future, if you want samples removed from the specimen bank, call us toll-free at 1-800-452-6115.

The results of continuing study of your stored specimens may help find new ways to prevent, treat, and cure many diseases.

For **persons ages 7 and over,** check this box
☐ I agree that my blood and urine may be kept for future health studies

For **parent/guardian of a child under the age of 18**, check this box
☐ I agree that my child's blood and urine may be kept for future health studies

---

____ ____________________
Signature of participant age 7 or over Date

____ ____________________
Signature of parent/guardian of participant under 18 Date
(Unless the participant is an emancipated minor ☐)

____________________ ________ _________________________ __________
Signature of staff member Date Witness (if required) Date

__ __ __ __ __ __
SP ID

04-0564 (10/04)