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ANALYSIS OF TRENDS AND EFFECTS OF LIFESTYLE BEHAVIORS RELATED TO OBESITY AMONG OLDER ADULTS: FINDINGS FROM THE NATIONAL HEALTH AND NUTRITION EXAMINATION SURVEY (NHANES) BETWEEN 2005-2018

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ABSTRACT

Obesity in older adults is a public health challenge in the United States and many regions of the world. This study analyzed data from the National Health and Nutrition Examination Survey (NHANES) ranging between 2005-2006 to 2017-2018 to examine associations between lifestyle behaviors and obesity, and identify trends and contributions of lifestyle behaviors in older adults. A total of 5,812 participants in a body mass index (BMI)-based obesity group and 5,655 participants in a waist circumference (WC)-based obesity group were selected for association and trend analyses. Logistic regression was applied to estimate the associations between lifestyle behaviors and obesity. Tests for trends of significant lifestyle behaviors across seven cycles were evaluated using orthogonal polynomial coefficients in a regression analysis. Students' t-test was used for comparing the slope of obesity trends and the slope of significant lifestyle behaviors trends. A total of 1,461 participants in both BMI-based and WC-based obesity groups were selected for Oaxaca-Blinder regression decomposition analysis to detect how much obesity change could be explained by the lifestyle behaviors in 2017-2018, compared to 2005-2006. Logistic regression showed that significant lifestyle behaviors related to obesity were total sugar intake, dietary fiber intake, protein intake, food away from home, three intensities of physical activity, alcohol consumption (moderate), smoking (heavy), sleep problem (nearly every day), and intentional weight loss. Among these significant lifestyle behaviors, trends of total sugar intake and heavy smoking behaviors were significantly different from the BMI- based obesity trend. The rest of lifestyle behaviors were similar to the trends of BMI-based and WC-based obesity. Lifestyle behaviors explained half of the increase in obesity from 2005 to 2018. These findings provide important guidance on targeting interventions related to lifestyle behaviors that might be effective in reducing the high prevalence of obesity in older adults.

LIST OF ABBREVIATIONS

AMPM Automated Multiple Pass Method

BF% body fat percentage

BMI body mass index

BMR basal metabolic rate

CDC Center for Disease Control and Prevention

CI confidence interval

DXA dual-energy X-ray absorptiometry

EAR Estimated Average Requirement

FAFH food away from home

kcal kilocalories

NCHS National Center for Health Statistics

ng/dL nanograms (ng) per deciliter (dL)

NHANES National Health and Nutrition Examination Survey

OB decomposition Oaxaca-Blinder decomposition

OR odd ratio

PA physical activity

RDA Recommended Dietary Allowance

SD standard deviation

SE standard error

SFA saturated fatty acids

SO sarcopenic obesity

WC waist circumference

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CHAPTER 1

OBESITY IN OLDER ADULTS: TRENDS AND CONTRIBUTING FACTORS

Obesity is a multifactorial disease and can lead to increased morbidity and mortality in individuals across the lifespan. The prevalence of obesity in America has increased gradually every year, not only in children and young adults but also in older adults whose prevalence is more than 40% (CDC, 2020). Several demographic characteristics, such as gender, ethnicity, education and income, have varying relationships with obesity among older adults (Ismail and Hamid, 2019). Some of these factors are non-modifiable, however, other factors, like lifestyle behaviors, are modifiable, and developing specialized interventions to address them might improve or prevent a larger obesity epidemic (Brown, 2019), as well as, reduce the risk of morbidity and early mortality in older adults.

Research that focuses on the comprehensive factors of lifestyle behaviors is needed to understand the persistent trends of obesity in older adults. Studying independent trends of factors related to obesity may help expand the health-related knowledge of American older adults and develop sound public health policies and evidence-based interventions to decrease obesity in older adults. However, the trend analysis of lifestyle behaviors on obesity in older adults is limited.

Changes in lifestyle behaviors, such as physical activity (PA), sedentary lifestyle, and diet, may have modified the genetic susceptibility to obesity in Caucasians (Heianza and Qi, 2019). Knowing the extent of the impact of individual lifestyle behaviors can help health providers and policymakers target therapies, interventions and policy decisions in areas that show the greatest potential to produce a reduction in the obesity trends in older adults. This could positively impact longevity and quality of life in older adults for future generations.

Therefore, due to the limited research on obesity in American older adults and the limited trend analyses of obesity in this population, the present study sought to investigate some selected demographics and independent components of lifestyle behaviors to determine if any were significantly associated with obesity in older adults and if any impacted obesity disproportionately. Two separate studies were conducted to investigate these questions.

Study one investigated the significant associations that selected demographics and lifestyle behaviors between obesity in the older adult population. A separate study used a relatively new approach to assessing the specific contribution of lifestyle behaviors to obesity, the Oaxaca-Blinder regression decomposition analysis was conducted to determine if some behaviors contribute more strongly to obesity in this age group. Findings from these studies provide new knowledge that will help researchers and clinicians target resources to develop the most optimal prevention strategies and/ or interventions needed to address the prevalence of obesity in older generations. The study aims are detailed below for both studies.

Specific Aims:

Study one:

First, to examine associations between obesity (defined by body mass index and waist circumference obesity standards) and selected lifestyle behaviors in the NHANES data (2005-2018), which are diet, physical activity, alcohol, smoking, sleep and intentional weight loss, in older adults.

Hypothesis 1:

There will be significant associations between obesity and selected lifestyle behaviors in older adults.

Null Hypothesis 1:

No significant associations between obesity and selected lifestyle behaviors in older adults will be found.

Second, if a lifestyle behavior component is found to have a significant association to obesity in older adults, trend analysis from 2005 to 2018 will be conducted to find if the trend parallels the trend of obesity in older adults.

Hypothesis 2:

The trend of significant lifestyle behaviors will parallel the trend of obesity in older adults.

Null Hypothesis 2:

No parallel will be found between the trend in significant lifestyle behaviors and the trend of obesity in older adults.

Study Two:

The Oaxaca-Blinder regression decomposition used to examine relative contributions of lifestyle behaviors and demographic characteristics in explaining the difference of obesity between 2005-2006 and 2017-2018.

Hypothesis:

The increase of obesity in older adults over the 2005-2018 year period is explained by the changes in demographic changes as well as by the changes in lifestyle behaviors.

Null Hypothesis:

The change of obesity in older adults over the 2005-2018 year period cannot be explained by the change of demographic changes or by the changes in lifestyle behaviors.

CHAPTER 2

ASSOCIATIONS AND TRENDS OF LIFESTYLE BEHAVIORS RELATED TO OBESITY IN OLDER ADULTS: FINDINGS FROM THE NATIONAL HEALTH AND NUTRITION EXAMINATION SURVEY (NHANES) BETWEEN 2005-2018

Much of the focus on obesity prevention in past decades has been understandably targeted on younger generations. If successful interventions can be developed to help younger generations maintain healthy weights, the course of the well-documented obesity epidemic may be reversed (Wengreen and Moncur, 2009). Although persistent increases in obesity has been a major health concern for decades, very little focus has been given to the continued increase of obesity in older adults. However, adults are living longer and thus constitute a larger portion of the American population, therefore, obesity in older adults is now gaining more attention and becoming a public health challenge in many regions of the world (Gao et al., 2021). Similar to other age groups, the increase in obesity in older adults is affected by many lifestyle behaviors. However, known associations between lifestyle behaviors and obesity among older adults is still scarce, and little is known about the trends and/ or contributions of specific lifestyle behaviors on the prevalence of obesity in older adults. This study analyzed data from the National Health and Nutrition Examination Survey (NHANES) ranging from 2005-2006 to 2017-2018 to examine associations between lifestyle behaviors and obesity, and to analyze trends of significant lifestyle behaviors in older adults.

Body mass index (BMI), as a commonly used anthropometric measure, represents general obesity in public health, and WC signifies central obesity compared to BMI. The most broadly used anthropometric measure of obesity is based on BMI, because of its easy obtainment. BMI is calculated by dividing body mass in kilograms by height in meters squared (Index, 2019). Based on the World Health Organization (WHO) standard (on Obesity and Organization, 1998), adult obesity is defined as a person having a BMI $\geq 30kg/m^2$. However, BMI does not represent the distribution of body fat, and should not be used in certain populations, like athletes (Kruschitz et al., 2013) and children with special body composition characteristics (Hübers et al., 2017).

Excess fat, typically deposited in the abdomen, has been associated with adverse health consequences. Abdominal fat is considered a strong predictor of cardiovascular disease (De Koning et al., 2007). So the simple, convenient, and practical measure by waist circumference (WC) has gained greater acceptance in obesity research. Because of the relationship with cardiovascular disease, WC has also become a cost-effective approach for assessing obesity and has been integrated into many studies over the past several decades and thus, should be taken into account when classifying obesity. The cutoff points for obesity vary between ethnic groups (Carroll et al., 2008). Similarly, differences also exist between genders with higher cutoff points for men than for women (Moreno et al., 1999). Consequently, the definition of obesity using WC is $\geq$ 102cm for adult men, and $\geq$ 88cm for adult women in America (on Obesity and Organization, 1998).

Besides BMI and WC, there are other measures that can be used to define obesity. For example, body fat percentage (BF%) reflecting the distribution of body fat is considered more accurate than BMI to identify elder obesity (Batsis et al., 2016). In addition, sarcopenic obesity has been gaining importance in research conducted on older adults, due to the dramatic decline in muscle mass for older adults (Roh and Choi, 2020). However, the calculations of BF% and SO depend on the data collected through technologically complex methods such as bioelectrical impedance, dual-energy X-ray absorptiometry (DXA), and others. The DXA data for older adults cannot be obtained from the NHANES website from 2005 to 2018. Therefore, despite the limitations, many studies that used secondary data such as the NHANES among older adults defined obesity by BMI (Jun et al., 2019; Karvonen-Gutierrez et al., 2012; Vásquez et al., 2014). It has been reported that BMI and

WC might be better predictors of insulin resistance than BF% in middle-aged and older Taiwanese (Cheng et al., 2017).

After a thorough evaluation of the measures that could accomplish this retrospective trend analysis in using NHANES data for older adults, BMI and WC were found to be the measures that were available for all the required cycles and the adult age group this study focuses on. Once additional measures are collected over multiple cycles, other measures may be more optimal for future trend analysis comparisons. This will be addressed in further detail in the discussion section.

Most research on lifestyle behaviors related to obesity focus on diet intake and physical activity (PA). These represent important sources of energy and expenditure of energy. In one trend study on diet intake and type 2 diabetes, findings in the NHANES database from 1988 to 2012 revealed that total energy intake increases among those with diabetes, but remains stable in the non-diabetic group of individuals. There was no change in the percentages of calories from macronutrients (carbohydrate, fat and protein) with fiber intake rising from 1988 to 2012 (Casagrande and Cowie, 2017). The intake of energy and all kinds of nutrients are known to have an impact on obesity for different reasons. The trend of individual nutrient intake over time among older adults is still not clearly well documented. Dietary behavior, such as eating at home or eating away from home, appears to be a significant factor influencing overall energy intake. Eating out (meaning eating away from home) can often result in individuals eating unhealthy food and more high fat foods than when they consume home-cooked foods. Some studies in Korean populations have reported that the behavior of eating away from home carried an elevated 36.22% chance of being obese (Kim and Ahn, 2020). So the research on the relationship between eating behavior and obesity is important to continue trying to better identify new weight control intervention models. Physical activity, specifically the PA intensity, is strongly related to energy expenditure. Each hourly increment of moderate and vigorous PA was negatively associated with sarcopenic obesity, while no significant association was shown in low PA. The opposite had been documented in the screen-based sedentary behavior which was positively related to WC and fat mass in Spanish aged adults (Rosique-Esteban et al., 2019).

Smoking, alcohol intake, sleep habits, intentional weight control are also lifestyle behaviors besides diet and PA that should be considered when evaluating obesity trends. In a study about smoking in Korean older adults ($\geq$ 50 years), it is indicated that being a current smoker was associated with sarcopenic non-obese status, and heavy smokers were more likely to develop sarcopenic obesity (Jo et al., 2019). A similar result was found in the United States (U.S.) Cigarette smokers showed lower weights than non-smokers (Albanes et al., 1987). Alcohol, meanwhile, can produce more calories than carbohydrates per gram, so it could be assumed that alcohol consumption is related to increased risk of obesity. However, some research suggests no association exists between the consumption of alcohol and obesity (Tumwesigye et al., 2019). There are confounding issues that can impact studies on alcohol consumption and energy intake, which should direct future studies. Sleep habits are thought to be related to obesity in lifestyle behavior research. In one study of 1,781 older subjects, the sleep duration and sleep problem were inversely related to WC in women, but this relationship was not found in men (Mamalaki et al., 2019).

2.1 LITERATURE REVIEW

2.1.1 Associations between lifestyle behaviors and obesity

By 2050, it is predicted that the population of adults over 65 years will be 17% of the total population (He et al., 2016). At the same time, obesity is also an international public health problem, particularly in the U.S. where the prevalence has increased rapidly. Due to the physiological changes of loss in muscle mass and storage in fat tissue, obesity is very prevalent among older adults. In a report by the Centers for Disease Control (CDC) using BMI to classify obesity, 24.1% of men and 26.9% of women aged 65-74 years old were classified as obese from 1988 to 1994. These numbers almost doubled between 2013 to 2016, because obesity prevalence in older men climbed up to 40.2% and up to 43.5% in older women at the same age (CDC, 2020). Obesity in older adults is a challenge to healthy aging because it can lead to increased morbidity and mortality.

Obesity is a multi-factorial disease; thus, many factors can influence the increase of body weight or storage of fat mass. Besides genetic factors, other characteristics, such as gender, age, educational level, marital status, income, diet, and PA, can promote the development of obesity. Compared to the change of demographic characteristics and genetic factor, lifestyle behaviors are more easily modified and thus are a major focus of ways to change the negative increases in obesity trends over the past several decades. Confirming associations of lifestyle behaviors to obesity and finding optimal prevention and/or intervention strategies could have a positive impact on decreasing the trends of obesity in older adults.

Obesity has traditionally been attributed to the consequence of energy imbalance. Energy intake that excessively exceeds energy expenditures, as one part of energy balance, was thought to be the primary cause of obesity. However, from 1976 to 1991, people's total caloric intake dropped from 1854 kcal to 1785 kcal per day. Researchers proposed that the increasing trend of obesity was paradoxical (Heini and Weinsier, 1997). Opposite results were reported by an analysis of the NHANES during similar years (from 1977 to 2000). These analyses showed that energy intake in males increased 168 kcal/day with a weight gain of 18 lbs, and energy in females increased 335 kcal/day with a weight gain of 35 lbs (Wright et al., 2004). Similar increases in total energy intake also exist among older adults. Total energy intake was positively related to BMI (Howarth et al., 2007). Total intake extends beyond meal consumption and thus other sources of intake must be considered. An example of this is although snacking is commonly associated more with children and young adults, eating snacks is common among older adults as well (Howarth et al., 2007). Snacks provided up to 20% of daily energy intake in 2015-2016 (Moshfegh et al., 2019), compared to 7.7% in 1977 and 14.4% in 1996, among older adults (Nielsen et al., 2002). Older adults were also less likely to skip meals than young adults (Howarth et al., 2007). It is well known that timing of meals is strongly correlated with energy intake and the more meals consumed, the higher the energy intake. Finally, older adults can exhibit less sensitivity to satiety cues than young adults (Howarth et al., 2007), which results in more food intake. All these examples of energy intake contribute to the increasing thought that there may be a relationship between various types of energy intake and increasing prevalence of obesity in older adults.

2.1.1.1 Carbohydrates (includes total sugars and dietary fiber)

Carbohydrates, as one of three macronutrients, are a major source of energy and produce 4 kcal/g energy, which parallels the same energy produced by protein and less energy produced by fat. Glucose is the simplest form of carbohydrate, and is an essential energy provider for the brain and red blood cells. Some research indicates that a large percentage of carbohydrate intake caused weight gain (Van Dam and Seidell, 2007), while low-carbohydrate intake promoted weight loss (Foster et al., 2003). In a dietary study of the American population from 1999 to 2016, energy percentages from carbohydrates declined from 52.5% to 50.5%. Decreases were also found in energy from low-quality carbohydrates (primarily added sugar) (3.25%). Energy from high-quality carbohydrates (primarily whole grains and nuts) increased by 1.23%. But intake of low-quality carbohydrates was still high, which accounts for 41.8% of total energy intake (Shan et al., 2019).

There is some evidence that the types of carbohydrates consumed are more closely associated with increased obesity. Because it is cheaper and more efficient for the food companies to transport and use, fructose is widely used in food, such as high-fructose corn syrup. Due to the effect of hormones, fructose intake had less satiety, which led to more food intake. Fructose is an important factor in energy intake. Trends of fructose use were parallel with the increasing trend of obesity (Wylie-Rosett et al., 2004). On the other hand, the natural state of food can influence energy intake. Generally, liquid food had less satiety than solid food because rapid transit of liquid through the digestive system reduced stimulation of satiety signals, compared to solid food (Pan and Hu, 2011). In the study by Leidy et al. (2010), food form affected postprandial appetite and fullness among older adults (beverage vs. solid meal), who feel hunger and prefer to eat more following beverage intake (Leidy et al., 2010). One report from the NHANES from 2003 to 2016 found that decreases had been observed in energy intake from sugar-sweetened beverages, and in total sugar intake in the American adults aged more than 20 years old (Marriott et al., 2019). Although declines in sugar-sweetened beverage intakes had been documented, sweetened colas were still the best-liked beverages among American older adults (Wierenga et al., 2020). Therefore, sugar-sweetened beverages, which are not only liquid food but also may have added fructose, should be limited or replaced during weight control programs among elderly obese individuals.

Generally speaking, excessive intake of carbohydrate can result in weight gain. However, dietary fiber is a special kind of carbohydrate, which can decrease the caloric density of food, slow the rate of food ingestion, and promote the feeling of fullness. These functions of fiber can prevent the storage of fat and can restrict energy intake, thereby protecting against obesity (Van Dam and Seidell, 2007; Van Itallie, 1978). This viewpoint is supported by a review, in which fiber intake was inversely related to body weight, body fat and BMI through decreasing absorption of macronutrients and altering secretion of gut hormones (Slavin, 2005). Although dietary fiber has many benefits in reducing obesity and although intake of mean daily dietary fiber appears to have increased from 1999 to 2008, the intake reports still do not meet recommendations (King et al., 2012). The prevalence of inadequate dietary fiber intake was up to 90.1% among older adults and was even more serious in males in 2019 (da Silva et al., 2019). In a study of 434 older participants between 60 to 80 years old, cereal fiber was inversely associated with BMI and trunk fat percentage. If cereal fiber came from whole-grain sources, it was related to lower BF% (McKeown et al., 2009). Thus, improving the forms of dietary fiber intakes could play a very important role in reducing obesity in older adults. Current recommendations are for women to consume 25g of dietary fiber per day and increases up to 38g per day for men (Hennessey, 2010). For now, analysis of trend changes of dietary fiber intake is still limited. Additional reviews of whether older adults have increased fiber intake or not in recent decades would provide evidence to support interventions and development of updated recommendations.

2.1.1.2 Total saturated fatty acids

Fat is the most efficient source of energy. It provides more than twice the energy of carbohydrates or proteins. With the exception of medium-chain saturated fatty acids (SFAs), total saturated fat (as well as long-chain SFA) are positively associated with BMI (Raatz et al., 2017). Several studies have echoed these conclusions (Field et al., 2007; Hannon et al., 2017). Higher percentages of calories from SFAs, commonly found in animal products, such as red meat, butter, and dairy products, have a strong relationship to weight gain. Dietary Guidelines for Americans (2015-2020) suggests that SFA intake should account for less than 10% of calories per day (You, 2015). From 1971 to 2010, there has been a documented decrease in SFA intake in the U.S. (Heini and Weinsier, 1997; Storey and Anderson, 2015). The decreased intake of SFA contradicts the increasing trend of obesity in America, the association between SFA and BMI and WC was observed in a study of rural older adults (Ledikwe et al., 2003). This association was not present in female participants, so sex differences may influence this association. A survey of European dietary patterns indicated that European older adults generally consumed diets high in saturated fats (Ruxton et al., 2016). Considering similar dietary habits, it is predicted that high saturated fat intake also exists among American older adults. Evidence that a strong association between SFA intake and weight gain is continuing to emerge; however, research about the association between SFA consumption and obesity in older adults, and the trend of SFA intake among American older adults remains scarce.

2.1.1.3 Protein intake

Protein is a macronutrient that is very important for health by maintaining muscle mass and preventing muscle loss. Dietary protein intake was positively associated with lean body mass in older adults (Geirsdottir et al., 2013), and the intake of protein/ protein supplements could prevent or mitigate sarcopenia (Beasley et al., 2013), which is prevalent among older adults and caused by an age-related decrease in muscle mass. A diet with deficient protein intake results in a relative increase of sarcopenic obesity (SO) (Oh et al., 2017), while adequate protein intake might be one factor in reducing muscle mass loss to prevent SO (Mathus-Vliegen, 2012).

Research outcomes on the association between protein intake and obesity are not consistent. A review of findings from the NHANES 1999-2012 indicated that the total protein score was positively associated with central obesity (Yoshida et al., 2017), whereas a negative relationship between protein intake and abdominal obesity (waist-hip ratio) was found (SHARE and anwar. merchant@ post. harvard. edu Anand Sonia S. Vuksan Vlad Jacobs Ruby Davis Bonnie Teo Koon Yusuf Salim, 2005). Research on the effects of sources of protein has led to conflicting results. In longitudinal research on the association between protein and obesity, animal protein intake was positively related to obesity, while participants with higher vegetable protein intake had lower odds of being obese (Bujnowski et al., 2011). It is inferred then that plant protein may have a protective effect against obesity.

Given the importance of protein for healthy aging, older adults need adequate amounts of protein per day. Based on the Recommended Dietary Allowance (RDA), adults should consume 0.8 grams of protein per kilogram of body weight per day. Although, it is reported that most older adults meet or exceed this requirement, there are still 10-25% of older adults who eat less protein than the RDA, and even 5-9% of female older adults who consume less than the Estimated Average Requirement (EAR) (0.66 g/kg·day) (Volpi et al., 2013). Meanwhile, protein tissue accounts for whole-body protein turnover from 30% to 20% or less with aging. The importance of protein intake is not always appreciated in older adults' diets (Chernoff, 2004). Suggestions about setting the recommendations from 0.8 up to 1.0 g/kg·day were thrown out. In a study between 2001 to 2014 in the NHANES, even though protein intake was reported to exceed the minimum recommendation, it was still below the upper end of the acceptable macronutrient distribution range (Berryman et al., 2018). This result was not supported by other researchers, who found that about 92% of older participants met or exceeded the RDA for protein intake, and 76% of them were above alternative recommendation (1.0 g/kg·day). The average protein intake was 1.14 g/kg·day among older adults (Cardon-Thomas et al., 2017). Although experts differ regarding their assessment of whether protein intake meets RDA or is inadequate in older adults, none dispute the important role protein intake playing a role in older adults' health and wellbeing.

In studies on childhood obesity risk, a higher protein intake, especially from dairy sources, can increase weight gain and lead to higher adiposity in future growth (Leidy et al., 2007). Some popular diets which include higher protein than the recommended value, such as Atkins Diet, Zone, and South Beach Diet (Astrup, 2005), are emerging as alternative methods for reducing the obesity epidemic. This new body of thought is possibly explained by the protein leverage model. In 2005, Simpson and Raubenheimer formalized a hypothesis in a mathematical model, which was called the protein leverage hypothesis (Simpson and Raubenheimer, 2005). In this model, decreasing protein intake leads to compensatory increases in total energy intake by carbohydrates and fat, thereby causing weight gain. Although this model has not been proven, the influence of protein on obesity cannot be ignored.

2.1.1.4 Diet consumption patterns of food away from home (FAFH)

With aging, which is a gradual process, there are also, whether noticeable or not, food choices and dietary habits which typically change gradually as well. Among older adults, key motivations of food choice are the sensory appeal, convenience, and price, while key barriers are health, being on a special diet, and being unable to shop (Locher et al., 2009). Simple and inexpensive food has been shown as a primary choice for older adults. Food prepared at home usually requires much time and effort. For older adults, especially older adults living alone, there is often a lack of enthusiasm and passion to cook food for themselves. Simultaneously, it can be difficult to calculate the amount of food to cook for one person, which can cause excessive waste. It is reported that older adults living alone in the U.S. consumed higher calories from consumption of food away from home (Davis et al., 1988). Since growing numbers of restaurants and fast-food outlets provide the convenience of eating out, the percentage of regular dining out by all Americans has increased. From the 1970s to 1990s, percentages of FAFH increased from 26% to 39% of food expenditures (Lin, 1949). In a 2002 survey on food-consumption patterns among older adults, nearly 27% of weekly food expenditures were for FAFH (Harris and Blisard, 2002).

In addition to those previously addressed, other benefits encourage older adults to visit restaurants frequently. First, some older adults, particularly those living alone, feel alone when dining in their home. A restaurant is a good place to be together with others, which can bring a lot of happiness into their lives. Second, personal expression is achieved among older adults in a restaurant setting. There can be a loss of value with aging, and elders seek socialization in order to feel valued by their peers. Finally, for seniors who are sociable, eating out provides a venue to talk with others (Cheang, 2002). Therefore, restaurants are attractive pastime venues for older adults and can provide positive and negative healthy aging benefits. This is why FAFH can become a usual and customary eating behavior for many older adult and should be evaluated when considering lifestyle behaviors.

Food from restaurants is often high in calories, sugar, and fat, and therefore can contribute to weight gain. About 25% of Americans eat fast food, which provides one-third of the daily total energy, total fat, and saturated fat. These higher-energy foods contribute to higher BMI in individuals (Bowman and Vinyard, 2004). In recent research from the NHANES 2015-2016, 40% of older adults consumed at least one food or beverage from restaurants per week. In older adults, energy from restaurants accounted for 42% of daily energy intake, and half of their intake of fat and saturated fat comes from restaurant food (Moshfegh et al., 2019).

Compared to other age groups, older adults, aged 60-64 years old, are more likely to prefer fast-food restaurants. Gender also plays a role in the association between FAFH and BMI. Male older adults patronize eating out more than their female counterparts (Reynolds et al., 1998). Sex differences also existed in older Europeans, but opposite results were shown. No association was observed between FAFH expenditure and BMI in males, but a negative association was seen in females (Drichoutis et al., 2012). Consequently, FAFH might be a barrier to control body weight and thus research and education on this topic could produce positive outcomes when working with older adults. Further study is needed to determine the positive or negative association among older adults of different genders to help personalize interventions.

2.1.1.5 Physical activity behaviors (physical activity intensity)

Physical activity is thought to be the most common method to expend energy and is considered a behavioral intervention to control or modify body weight. A combination of appropriate PA and restricted dietary intake was recognized as the most effective approach to address obesity problems (Brown and Summerbell, 2009). One cross-sectional study in Switzerland showed that the energy expenditure of high-intensity PA was negatively related to obesity (Bernstein et al., 2004). Similarly, in obese individuals, BMI was strongly related to PA intensities, including moderate PA and vigorous PA. However, in non-obese individuals, this association was weak. It has been hypothesized that PA intensities had more effect on obese individuals than non-obese (Hemmingsson and Ekelund, 2007).

Although the benefits of PA are well known by the public, results on reducing obesity are not very strong. In 2005-2006, American obese adults spent 17.3 $\pm$ 0.7 minutes/day in the moderate-intensity PA and 3.2 $\pm$ 0.4 minutes/day in the vigorous-intensity PA. Corresponding numbers for American normal-weight adults were 25.7 $\pm$ 0.9 minutes/day and 7.3 $\pm$ 0.4 minutes/day. In the whole waking day, American adults spent 2.6% of their time on moderate PA and only 0.2% of their time on vigorous PA, but up to 56.8% of their time was spent on activities that were classified as sedentary behaviors (Tudor-Locke et al., 2010). For American adults, more than half of waking time was spent sedentary and less than 3% of time spent on moderate and vigorous PA. Together these findings contribute to possible relationships to the high obesity epidemic in the American population. On the other hand, the obesity epidemic might also be caused by the change of occupation characteristics. In an over fifty-year analysis on occupation-related energy expenditure and obesity in the U.S., it was reported that energy expenditure dropped more than 100 calories, which resulted in the intensity of occupation-related PA decrease. Compared to now, almost half of the jobs required at least moderate-intensity PA in the 1960s. (Church et al., 2011). The decline of PA intensity is one other possible explanation for the increase in body weight in the American population.

The American College of Sports Medicine and the American Heart Association recommend that older adults should participate in at least 150 minutes of moderate-intensity and 75 minutes of vigorous-intensity aerobic activity each week (Elsawy and Higgins, 2010; Nelson et al., 2007). More than half (52.5%) of American adults older than 60 years old had no leisure-time PA. Only 27% of them had more than weekly 150 minutes leisure-time PA (Hughes et al., 2008). Older adults engaged in significantly fewer minutes of moderate-to-vigorous PA than young adults (Davis and Fox, 2007). In 2005-2006, older male adults aged 60-69 years spent 2.1% of their day on moderate-to-vigorous PA, and 0.1% of their day on vigorous PA. There was more decline among female older adults, in which 1.3% of their day was spent on moderate-to-vigorous PA and 0.02% of their day on vigorous PA. These numbers decreased even more with aging (Chastin et al., 2014). Therefore, most older adults typically do not meet the recommendations for moderate and vigorous PA.

Light-intensity PA can be beneficial for older adults. Light-intensity PA had been associated with a lower BMI (Bann et al., 2015) and abdominal fat distribution among obese older adults (Pescatello and Murphy, 1998). However, in a survey among older adults from 2005 to 2010, obesity was related to functional limitations regardless of PA status (Vásquez et al., 2014). Because of inconsistent results and the fact that most previous research have been focused on children and adolescent obesity and PA, it seems that the association between PA and obesity in older adults has been somewhat ignored. With the future increase of older adults in the American population, this may need to be evaluated more closely to help direct effective innovations in PA programs targeting older adults.

2.1.1.6 Alcohol consumption behavior

Alcohol is considered the most commonly used addictive substance among the older population in the U.S. when compared with tobacco and nonmedical drugs (Moore et al., 2009). Approximately 60% of the American population are moderate drinkers (Gunzerath et al., 2004). Most current older drinkers over 60 years old are moderate drinkers in the U.S., and there has been a decline in alcohol consumption among older populations documented (Ferreira and Weems, 2008).

One gram of alcohol intake produces 7 calories, which is higher than carbohydrates' and proteins' energy production. It is possible that alcohol consumption results in an increase in energy intake. However, the association between alcohol intake and body weight may be paradoxical. This means that the consumption of alcohol does not appear to provide a full explanation for the increase in body weight in many older adults. This assumption is supported by one study, in which elderly participants who consumed higher amounts of alcohol were less likely to gain weight. This study found that after higher alcohol consumption, participants were more active and they engaged in more physical activities (Westerterp et al., 2004). Thereby, it is possible that the energy produced by alcohol is expended by physical activity after drinking in some older adults. In this way, alcohol consumption was felt not to promote obesity, but could in some older adults who remain engaged in PA, prevent or reduce obesity.

The frequency of drinking influences the association between alcohol consumption and obesity. Moderate drinkers had lower odds of obesity, whereas odds for binge drinkers had higher odds of obesity (Arif and Rohrer, 2005). The light-to-moderate alcohol intake was not associated with fat mass storage, while heavy drinking was related to weight gain. Researchers in one study found moderate drinking was beneficial to weight control (Traversy and Chaput, 2015). In another study of older adults, older men with light or moderate drinking were 28% more likely to be obese, and older women with heavy drinking were 55% less likely to be obese (Kruger et al., 2008). More than three drinks per day of alcohol were associated with abdominal obesity (Schröder et al., 2007). Metabolic studies have explained this relationship between alcohol consumption and abdominal obesity. Because alcohol has an impact on the suppression of lipid oxidation, non-oxidized fat will preferentially deposit near the area of the abdomen (Suter and Tremblay, 2005). It is supposed that heavy drinking is strongly related to WC, and from that perspective, alcohol could be considered a risk factor for obesity.

Another study found that although the intake in alcohol consumption may result in extra calories, alcohol intake inhibits consumption of candy and sugar (Colditz et al., 1991). Additionally, through the actions of hormones, such as peptide YY, leptin, or glucagon-like peptide-1, alcohol intake affected appetite and then decrease food intake. Alcohol consumption could even influence hunger through some mechanisms (Traversy and Chaput, 2015). Therefore, alcohol consumption can decrease energy intake by roles of inhibition hormone actions and appetite, helping to prevent obesity in some individuals.

The association between alcohol consumption and obesity is complex. It is important to assess the amount of intake, drinking patterns, type of alcohol, frequency of drinking, gender and additional intake to truly determine the impact. Few studies are focused on aging adults' alcohol intake and obesity, even though there is research on other age groups. There are also associated risks with alcohol consumption related to co-morbidities in older adults that must be considered that are beyond the scope of this study. Therefore, with an increasing share of older persons in the American population, an investigation of the effects of alcohol consumption on obesity among older adults might be an additional informative future research topic.

2.1.1.7 Smoking behaviors

Smoking is a major cause of disease and death around the world. It not only threatens the health of smokers themselves but also influences the lives of the people around them. However, a large portion (22.7%) of the population is still smoking (Healton et al., 2006). The proportion of American adults who smoke cigarettes declined from 2005 to 2016 (Jamal et al., 2018), but the prevalence of smoking among older adults ($\geq$ 65 years) remained stable. It is reported that 10.5% of investigated participants were current smokers (Kulak and LaValley, 2018). So smoking remains a risk factor that does not promote healthy aging.

The high prevalence of obesity and smoking puts forward a question about the association between them. Is there any relationship between obesity and smoking? First, different body weights between smokers and non-smokers were found. Male non-smokers over 40 years old were on average 5.4 kg heavier than smokers (Khosla and Lowe, 1971). A study of 40,036 Scottish adults in 1995-2010 showed that current smokers had a reduced risk to be overweight compared to never-smokers (Mackay et al., 2013). In this situation, if not considering other adverse effects of smoking, smoking might be considered as one form of protection against obesity. Nicotine might explain lower body weight. Nicotine is a metabolic stimulant and appetite suppressant. It is possible that current smokers' reduced food intake is due to the suppressant role of nicotine, which explains the occurrence of weight gain after quitting or reducing smoking (Courtemanche et al., 2018). Gender differences also affect this association. Obesity is less prevalent among female smokers than non-smokers, but male smokers have higher odds of being obese (Lahti-Koski et al., 2002).

From 1992 to 2012, the Swiss Health Survey showed that smoking prevalence decreased in normal-weight participants, but not in obese individuals (Lohse et al., 2016). However, the association between smoking and obesity depended on the classifications of obesity by different anthropometric measures. In a study of 5,287 Iranian participants, smokers had a low rate of obesity and BMI, but higher WC (Meysamiea et al., 2017). Thus, determining the association between smoking and obesity requires the consideration of obesity definitions by different measuring methods and possible confounders.

Interestingly, a positive relationship between perceived obesity status and smoking behavior was observed. Females who perceived themselves as obese were 21.2% more likely to smoke than those who did not perceive themselves as obese (Kim, 2018). This opposite-direction relationship indicates more prevalence of smoking in the obese by the interaction between smoking and obesity. However, findings that females smokers had higher rates of obesity and BMI were reported (Meysamiea et al., 2017), which appears to refute the myth that smoking can help an individual lose weight.

Pattern or quantity of smoking influences obesity as well. Women who are overweight/ obese with heavy smoking daily are particularly vulnerable to develop abdominal obesity (Tuovinen et al., 2016). This is supported by research in Indonesian adult populations. Heavy smokers have a higher risk of obesity than light smokers among current smokers (Nawawi et al., 2020). The relationship between smoking and obesity was negative in this previous study, and the amount of smoking was a major determinant in this relationship.

Smoking status, including light, moderate, or heavy smoking of current smoking individuals contributes knowledge that can help identify relationships to risks of obesity. However, there is little research on this association among older adults. In addition to current smoking behavior, the trend of older adults' smoking behavior in past decades and smoking trends of younger generations need to be analyzed to prepare to provide appropriate lifestyle behavior interventions.

2.1.1.8 Sleep behaviors

Sleep accounts for a large proportion of time in people's daily lifestyles. The quality of nocturnal sleep determines the quality of one's day. It is acknowledged that newborn babies have the longest sleep duration, but as they get older, sleep hours decrease. Does this mean older adults have the least sleeping duration and/ or poorest sleep quality?

The difficulty of sleep is a problem for many older adults and can increase with age. In 876 older subjects, 23.8% of females and 13.3% of males reported sleep problems. In these problems, 43.5% of them had difficulty maintaining sleep, 33.4% of them were early morning awakenings, and 31.4% of them reported difficulties falling asleep (Mallon and Hetta, 1997). Supported by the University of Michigan National Poll on Healthy Aging, 46% of older adults reported having trouble falling asleep. Interestingly, more than half of them considered poor sleep as a normal part of aging (Malani et al., 2017). In the self-report and diary, healthy older people experienced satisfactory nocturnal sleep quality and daytime alertness (Driscoll et al., 2008). Personal feelings about sleep issues are complex, and the health conditions of participants can also influence their feelings on sleep.

An inverse relationship between sleep duration and age was reported (Chaput et al., 2018). However, sleeping hours among different age groups showed a U-shaped relationship, with the lowest value at 35-55 years old. Sleep duration in older adults was usually 7 hours (Léger et al., 2014). A study with 24,671 adult subjects suggests the average total sleep time was from 7 hours to 13 hours. In this study, 2.7% were long sleepers, who slept 10 hours or more, and 7.5% were short sleepers, who slept less than 5 hours. Long sleepers are more often females and older adults (> 65 years).

It is important to note that in relation to lifestyle behavior research that long sleepers were more likely to have greater BMI (Léger et al., 2014). These previous studies suggest that female older adults have a high risk of being obese if they sleep for more than ten hours. So, what is the optimal sleep duration for older adults? Evidence shows that both less sleep and more sleep can be associated with sleep quality (Wrzus et al., 2014). Researchers recommend that optimal sleep duration for older adults should be based on the individual's specific situation. There is no "magic number" for all of the older population (Chaput et al., 2018).

Given the serious sleep problems in older adults, its association with obesity needs to be better established. First, sleep duration is associated with obesity. The U-shaped association between duration hours and WC was reported in female participants. Short ($<$ 5 hours) and long ($>$10 hours) sleepers had higher WC than normal sleepers (7-8 hours) (Theorell-Haglöw et al., 2012). Plus, the odds of obesity were 3.7-fold greater in men and 2.3-fold greater in women if sleep was less than 5 hours. Short sleep was related to central fat distribution and BF% in an older population (Patel et al., 2008). So, both short sleep and long sleep can be a risk factor for obesity. These results are confirmed by other research. In 2004-2005, the U.S. National Health Interview Survey reported that sleep duration had the strongest association with health risks (obesity) among demographic characteristics, health behaviors, family environment, and geographic context. Normal sleep, which was 7-8 hours, could reduce the risk of obesity (Buxton and Marcelli, 2010). Interestingly, no association between sleep duration and weight gain was observed in Japanese participants (Nagai et al., 2013), and daily sleep hours were not associated with increased WC (Georgousopoulou et al., 2018). Inconsistent results call for further study.

Similar to sleep duration, sleep problems are also associated with obesity. Sleep problems referred to as night awakening, slow-wave sleep and daytime sleep can lead to obesity because of disordered eating behaviors (Norton et al., 2018). Gender differences might influence this association. Sleep problems were negatively associated with BMI and WC in female older adults, but this association was not seen in males (Mamalaki et al., 2019). So females who have poor sleep quality will have a high risk of obesity. However, the opposite result – that poor sleep quality does not contribute to obesity – is also found. High quality of sleep was associated with increased BMI and WC among male older adults (Gildner et al., 2014). Gender should be taken into account when analyzing the association between sleep problems and obesity.

Additionally, sleep patterns are factors that impact obesity among older adults. In a study that tracked the night-to-night change in sleep duration, every hour of night sleep increased 1.63-fold the odds of obesity in men and increased 1.22-fold the odds of obesity in women. For day-time napping, every hour of napping increased 1.23-fold the odds of obesity in men and 1.29-fold in women. Irregularity in sleep habits was always combined with an irregular eating pattern, thereby causing metabolic issues (Patel et al., 2014). Weight gain was the ultimate result.

Sleep habits can have serious impact on overall health among the older adult population. It should receive the same attention from the public as dietary and physical activity does in regards to successful aging.

2.1.1.9 Intentional weight loss behaviors

It has been reported that males care less about their body weight than females and more females than males are trying to lose weight (Wardle et al., 2000). Thus, gender differences influence the success of a weight loss program. Only when the obese perceive themselves as having a weight problem, will they tend to change their body weights through weight-loss strategies.

The most common methods used for weight loss are exercise and dietary control measures, such as keeping healthy foods at home, regular consumption of vegetables, eating breakfast daily, and reduced consumption of some foods (Santos et al., 2017). In the NHANES 2007-2012, carbohydrate intake was lower and the percentage of protein intake was higher in the intentional weight loss group. Poor diet quality was also observed when participants are intentionally losing weight (Davidson, 2017). Whereas body health is more important than weight loss, the final target should be weight loss that focuses on overall body health.

Effective strategies for losing weight include increased PA, decreased high-calories foods, and a change to healthier dietary habits. While intentional weight loss indeed helps the obese control weight, the process is also influenced by other factors. First, demographic characteristics play a role in the process, such as age, marital status, race, and educational level. Second, emotional support and alcohol drinking can promote a successful plan. Finally, a satisfaction of body weight is negatively associated with achieving decreased weight (Moore et al., 2020). Consequently, professional guidance should be based on the specific case. A sustainable individual strategy to lose weight is key for reducing obesity.

In general, if someone intentionally controls their energy intake and expenditure, weight loss can be achievable in the short term. Maintaining ideal weight in the long term is the larger challenge, and weight loss is often followed by weight regain. Research indicates that approximately 20% of overweight individuals can successfully maintain weight loss for at least one year. If they are able to maintain it for 2-5 years, it is easier to maintain for the rest of their lives (Wing and Phelan, 2005). Several other approaches promote maintaining weight loss for the long term. Beyond continuously increasing PA and having a low-calorie diet, confidence of being able to lose weight and self-monitoring of weight will benefit the maintenance of weight (Montesi et al., 2016). Changes in lifestyle and attitude facilitate weight control. Thus, the perception of weight loss at first combined with appropriate approaches for maintaining it will ensure weight control be successful and sustainable which could prevent, and/or reduce obesity in this population.

However, it should be noted that weight loss in older adults is often accompanied by the loss of muscle mass, which results in sarcopenia (Darmon, 2013). Weight loss through caloric restriction may best be avoided to prevent loss of fat-free mass (Miller and Wolfe, 2008). In the short-term studies among older populations, PA, particularly resistance training, expresses its advantage in weight loss programs. Resistance training can attenuate the loss of fat-free mass, which is essential for physical function in older adults (Rejeski et al., 2010). So weight loss through resistance training is recommended for older obese individuals. The percentage of older populations that try to lose weight in recent decades is still unclear. Whether the trend of weight loss is associated with the trend of obesity in older adults needs to be investigated further.

It is evident that although research has helped us gain greater knowledge regarding the complexity of interrelationships that can impact obesity, the persistent increases in obesity despite interventions in many areas, indicate that much remains to be discovered. As previously discussed, with the CDC projections of adults outnumbering children by 2030 for the first time in history (McCullough et al., 2019), it is prudent to begin to focus research on the demographic and lifestyle behaviors of older adults to determine which could be modified through targeted interventions to reduce the prevalence of obesity in this age group. These same interventions would also impact morbidity and mortality rates as well.

This study seeks to add to the body of limited knowledge by identifying selected lifestyle behaviors which have significant associations to obesity in older adults and conduct a trend analysis to determine which behaviors may hold greater promise with use of individualized interventions developed to appeal to older adults. Below is a table that provides the lifestyle behaviors selected to examine in this study and the hypothesis and null hypothesis for each.

2.2 METHODOLOGY

2.2.1 Data

This study used data from the National Health and Nutrition Examination Survey (NHANES). The NHANES is a nationally-representative cross-sectional study, repeated in two-year cycles by the National Center for Health Statistics (NCHS) at the Centers for Disease Control and Prevention (CDC) to assess the health and nutritional status of the American population. The NHANES uses structured interviews to gather demographic, socioeconomic, dietary, and health-related information; physical examination for medical, dental, physiological information; and laboratory tests. The NHANES uses the Automated Multiple Pass Method (AMPM) to collect accurate data on dietary intake by five steps (quick list, forgotten foods, time & occasion, detail cycle, and final probe) and calculates nutrient intakes based on a two-day dietary interview (NHANES - What We Eat in America, 2020).

This study used public-use files downloaded from the NHANES website (NHANES Questionnaires, Datasets, and Related Documentation, n.d.). in the waves of 2005-2006, 2007-2008, 2009-2010, 2011-2012, 2013-2014, 2015-2016, and 2017-2018. The NHANES research procedure was approved by the National Center for Health Statistics Research Ethics Review Board, and all participants provided the written informed consent.

Overall, steps are outlined in Figure 2.1.

2.2.2 Subjects

The sample consisted of older adults defined as individuals of ages equal to or greater than 65 years old at the time of screening. Seven waves of data, which were 2005-2006, 2007-

Table 2.1. Hypothesis and null hypothesis in associations between lifestyle behaviors and obesity

Lifestyle behaviors	Hypothesis	Null Hypothesis
Diet	The intake of nutrients (energy intake, carbohydrate, total sugars, saturated fatty acid and protein) are positively associated with obesity in older adults. The intake of dietary fiber is negatively associated with obesity in older adults. The dietary behavior (food away from home) is positively associated with obesity in older adults.	No association between the intake of nutrients (energy intake, carbohydrate, sugar, dietary fiber, saturated fatty acid and protein) and elder obesity will be found. No association between dietary behavior and elder obesity will be found.
Physical activity	Intensities of physical activity (vigorous, moderate or low/none) are negatively associated with obesity in older adults.	No association between intensities of physical activity (vigorous, moderate or low/none) and elder obesity will be found.
Alcohol	There is a negative correlation between alcohol intake and obesity in older adults.	No association between alcohol intake and elder obesity will be found.
Smoking	Smoking is negatively associated with obesity in older adults.	No association between smoking and elder obesity will be found.
Sleep habits	Sleep duration is positively associated with obesity in older adults.	No association between sleep duration and elder obesity will be found.
	Sleep problems are positively associated with obesity in older adults.	No association between sleep problems and elder obesity will be found.
Intentional weight loss	Intentional weight loss is negatively associated with obesity in older adults.	No association between intentional weight loss and elder obesity will be found.

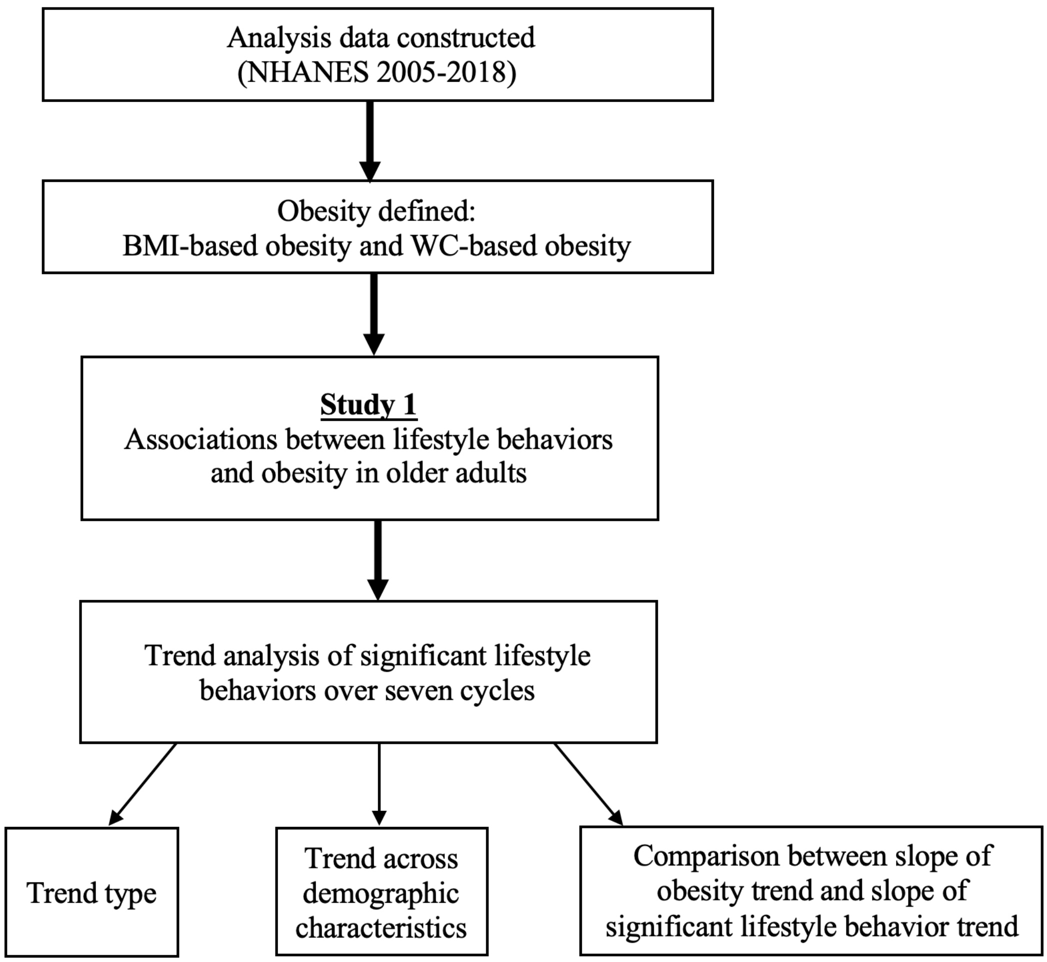

Figure 2.1. Research steps in Study 1

2008, 2009-2010, 2011-2012, 2013-2014, 2015-2016, and 2017-2018, were pooled together for association analysis and trend analysis. The total number of subjects were 9,702. The subjects who answered “do not know”, refused to answer questions, or have missing data on any of the key variables used in this study were excluded from the sample. This resulted in a sample of 5,812 for the BMI-based obesity analysis, and a sample of 5,655 for the WC-based obesity analysis.

2.2.3 Variables

2.2.3.1 Obesity (BMI and WC)

BMI (kg/m^2) and WC (cm) were obtained from the Body Measures file in Examination Data. Although a new body of research encouraged the use of additional measures for the assessment of obesity in older adults, BMI and WC were chosen as obesity standards in this study due to the unavailability of DXA measures in the NHANES data cycles being used. This is appropriate given these were the acceptable measures during the retrospective cycles that were included in this trend analysis. As noted previously, although there are new measures being evaluated which may can be used for future analysis with future NHANES waves, for retrospective trend analysis, BMI and WC are appropriate variables to use and can contribute new knowledge until newer measures can be integrated into the NHANES assessment for older adults. It should be noted that DXA for older adults was not available during the retrospective cycles this study used and has not yet been collected consistently in older adults.

A dichotomous variable of BMI-based obesity was defined with 1 if BMI ≥ 30 (kg/m^2) and 0 otherwise. A dichotomous variable of WC-based obesity was defined with 1 if WC $\geq$ 102cm and 0 if otherwise for men; 1 if WC $\geq$ 88cm and 0 if otherwise for women. Because BMI and WC yield different obesity measures, association analysis were conducted separately for the BMI-based obesity variable and the WC-based obesity variable.

Table 2.2. Sources of lifestyle behavior variables

Lifestyle behavior	NHANES File Name
energy	Dietary Interview – Total Nutrient Intakes 1st & 2nd Day
carbohydrate	Dietary Interview – Total Nutrient Intakes 1st & 2nd Day
sugar	Dietary Interview – Total Nutrient Intakes 1st & 2nd Day
fiber	Dietary Interview – Total Nutrient Intakes 1st & 2nd Day
SFA	Dietary Interview – Total Nutrient Intakes 1st & 2nd Day
protein	Dietary Interview – Total Nutrient Intakes 1st & 2nd Day
FAFH	Questionnaire - Diet Behavior & Nutrition
PA	Questionnaire - Physical Activity
alcohol	Dietary Interview – Total Nutrient Intakes 1st & 2nd Day
smoking	Laboratory Data - Cotinine-Serum, Cotinine-Serum & Total NNAL-Urine, Cotinine and Hydroxycotinine-Serum
sleep habits	Questionnaire - Sleep Disorders; Mental Health - Depression Screener
Intentional weight loss	Questionnaire - Weight History

2.2.3.2 Lifestyle behavior variables

The specific NHANES files from which lifestyle behavior variables were extracted are listed in Table 2.2.

Dietary consumption behavior (nutrient data) Daily intake amounts of energy, carbohydrate, total sugar, dietary fiber, total saturated fatty acids, protein, and alcohol were obtained from the NHANES dataset. Because dietary intakes were collected for two days for each individual, a daily amount was calculated by averaging the values of the first-day and second-day data. For the individuals with only first-day dietary data (0.9% of total data), first -day data was used. Through the test of collinearity (VIF: variance inflation factor), values of VIF in energy intake and carbohydrate intake were more than 10, which means collinearity exists. So, the variables of energy intake and carbohydrate intake were dropped. The units of total sugar intake, protein intake, dietary fiber intake, and saturated fatty acids intake were grams.

Dietary consumption behavior (FAFH) Frequencies of FAFH were obtained based on the dietary behavior questionnaires using the questions "During the past 7 days, how many meals did you get that were prepared away from home in places such as restaurants, fast food places, food stands, grocery stores, or from vending machines?" Respondents were instructed not to include meals provided as part of the community programs. The range of answers was from 0 to 21.

Intensities of physical activity The Physical Activity file of the NHANES questionnaire data included questions on whether or not the respondent engaged in moderate and vigorous physical activities in their leisure time. The questionnaire described the vigorous activity as "sports, fitness, or recreational activities that cause heavy sweating or large increases in breathing or heart rate." In the 2005-2006 cycle, running, lap swimming, aerobics class or fast bicycling were given as examples, while in the 2017-2018, running or basketball were the examples. The moderate activity was described as "sports, fitness, or recreational activities that cause a small increase in breathing or heart rate." Examples provided in the 2005-2006 cycle were brisk walking, bicycling for pleasure, golf, and dancing, while in the 2017-2018, brisk walking, bicycling, swimming, or volleyball were given as examples. The exact questions were phrased as "Over the past 30 days, did you do [. . .] activities for at least 10 minutes [. . .]?" (2005-2006) and "In a typical week, do you do [. . .] activities for at least 10 minutes [. . .]?" (2017-2018). For each of the questions for moderate and vigorous-intensity activities, respondents provided "yes" or "no" answers. In this analysis, four categories of intensity were created based on those two questions: moderate-intensity if the answer of moderate-intensity PA question was "Yes" but the answer of vigorous-intensity PA question was "No"; vigorous-intensity if the answer of vigorous-intensity PA question was "Yes" but the answer of moderate-intensity PA question was “No”; moderate combined with vigorous-intensity if both answers were “Yes”; low-intensity or none if the answer was “No” in both questions. In the regression, compared to vigorous-intensity PA, moderate-intensity PA, and moderate combined with vigorous-intensity PA groups, group of low-intensity or none PA was set as the reference group.

Alcohol consumption behavior Alcohol status was defined using the average value of two-day Dietary Intake data of NHANES. Respondents were categorized on the basis of alcohol intake (g/day) into three levels including none/light, moderate, and heavy, based on Maher et al. (2013). None/light alcohol intake was defined as alcohol intake $< 28g/day$ for men and $< 14g/day$ for women. A moderate alcohol intake was defined as alcohol intake between 28 and 56 g/day for men, and between 14 and 28 g/day for women. A heavy alcohol intake was defined as alcohol intake $\geq$ 56 g/day for men, and $\geq$ 28 g/day for women. In the regression, the none/ light alcohol group was set as the reference group compared to the moderate/ heavy alcohol group.

Smoking status Smoking status was categorized based on serum-cotinine levels (ng/mL) into four levels following the literature (Maher et al., 2013). Compared to the self-report measures in the Cigarette Use questionnaire of NHANES, using biomarkers such as the level of serum-cotinine provided a more objective measure. In addition, serum-cotinine levels can reflect second-smoking which might be a lifestyle factor.

A non-smoker was defined as serum-cotinine levels $< 0.1ng/mL$. A light smoker was defined as serum-cotinine levels between 0.1 and 1 ng/mL. A moderate smoker was defined as serum-cotinine levels between 1 and 3 ng/mL. A heavy smoker was defined as serum-cotinine levels $\geq$ 3 ng/mL. The non-smoker was set as the reference group compared to light, moderate, and heavy smokers.

Sleep patterns Two variables representing the sleep patterns were created based on the NHANES Sleep Disorder questionnaire file. Sleep duration was "how much sleep do you get (hours/day)", and units were hours. Sleep quality was defined based on the questionnaire item (sleep problems), "Trouble sleeping or sleeping too much over the last two weeks". Answers were a choice from "not at all", "several days", "more than half the days", and "nearly every day". In regressions, the reference group was the "not at all" group.

Intentional weight loss The question in intentional weight loss was "During the past 12 months, have you tried to lose weight?". Answers were "Yes" and "No". The answer of "No" (Did not try to lose weight) was set as the reference group in regressions.

2.2.3.3 Demographic characteristics

The participants' demographic characteristics were obtained from the Demographic Variables & Sample Weights file.

Gender In regressions, women were set as the reference group.

Age The "Age in years at screening" were used for analysis. The range of age was from 65 to 80 years old, as the NHANES top-codes the age at 80. Dichotomous variables representing four categories of age were created: 65-69 years old, 70-74 years old, 75-79 years old, and 80 years old and over. The reference group in regression models is 65-69 years old.

Ethnicity Dichotomous variables indicating Non-Hispanic White, Mexican Americans, other Hispanic, Non-Hispanic Black, and other race were used. In regressions, non-Hispanic White was set as the reference category.

Education level The demographic questionnaire of NHANES included a question "What is the highest grade or level of school completed or the highest degree received". Five dichotomous variables were created indicating less than 9^{th} grade, $9 - 11^{th}$ grade, high school, some college or associate (AA) degree, and college graduate or above. In regressions, less than 9^{th} grade was used as the reference category.

Marital status Marital status was combined into four categories: never married, married or living with a partner, widowed, and divorced or separated. The reference group in regression models was married or living with a partner.

Annual family income Dichotomous variables representing six categories of annual family income (gross) were created: under $20,000, $20,000-34,999, $35,000-44,999, $45,000-54,999, $55,000-64,999 and $65,000 and over. The reference group in regression models was the under $20,000 group.

2.2.4 Statistical analyses

All analyses were weighted using the multi-year survey weights and conducted using Stata software (Version 15.1, StataCorp, LP). The multi-year sample weight was computed by dividing the two-year sample weights by the number of two-year cycles, following the formulas are provided in the website of the CDC (https://wwwn.cdc.gov/nchs/nhanes/tutorials/module3.aspx). We computed a multivariable logistic regression analysis, with the outcome being obese (vs. not) defined by two alternate anthropometric measures (BMI and WC) and independent variables were lifestyle behaviors, including total sugar intake, dietary fiber intake, saturated fatty acids intake, protein intake, FAFH, PA, alcohol intake, smoking, sleep duration and quality, and intentional weight loss. In this logistic regression, covariates included age, gender, ethnicity, education level, marital status, and annual family income. Separate analyses were computed for the 11 aforementioned lifestyle behaviors in both BMI-based obesity and WC-based obesity. Among the lifestyle behaviors that were statistically significantly ($p < 0.05$) associated with obesity, subsequent trend analyses for these lifestyle behaviors were computed.

Tests for secular trends of significant lifestyle behaviors across seven cycles were evaluated using linear, quadratic, cubic, quartic, quintic, and sextic orthogonal polynomial coefficients in a regression analysis. Second, trends of significant lifestyle behaviors were conducted across statistically significant ($p < 0.05$) demographic characteristics over seven cycles. Finally, Student's t-test was used for comparing the slope of the obesity trend with the slope of each statistically significant lifestyle behavior trend. Calculation of this t-value had been detailed by Estevez-Perez et al. (2014). In brief, we first developed two regression lines for the obesity trend and the trend of significant lifestyle behavior, then calculated residual variances (squared standard errors of two regressions) to estimate the variances of two regressions, and then compared the F value of experimental t-test and the F value of the tabulated one. If the F value of the experimental t-test was less than the F value of the tabulated one ($p > 0.05$), the null cannot be rejected. If, however, the F value of experimental t-test was greater than the F value of the tabulated one ($p < 0.05$), the null was rejected, and thus, the two slopes were considered to be statistically significantly different. An alpha level of 0.05 was set to determine statistical significance.

2.3 RESULTS

2.3.1 Associations between lifestyle behaviors and obesity among older adults

Table 2.3 presents the characteristics of the sample in both BMI-based and WC-based obesity. A total of 5,812 subjects were included if obesity was defined by BMI, and 5,655 subjects were included if obesity was defined by WC. Associations between lifestyle behaviors and obesity among older adults from the NHANES 2005-2018 were listed in Table 2.5 2.6 for BMI-based obesity and in Table 2.7 2.8 for WC-based obesity. Demographic variables were included in logistic regression as covariates. As noted, among older adults, total sugar intake, protein intake, FAFH, intensities of PA, alcohol, smoking, sleep problem, and intentional weight loss were lifestyle behaviors significantly related with BMI-based obesity ($p < 0.05$). Dietary fiber intake, intensities of PA, smoking, and intentional weight loss were lifestyle behaviors significantly related with WC-based obesity ($p < 0.05$).

Specially, in BMI-based obesity, the total intake of sugar, PA intensities (vigorous PA, moderate PA, and vigorous and moderate PA), moderate alcohol, and heavy smoking were associated with a reduced risk of obesity. The intake of protein, FAFH, trouble sleeping nearly every day, and intentional weight loss were associated with an increased risk for obesity among older adults. In the WC-based obesity, the intake of dietary fiber, PA intensities (vigorous PA, moderate PA, and vigorous combined moderate PA), and heavy smoking were associated with a reduced risk of obesity. Intentional weight loss was associated with an increased risk of obesity among older adults.

2.3.2 Trend analysis for significant variables of lifestyle behaviors in BMI-based and WC-based obesity

2.3.2.1 Trend of each significant lifestyle behavior

Table 2.9 presents trends of significant lifestyle behaviors over 7 two-year cycles (2005-2018), including total sugar intake, protein intake, FAFH, intensity of PA (vigorous, moderate, vigorous and moderate), alcohol (moderate), smoking (heavy), sleep problem (nearly every day), and intentional weight loss (yes) in BMI-based obesity. There were a quartic trends for total sugar intake and FAFH from 2005-2006 to 2017-2018 (Figure 2.2, 2.3). The trends of protein intake and alcohol (moderate) were cubic (Figure 2.4, 2.5). In the intensities of PA, the trends were quadratic, cubic, and cubic for vigorous PA, moderate PA, and vigorous combined moderate PA, separately (Figure 2.6-2.8). The trend of intentional weight loss is quadratic (Figure 2.9). There were no trends for smoking (heavy) and sleep problem (nearly every day).

In WC-based obesity, Table 2.10 presents trends of significant lifestyle behaviors over 7 two-year cycles (2005-2018). Trends of three intensities of PA and intentional weight loss in WC-based obesity were same as that in BMI-based obesity (Figure 2.10-2.13). There were no trends for dietary fiber intake and smoking (heavy).

Table 2.3. Characteristics of the sample in BMI-based and WC-based obesity (mean $\pm SD$)

Characteristics		Descriptive Statistics	
		BMI-based	WC-based
Lifestyle Behavior			
Total sugar		94.32 ± 0.89	94.31 ± 0.89
Dietary fiber		16.19 ± 0.15	16.26 ± 0.15
Saturated fatty acids		22.65 ± 0.21	22.75 ± 0.22
Protein		135.26 ± 1.14	135.86 ± 1.15
FAFH		2.52 ± 0.07	2.54 ± 0.07
PA (%)	low/none	54.29% ± 0.01	53.58% ± 0.01
	vigorous	2.59% ± 0.00	2.67% ± 0.00
	moderate	35.44% ± 0.01	35.86% ± 0.01
	vigorous & moderate	7.68% ± 0.01	7.89% ± 0.01
Alcohol (%)	none/light	88.50% ± 0.01	88.38% ± 0.01
	moderate	7.42% ± 0.01	7.53% ± 0.01
	heavy	4.08% ± 0.00	4.09% ± 0.00
Smoking (%)	non-smoker	78.09% ± 0.01	77.99% ± 0.01
	light	8.19% ± 0.01	8.21% ± 0.01
	moderate	1.12% ± 0.00	1.15% ± 0.00
	heavy	12.60% ± 0.01	12.65% ± 0.01
Sleep duration		7.51 ± 0.03	7.51 ± 0.03
sleep problem (%)	not at all	65.16% ± 0.01	65.24% ± 0.01
	several days	20.06% ± 0.01	20.05% ± 0.01
	more than half the day	6.50% ± 0.00	6.54% ± 0.00
	nearly every day	8.27% ± 0.00	8.17% ± 0.00
Intentional weight loss (%)	No	67.58% ± 0.01	67.16% ± 0.01
	Yes	32.42% ± 0.01	32.83% ± 0.01
Demographics			
Age (%)	65-69	33.54% ± 0.01	34.19% ± 0.01
	70-74	26.35% ± 0.01	26.65% ± 0.01
	75-79	17.59% ± 0.01	17.55% ± 0.01
	80 and over	22.52% ± 0.01	21.61% ± 0.01
Gender (%)	female	56.46% ± 0.01	56.26% ± 0.01
	male	43.54% ± 0.01	43.74% ± 0.01
Ethnicity (%)	Non-Hispanic White	82.69% ± 0.01	82.64% ± 0.01
	Mexican American	3.18% ± 0.00	3.21% ± 0.00
	other Hispanic	2.99% ± 0.00	3.02% ± 0.00
	other race	4.19% ± 0.00	4.20% ± 0.00
	Non-Hispanic Black	6.95% ± 0.01	6.94% ± 0.01

Table 2.4. Characteristics of the sample in BMI-based and WC-based obesity (mean $\pm SD$) (continued)

Characteristics		Descriptive Statistics	
		BMI-based	WC-based
Education level (%)	less than 9th	8.30% ± 0.01	8.19% ± 0.01
	9-11 grade	11.51% ± 0.01	11.47% ± 0.01
	high school graduate	25.93% ± 0.01	26.15% ± 0.01
	some college or AA degree	27.38% ± 0.01	27.29% ± 0.01
	college graduate above	26.88% ± 0.01	26.90% ± 0.01
Marital status (%)	married & living with partner	62.44% ± 0.01	62.92% ± 0.01
	divorced & separated	12.10% ± 0.01	12.10% ± 0.01
	widowed	22.68% ± 0.01	22.13% ± 0.01
	never married	2.78% ± 0.00	2.86% ± 0.00
Annual family income (%)	under 20,000	18.68% ± 0.01	18.20% ± 0.01
	20,000 – 34,999	22.05% ± 0.01	22.13% ± 0.01
	35,000 – 44,999	11.85% ± 0.01	11.83% ± 0.01
	45,000 – 54,999	9.50% ± 0.01	9.75% ± 0.01
	55,000 – 64,999	5.40% ± 0.00	5.45% ± 0.00
	65,000 and over	29.00% ± 0.02	29.10% ± 0.02
	20,000 and over	3.52% ± 0.00	3.52% ± 0.00

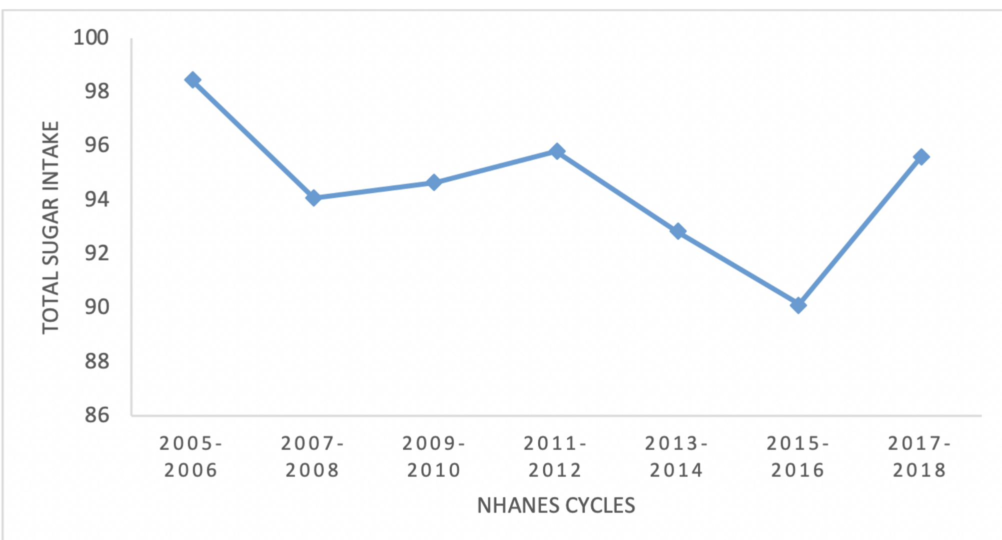

Figure 2.2. A quartic trend for total sugar in BMI-based obesity

Table 2.5. Associations between lifestyle behaviors and obesity among older adults in BMI-based obesity

NHANES 2005-2018		OR	SE	t	$P > \|t\|$	95%CI	
Lifestyle Behavior							
Total sugar		0.97	0.00	-2.98	0.00*	0.95	0.99
Dietary fiber		0.96	0.01	-0.72	0.47	0.84	1.08
Saturated fatty acids		1.10	0.01	1.61	0.11	0.98	1.23
Protein		1.02	0.00	2.03	0.05*	1.00	1.05
FAFH		1.04	0.02	2.50	0.01*	1.01	1.08
PA	low/none (reference)						
	vigorous	0.52	0.14	-2.42	0.02*	0.31	0.89
	moderate	0.53	0.05	-6.71	0.00*	0.44	0.64
	vigorous & moderate	0.22	0.05	-6.96	0.00*	0.15	0.34
Alcohol	none/light (reference)						
	moderate	0.65	0.10	-2.69	0.01*	0.48	0.89
	heavy	0.66	0.15	-1.77	0.08	0.42	1.05
Smoking	non-smoker (reference)						
	light	0.92	0.12	-0.68	0.50	0.72	1.18
	moderate	0.82	0.24	-0.68	0.50	0.46	1.46
	heavy	0.52	0.06	-5.30	0.00*	0.41	0.66
Sleep duration		1.04	0.03	1.41	0.16	0.99	1.09
sleep problem	not at all (reference)						
	several days	0.90	0.09	-1.10	0.27	0.74	1.09
	more than half the day	1.16	0.20	0.86	0.39	0.82	1.64
	nearly every day	1.41	0.24	2.03	0.05*	1.01	1.96
Intentional weight loss	No (reference)						
	Yes	3.56	0.32	14.05	0.00*	2.98	4.26
Demographics							
Age	65-69 (reference)						
	70-74	1.02	0.11	0.18	0.86	0.82	1.28
	75-79	0.90	0.12	-0.80	0.43	0.69	1.17
	80 and over	0.53	0.07	-4.98	0.00*	0.41	0.68

Table 2.6. Associations between lifestyle behaviors and obesity among older adults in BMI-based obesity (continued)

NHANES 2005-2018		OR	SE	t	$P > \|t\|$	95%CI	
Gender	female (reference)						
	male	1.14	0.11	1.39	0.17	0.95	1.37
Ethnicity	Non-Hispanic White (reference)						
	Mexican American	0.97	0.11	-0.26	0.80	0.78	1.21
	other Hispanic	0.83	0.11	-1.40	0.16	0.63	1.08
	other race	0.46	0.08	-4.39	0.00*	0.32	0.65
	Non-Hispanic Black	1.74	0.17	5.56	0.00*	1.43	2.12
Education level	less than 9th (reference)						
	college graduate or above	0.69	0.12	-2.16	0.03*	0.49	0.97
	9-11 grade	1.04	0.16	0.29	0.77	0.78	1.40
	high school	0.93	0.12	-0.53	0.60	0.72	1.21
	some college or AA degree	0.95	0.11	-0.47	0.64	0.75	1.19
Marital status	married & living with partner (reference)						
	divorced & separated	1.16	0.15	1.09	0.28	0.89	1.50
	widowed	1.16	0.13	1.31	0.19	0.93	1.44
	never married	1.11	0.25	0.44	0.66	0.70	1.74
Annual family income	under 20,000 (reference)						
	20,000 – 34,999	0.81	0.10	-1.75	0.08	0.63	1.03
	35,000 – 44,999	0.81	0.12	-1.41	0.16	0.61	1.09
	45,000 – 54,999	0.76	0.13	-1.55	0.12	0.53	1.08
	55,000 – 64,999	0.95	0.22	-0.23	0.82	0.60	1.51
	65,000 and over	0.81	0.12	-1.45	0.15	0.60	1.08
	20,000 and over	0.74	0.19	-1.18	0.24	0.44	1.23

Table 2.7. Associations between lifestyle behaviors and obesity among older adults in WC-based obesity

NHANES 2005-2018		OR	SE	t	$P > \|t\|$	95%CI	
Lifestyle Behavior							
Total sugar		0.98	0.00	-1.96	0.052	0.96	1.00
Dietary fiber		0.85	0.01	-2.34	0.02*	0.74	0.98
Saturated fatty acids		1.11	0.01	1.79	0.08	0.99	1.24
Protein		1.01	0.00	0.50	0.62	0.98	1.03
FAFH		1.03	0.02	1.66	0.10	1.00	1.06
PA	low/none (reference)						
	vigorous	0.39	0.10	-3.79	0.00*	0.23	0.63
	moderate	0.56	0.05	-6.30	0.00*	0.46	0.67
	vigorous & moderate	0.34	0.06	-6.01	0.00*	0.24	0.49
Alcohol	none/light (reference)						
	moderate	0.75	0.13	-1.70	0.09	0.54	1.05
	heavy	0.88	0.18	-0.62	0.54	0.58	1.33
Smoking	non-smoker (reference)						
	light	0.95	0.14	-0.35	0.72	0.71	1.27
	moderate	0.86	0.24	-0.53	0.60	0.49	1.51
	heavy	0.62	0.08	-3.50	0.00*	0.48	0.81
Sleep duration		1.02	0.03	0.71	0.48	0.96	1.08
sleep problem	not at all (reference)						
	several days	0.92	0.09	-0.84	0.41	0.75	1.13
	more than half the day	0.93	0.16	-0.40	0.69	0.67	1.31
	nearly every day	1.15	0.17	0.97	0.33	0.86	1.54
Intentional weight loss	No (reference)						
	Yes	4.29	0.47	13.35	0.00*	3.46	5.33
Demographics							
Age	65-69 (reference)						
	70-74	1.29	0.15	2.24	0.03*	1.03	1.62
	75-79	1.16	0.17	1.02	0.31	0.87	1.54
	80 and over	0.78	0.09	-2.07	0.04*	0.61	0.99

Table 2.8. Associations between lifestyle behaviors and obesity among older adults in WC-based obesity (continued)

NHANES 2005-2018		OR	SE	t	$P > \|t\|$	95%CI	
Gender	female (reference)						
	male	0.59	0.05	-6.03	0.00*	0.50	0.71
Ethnicity	Non-Hispanic White (reference)						
	Mexican American	1.05	0.14	0.35	0.73	0.81	1.36
	other Hispanic	0.71	0.09	-2.70	0.01*	0.55	0.91
	other race	0.37	0.07	-5.43	0.00*	0.25	0.53
	Non-Hispanic Black	0.90	0.10	-1.02	0.31	0.72	1.11
Education level	less than 9th (reference)						
	college graduate or above	0.91	0.15	-0.57	0.57	0.66	1.26
	9-11 grade	1.17	0.17	1.09	0.28	0.88	1.55
	high school	1.09	0.13	0.69	0.49	0.85	1.39
	some college or AA degree	0.98	0.13	-0.15	0.88	0.76	1.26
Marital status	married & living with partner (reference)						
	divorced & separated	1.05	0.16	0.32	0.75	0.78	1.42
	widowed	1.25	0.15	1.90	0.06	0.99	1.58
	never married	0.98	0.24	-0.10	0.92	0.61	1.57
Annual family income	under 20,000 (reference)						
	20,000 – 34,999	0.92	0.12	-0.66	0.51	0.71	1.19
	35,000 – 44,999	0.85	0.12	-1.17	0.24	0.65	1.12
	45,000 – 54,999	0.74	0.13	-1.75	0.08	0.53	1.04
	55,000 – 64,999	0.95	0.23	-0.20	0.84	0.60	1.53
	65,000 and over	0.86	0.12	-1.04	0.30	0.65	1.14
	20,000 and over	1.53	0.42	1.54	0.13	0.89	2.65

*statistically significant ($p < 0.05$). The units of total sugar, dietary fiber, saturated fatty acid, and protein are ten grams in order to optimize OR values.

Table 2.9. Weighed descriptive characteristics of significant lifestyle behaviors in BMI-based obesity in 2005-2018 (n = 5,812)

Lifestyle behavior	2005-2006 (n=702)	2007-2008 (n=995)	2009-2010 (n=976)	2011-2012 (n=722)	2013-2014 (n=806)	2015-2016 (n=811)	2017-2018 (n=800)	P-trend linear[a]	P-trend quadratic[b]	P-trend cubic[c]	P-trend quartic[d]	P-trend quintic[e]	P-trend sextic[f]
sugar (g)	98.44	94.09	94.65	95.83	92.84	90.15	95.61	0.00*	0.22	0.11	0.048*	0.51	0.52
protein (g)	132.71	128.01	134.17	138.04	136.77	136.72	138.67	0.89	0.94	0.03*	0.06	0.16	0.31
FAFH	1.93	2.74	2.40	2.48	2.61	2.74	2.61	0.02*	0.26	0.01*	0.01*	0.02*	0.07
PA (vigorous) (%)	3.17	2.25	2.23	1.62	2.38	3.28	3.04	0.75	0.00*	0.13	0.81	0.33	0.32
PA (moderate) (%)	40.44	33.54	33.55	30.62	37.17	35.94	36.78	0.00*	0.00*	0.00*	0.00*	0.15	0.02*
PA (vigorous & moderate) (%)	13.34	3.70	3.55	9.51	6.90	7.76	9.31	0.54	0.00*	0.00*	0.048*	0.90	0.35
alcohol (moderate) (%)	9.09	5.03	6.23	7.93	10.41	6.91	6.40	0.08	0.59	0.00*	0.15	0.87	0.53
smoking (heavy) (%)	14.34	14.57	11.46	12.11	10.19	12.71	13.27	0.16	0.09	0.97	0.58	0.98	0.07
sleep problem (nearly every day) (%)	7.67	9.04	9.16	6.44	7.84	9.09	8.44	0.07	0.29	0.52	0.33	0.67	0.54
intentional weight loss (yes) (%)	33.12	26.70	26.74	30.39	30.76	34.64	42.11	0.00*	0.00*	0.14	0.69	0.93	0.78

a Tests for linear trend were conducted using linear-specific orthogonal polynomial coefficients.
b Tests for quadratic trend were conducted using quadratic-specific orthogonal polynomial coefficients.
c Tests for cubic trend were conducted using cubic-specific orthogonal polynomial coefficients.
d Tests for quartic trend were conducted using quartic-specific orthogonal polynomial coefficients.
e Tests for quintic trend were conducted using quintic-specific orthogonal polynomial coefficients.
f Tests for sextic trend were conducted using sextic-specific orthogonal polynomial coefficients.

Table 2.10. Weighed descriptive characteristics of significant lifestyle behaviors in WC-based obesity in 2005-2018 (n = 5,655)

Lifestyle behavior	2005-2006 (n=697)	2007-2008 (n=979)	2009-2010 (n=959)	2011-2012 (n=696)	2013-2014 (n=774)	2015-2016 (n=765)	2017-2018 (n=785)	P-trend *linear*[a]	P-trend *quadratic*[b]	P-trend *cubic*[c]	P-trend *quartic*[d]	P-trend *quintic*[e]	P-trend *sextic*[f]
dietary fiber	16.07	15.92	16.30	16.57	16.34	16.44	16.12	0.80	0.51	0.11	0.61	0.15	0.80
PA (vigorous)	3.21	2.25	2.26	1.67	2.56	3.45	3.09	0.54	0.00*	0.06	0.77	0.33	0.29
PA (moderate)	41.19	33.92	33.02	31.29	37.59	37.39	36.58	0.00*	0.01*	0.00*	0.00*	0.17	0.05
PA (vigorous & moderate)	13.50	3.77	3.50	9.82	7.07	8.15	9.67	0.79	0.00*	0.00*	0.06	0.93	0.23
smoking (heavy)	13.97	14.80	11.36	12.04	10.66	12.63	13.38	0.18	0.08	0.91	0.57	0.67	0.07
intentional weight loss (yes)	32.55	27.92	26.97	30.27	31.40	35.28	43.00	0.00*	0.00*	0.23	0.96	0.91	0.78

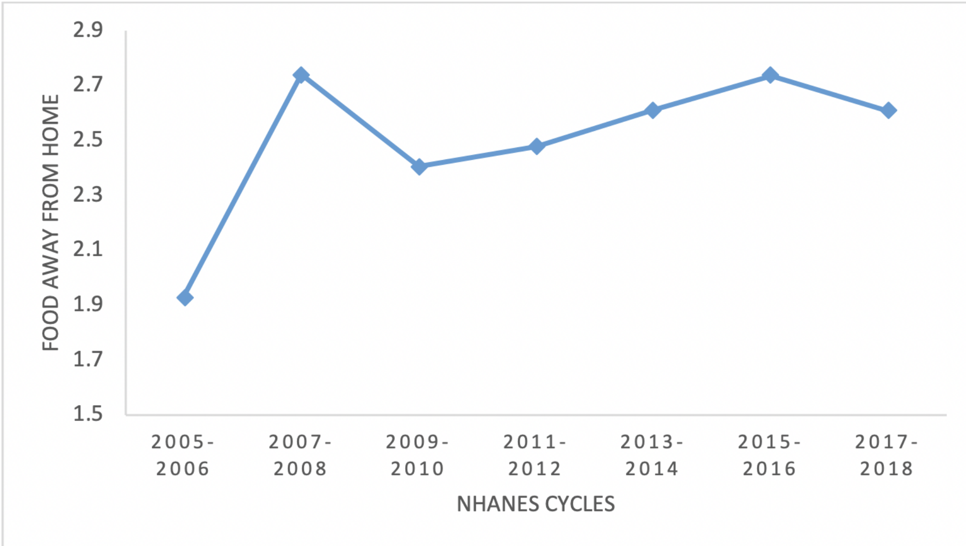

Figure 2.3. A quartic trend for FAFH in BMI-based obesity

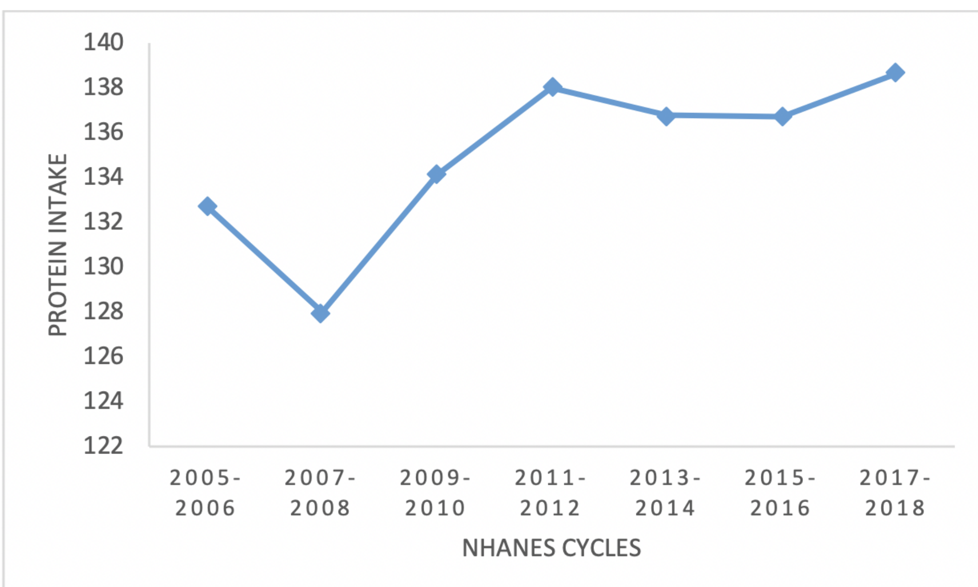

Figure 2.4. A cubic trend for protein intake in BMI-based obesity

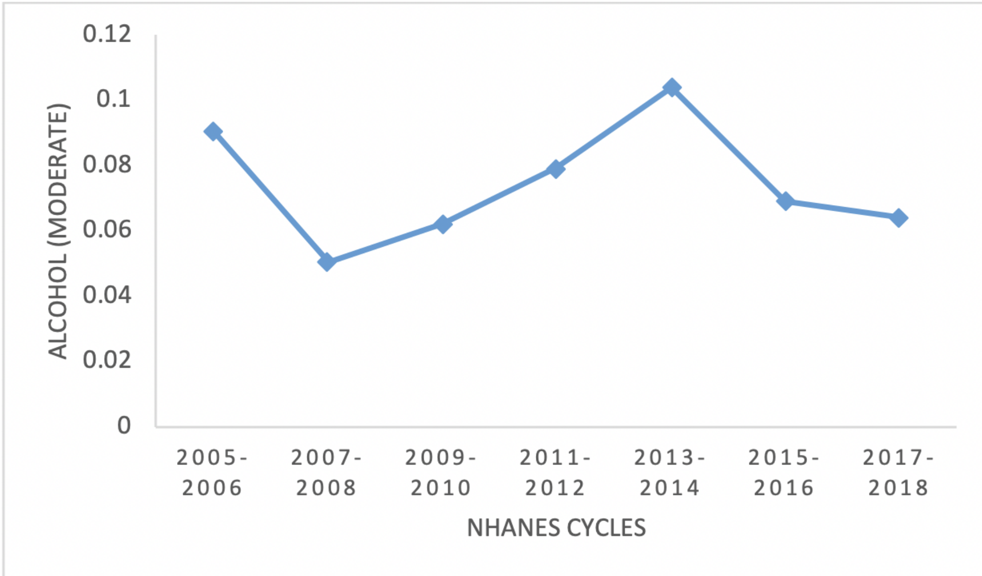

Figure 2.5. A cubic trend for alcohol (moderate) in BMI-based obesity

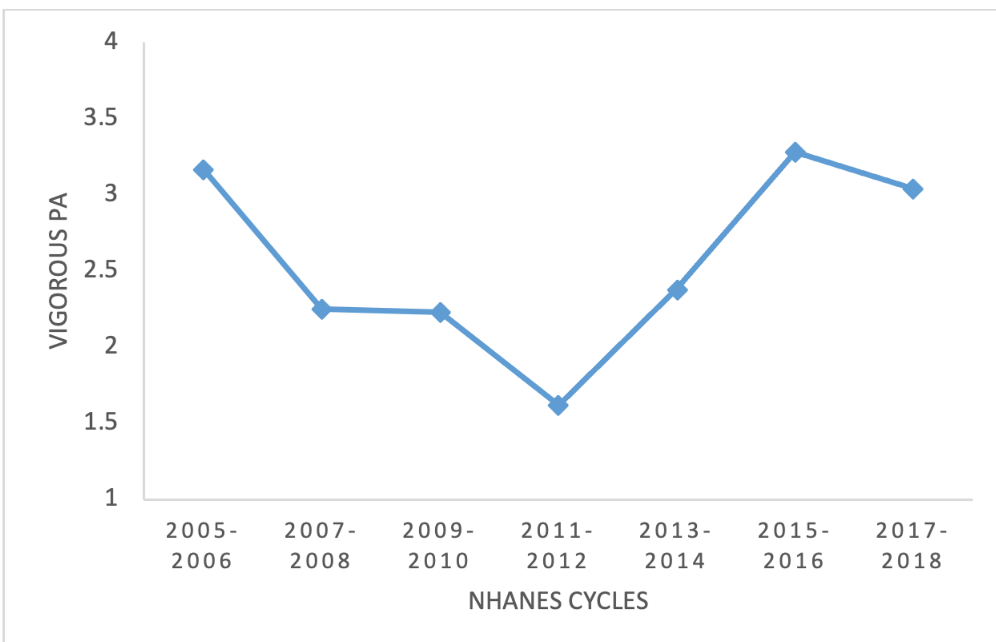

Figure 2.6. A quadratic trend for vigorous PA in BMI-based obesity

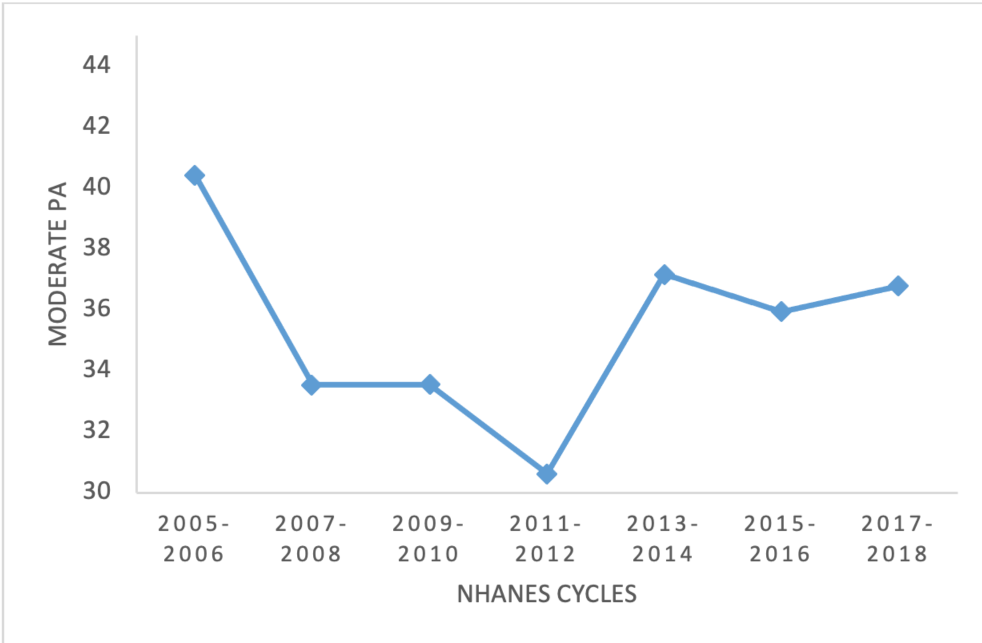

Figure 2.7. A cubic trend for moderate PA in BMI-based obesity

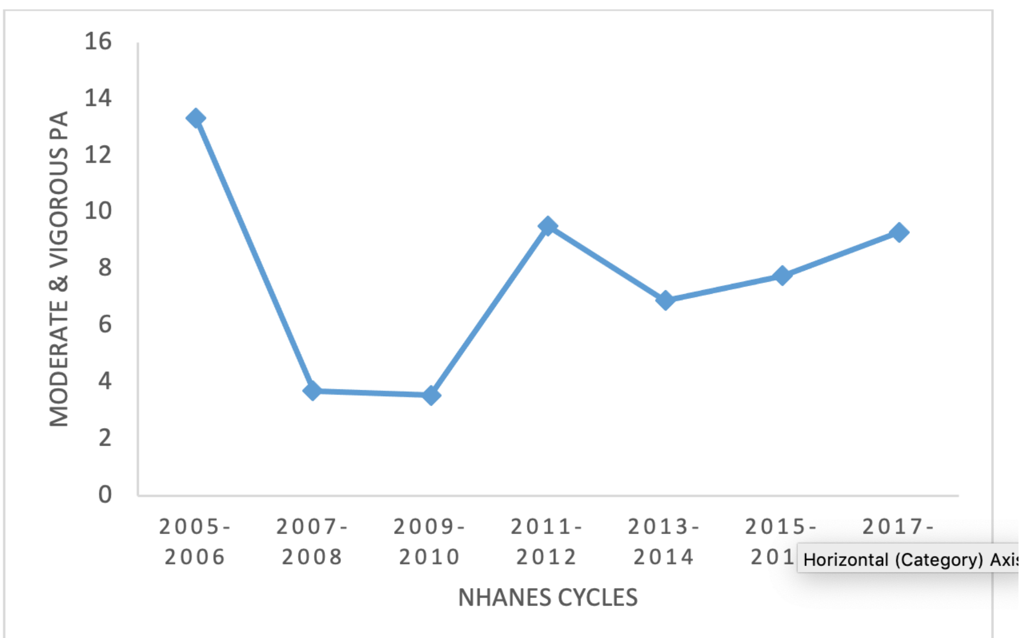

Figure 2.8. A cubic trend for vigorous combined moderate PA in BMI-based obesity

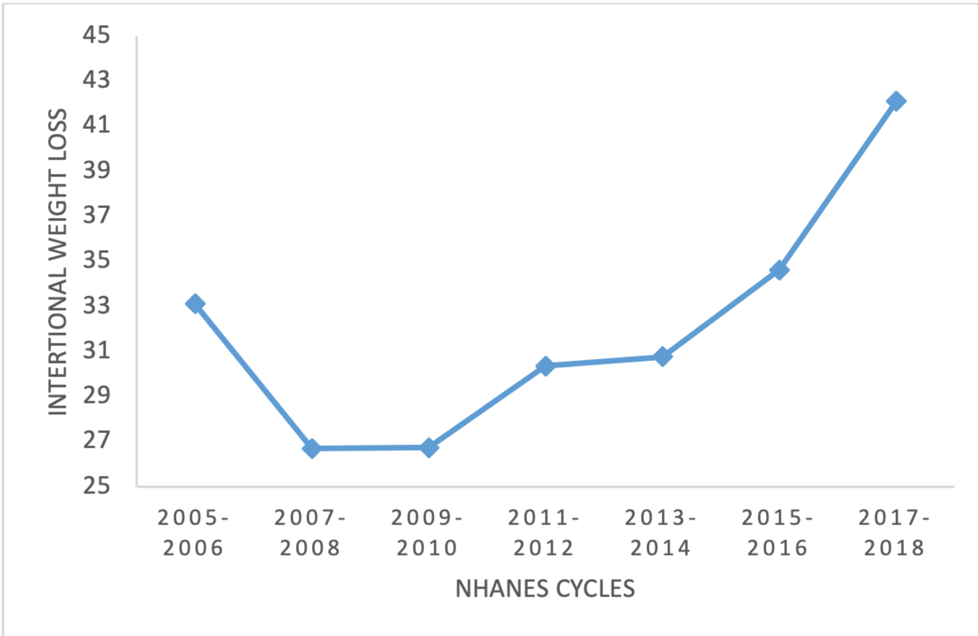

Figure 2.9. A quadratic trend for intentional weight loss in BMI-based obesity

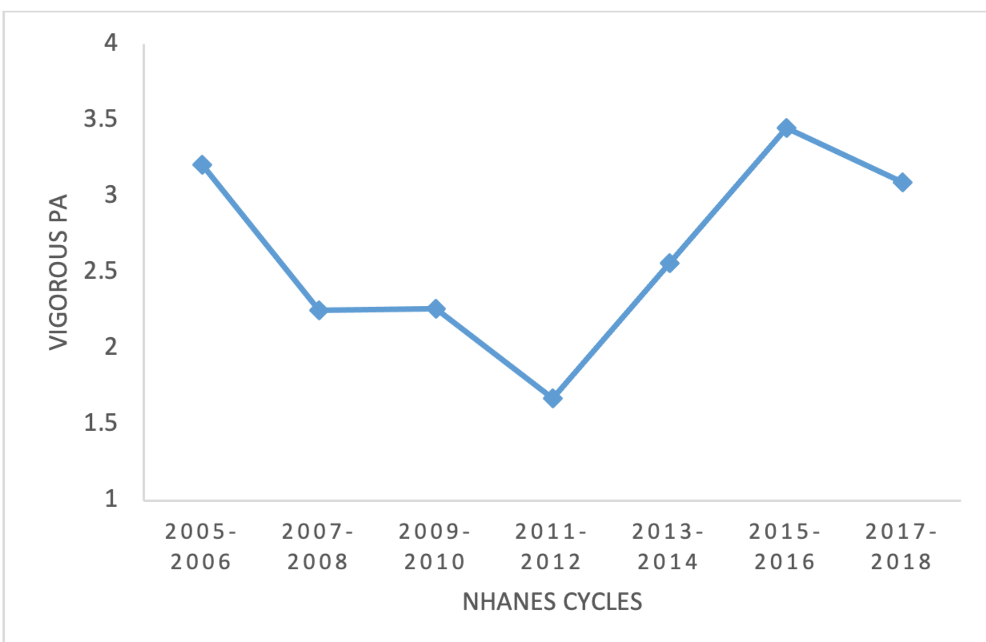

Figure 2.10. A quadratic trend for vigorous PA in WC-based obesity

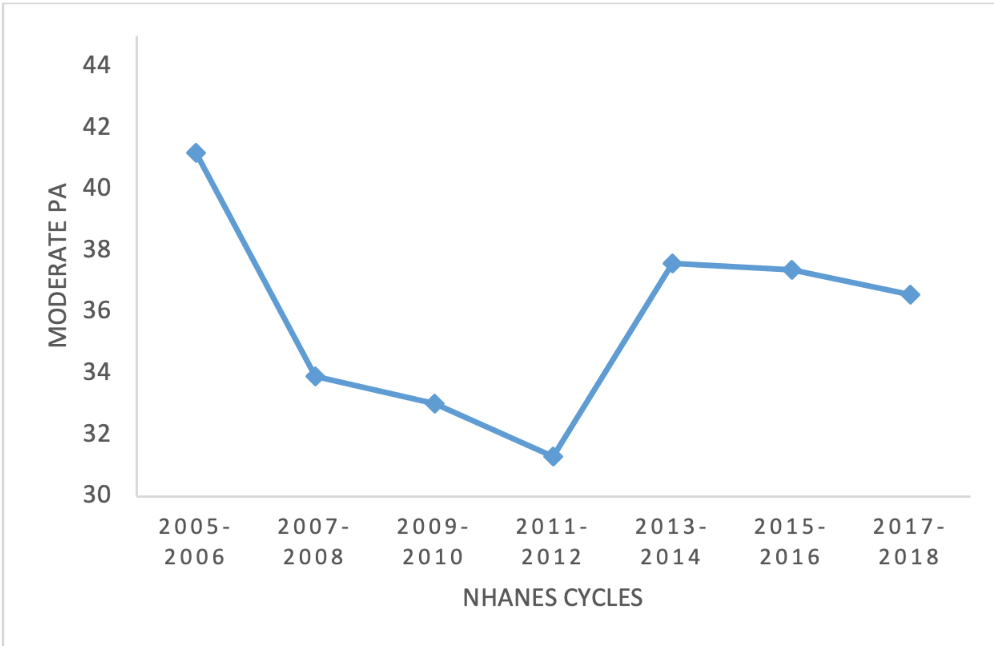

Figure 2.11. A cubic trend for moderate PA in WC-based obesity

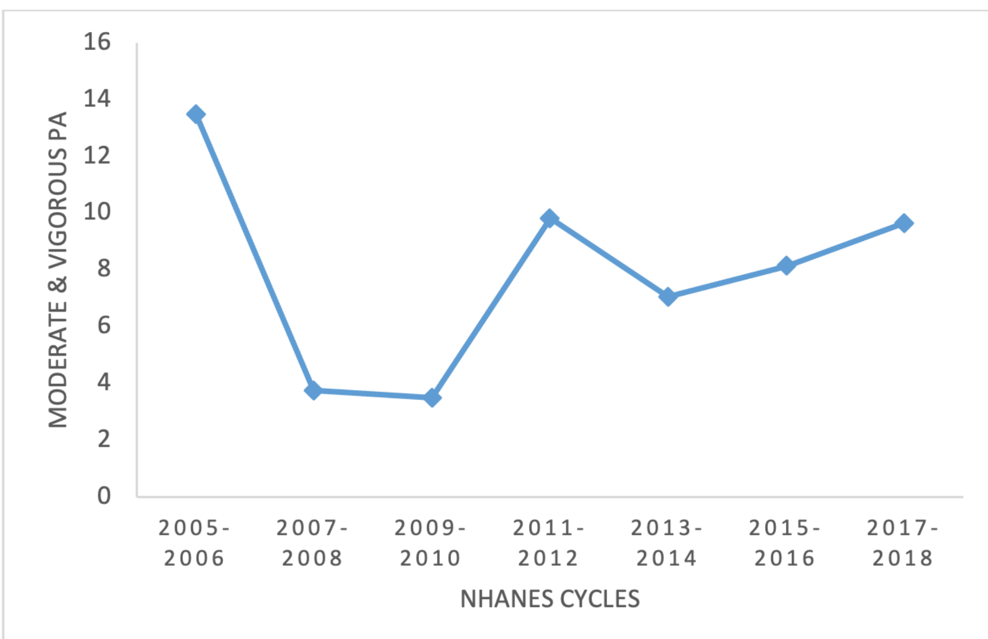

Figure 2.12. A cubic trend for vigorous combined moderate PA in WC-based obesity

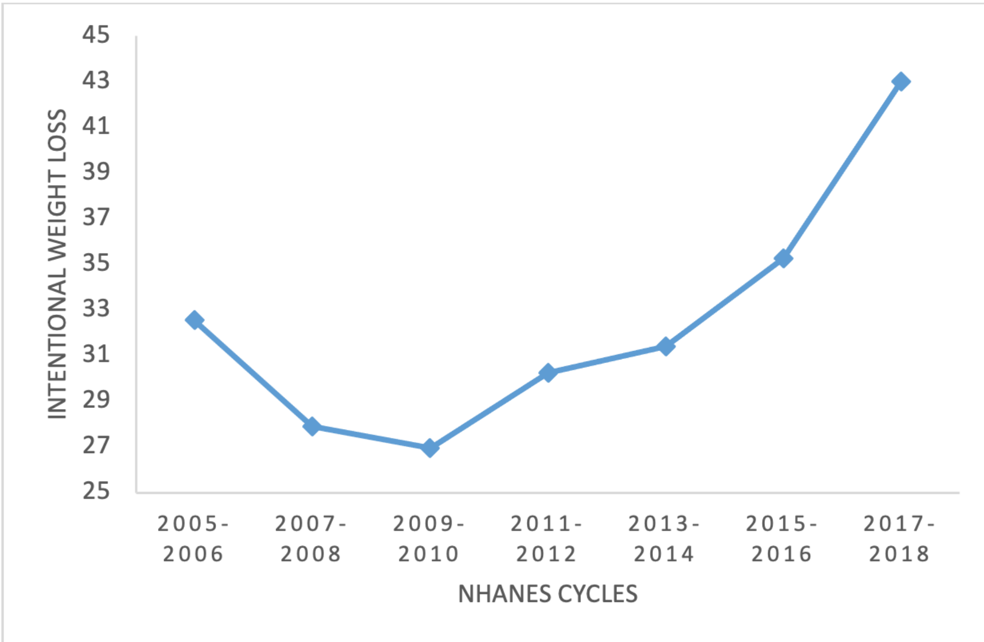

Figure 2.13. A quadratic trend for intentional weight loss in WC-based obesity

2.3.3 Trend of each significant lifestyle behavior across significant demographics

In the analysis of association between lifestyle behaviors and BMI-based obesity, significant demographic factors were age, ethnicity and educational level. Each significant lifestyle behaviors across significant demographics were shown in Figure 2.14-2.43. In the WC-based obesity, significant demographics were age, ethnicity and gender. Each significant lifestyle behaviors across significant demographics were shown in Figure 2.44-2.61.

2.3.4 Comparison between the trend of significant lifestyle behaviors and the trend of obesity among older adults

We hypothesized that there would not be a difference in the slopes between the statistically significant lifestyle behavior and obesity, and thus, a non-significant difference would suggest that perhaps the trend in the lifestyle behavior was what was driving the trend in obesity. Through use of the Student's t-test, in BMI-based obesity, trends of protein intake, FAFH, intensities of PA (vigorous, moderate, and moderate combined vigorous),

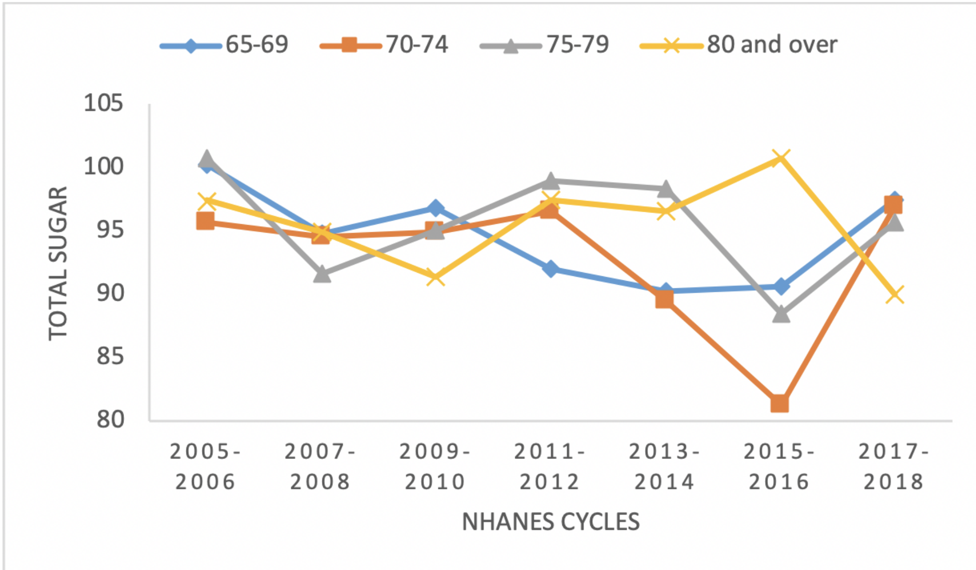

Figure 2.14. Trend of total sugar (g) across age in BMI-based obesity

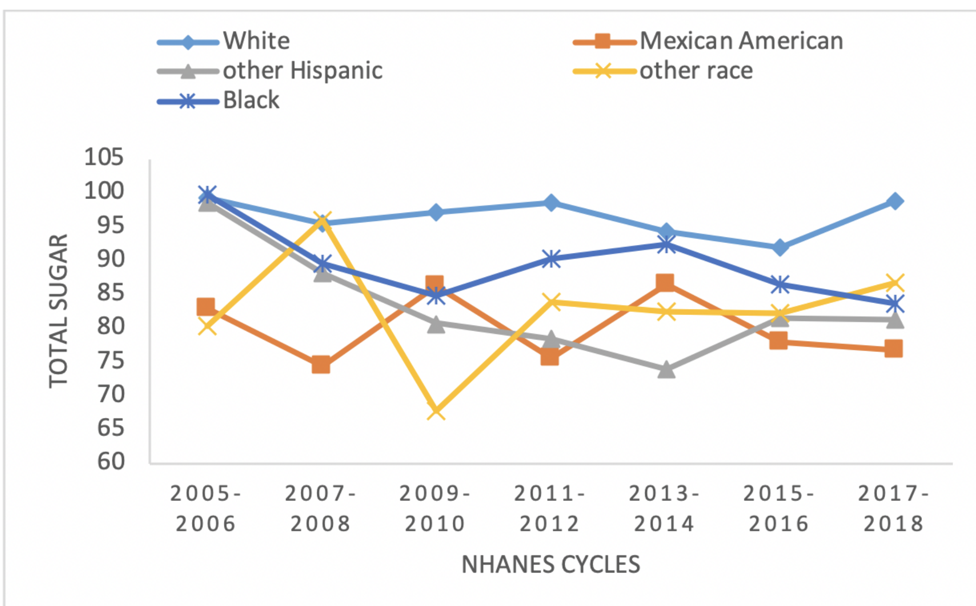

Figure 2.15. Trend of total sugar (g) across ethnicity in BMI-based obesity

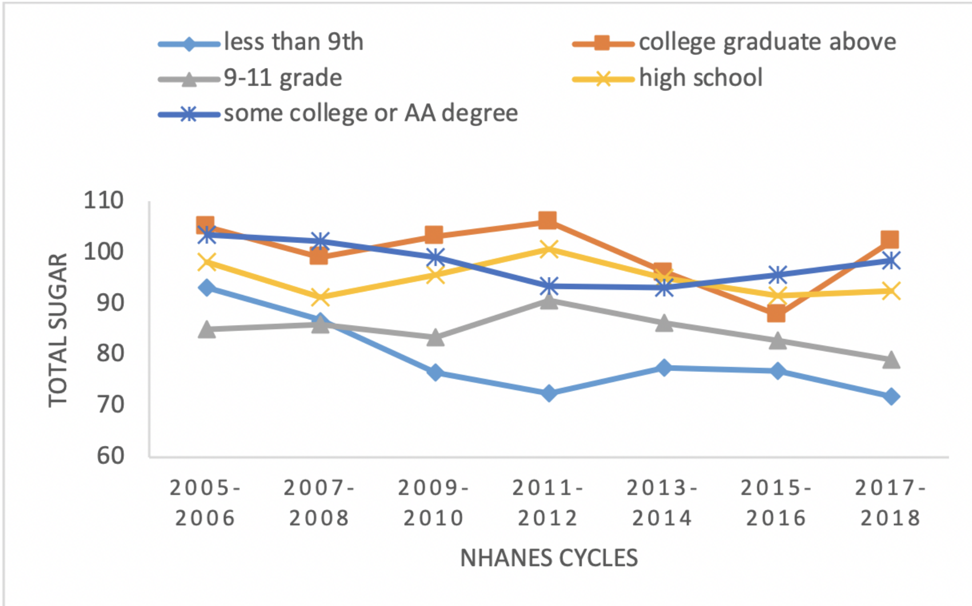

Figure 2.16. Trend of total sugar (g) across education level in BMI-based obesity

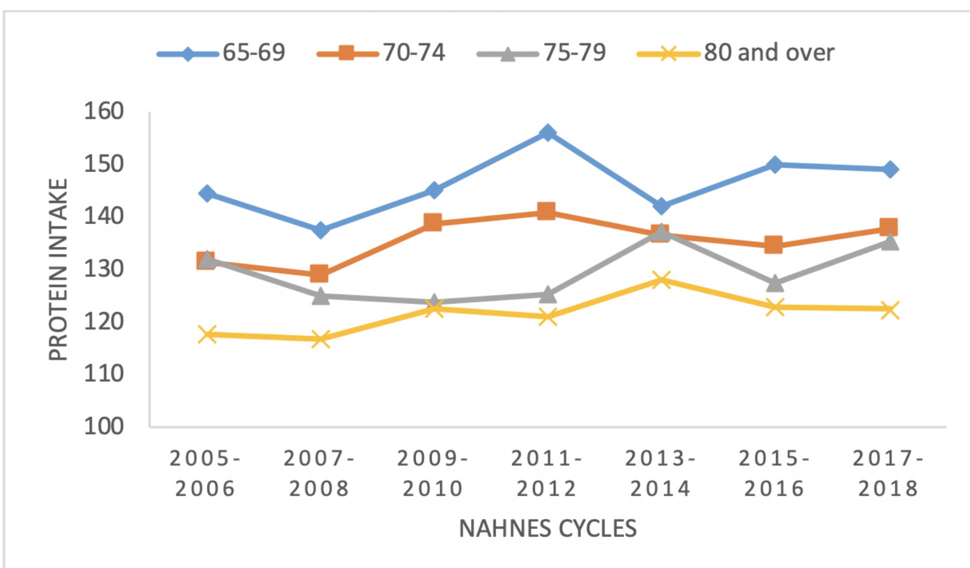

Figure 2.17. Trend of protein (g) across age in BMI-based obesity

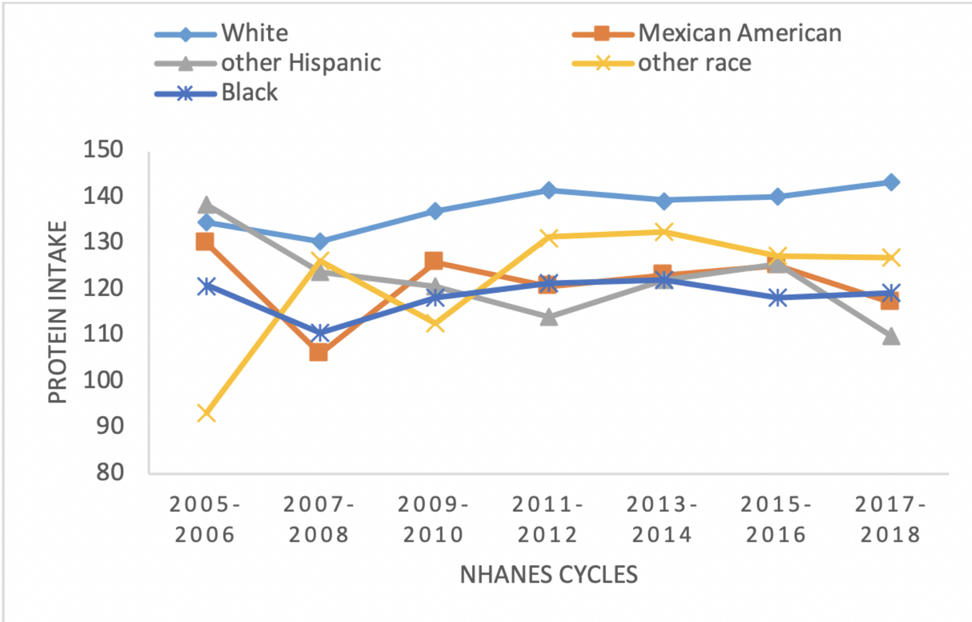

Figure 2.18. Trend of protein (g) across ethnicity in BMI-based obesity

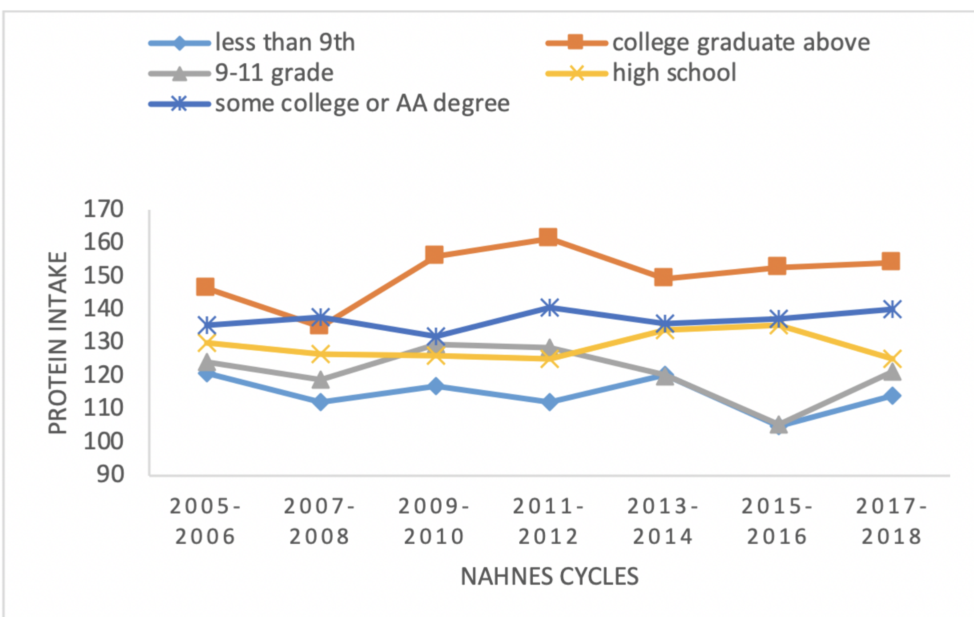

Figure 2.19. Trend of protein (g) across education level in BMI-based obesity

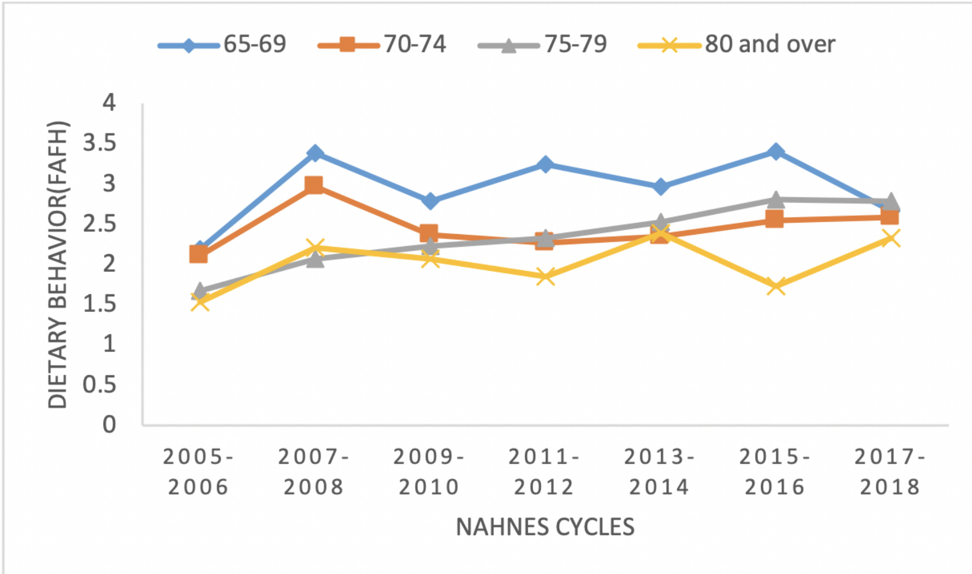

Figure 2.20. Trend of FAFH across age in BMI-based obesity

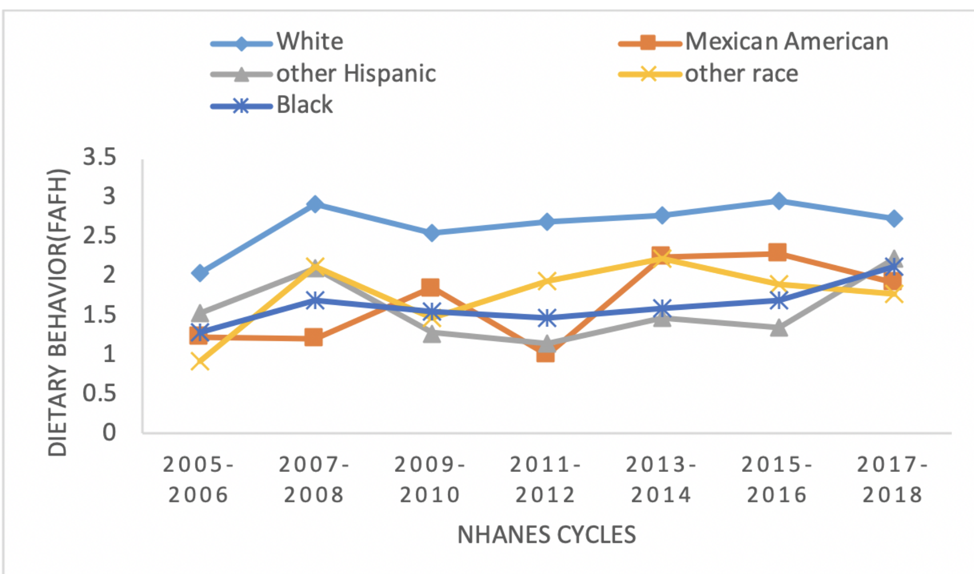

Figure 2.21. Trend of FAFH across ethnicity in BMI-based obesity

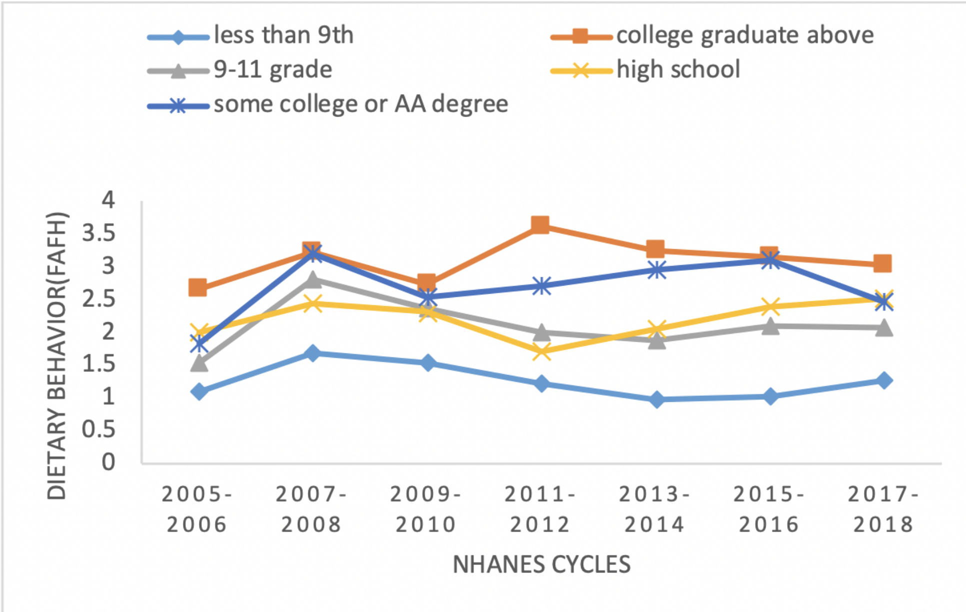

Figure 2.22. Trend of FAFH across education level in BMI-based obesity

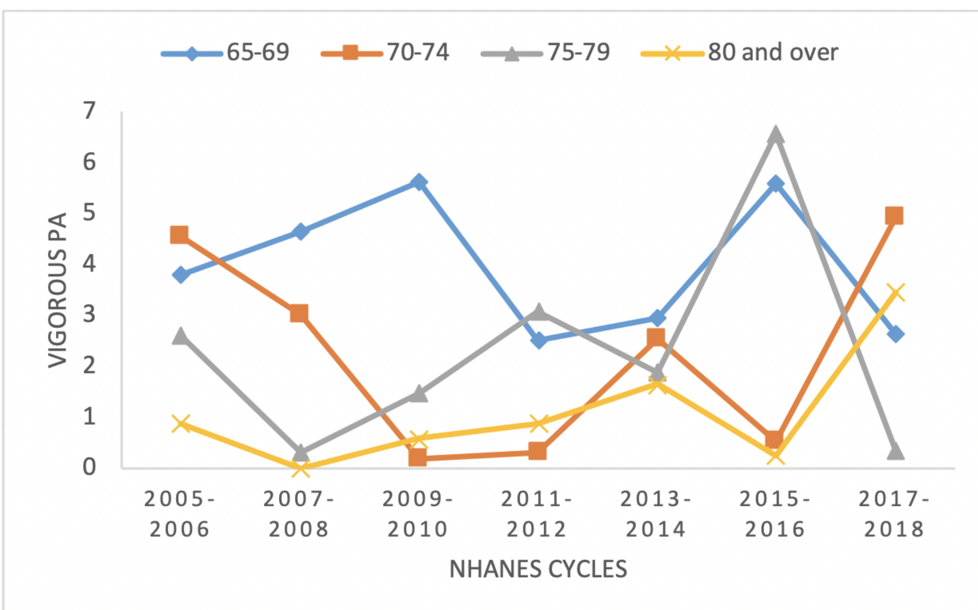

Figure 2.23. Trend of vigorous PA across age in BMI-based obesity

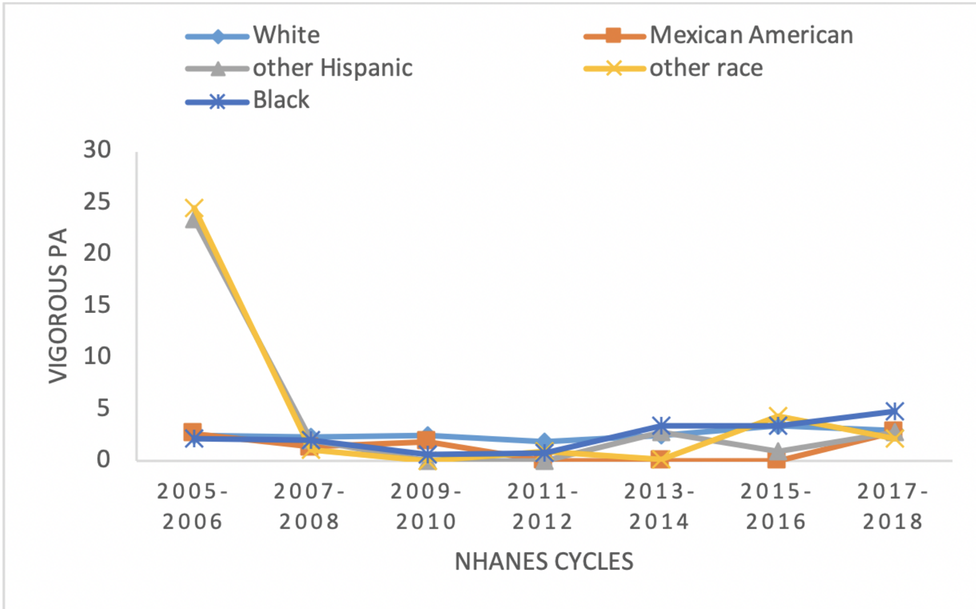

Figure 2.24. Trend of vigorous PA across ethnicity in BMI-based obesity

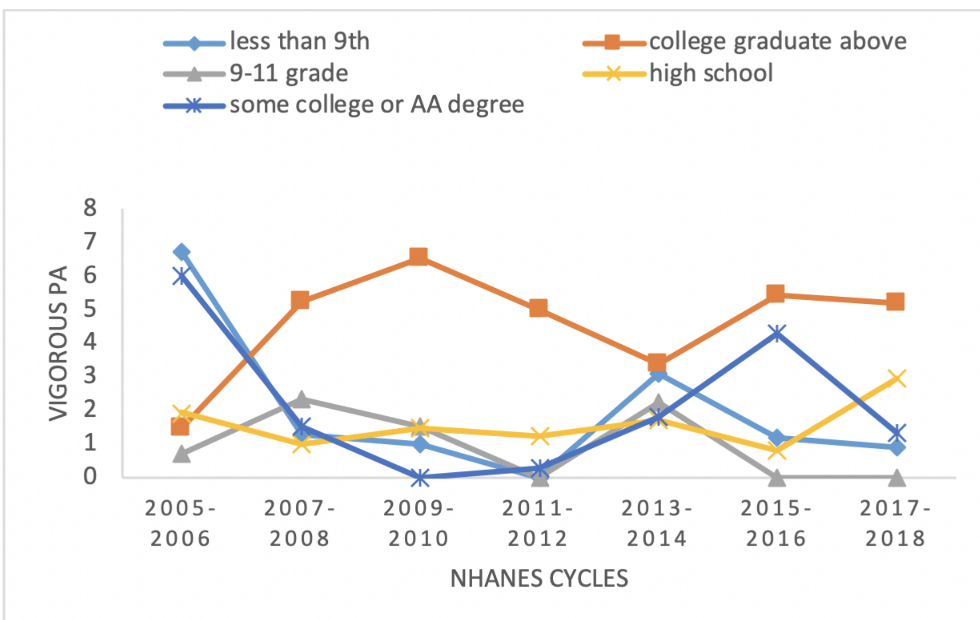

Figure 2.25. Trend of vigorous PA across education level in BMI-based obesity

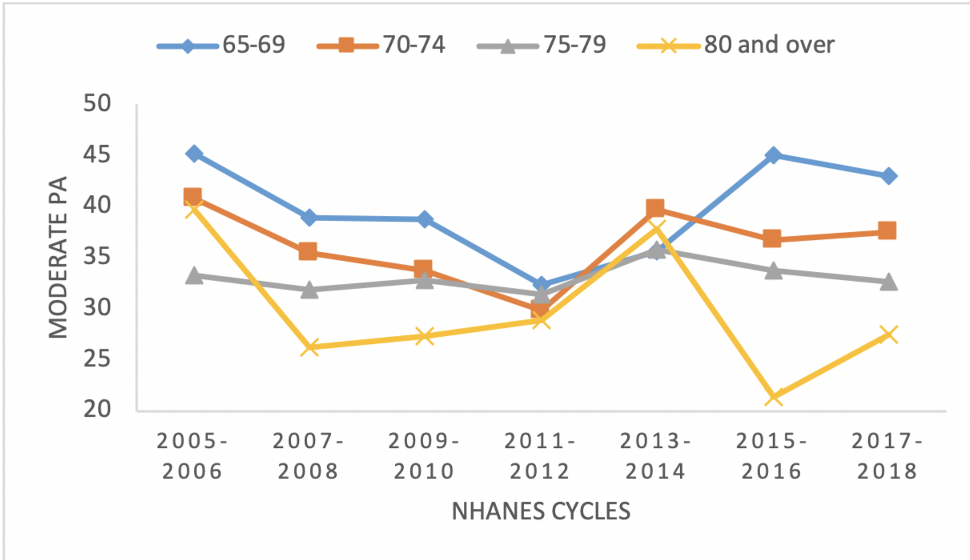

Figure 2.26. Trend of moderate PA across age in BMI-based obesity

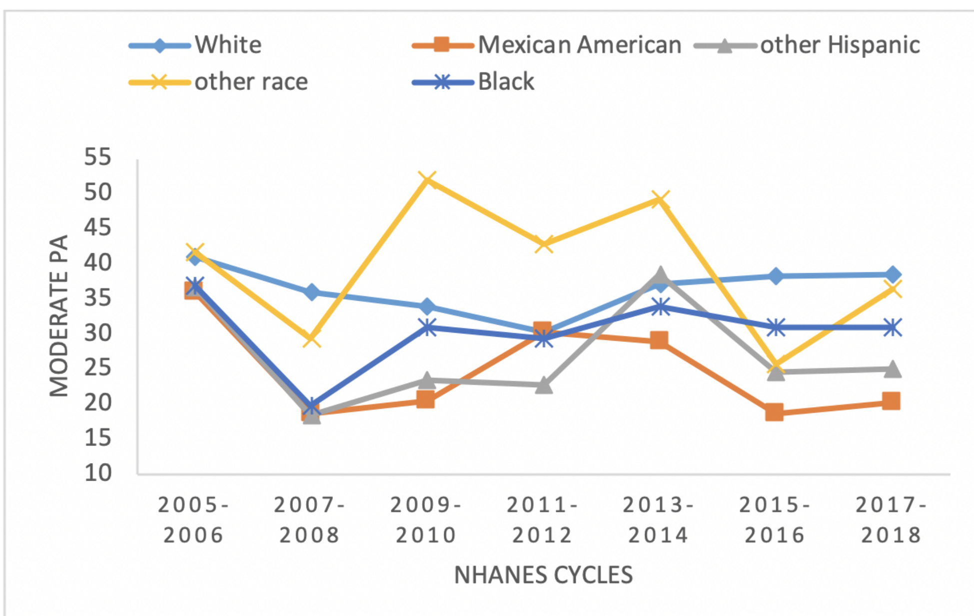

Figure 2.27. Trend of moderate PA across ethnicity in BMI-based obesity

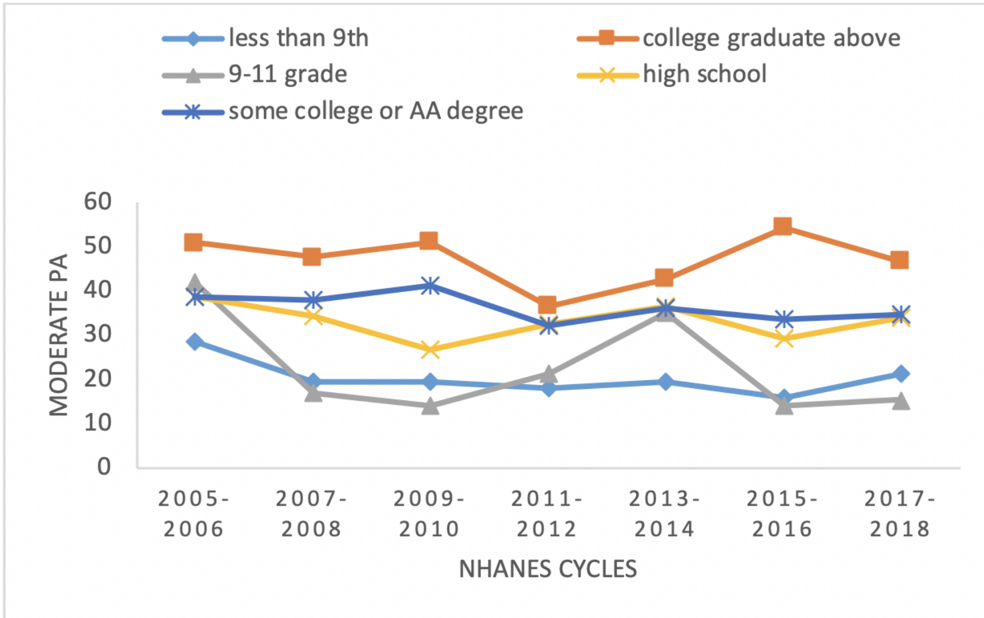

Figure 2.28. Trend of moderate PA across education level in BMI-based obesity

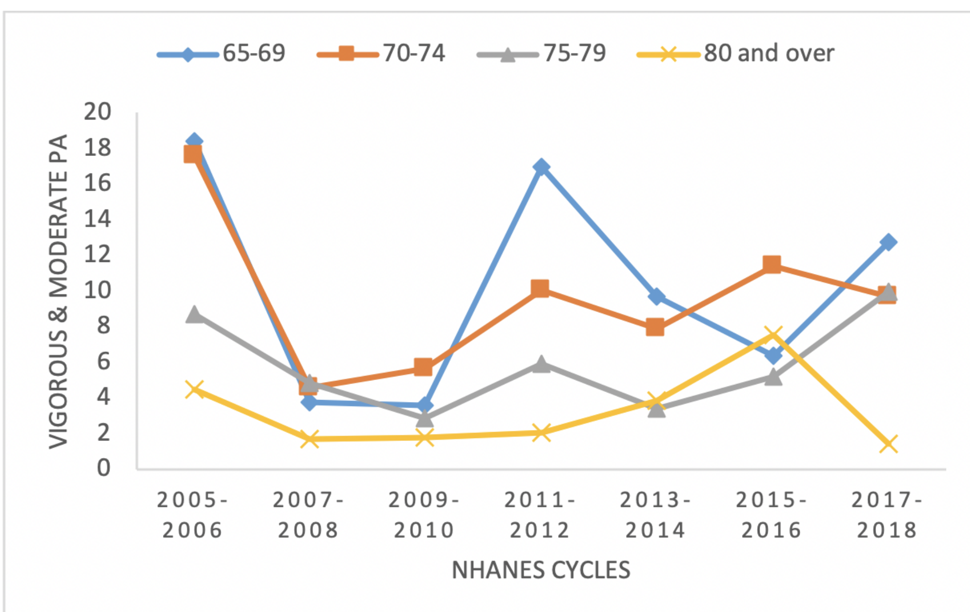

Figure 2.29. Trend of vigorous combined moderate PA across age in BMI-based obesity

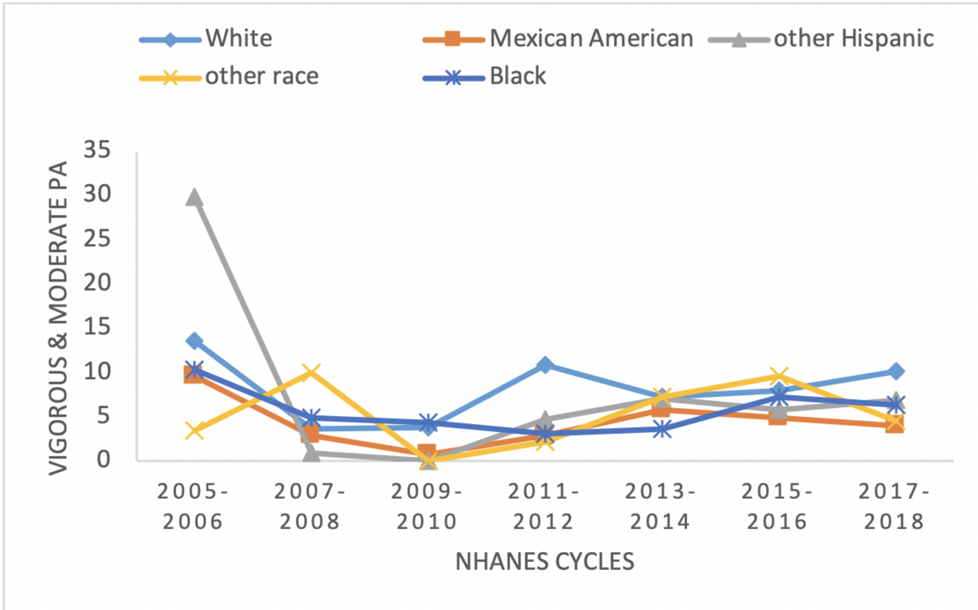

Figure 2.30. Trend of vigorous combined moderate PA across ethnicity in BMI-based obesity

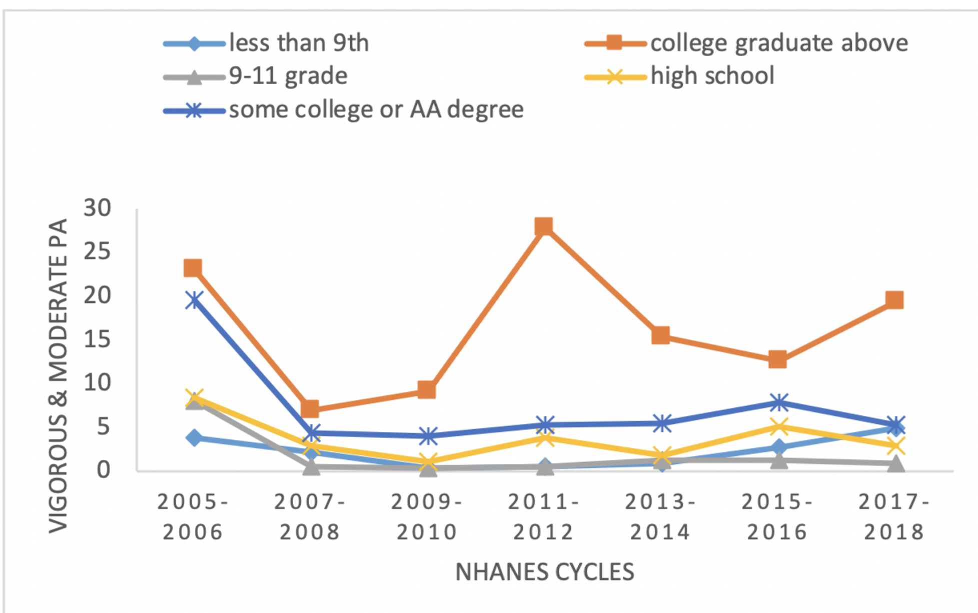

Figure 2.31. Trend of vigorous combined moderate PA across education level in BMI-based obesity

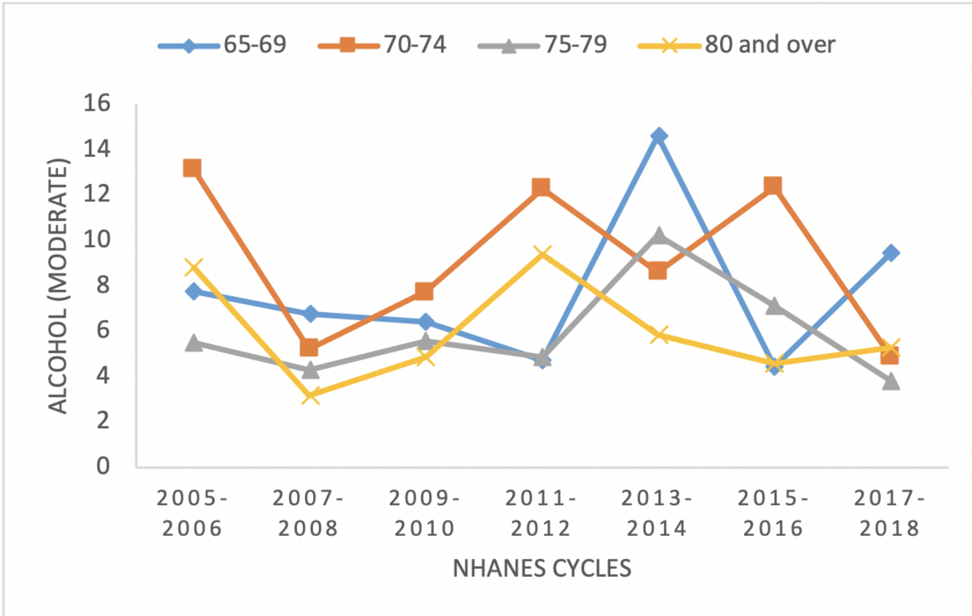

Figure 2.32. Trend of alcohol (moderate) across age in BMI-based obesity

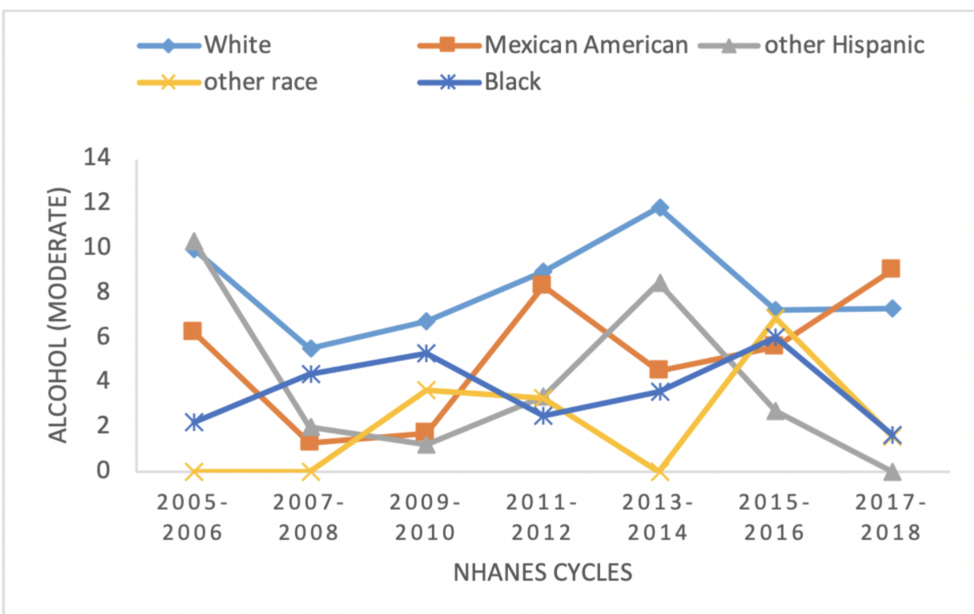

Figure 2.33. Trend of alcohol (moderate) across ethnicity in BMI-based obesity

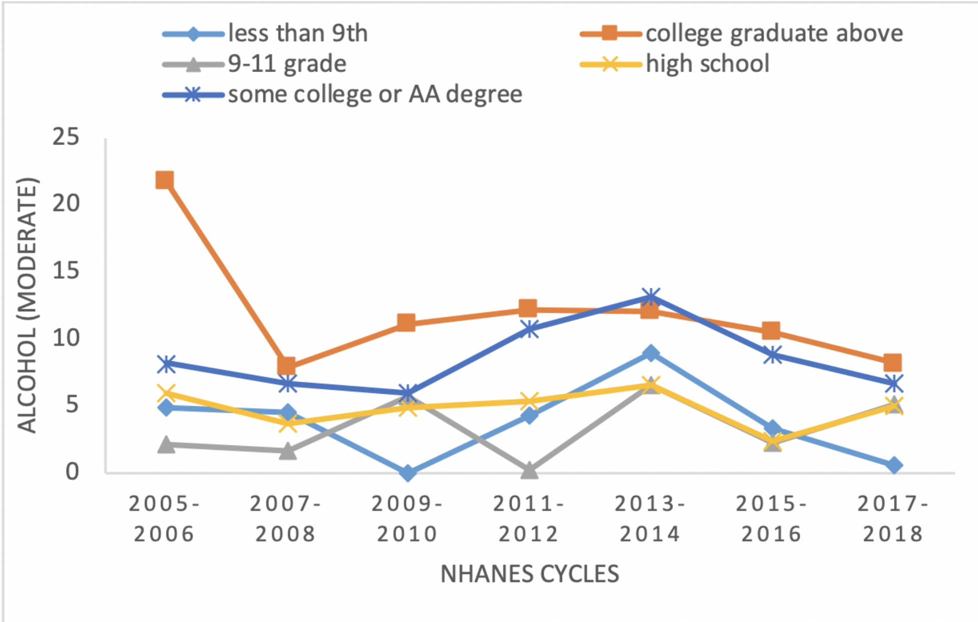

Figure 2.34. Trend of alcohol (moderate) across education level in BMI-based obesity

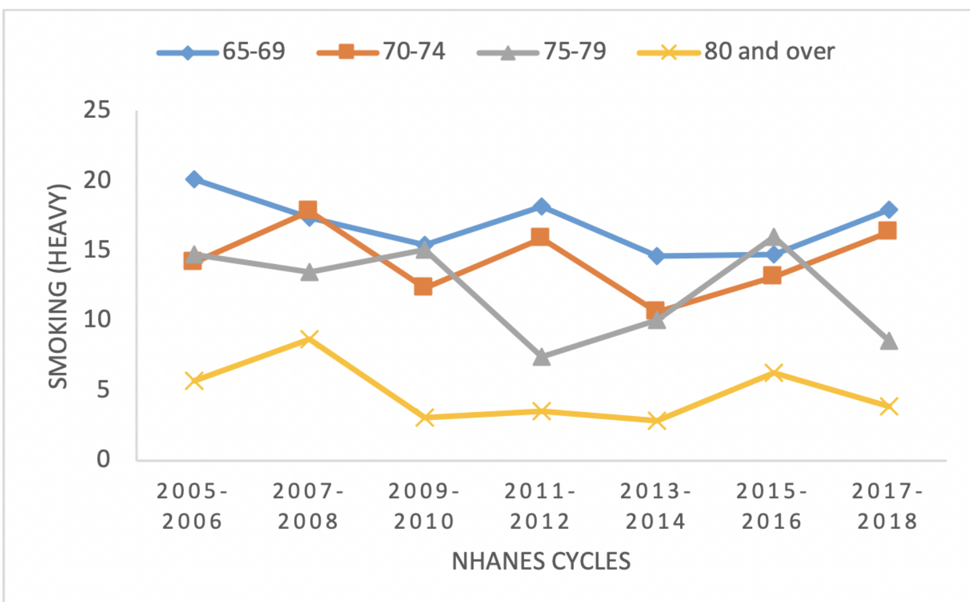

Figure 2.35. Trend of smoking (heavy) across age in BMI-based obesity

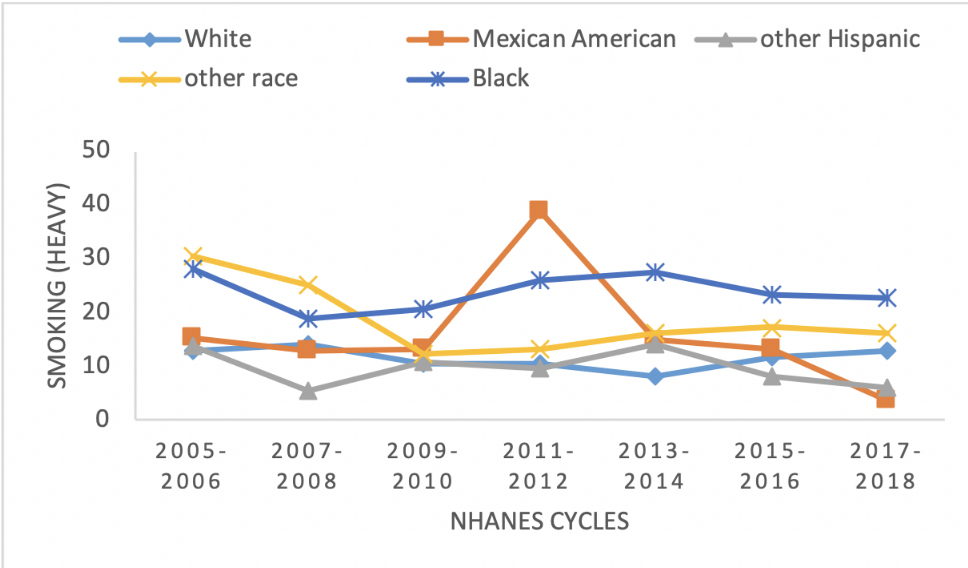

Figure 2.36. Trend of smoking (heavy) across ethnicity in BMI-based obesity

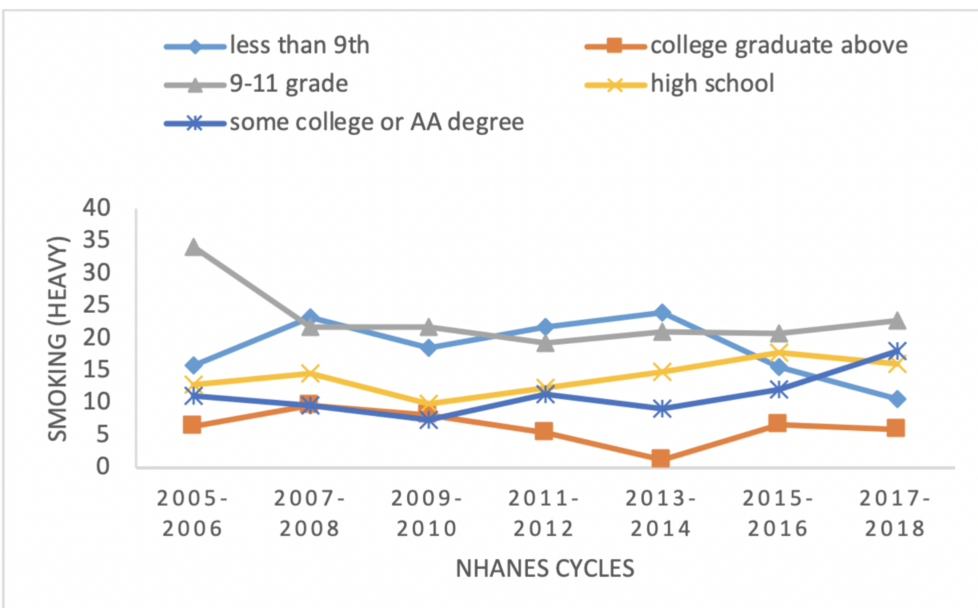

Figure 2.37. Trend of smoking (heavy) across education level in BMI-based obesity

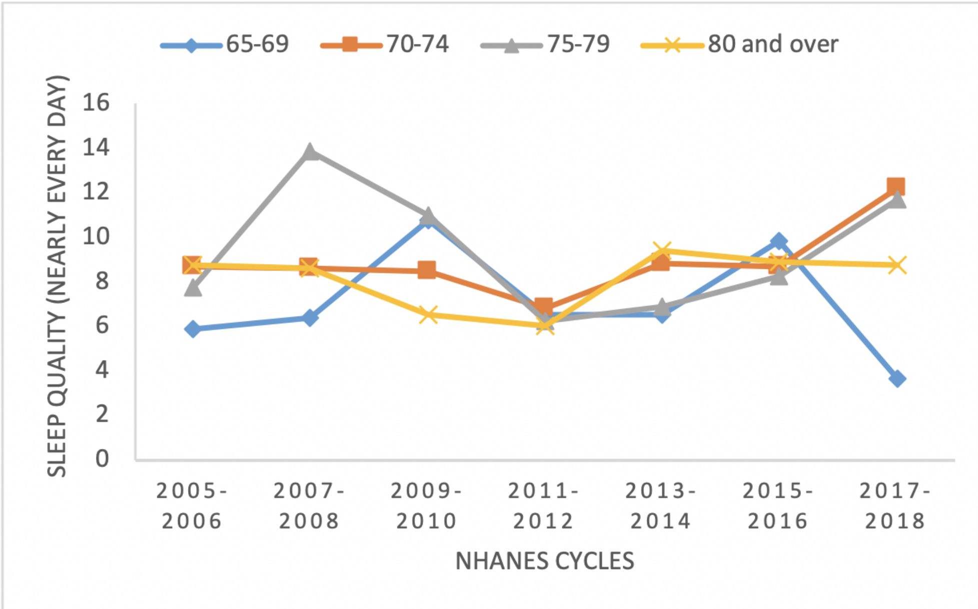

Figure 2.38. Trend of sleep problem (nearly every day) across age in BMI-based obesity

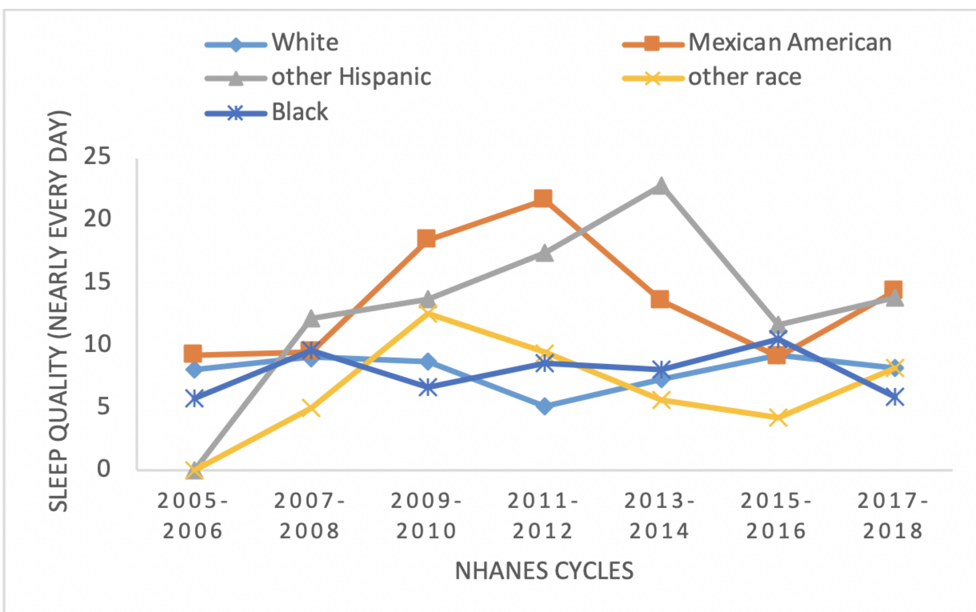

Figure 2.39. Trend of sleep problem (nearly every day) across ethnicity in BMI-based obesity

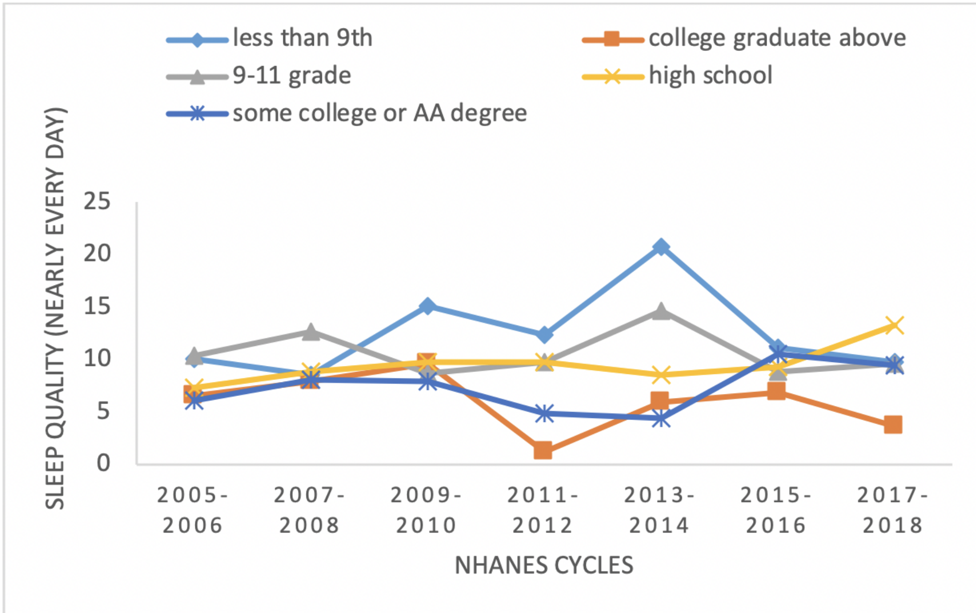

Figure 2.40. Trend of sleep problem (nearly every day) across education level in BMI-based obesity

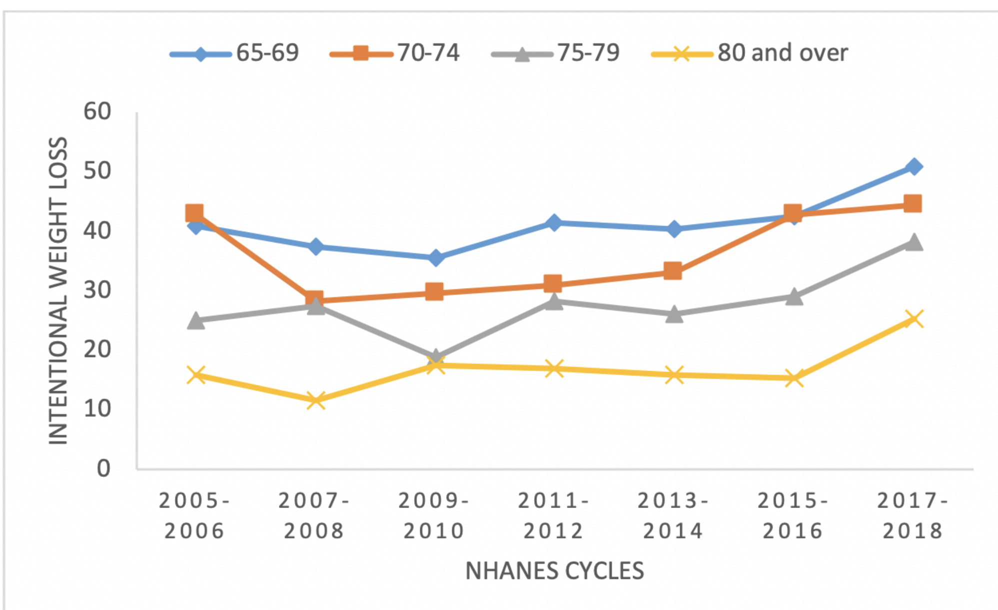

Figure 2.41. Trend of intentional weight loss across age in BMI-based obesity

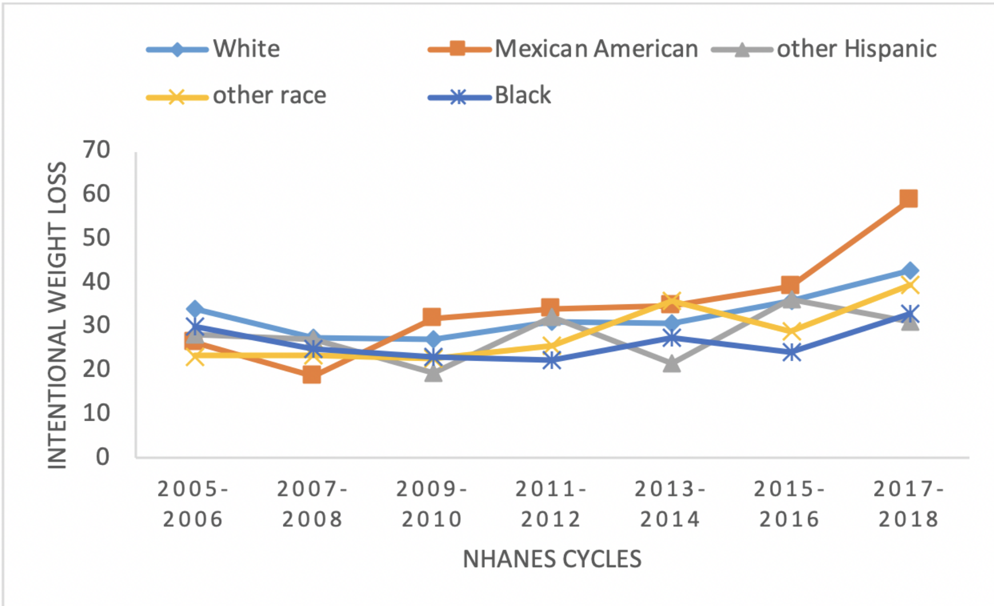

Figure 2.42. Trend of intentional weight loss across ethnicity in BMI-based obesity

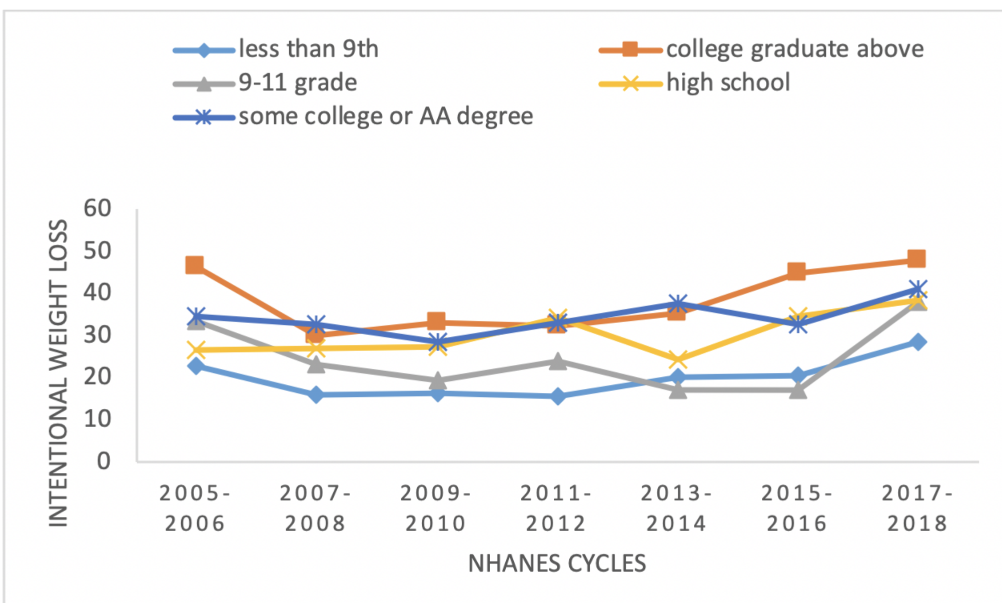

Figure 2.43. Trend of intentional weight loss across education level in BMI-based obesity

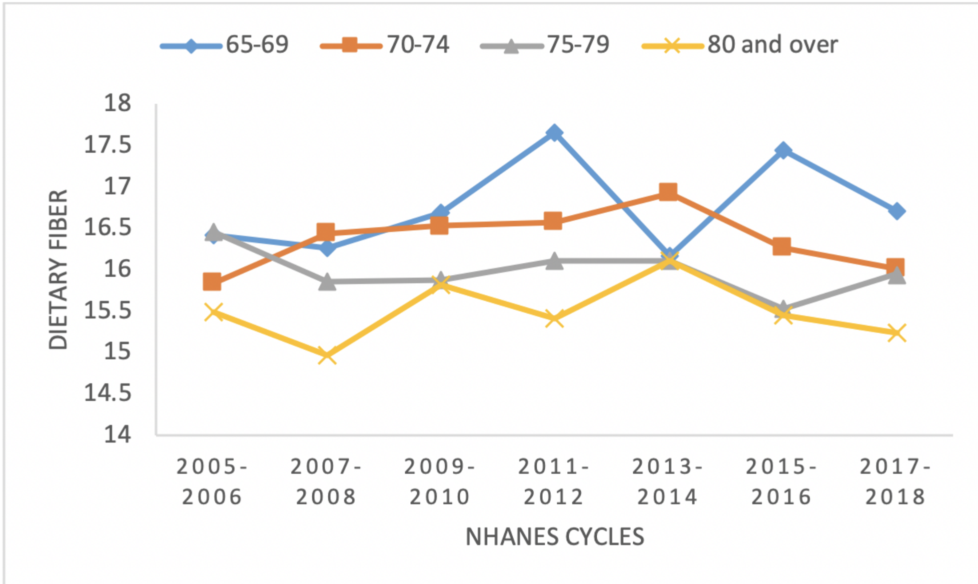

Figure 2.44. Trend of dietary fiber across age in WC-based obesity

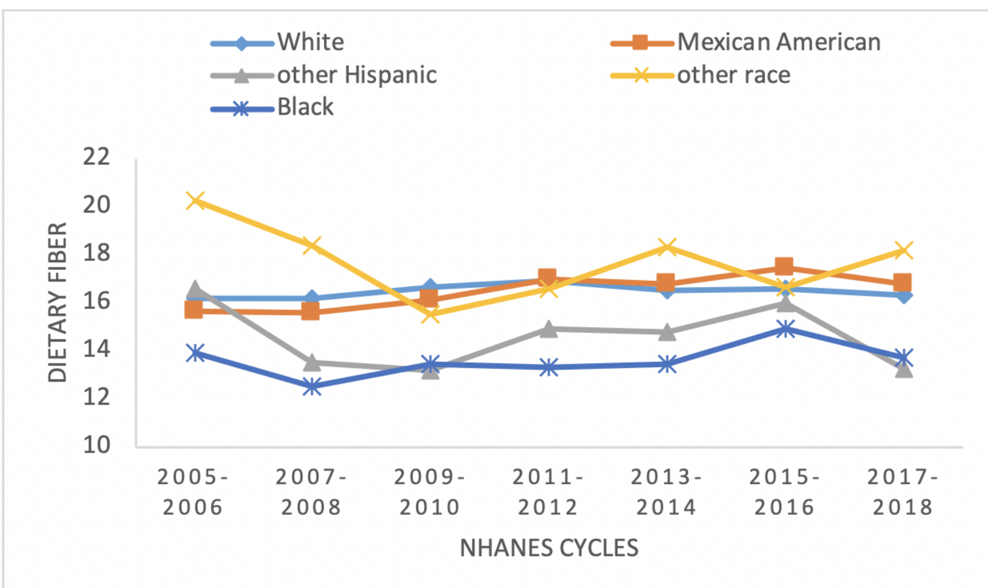

Figure 2.45. Trend of dietary fiber across ethnicity in WC-based obesity

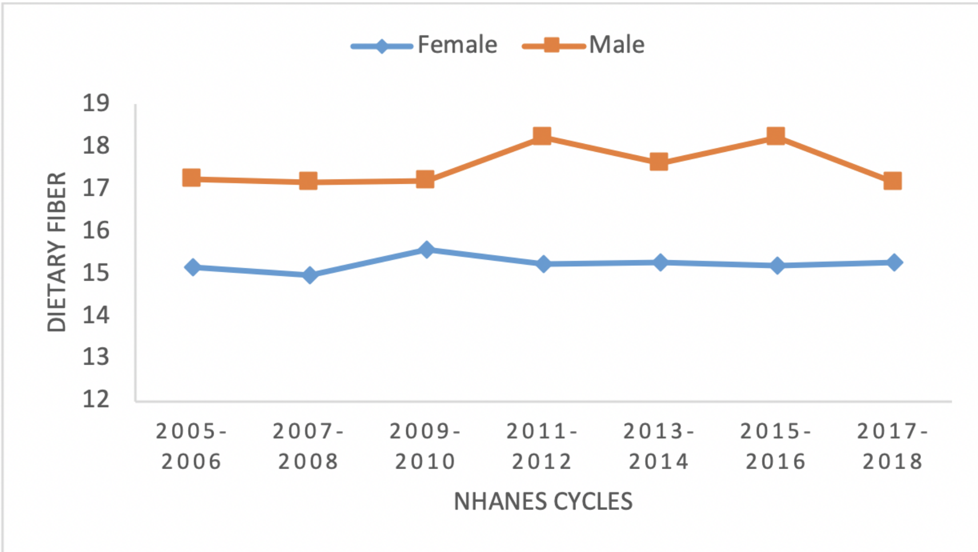

Figure 2.46. Trend of dietary fiber across gender in WC-based obesity

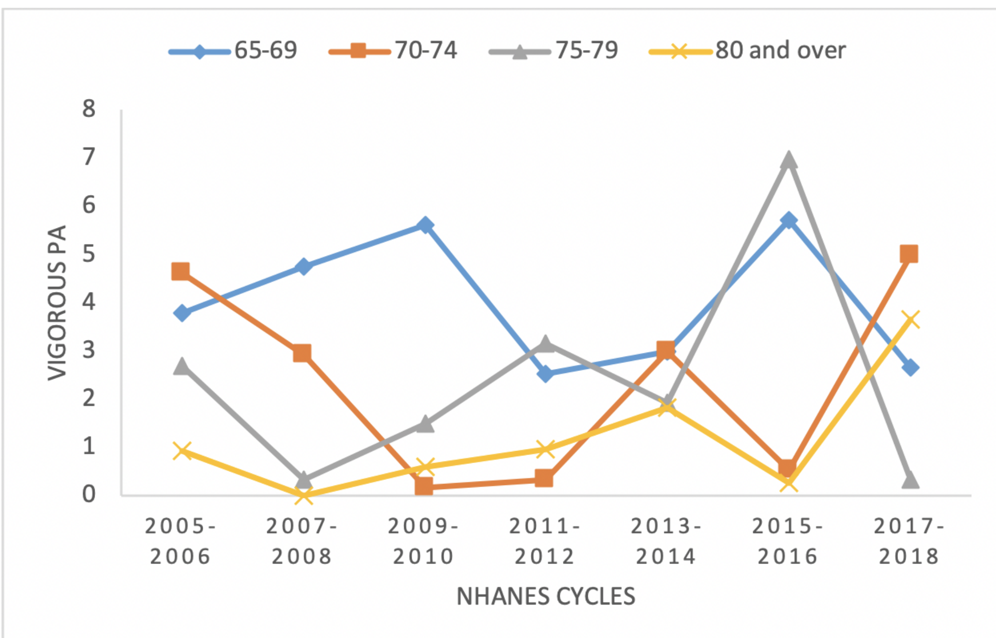

Figure 2.47. Trend of vigorous PA across age in WC-based obesity

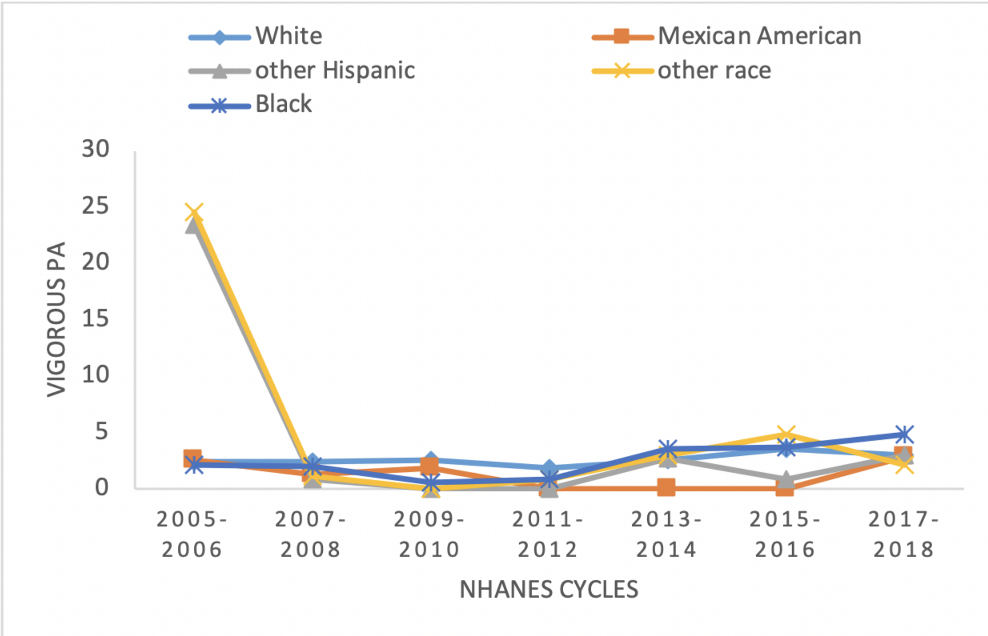

Figure 2.48. Trend of vigorous PA across ethnicity in WC-based obesity

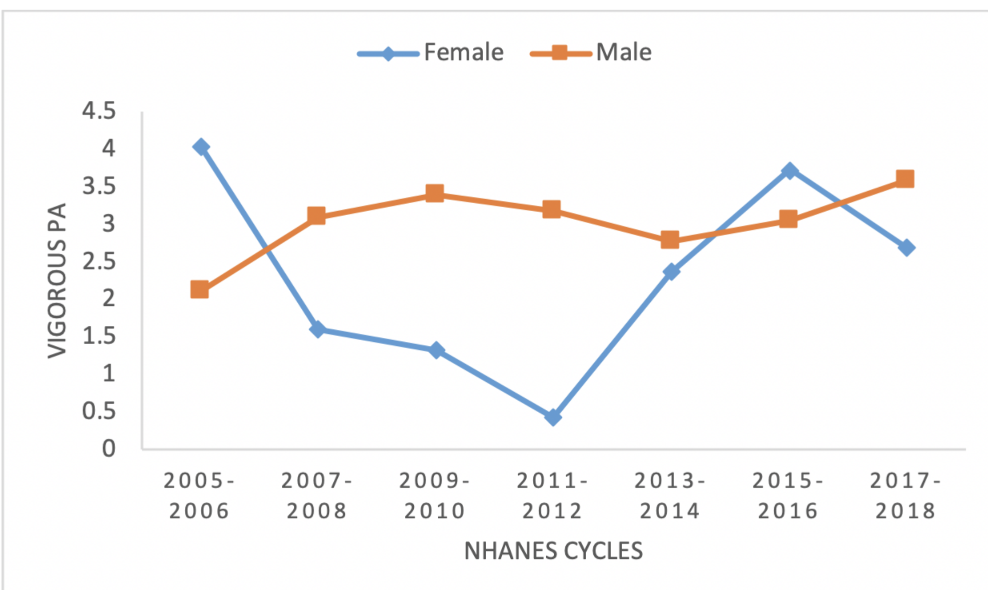

Figure 2.49. Trend of vigorous PA across gender in WC-based obesity

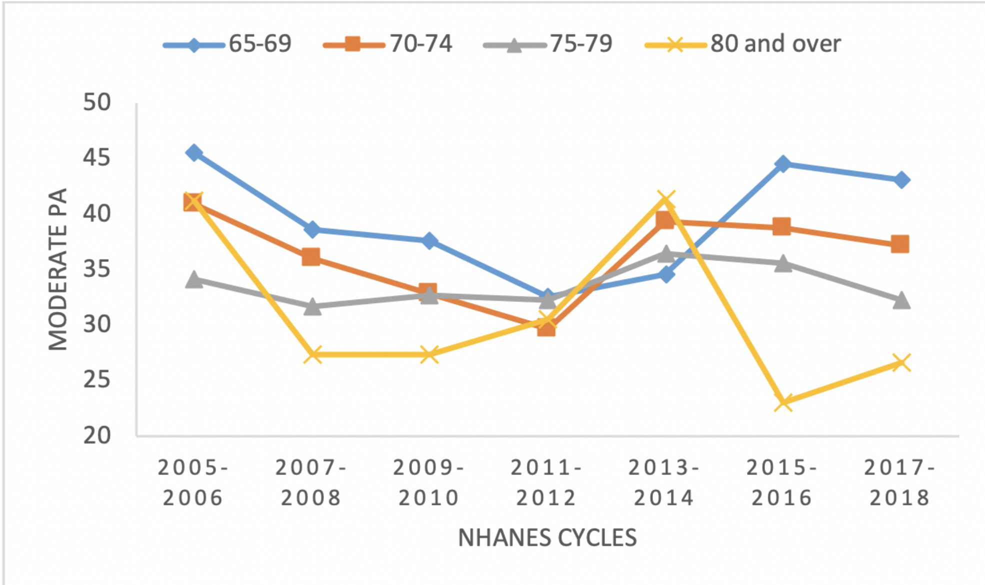

Figure 2.50. Trend of moderate PA across age in WC-based obesity

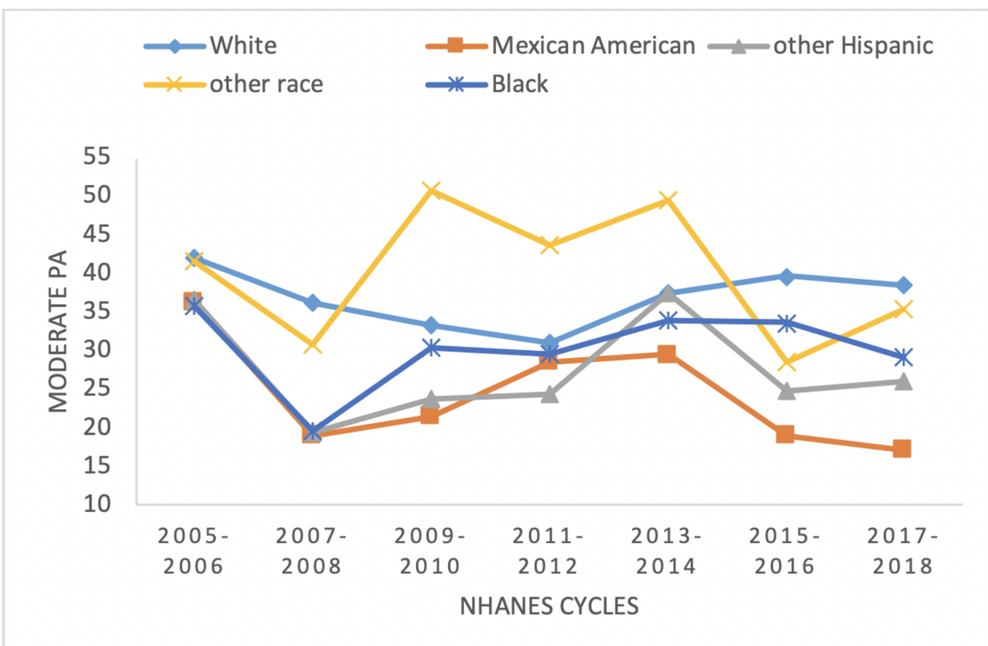

Figure 2.51. Trend of moderate PA across ethnicity in WC-based obesity

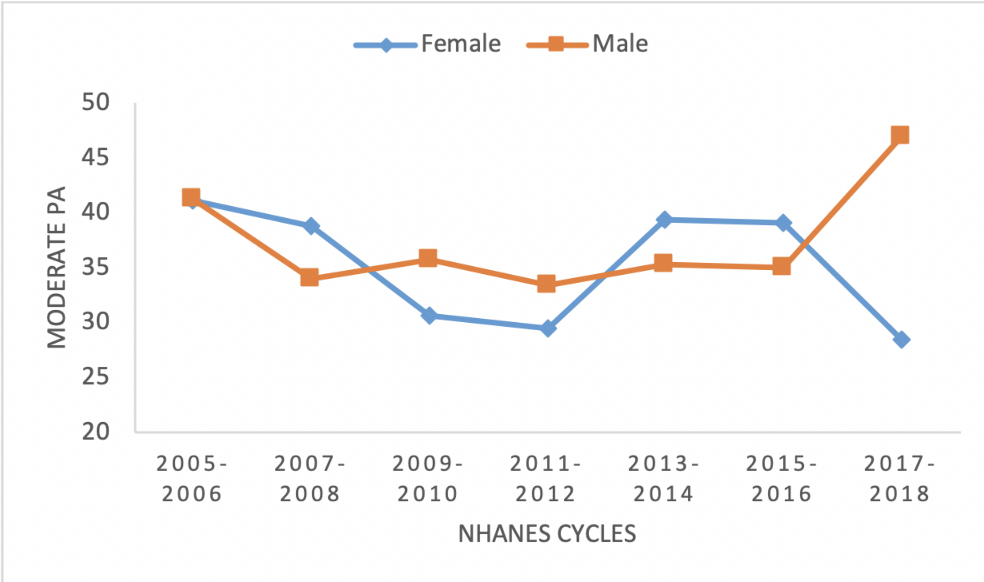

Figure 2.52. Trend of moderate PA across gender in WC-based obesity

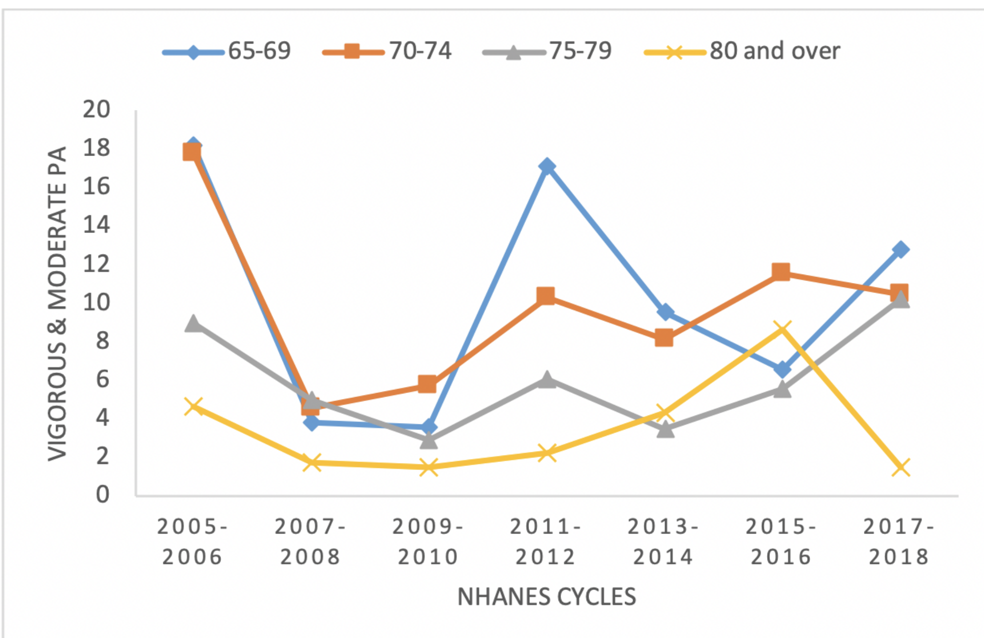

Figure 2.53. Trend of vigorous combined moderate PA across age in WC-based obesity

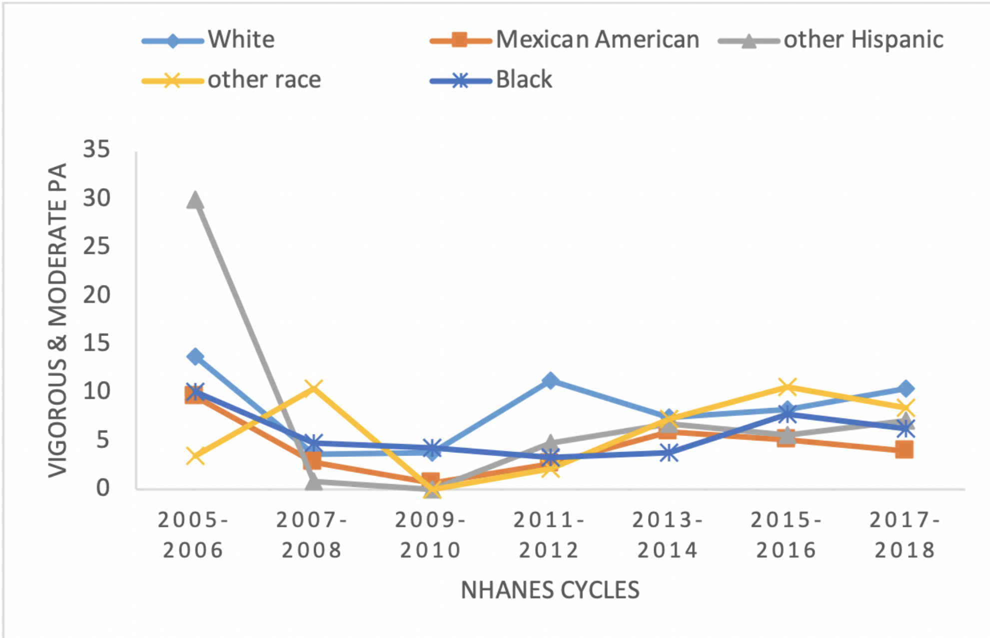

Figure 2.54. Trend of vigorous combined moderate PA across ethnicity in WC-based obesity

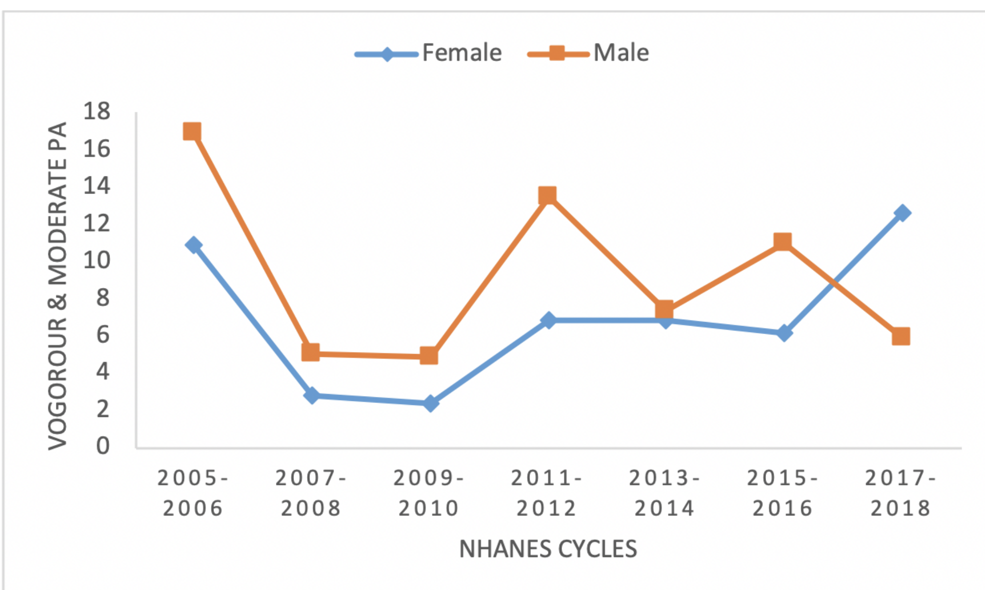

Figure 2.55. Trend of vigorous combined moderate PA across gender in WC-based obesity

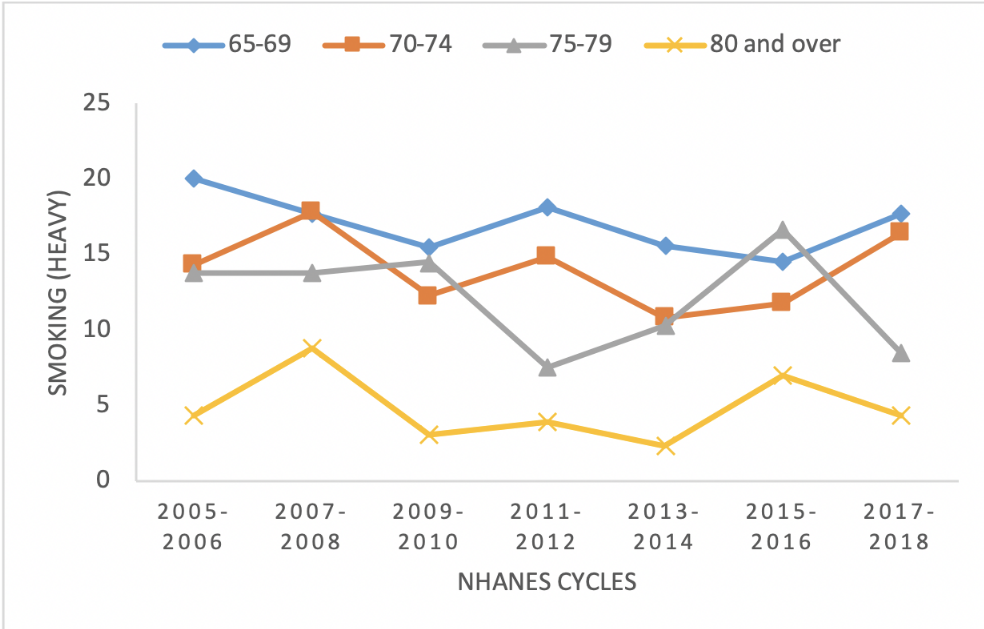

Figure 2.56. Trend of smoking (heavy) across age in WC-based obesity

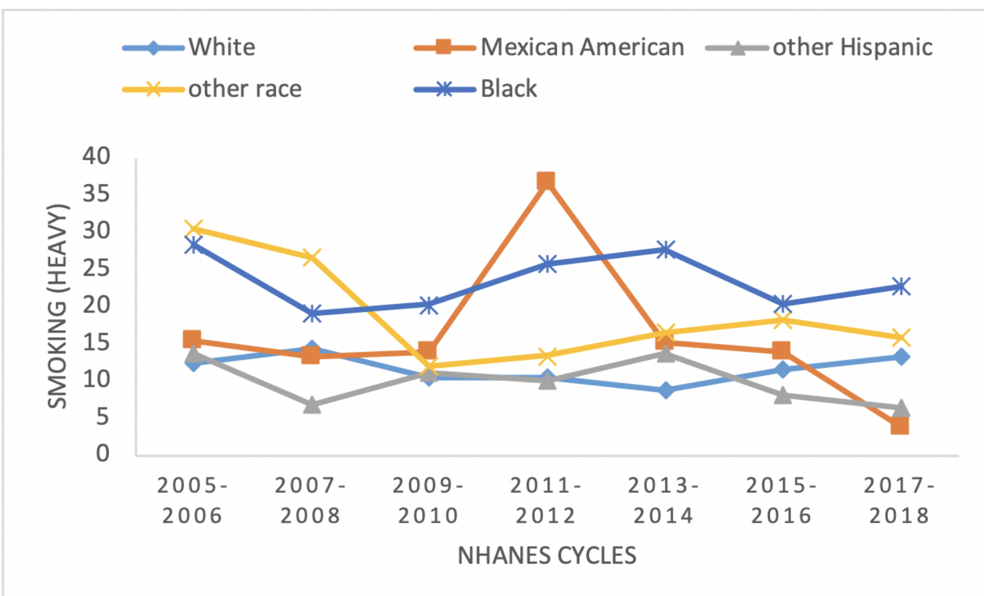

Figure 2.57. Trend of smoking (heavy) across ethnicity in WC-based obesity

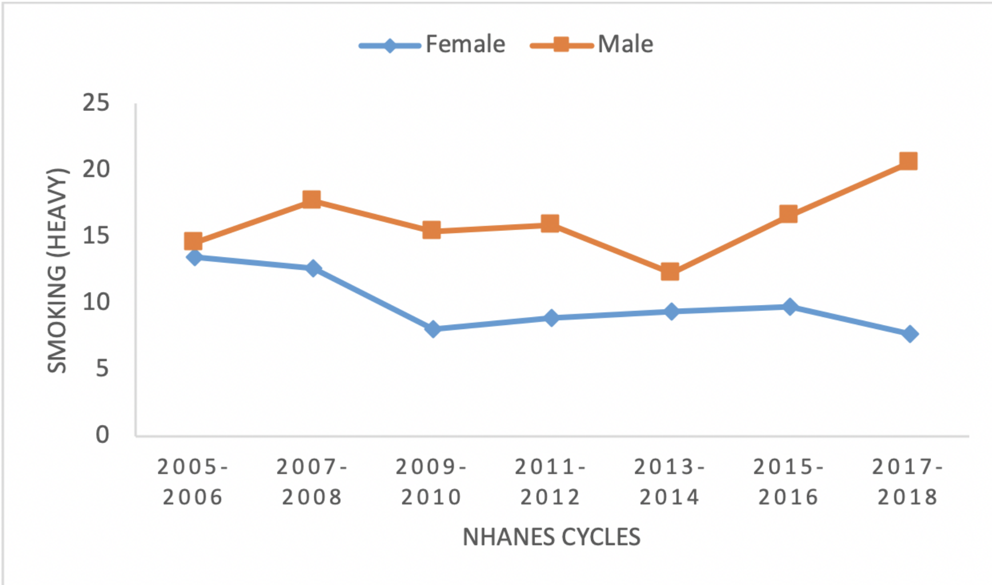

Figure 2.58. Trend of smoking (heavy) across gender in WC-based obesity

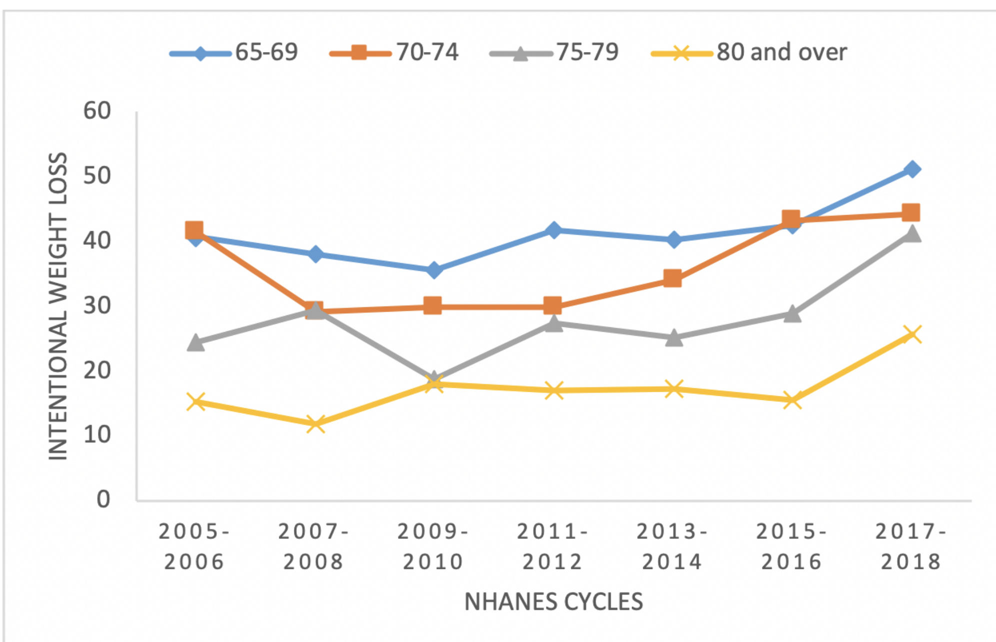

Figure 2.59. Trend of intentional weight loss across age in WC-based obesity

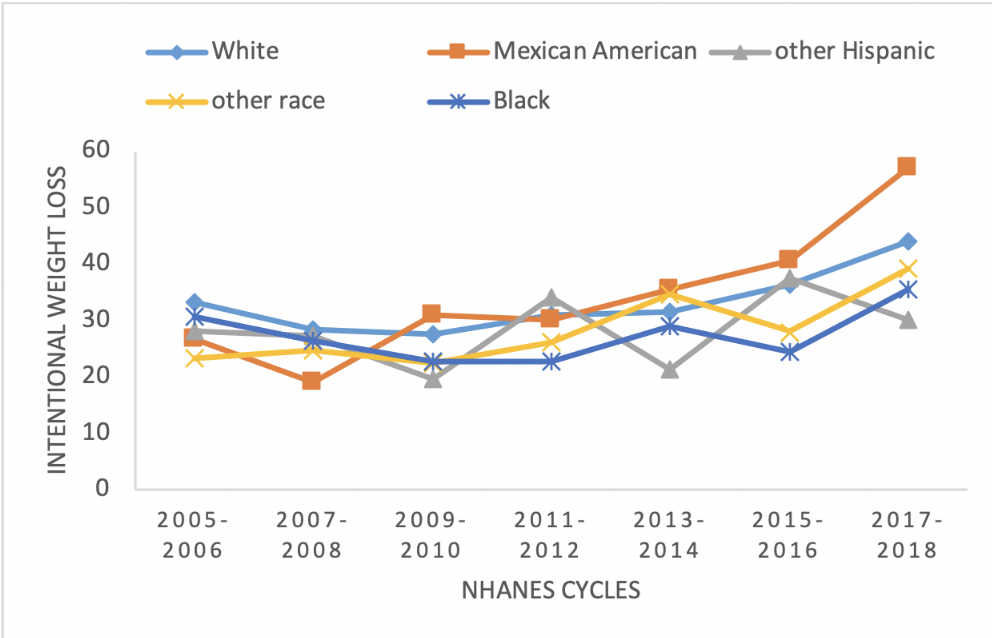

Figure 2.60. Trend of intentional weight loss across ethnicity in WC-based obesity

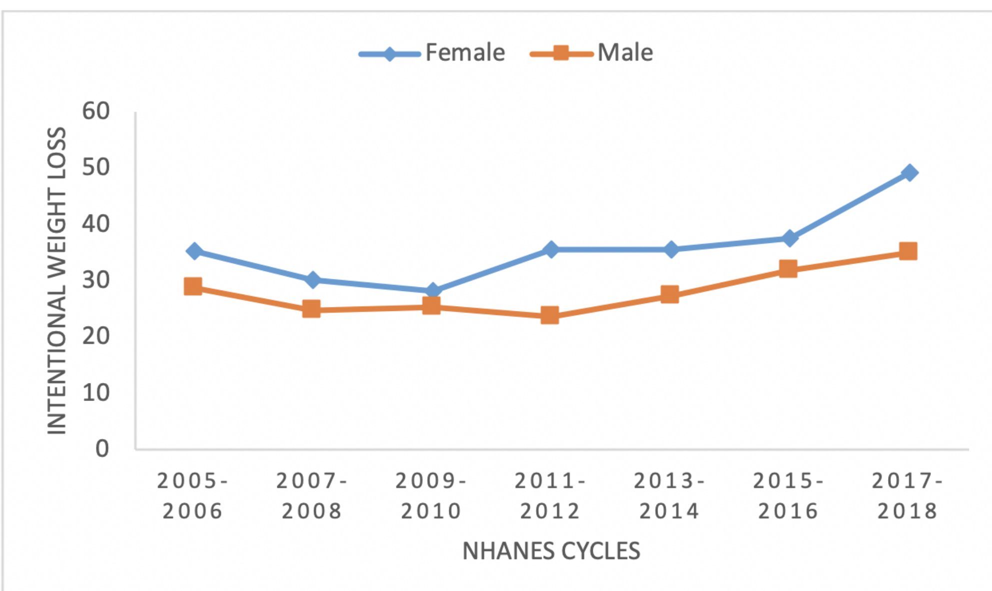

Figure 2.61. Trend of intentional weight loss across gender in WC-based obesity

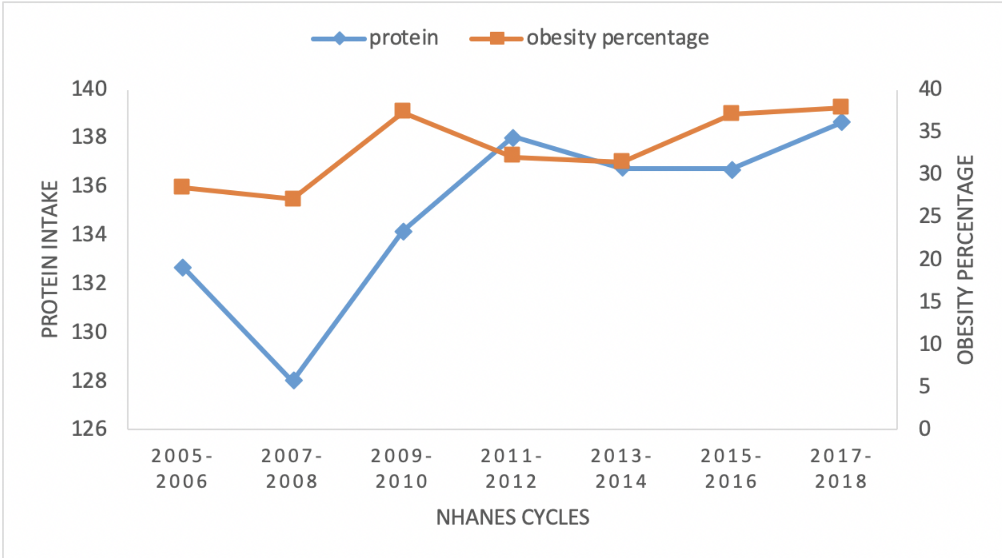

Figure 2.62. Similar trends of protein intake and BMI-based obesity

alcohol (moderate), and intentional weight loss (yes) were similar to the trend of obesity in older adults between 2005 and 2018 ($p > 0.05$) (Figure 2.62-2.68). However, results noted that trend of total sugar intake was significantly different from the trend of obesity from 2005 to 2018 ($p < 0.05$).

In WC-based obesity, results indicated that trends of intensities of PA (vigorous, moderate, and vigorous combined moderate) and intentional weight loss (yes) were all similar to the trend of obesity in older adults between 2005 and 2018 ($p > 0.05$) (Figure 2.69-2.72).

2.4 DISCUSSION

Although the "gold standard" to classify obesity in older adults is measuring body fat percentage through DXA, there are still a great number of studies using BMI and/ or WC for analyzing obesity, especially the data coming from the NHANES (Chang et al., 2016; Karvonen-Gutierrez et al., 2012; Palakshappa et al., 2019; Palmer and Toth, 2019; Vásquez et al., 2014). No DXA data for older adults (> 65 years old) in the NHANES dataset exits for the cycles this investigation required. In one study on body fat percentage prediction, equations developed from BMI and WC were also acceptable after comparing the results

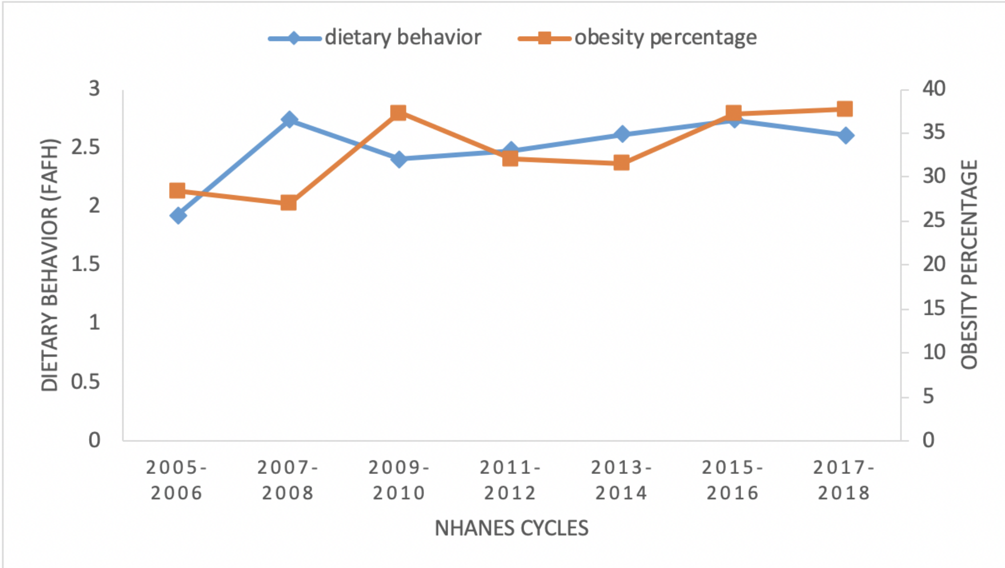

Figure 2.63. Similar trends of FAFH and BMI-based obesity

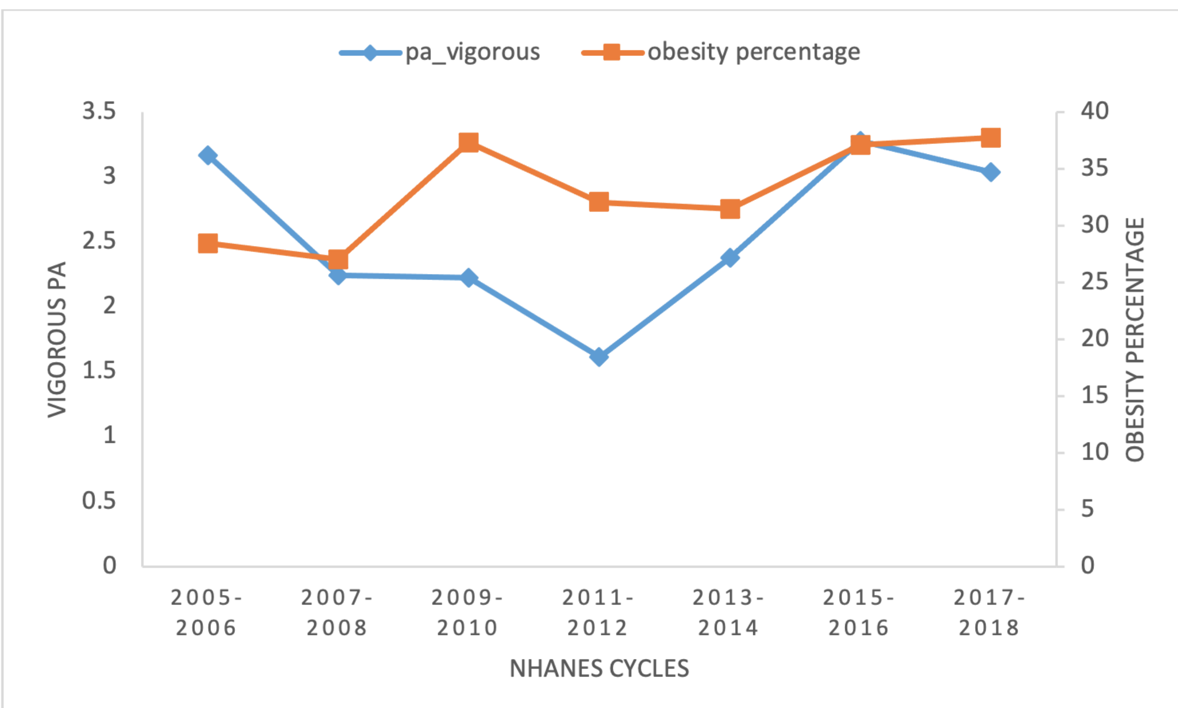

Figure 2.64. Similar trends of vigorous PA and BMI-based obesity

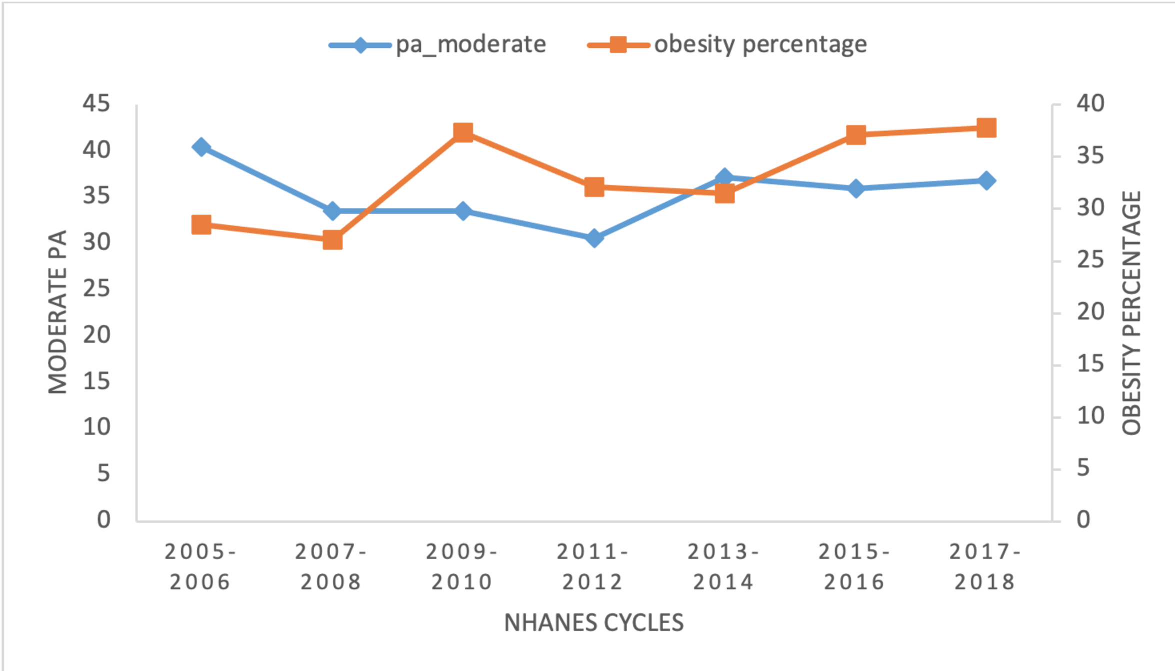

Figure 2.65. Similar trends of moderate PA and BMI-based obesity

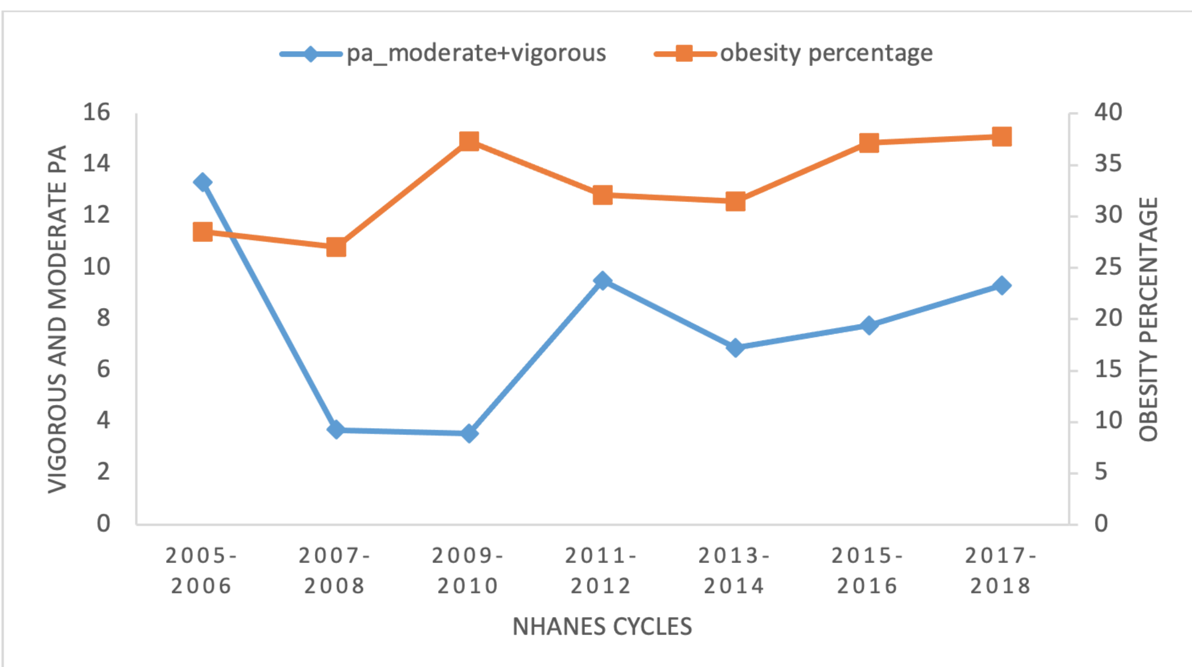

Figure 2.66. Similar trends of vigorous combined moderate PA and BMI-based obesity

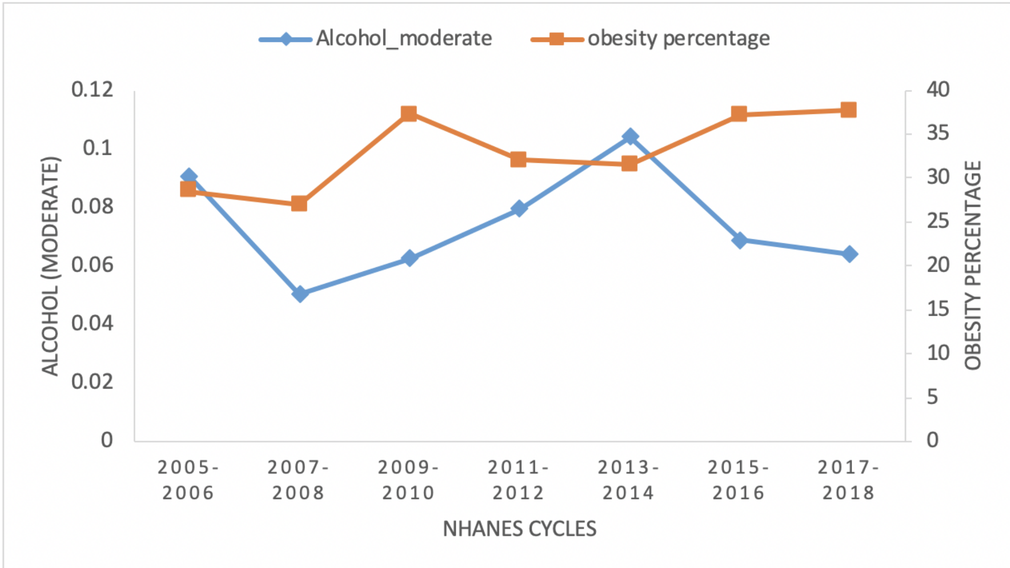

Figure 2.67. Similar trends of alcohol (moderate) and BMI-based obesity

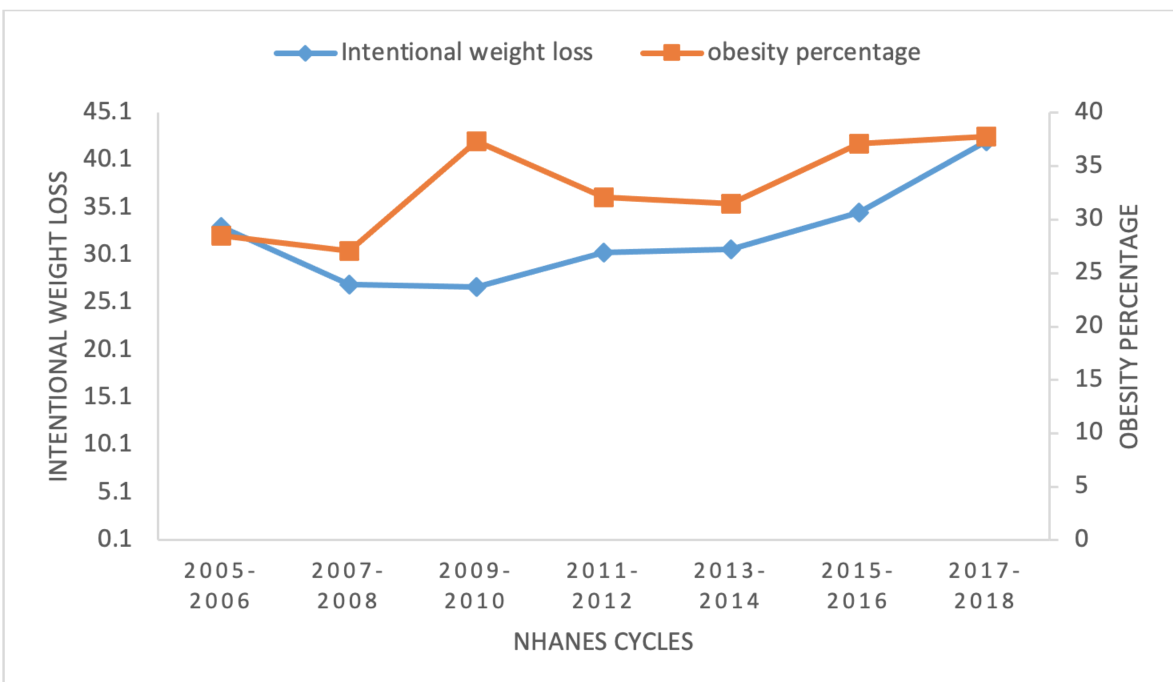

Figure 2.68. Similar trends of intentional weight loss and BMI-based obesity

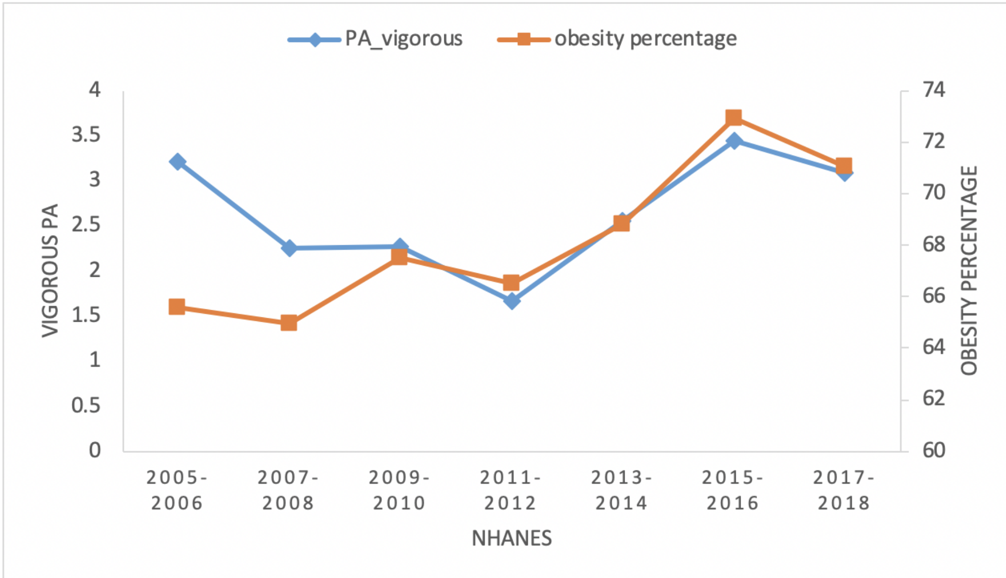

Figure 2.69. Similar trends of vigorous PA and WC-based obesity

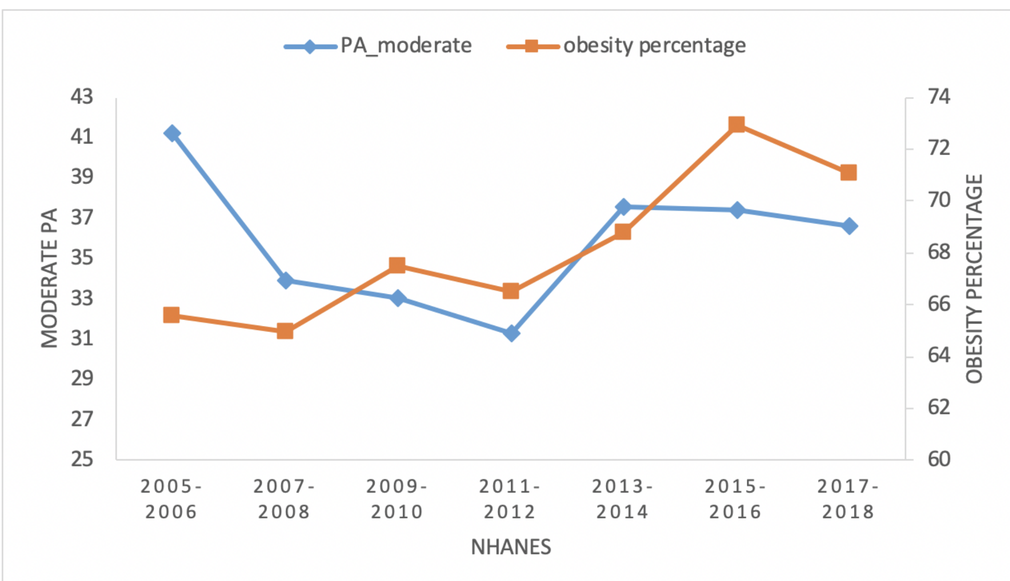

Figure 2.70. Similar trends of moderate PA and WC-based obesity

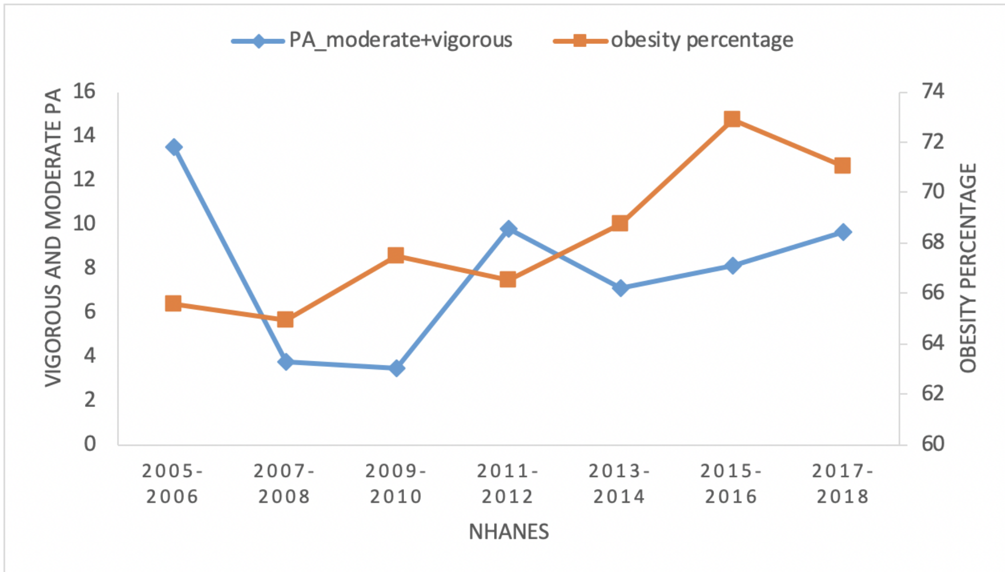

Figure 2.71. Similar trends of vigorous combined moderate PA and WC-based obesity

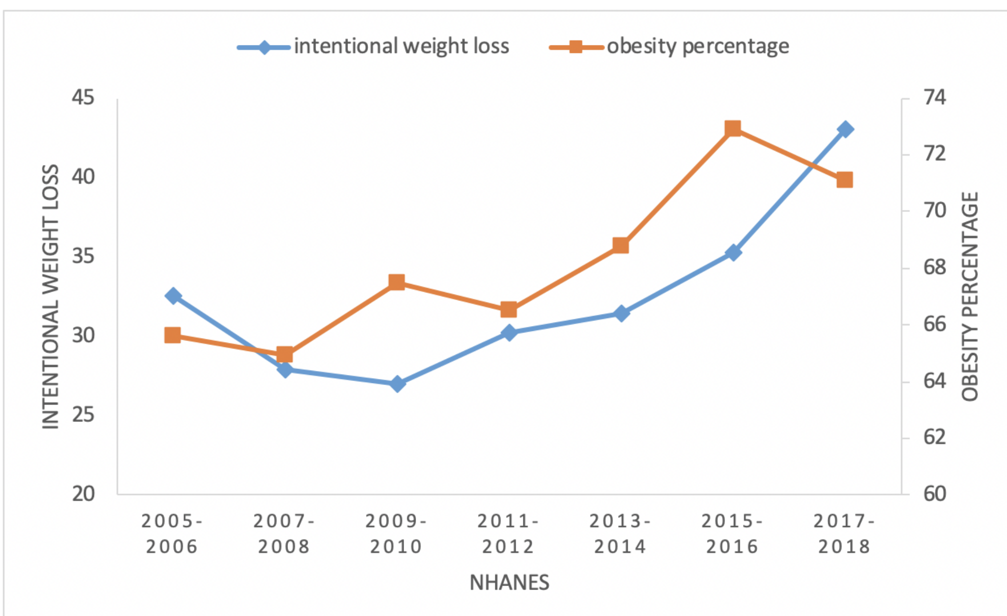

Figure 2.72. Similar trends of intentional weight loss and WC-based obesity

of DXA (Silveira et al., 2020). Additionally, both BMI and WC were better predictors of insulin resistance than body fat in the older adults (Cheng et al., 2017).

In the current study, the results noted the obesity percentage increased from 28.48% to 37.78% in BMI-based standard among older adults from 2005 to 2018 (Table 2.11). This finding of obesity percentage in the 2017-2018 cycle was a slightly lower than the report by the CDC, which reported the obesity percentage among older adults was over 40% in 2013-2016 (CDC, 2020). Compared to 2005-2006, the obesity percentage during 2017-2018 increased by 32.65%. Over fourteen years (seven two-cycles), the mean change of obesity percentage per year increased 0.66 percentage points. There was a linear increasing trend for BMI-based obesity percentage and BMI values ($p < 0.05$). These results echoed the previous research that obesity increased recently (CDC, 2020). In the WC-based obesity, obesity percentage increased from 65.59% to 71.07% among older adults from 2005 to 2018 (Table 2.11). It was reported that abdominal obesity increased from 60% to 69.9% among adults aged 65 years old between 1999 and 2014 (Caspard et al., 2018). It is suggested that obesity is still increasing over these years. Over fourteen years, the mean change of obesity percentage per year increased 0.6 percentage points, which was the same as the report between 1999 and 2014 (Caspard et al., 2018). An increasing linear trends for the WC-based obesity percentage and WC values were similar as BMI-based obesity percentage and BMI values ($p < 0.05$). Therefore, in the recent years, obesity still increased in both BMI-based and WC-based obesity among older adults. It is very necessary to identify the risk factors of obesity to prevent and intervene in the increasing trend due to the morbidity and mortality risks associated with obesity in older adults.

2.4.1 Analysis of significant lifestyle behaviors related to obesity among older adults

2.4.1.1 Dietary consumption (total sugar)

Logistic regression, adjusted for other lifestyle behaviors and demographic factors, revealed a significantly inverse association between the intake of total sugar and the risk of

Table 2.11. Trend analysis of obesity among older adults from 2005 to 2018

		2005-2006	2007-2008	2009-2010	2011-2012	2013-2014	2015-2016	2017-2018	P trend linear
BMI-based obesity	BMI	27.81±0.29	27.67±0.24	28.66±0.21	28.21±0.38	28.05±0.25	28.77±0.33	29.00±0.26	0.00*
	obesity%	28.48±0.03	27.05±0.02	37.33±0.02	32.11±0.24	31.50±0.03	37.14±0.03	37.78±0.03	0.00*
WC-based obesity	WC	99.30±0.64	100.10±0.64	101.41±0.51	101.03±1.07	101.23±0.76	102.76±0.91	103.15±0.69	0.00*
	obesity%	65.59±0.02	64.94±0.03	67.48±0.02	66.52±0.03	68.78±0.03	72.90±0.03	71.07±0.02	0.00*

BMI-based obesity among older adults (BMI: OR=0.97, 95% CI: 0.95, 0.99). This suggests that the odds of becoming obese are lower with a higher intake of total sugar. It was obvious that the lower intake of fat happened when added sugar intake was high (Barclay and Brand-Miller, 2011). As a result, the intake of sugar blocks the fat consumption, which produces more energy, and then the risk of being obese decreases. While, the reduced consumption of sugar was replaced by other high-energy food. Therefore, some researchers suggested that the reduced consumption of sugar might decrease the energy intake, but could not decrease the prevalence of obesity (Barclay and Brand-Miller, 2011).

There was a quartic trend of total sugar intake over 7 two-year cycles, decreasing from 2005-2006 to 2007-2008, then smoothly increasing up to 2011-2012, followed by a decrease to 2015-2016 and then increasing again in 2017-2018. In total, the trend of sugar intake roughly decreased over 14 years. Compared to the NHANES cycle of 2005-2006, in 2017-2018, the intake of total sugar decreased by 2.88% and 3.51% in BMI-based obesity and in WC-based obesity, separately. This finding is consistent with the study undertaken by Marriott (2019) which found adult total sugar intake from diet declined 17% from 2003 to 2016 (Marriott et al., 2019).

There was no clear difference among the trends of total sugar intake across age. The intake of total sugar was higher in non-Hispanic Whites than other ethnicities, which is inconsistent with the report that the highest intake of added sugar was observed in non-Hispanic Blacks (Thompson et al., 2009). Moreover, the higher intake of total sugar was observed in the population with an education level of college education above. This kind of population had a lower risk of being obese compared to those of low education attainment (OR=0.69, 95% CI: 0.49, 0.97). Sugar intake was not affected by the educational level in France and the Netherlands (Azaïs-Braesco et al., 2017), which may indicate that the effects of education on sugar intake may have cultural components to consider.

The significant association between total sugar intake and obesity was observed in BMI-based obesity rather than WC-based obesity. In these two obesity groups, samples were obtained from the same NHANES cycles (2005-2018), while the different findings were due to the different measures of obesity. The different results on PA were also reported between the studies of Maher et al. and Healy were because of BMI-based obesity or WC-based obesity (Healy et al., 2011; Maher et al., 2013). As a result, the total sugar intake is correlated with general obesity, but not with abdominal obesity.

2.4.1.2 Dietary consumption (dietary fiber)

In this study, there was no significant trend for dietary fiber intake over 14 years. Despite a slight dietary fiber intake increased of 0.79% in the BMI-based group and of 0.3% in WC-based group from 2005-2006 to 2017-2018, the amount of dietary fiber intake (mean: 16.26 ± 0.15g) still does not meet the recommendation value which is a suggested 25-38 g/day for adults (King et al., 2012). The finding of the present study was contrary to what has been reported that fiber intake significantly decreased between 1988-1994 and 2011-2012 (Casagrande and Cowie, 2017). Beneficial functions of dietary fiber, which induced satiation and satiety to suppress energy intake (Blundell and Burley, 1987), had gradually been acknowledged by the public. Analysis of logistic regression also highlights the protective role of dietary fiber against obesity (BMI: OR=0.96, 95% CI: 0.84, 1.08; WC: OR=0.85, 95% CI: 0.74, 0.98).

A previous study of 434 older adults between the ages of 60 and 80 years old documented a similar association between cereal fiber intake and body fat. The higher cereal fiber intake was associated with lower total percent body fat and percent trunk fat mass measured by DXA (McKeown et al., 2009). From this finding, it can be assumed that dietary fiber intake is linked with body fat among older adults. This standpoint explains that fiber intake is only associated with WC which represents abdominal obesity rather than BMI which reflects general obesity.

Although older adults in the age group of 80 years old and older had a lower risk of being obese than other age groups, their intake amount of dietary fiber was the lowest. According to benefits of dietary fiber intake, people aged 80 years old or over are encouraged to intake more fiber for a healthy life. Non-Hispanic Blacks had the lowest amount of fiber intake among all ethnicities, while the older adults in the "other race" group consumed higher dietary fiber than other ethnicities. This result highlights the low odds of obesity for the "other race" group (OR=0.37, 95% CI: 0.25, 0.53). As a consequence, the intake of dietary fiber is considered as a protective factor against obesity. Males consumed more fiber than females, and males had a lower risk of being obese compared to females (OR=0.59, 95% CI: 0.50, 0.71). A reverse finding in Brazil was noted by (da Silva et al., 2019) that inadequate intake of fiber in males was worse than in females. The different dietary patterns in different countries may account for the different results and also require researchers to assure intake instruments are culturally sensitive.

The trend of dietary fiber intake was similar to the trend of obesity from 2005 to 2018. It seems possible that the protective function of dietary fiber could help slow down the trend of obesity among older adults. Therefore, nutrition interventions that promotes intake of dietary fiber among older adults should be considered by clinic practitioners and by policy makers.

2.4.1.3 Diet consumption (protein)

Compared to the cycle of 2005-2006, the intake of protein increased by about 5.00% in both BMI-based and WC-based groups in 2017-2018. Even though adequate protein intake could maintain muscle mass and prevent sarcopenia in older adults (Beasley et al., 2013), findings of the present study demonstrated that protein intake was associated with a higher risk of obesity in the analysis of logistic regression (BMI: OR=1.02, 95% CI: 1.00, 1.05; WC: OR=1.01, 95% CI: 0.98, 1.03).

In this study, the significant association between protein intake and obesity was only noted in BMI-based obesity, but not in WC-based obesity. Different association between the total protein score and central obesity have been reported in the study on the NHANES 1999-2012 among Mexican Americans (Yoshida et al., 2017). Several reasons possibly explain the different results. First, although both studies' data came from the NHANES, they covered different cycles (1999-2012 vs. 2005-2018). Second, this study focused on older adults aged 65 years old and over, and participants' age in (Yoshida et al., 2017)'s study were 20 years old and over. Including young adults may have changed the association between protein intake and obesity. Finally, the represented ethnicities were not only Mexican Americans in this study. Different ethnicities consume different kinds and amount of protein. In this study, non-Hispanic Whites consumed the highest value of protein among all ethnicities. For these reasons, protein intake is significantly associated with general obesity rather than abdominal obesity among older adults in this study.

The intake of protein decreased as age increased. Protein intake was lowest among the older adults aged 80 years and over. Depending on the negative association between protein intake and obesity, the population in the group of 80 years and over have a lower risk of being obese than other age groups. Indeed, due to the increasing occurrence of sarcopenia with aging, older adults are recommended to intake enough protein to prevent muscle loss. Educational level is associated with the intake of protein. The highest value of protein intake was found in the population with higher education attainment, and the lowest value of protein intake was in the population with lower education attainment. The beneficial functions of protein is spread by education, thus the higher the educational level is, the higher the protein intakes. Beyond the benefits of protein, it is important to notice the reverse effect of it causing obesity by protein.

There was a cubic trend of protein intake over 14 years, increasing substantially from 2007-2008 to 2011-2012, and then little change after 2011-2012. The trend of protein intake was similar to the trend of obesity from 2005 to 2018 ($p > 0.05$). In the present study, only total protein intake was included without discerning animal protein and plant protein. Additional work is needed to better understand the association between animal protein and obesity, and the association between plant protein and obesity, in order to encourage older adults to intake different proteins to prevent sarcopenia and prevent obesity simultaneously.

2.4.1.4 Dietary behavior focusing on food away from home (FAFH)

Consumption of FAFH is many times more closely associated with younger generations and young families due to both parents working leaving less time for meal preparation. However, there are reasons why FAFH is a frequent trend for older adults. Besides the convenient and economical effects of FAFH, it can also alleviate the feeling of loneliness which is common among older adults. In this study, there were almost three meals prepared from restaurants, fast food places, food stands, grocery stores or vending machines per week among older adults. From 2005 to 2018, meals of non-home prepared increased by 34.89% in BMI-based group and increased by 35.46% in WC-based group.

In the four age groups, consumption of FAFH decreased with the increase of age. Specifically, older adults, aged 65-69 years old, appeared as the highest value of FAFH, and the 80 and over group showed the lowest times of FAFH. Consistent with findings of the present study, Reynolds et al. (1988) reported that older adults aged 60-64 years old are more likely to patronize fast-food restaurants than their older or younger counterparts, because this age group population had more time to eat out and had not slowed down their lifestyles (Reynolds et al., 1998). Compared to the younger older adults group (65-69 years old), the oldest older adults group (80 years old and over) may suffer physical limitations inhibiting FAFH, thus helping explain the lowest value. This result concurred with a study on food consumption among older adults, in which the older adults aged 75 years old and over was lower than 65-74 years old group for FAFH (Harris and Blisard, 2002).

However, FAFH becoming a general eating behavior among older adults was often the indication of a high energy and fat diet, especially if they often consumed fast food (Paeratakul et al., 2003), since it provided more than one-third of the day's energy, total fat and saturated fat, causing a higher BMI (Bowman and Vinyard, 2004). The logistic regression findings in this studied verified the positive association between FAFH and obesity. Among older adults, one additional occurrence of non-home prepared food per week was associated with 4% increase in the likelihood of BMI-based obesity (OR=1.04, 95% CI: 1.01, 1.08). There was a quartic trend for FAFH over 14 years. Compared to 2005-2006, FAFH expressed a gradually increasing trend from 2007 to 2018. It is suggested that frequently visiting fast-food restaurants contributed to the increase of body weight and waist circumference (Li et al., 2009). As a risk factor of obesity, FAFH should be limited among the older adults.

FAFH consumption changes depending on educational levels. Older adults with a high education attainment consumed FAFH more often than other educational level groups. This result is in agreement with a cross-sectional survey that found that women with higher education were more likely to eat fast food (Hidaka et al., 2018). Nevertheless, findings demonstrated that the high education attainment group had a lower risk of being obese. Perhaps the specific foods eaten away from home help to explain the conflicting results. One example of this phenomenon is that people can choose healthier food away from home, such as a salad with more vegetables and less fat. This shows that a detailed composition of FAFH needs to be analyzed in the future study.

Accordingly, the odds of obesity may be higher in non-Hispanic Whites than other ethnicities due to the meals of FAFH consumed. In 2001, in the city of New Orleans, Louisiana, more fast-food restaurants appeared in Black neighborhoods than White neighborhoods (Block et al., 2004). Conversely, the opposite result was observed among all ethnicities, where non-Hispanic Whites had the most times of FAFH. This study focused on the older adults' dietary behavior (FAFH), and the number of restaurants could not represent the intake behavior.

The trend of FAFH was similar to the trend of obesity from 2005 to 2018 ($p > 0.05$). This result suggests that FAFH plays a vital role in obesity prevalence over 14 years. This finding provides evidence that more attention should be given to encouraging healthy restaurant and prepared meal options through industrial and food technology groups. It also provides a strong foundation for educational interventions that help older adults understand and appreciate the added value of home prepared meals versus FAFH in their desire to sustain their health as they age.

2.4.1.5 Physical activity (vigorous, moderate, and vigorous combined moderate intensities)

PA has always been considered to be one of the most effective methods to control obesity (Dubnov et al., 2003). Undoubtedly, the findings of the present study help to validate this conclusion. Among older adults, participations in vigorous, moderate, and vigorous combined moderate PA were all negatively associated with obesity. Specifically, in BMI-based obesity, those who engaged in vigorous combined moderate PA had a lower risk of being obese than those who engaged in the other two intensities of PA. While in WC-based obesity, those who participated in vigorous combined moderate PA and those who participated in vigorous PA had a lower risk than those who participated in moderate PA for obesity. Thus, regardless of BMI-based or WC-based obesity, the combination of vigorous PA and moderate PA can reduce the odds of becoming obese. This is supported by previous studies which found that the high-intensity PA was correlated to lower rates of obesity rather than moderate PA (Bernstein et al., 2004), and that the moderate-to-vigorous PA was strongly related to obesity (Maher et al., 2013). Thus, older adults with the physical capacity to do so should be encouraged to engage in both vigorous PA and moderate PA for obesity prevention and control.

A national estimate of among 5,589 older adults aged 60 years and over, based on the NHANES 1999-2004, found that 52.5% of American older adults had no leisure-time PA (Hughes et al., 2008). This study continued this research on older adults and found the percentages of participation in the no/low PA were 54.29% in BMI-based obesity and 53.58% in WC-based obesity. This means that the number of older adults in low or no PA increased after 2004. Additionally, more than one-third of individuals took part in moderate PA. Only 3% of the population took part in vigorous PA. The percentage of those who engaged in both vigorous and moderate PA was less than 10%. All of this data shows a low participation in PA among older adults. Furthermore, the trends of all three PA intensities were similar to the trends of BMI-based and WC-based obesity. Therefore, PA intensities possibly drive the prevalence of obesity.

Besides, the low participation in PA among older adults, those who took part in all three intensities of PA decreased from 2005 to 2018. Specifically, the number of participating in vigorous PA decreased by 4 percentage points in both obesity groups over 14 years. The number of participating in moderate PA decreased by 15.97 percentage points in BMI-based group and decreased by 11.21 percentage points in WC-based group over 14 years. And the largest decrease among three PA intensities was vigorous combined moderate PA group, which decreased 30.18 percentage points in BMI-based group and decreased by 28.4 percentage points in WC-based group over 14 years. Over 14 years, with the changes of environment and lifestyle, the participation of PA decreased among older adults across all intensities of PA. Therefore, PA can be targeted to reduce the increase of obesity.

The participation in vigorous PA among older adults aged 65-69 years old was the highest out of all the age groups. A similar result was observed in the moderate and vigorous combined moderate PA, with the highest participation in the 65-69 age group and lowest in the 80 and over group. The decline in PA with age may be explained by the dopamine system, which regulates the motivation of locomotion (Sallis, 2000). Additionally, mobility limitations increase with age. Although the youngest older adults group is more likely to take part in PA, no result of lower obesity risk has been indicated in this group. This suggests that there are other factors to affect obesity besides PA.

After 2005-2006, non-Hispanic Whites appeared as the highest participating group in vigorous and vigorous combined moderate PA, more so than other ethnicities in BMI-based obesity. Similar reports have been shown in the study on the NHANES 1999-2004 (Hughes et al., 2008). Non-Hispanic White older adults engaged in more PA than other ethnicities from 1999 to 2018, but no results confirmed a lower risk of obesity in this group from the current study.

With respect to the findings on the relationship between educational level and PA, the current study demonstrates that older adults with high educational attainment had the highest participation of the three PA intensities over all cycles in BMI-based obesity. Occupation may be a factor. Due to individuals with less education more likely having to engage in strenuous jobs, they had less time to participate in recreational activity (Walsh et al., 2001). A higher educational level promotes a higher participation in PA, which can help protect against becoming obese.

In WC-based obesity, more males than females were active in vigorous and vigorous combined moderate PA, which aligned with the result that males were associated with 4% lower odds of obesity compared to females (OR= 0.59, 95% CI: 0.50, 0.71). Overall, physical activity has enormous potential to reduce obesity and to promote a healthy lifestyle among older adults.

2.4.1.6 Alcohol consumption (moderate)

In the U.S., the majority of current drinkers have been reported as moderate drinkers (Ferreira and Weems, 2008). The moderate drinkers accounted for 7.42% of total participants in this study. Moreover, the cubic trend of moderate alcohol intake shows that there was an increased trend of moderate drinkers from 2007 to 2014 with the highest in 2013-2014, which agrees with findings from Molander et al. of an increasing number of moderate drinkers (Molander et al., 2010). However, compared to 2005-2006, the moderate intake of alcohol was decreased by 30% in 2017-2018.

Although, some researchers documented that alcohol was related to abdominal obesity because the suppression of lipid oxidation by alcohol promoted the deposit of abdominal fat (Schröder et al., 2007; Suter and Tremblay, 2005), a significant association was only observed in BMI-based obesity and not in WC-based obesity. A moderate intake of alcohol was associated with a lower risk of BMI-based obesity in this study (OR=0.65, 95% CI: 0.48, 0.89).

A cross-sectional study in the NHANES 1988-2004 revealed an inverse relationship between moderate consumption of alcohol and obesity (Arif and Rohrer, 2005). Traversy and Chaput (2015) suggested that moderate drinkers were more likely to accommodate their lifestyles of exercise and healthy food intake over a long time (Traversy and Chaput, 2015). A healthy lifestyle can protect against obesity. Potential reasons for the negative association between moderate alcohol intake and obesity include the following. First, more PA is engaged after drinking (Westerterp et al., 2004). The calories caused by alcohol intake are then expended by PA. Second, moderate drinking inhibits the consumption of candy and sugar (Colditz et al., 1991). And last, the appetite decreases after drinking due to the effects of hormones (Traversy and Chaput, 2015). As a consequence, the moderate intake of alcohol causes more energy expended and less energy intake, limiting body weight gain.

The result of the current study demonstrated that the percentage of moderate alcohol intake in older adults with the education of above college graduation were more than those with other educational levels. A growing body of research documented the health benefits of moderate drinking, including cardiovascular benefits, declines in body weight, sleep quality improvement, mood enhancement and stress reduction (Ashley et al., 1994; Baum-Baicker, 1985; Naimi et al., 2005; Peele and Brodsky, 2000). In a national population health survey among 72,375 Canadian participants, 57% respondents believed the health benefits of moderate drinking (Ogborne and Smart, 2001). Individuals with higher education easily obtain and master the knowledge of health benefits associated with moderate drinking, leading to the increasing number of moderate drinkers.

Similar trends appeared between moderate alcohol intake and obesity from 2005 to 2018. As shown through findings of this study, moderate intake of alcohol is thought to be an effective protective factor to prevent obesity among older adults.

2.4.1.7 Smoking behavior

Possibly due to the adverse health effects of smoking, most older adults (78%) were non-smokers in the current study. However, 13% of the older adults were still heavy smokers. Without considering the detrimental effects of smoking, heavy smokers were associated with a lower risk of BMI-based and WC-based obesity compared to non-smokers (OR= 0.52, 95% CI: 0.41, 0.66 in BMI-based obesity; OR= 0.62, 95% CI: 0.48, 0.81 in WC-based obesity).

This result is in agreement with one cross-sectional study among 40,036 Scottish adults, in which smoking protected some older adults from weight gain (Mackay et al., 2013). Nevertheless, opposing results from another study showed that the heavy smokers had a higher risk of obesity than non-smokers (Nawawi et al., 2020). According to measurements of obesity, even though the BMI of Iranian smokers was low, their WCs were higher. As a result, smoking was a risk factor for central obesity rather than for general obesity (Meysamiea et al., 2017). Smoking was often accompanied with other obstacles that hindered healthy lifestyles, such as physical inactivity and psychological problems, which resulted in the deposit of fat (Rabaeus et al., 2013). For this reason, some kinds of smoking were also linked with the increased abdominal fat. However, it was the heavy smoking in particular that was associated with BMI-based obesity in this study. Because of the role of nicotine, the frequency of smoking influences the association between smoking and obesity. Nicotine served as a metabolic stimulant, which stimulated metabolism and burned more calories. Nicotine was also an appetite suppressant, which inhibited food intake (Courtemanche et al., 2018). The intake of nicotine, followed by smoking, leads to less energy intake and more energy expenditure, and then lowers body weight.

In the U.S., all-cause mortality was three times higher in smokers compared to non-smokers (Thun et al., 2013), and a high rate of death was caused by smoking after 65 years old (LaCroix and Omenn, 1992). In other words, in the youngest age in older adults, heavy smokers probably died before they reached eighty years old and over, since heavy smoking leads to a higher mortality rate. For this reason, the most heavy smokers appeared in the youngest age of older adults (65-69 years old) and the least amount of heavy smokers was in the oldest age of older adults (80 years old and over).

Many diseases result from smoking, including many types of cancer, chronic obstructive pulmonary disease, coronary heart disease, stroke and others (Fagerström, 2002). These threats to health caused by smoking are widely acknowledged by anti-smoking propaganda. Education does affect the behaviors of smoking. It is documented that individuals were less likely to smoke and they are more likely to decide to stop smoking after being educated on the harms of smoking, and college education had a negative effect on the prevalence of smoking (De Walque, 2007). In this study, the findings identify that the lowest percentage of heavy smokers was in older adults with education of "college graduate or above", and the highest percentage of heavy smokers was in older adults with education of less than 9^{th} grade. There also appeared to be a higher prevalence of heavy smokers in males than in females.

This finding was consistent with a study of smoking behaviors in Taiwan, which showed the prevalence of smoking in males was higher than that in females. It seems likely that smoking can help males reduce stress and depression, and males are more likely to be addicted smokers. In spite of the number of female heavy smokers being less than that of male heavy smokers, female smoking was correlated to a higher rate of obesity (Meysamiea et al., 2017), primarily to abdominal obesity (Tuovinen et al., 2016). What this means is that females smokers should be cautious of their body weight problems.

The trends of heavy smoking were different in BMI-based obesity (significantly different $p < 0.05$) and in WC-based obesity (similar, $p > 0.05$). The negative effect on the risk of obesity prevalence by heavy smoking was shown in this study. Although heavy smoking was negatively associated with obesity among older adults in the current study, smoking was not suggested as a tool to prevent obesity, concerning the harmful impact on healthy life. Simultaneously, intervention of weight management is recommended to smokers if they decide to pursue smoking cessation.

2.4.1.8 Sleep problems (nearly every day)

In this study, 35% of older adults reported they had been bothered by sleep troubles, and 8.27% reported suffering sleep problems nearly every day. A national poll documented that more than half of older adults did not realize the significance of their sleep problems, and had just considered it to be a normal phenomenon with aging (Malani et al., 2017). Thus, the real number of older adults suffering from sleep problems seems likely higher than the reported one.

Poor sleep quality can lead to many diseases, including obesity. It is reported that poor sleep quality had an adverse effect on weight in older females (Mamalaki et al., 2019). The current results verified this report that poor sleep quality (sleep troubles nearly every day) was associated with a 41% higher risk of becoming obese compared to older adults without sleep problems (BMI: OR= 1.41, 95% CI: 1.01, 1.96). This significant association may be explained by the following reasons. First, sleep quality was associated with physical function. Better sleep may improve the physical performance among older adults (Murakami and Livingstone, 2015), and poor sleep predicted less or insufficient PA (Holfeld and Ruthig, 2014). Individuals who experienced good sleep have more energy to engage in PA, compared to their poor sleep quality counterparts. Poor sleep quality limits the PA of older adults, leading to less energy expended and body weight gain as a result. Sleep problems also had a harmful impact on carbohydrate metabolism, which resulted in more food intake (Nedeltcheva and Scheer, 2014). Lastly, poor sleep quality increased the risk of physiological stress, which caused body weight gain through disordered eating behaviors (high calorie intake) (Norton et al., 2018). In addition, sleep problems can affect a regular lifestyle by interrupting regular mealtimes and causing less opportunities to exercise (Patel et al., 2014).

Different ethnicities reported different sleep problems. More Mexican Americans had poor sleep quality than non-Hispanic White older adults in the current study. Inconsistent results were found in a research study in the NHANES 2007-2008, which noted Mexican Americans had less sleep problems than non-Hispanic Whites (Grandner et al., 2013). The difference between this study and Grandner's study were the participants. Participants in this study were older adults aged 65 years old and over. This study did not include young adults. Also, in this study, the frequency of sleep troubles was analyzed, while specific sleep problems, such as snoring and early morning awakening, were examined in Grandner's research.

In this study, individuals with lower education attainment (less than 9^{th}) were shown to present more sleep problems than those with higher education attainment (college graduate or above), which was supported by other research (Grandner et al., 2010). Education can bring a healthy lifestyle through enhancing problem-solving abilities and buffering adverse life situations (Gellis et al., 2005), which decreases the psychological distress of life and encourages a good sleep quality. Gellis's result also verified that higher education attainment was associated with a lower risk of obesity compared to lower education attainment, since poor sleep quality has an adverse effect on obesity prevalence.

A similar trend between poor sleep quality and obesity was observed in the current study. It is possible that poor sleep quality is a contributor to obesity in older adults. Even though the present findings demonstrated the significant association between sleep problem and an obesity risk, sleep problems are often ignored by older adults. Given that sleep problem serves as a risk factor for obesity, poor sleep quality should be addressed and improved for weight management.

2.4.1.9 Intentional Weight Loss

From 2005 to 2018, results suggested that almost one-third of older adults thought they had weight problems and wanted to lose weight. There was a strong positive association between awareness of weight loss and obesity, which means the obese had a strong demand to control their weight (OR=3.56, 95% CI: 2.98, 4.26 in BMI-based obesity; OR=4.29, 95% CI: 3.46, 5.33 in WC-based obesity).

Even though intentional awareness of weight loss increased over 14 years, it did not result in the decline of obesity. Depending on the quadratic trend of intentional weight loss, along with an increasing concern on body weight among participants since 2007, one might suppose the obesity prevalence is slowing down. In contrast to the expectations at the outset of this study, intentional weight loss was not associated with decreased risk of obesity, but it was associated with an increased obesity trend. Why is obesity prevalence still increasing significantly? There are gaps between the awareness of body weight and the actual decline of obesity. It is not enough to realize one's weight problems, one must also take measures to lose weight. There is a huge difference between thinking and action. However, whether methods of losing weight are effective will determine the success of weight loss. It is well known that obesity is a multifactorial caused disease. Even though a certain method may be effective for some individuals, it may not be as helpful for others. For example, compared to young adults, the role of PA in losing weight was not as obvious in older adults (LaRose et al., 2013). For older adults, some methods, such as exhaustive exercise, are not suitable due to physiological reasons. It is notable that muscle can be lost during most processes of weight loss in older adults (Waters et al., 2013). And yet, resistance training could attenuate the loss of fat-free mass during this process (Rejeski et al., 2010). Lastly, even if effective measures promote the decline of body weight in the short term, maintaining a healthy weight is a larger challenge in the long term. Weight regain can occur easily after weight control, because physiological adaptation to weight loss encourages the weight regain through alteration of energy expenditure, substrate metabolism and effects of hormones (Sumithran and Proietto, 2013). Research documents that at least a one-year lifestyle intervention is needed to facilitate the achievement of weight loss (Waters et al., 2013). Consequently, it is a long journey from awareness of body weight to real obesity decreasing.

In the current study, there was a negative correlation between age and intentional weight loss. Those in the young older adults group were more likely to try to lose weight than those in the old age group of older adults. This result is not surprising, because young adults were motivated more by appearance and social influence (LaRose et al., 2013). Compared to young older adults, the old older adults are often limited by the poor physical function, which inhibits their thoughts towards controlling body weight.

In the WC-based obesity, more non-Hispanic Whites than non-Hispanic Blacks perceived themselves to be obese. This finding possibly explains the result found in a previous study in which non-Hispanic Whites lost more body weight than non-Hispanic Blacks (Khorgami et al., 2015). Differing genders also affected awareness of weight loss. Results of the current study showed that more females than males cared about their body weight and wanted to lose weight, and this was supported by other research as well (Serdula et al., 1994). As a previous study (Wardle et al., 2000) reported, findings also suggested that females who wanted to lose weight were more likely to be obese. As a result, this verifies again that intentional weight loss does not equal to actual decreasing of body weight.

With regards to education attainment, an increasing number of individuals with intentional weight loss was observed. When individuals receive more information about obesity, they will know its negative health effects, and then they are more likely to want to manage their body weight. Educational intervention programs showed a positive effect on the decreasing of BMI, body weight and WC (Mazloomy-Mahmoodabad et al., 2017; Riviere et al., 2001). Thus, education plays an important role in the process of obesity intervention, at least increasing the awareness of weight control.

While it is beneficial to conceive of the idea of weight loss, achievement of that goal of weight decrease is difficult. The intentional awareness of weight loss, as the statistically significant contributor to obesity increase, should be realized by the public. Additional, health promotion practitioners should provide effective guidance to help the obese control body weight. These should be especially targeted to specific age groups, offering specific strategies on weight management that includes increased resistance training, and limited high-calories diets options for a healthy lifestyle should be developed depending on their physiological characteristics.

2.4.2 Non-significant lifestyle behaviors and demographic factors related to obesity in older adults

In a study of rural female older adults, the intake of saturated fatty acids was associated with higher BMI and WC (Ledikwe et al., 2003), but no significant association between SFA intake and obesity was observed in the current study. The impacts of other factors on obesity perhaps are much more than the role of SFA are those such as fiber intake, total sugar intake, and PA. Even though the intake of SFA is not a significant factor linked to obesity, SFA intake increased might positively drove the increase of obesity over 14 years. It was reported that the overweight and obese had a high dietary intake of fat, especially SFA (Dooley and Ryan, 2019). In addition, a high intake of SFA could exacerbate sarcopenia in older adults (Granic et al., 2020). Therefore, public health professionals should suggest a limited SFA intake for healthy aging.

Both short sleep duration ($<$ 5 hours) and long sleep duration ($>$ 10 hours) were related to obesity (Marshall et al., 2008). So, the U-shaped association between sleep duration and obesity was brought up, which means short sleep or long sleep leads to obesity. The short or long sleepers had more risk factors of obesity than normal sleepers (6-9 hours), including physical inactivity and psychological distress (Theorell-Haglöw et al., 2012). Findings showed that there was no significant association between sleep duration and obesity ($p > 0.05$) because the mean sleep duration of participants in this study was in the normal range (mean: 7.51 ± 0.03).

In an analysis of logistic regression, some demographic factors correlated with obesity. Specially, age and ethnicity were significantly associated with both BMI-based and WC-based obesity. Education level was only related to BMI-based obesity, and gender was only linked with WC-based obesity. Age and gender are the biological characteristics for populations, and therefore they are not modifiable. Ethnicity can result in the difference of genetics and culture. Given that education attainment is a behavior and habit, it can be easily changed by individuals themselves, compared to age, gender or ethnicity. For this reason, education plays an essential role in preventing the prevalence of obesity. Health practitioners should give guidance and recommendations to older adults so that they better understand the adverse effect of obesity on their health, and so they can master effective measures to prevent it.

2.4.3 Strength and Limitation

2.4.3.1 Strength

The participants of this study are a nationally representative sample of older adults in the U.S., so results can be generalized to the American older adult population. In the current study, relatively comprehensive lifestyle behaviors including diet, PA, smoking, drinking, sleep and awareness of weight loss, were analyzed in relation to obesity among older adults. These identified associations between lifestyle behaviors and obesity provide a foundation for healthy aging.

2.4.3.2 Limitations

As with all studies, this study has some limitations. As we discussed previously, we chose to define obesity using the traditional measures of BMI and WC. Although body composition examined by DXA may be more accurate for measuring obesity in older adults, data on fat mass cannot be obtained from the NHANES dataset because older adults were not tested for body fat through DXA. This is suggested that an accurate anthropometric measure of fat mass, such as DXA, can be used for future obesity research in older adults.

Second, due to limited lifestyle behaviors in the NHANES dataset, several factors possibly related to obesity are omitted in order to search for the consistent variables over 7 two-year cycles, such as PA duration and frequency, sedentary activities (screen time), and physical function. Future data is needed to explore associations between other lifestyle behaviors not mentioned in this study and obesity among older adults.

Finally, the NHANES is a cross-sectional study, so it is not possible to establish causal relationships between lifestyle behaviors and obesity. Further research could be conducted to better understand these relationships and underlying mechanisms.

In conclusion, this study provides evidence of associations between lifestyle behaviors and obesity (both BMI-based and WC-based obesity) among older adults in the U.S. Significant lifestyle behaviors related to obesity in older adults, including total sugar intake, dietary fiber intake, protein intake, food away from home, three intensities of PA, alcohol (moderate), smoking (heavy), sleep problem (nearly every day) and intentional weight loss, were analyzed for trends over a 14 years period, for trends across significant demographic factors, and for trends compared to the obesity trend. Findings have important implications for obesity prevention and intervention by providing recommendations for weight management. It is possible to reduce the prevalence of obesity among older adults through effective strategies that improve their lifestyle behaviors.

CHAPTER 3

USING OAXACA-BLINDER DECOMPOSITION TO ASSESS THE ROLE OF LIFESTYLE BEHAVIORS IN THE INCREASE OF OBESITY AMONG OLDER ADULTS: FINDINGS FROM THE NATIONAL HEALTH AND NUTRITION EXAMINATION SURVEY (NHANES) 2005-2006 AND 2017-2018

3.1 INTRODUCTION

The prevalence of obesity has increased steadily in the United States (U.S.), not only in children and young adults but also in older adults. In 2015-2018, 42% of men and 46% of women aged 65-74 were obese, representing the prevalence rates as high as those in other adults ages 35 or older (CDC, 2020). Moreover, the obesity rates among those 65-74 years of age rose more than 15 percentage points over the past 30 years. Despite the high prevalence and dramatic increase, the problem of obesity among older adults has not received the attention it deserves as conversations on obesity has been dominated by the potential long-term health and economic consequences for children and working-age adults. Although benefits of voluntary weight loss in obese older adults have been documented (Simpson and Raubenheimer, 2005), age-related changes in body composition and possible decreases in muscle mass and bone mineral density accompanying a weight loss make obesity in older adults a complex problem for researchers and healthcare professionals (Villareal et al., 2005).

Part of the increase in obesity among older adults might reflect the physiological difference across generations. With the rise in adult obesity rates since the 1980s, the individuals recently entering old age are likely to have had a weight history different from the previous generation of the elderly. On the other hand, changes in lifestyle behaviors, such as physical activity, sedentary lifestyle, and diet, may have modified the genetic susceptibility to obesity in Caucasians (Heianza and Qi, 2019). In one literature review focusing on 18 cross-sectional studies, several demographic characteristics, such as gender, ethnicity, education, and income, were shown to have varying relationships with obesity among older adults (Ismail and Hamid, 2019). Compared to the non-modifiable demographic factors (such as age or gender), the factors of lifestyle behaviors (such as diet or exercise) might be modifiable. Such interventions, which are designed to modify lifestyle behaviors, might improve or prevent further growth of the obesity epidemic (Brown, 2019) and reduce the risk of morbidity and early mortality associated with obesity. Understanding the contributions of independent factors to obesity in older adults, and then treatment for each independent factor specifically targeted to the elderly, will help us better predict obesity prevalence in the older adult population. The present study sought to investigate how the demographic and behavioral risk factors of obesity explain the continued growth of obesity in older adults in the recent decade.

This study used a simple two-fold Oaxaca-Blinder regression decomposition to examine relative contributions of demographics and lifestyle behaviors to help explain the difference in two continuous measures underlying the obesity risk between two NHANES data cycles – 2005-2006 and 2017-2018. By determining the relative contribution of demographic factors and lifestyle behaviors, researchers can provide evidence-based guidance for developing more targeted interventions needed to help address and positively impact increasing obesity in older adults.

3.2 LITERATURE REVIEW

3.2.1 The trend of obesity in older adults

In the report by the Centers for Disease Control and Prevention (CDC), 24.1% of men and 26.9% of women aged 65-74 years old were classified as obese from 1988 to 1994, and 13.2% of men and 19.2% of women aged 75 years old and over were classified as obese in the same period. While, obesity prevalence between 2015 to 2018 was up to 41.9% in older men aged 65-74 years old and 45.9% in older women of the same age, an increase up to 31.8% in older men and 36.1% in older women aged 75 years old and over has also been documented in the same year period (NHA, 2020). The prevalence of obesity in older adult groups almost doubled from 1988 to 2018.

3.2.2 Associations between lifestyle behaviors and obesity in older adults

Many factors can influence the increase of body weight or storage of fat mass, including demographic factors and lifestyle behaviors. Lifestyle behaviors are more easily modified by people than demographic factors and are important variables to consider when trying to identify optimal weight control methods and/ or intervention.

3.2.2.1 Diet

Carbohydrate (includes total sugar and dietary fiber) Carbohydrates, as one of three macronutrients, typically constitute a major source of energy in dietary intake patterns. In a dietary study of American populations aged 20 years or older from 1999 to 2016, energy percentages from carbohydrates declined from 52.5% to 50.5%. Decreases were also found in energy from low-quality carbohydrates (primarily added sugar) (3.25%). Energy from high-quality carbohydrates (primarily whole grains and nuts) increased by 1.23%. But intake of low-quality carbohydrates remained high, which accounted for 41.8% of total energy intake (Shan et al., 2019).

Overconsumption of carbohydrates can result in weight gain. However, dietary fiber can decrease the caloric density of food, slow the rate of food ingestion, and promote the feeling of fullness. These functions of fiber can prevent the storage of fat and can restrict energy intake, and is felt to be protective against obesity (Van Dam and Seidell, 2007; Van Itallie, 1978). Although dietary fiber has many benefits in reducing obesity and although intake of mean daily dietary fiber appears to have increased from 1999 to 2008, the intake reports still do not meet recommendations (King et al., 2012). The prevalence of inadequate dietary fiber intake was up to 90.1% among older adults and was even more serious in males in 2019 (da Silva et al., 2019). Therefore, the intakes of total sugar and dietary fiber should be considered when evaluating the different causes of obesity, because their roles are different.

Protein Protein maintains muscle mass and prevents muscle loss. Given the importance of protein for healthy aging, older adults need adequate amounts of protein per day. It has been suggested that higher protein intake can improve perceptions of satiety and preserve lean body mass (Leidy et al., 2010). Outcomes on the association between protein intake and obesity are not consistent. Findings from the NHANES 1999-2012 indicated that the total protein score was positively associated with central obesity (Yoshida et al., 2017), whereas a negative relationship between protein intake and abdominal obesity (waist-hip ratio) was found (SHARE and anwar. merchant@ post. harvard. edu Anand Sonia S. Vuksan Vlad Jacobs Ruby Davis Bonnie Teo Koon Yusuf Salim, 2005).

Saturated fatty acids (SFA) Fat provides more than twice the energy of carbohydrates or proteins. Total saturated fat, commonly found in animal products, such as red meat, butter, and dairy product, has been positively associated with BMI (Raatz et al., 2017). There has been a documented decrease in SFA intake in the U.S. from 1971 to 2010 (Heini and Weinsier, 1997; Storey and Anderson, 2015). The decreased intake of SFA did not lead to the increasing trend of obesity in America.

Food away from home (FAFH) It is reported that older adults living alone in the U.S. consume higher calories from FAFH (Davis et al., 1988). In a 2002 survey on food-consumption patterns among older adults, nearly 27% of weekly food expenditures were for FAFH (Harris and Benedict, 1919). Food from restaurants are often high in calories, sugar, and fat, and thereby can lead to weight gain. In recent research from the NHANES 2015-2016, 40% of older adults consumed at least one food or beverage from restaurants per week. Among older adults, energy from restaurants accounts for 42% of daily energy intake, and half of their intake of fat and saturated fat comes from restaurant food (Moshfegh et al., 2019). These findings indicated that FAFH has increased among older adults recently.

Physical Activity (PA intensity) A combination of appropriate PA and restricted diet intake was recognized as the most effective approach to address obesity problems. One cross-sectional study in Switzerland showed that the energy expenditure of high-intensity PA was negatively related to obesity (Bernstein et al., 2004). Similarly, in obese individuals, BMI was strongly related to PA intensities, including moderate and vigorous PA. (Hemmingsson and Ekelund, 2007).

Although the benefits of PA have been communicated to the public, older adults engage in significantly fewer minutes of moderate-to-vigorous PA than young adults (Davis and Fox, 2007). More than half (52.5%) of American adults older than 60 years old had no leisure-time PA. Only 27% of them had more than 150 weekly minutes of leisure-time PA (Hughes et al., 2008). The situation of leisure-time PA was worse recently. In one survey in the NHANES 2011-2016, only 27.3% older adults aged 65 years or older met the leisure-PA guideline (Whitfield, 2020). Therefore, older adults did not meet the recommendations for moderate or vigorous PA during this study period.

Light-intensity PA can be beneficial for older adults. Light-intensity PA has been associated with a lower BMI (Bann et al., 2015) and low-intensity PA is closely associated with abdominal fat distribution among obese older adults (Pescatello and Murphy, 1998). However, in a survey among older adults between 2005 to 2010, obesity was related to functional limitations regardless of PA status (Vásquez et al., 2014). Because of inconsistent results and the fact that most previous research has been focused on children and adolescents obesity and PA, it seems that the association between PA and obesity in older adults has been somewhat ignored. With the future increase of older adults in the American population, this may need to be evaluated more closely to help direct effective innovations in PA programs targeting older adults.

3.2.2.2 Other lifestyle factors

Alcohol Consumption Most current drinkers over 60 years old are moderate drinkers in the U.S. (Ferreira and Weems, 2008). One gram of alcohol intake produces 7 calories. However, older drinkers were more active and they engaged in more physical activities after consuming higher levels of alcohol (Westerterp et al., 2004). It is possible that the energy produced by alcohol is expended by physical activity after drinking in some older adults.

The frequency of drinking influences the association between alcohol consumption and obesity. Current drinkers had lower odds of obesity, whereas binge drinkers had higher odds of obesity (Arif and Rohrer, 2005). The light-to-moderate alcohol intake was not associated with fat mass storage, while heavy drinking was related to weight gain. Researchers in one study found moderate drinking was beneficial to weight control (Traversy and Chaput, 2015). Alcohol has an impact on the suppression of lipid oxidation, non-oxidized fat will preferentially deposit near the area of the abdomen (Suter and Tremblay, 2005). Additionally, through the actions of hormones, such as peptide YY, leptin, or glucagon-like peptide-1, alcohol intake can affect appetite and then decrease food intake. Alcohol consumption can even influence hunger through some mechanisms (Traversy and Chaput, 2015). Therefore, alcohol consumption can decrease energy intake by roles of inhibition, hormones actions and appetite, helping to prevent obesity in some individuals. The association between alcohol consumption and obesity is complex and depends on many different variables including the amount of intake, drinking patterns, type of alcohol, frequency of drinking, or gender. An investigation of the effects of alcohol consumption on obesity among older adults might be an additional informative future research topic.

Smoking habits Different body weights between smokers and non-smokers have been found by previous researchers. Male non-smokers over 40 were on average 5.4 kg heavier than smokers (Khosla and Lowe, 1971). A study of 40,036 Scottish adults in 1995-2010 showed that current smokers had a reduced risk to be overweight compared to never-smokers

(Mackay et al., 2013). Nicotine might explain lower body weight. Nicotine is a metabolic stimulant and appetite suppressant. It is possible that current smokers reduced food intake is due to the suppressant role of nicotine, which explains the occurrence of weight gain after quitting or reducing smoking (Courtemanche et al., 2018).

Pattern or quantity of smoking influences obesity as well. Women who were overweight/ obese with heavy smoking daily were particularly vulnerable for abdominal obesity (Tuovinen et al., 2016). Indonesian heavy smokers had a higher risk of obesity than light smokers among current smokers (Nawawi et al., 2020). However, the falling smoking cannot lead to the increasing prevalence of obesity in the U.S. (Gruber and Frakes, 2006). Therefore, smoking status of current smoking individuals may be related to weight status, regardless of the quantity of smoking. However, there is little research on this association among American older adults.

Sleep habits Individuals who sleep for longer hours (> 10 hours) were more likely to be older adults and also likely to have greater BMI (Léger et al., 2014). The U-shaped association between duration hours and waist circumference (WC) was reported in only female participants. Short (< 5 hours) and long (> 10 hours) sleepers had higher WC than normal sleepers (7-8 hours) (Theorell-Haglöw et al., 2012). In sum, sleeping too little or sleeping too much has been found to be a risk factor for developing obesity.

The difficulty of sleeping is a problem that affects many older adults. Supported by the University of Michigan National Poll on Healthy Aging, 46% of older adults reported having trouble falling asleep (Malani et al., 2017). Sleep problems were negatively associated with BMI and WC in female older adults (Mamalaki et al., 2019). Meanwhile, the high quality of sleep was associated with increased BMI and WC among male older adults (Gildner et al., 2014).

Intentional weight loss The awareness of obesity within older adults is necessary, because it is a precondition for determining whether a weight-loss program will have a successful effect. In general, if someone intentionally controls their body weight, weight loss can be achievable in the short term. Maintaining ideal weight in the long term is the larger challenge, and weight loss is often followed by weight regain. Research indicates that approximately 20% of overweight individuals can successfully maintain weight loss for at least one year. If they are able to maintain it for 2-5 years, it is easier to maintain for the rest of their lives (Wing and Phelan, 2005). Thus, the perception of weight loss at first combined with appropriate approaches for maintaining it will ensure weight control be successful and sustainable which could prevent, and/or reduce obesity in this population.

However, it should be noted that weight loss in older adults is often accompanied by the loss of muscle mass, which results in sarcopenia (Darmon, 2013). In the short-term studies among older populations, PA, particularly resistance training, expresses its advantage in weight loss programs. Resistance training can attenuate the loss of fat-free mass, which is essential for physical function in older adults (Rejeski et al., 2010). So weight loss through resistance training is recommended for older obese individuals.

3.2.3 Oaxaca-Blinder regression decomposition use in obesity research

The OB decomposition (Blinder, 1973) is an approach originally developed in economics to analyze male-female and/or white-black wage differentials. These differentials can be attributed to various known determinants such as education and experience, expressed as absolute differences or percentages in either directions of contributions. The differential that remains unaccounted for by known determinants is interpreted to measure true disparity or discrimination. This method has been expanded in recent years to explain health disparity, including research on obesity (Sen, 2014). Race and gender disparities were analyzed by obesity researches (Shackleton et al., 2019; Singleton et al., 2016; Taber et al., 2016), and socioeconomic determinants were also analyzed using Oaxaca-Blinder regression decomposition (Emamian et al., 2017). As well as contributions of individual variables, the OB decomposition method could measure the contribution of groups of several variables to an outcome (Cuevas et al., 2020). Analogous to the analysis of group differences, the model has been applied to cross-period differentials (Nie et al., 2018).

This study explored the use of the OB regression decomposition method in explaining the increase in obesity among older adults in the U.S. Obesity is multi-factorial, affected by many factors such as fast-food consumption, sedentary lifestyle, sleeping time, hypercaloric nutrition, alcohol consumption, and depression (Popa et al., 2020). In a study of obesity trends in Cuba from 2001 to 2010, the changes in demographic and socioeconomic characteristics related to obesity were analyzed through the OB decomposition method. The model found that a 13-15% of the increase in overweight and obesity could be explained by changes in the risky behaviors, age and education (Nie et al., 2018).

Although multiple factors contribute to the obesity prevalence, analysis of lifestyle behaviors' contributions to obesity difference among American older adults is scarce. With the increasing population share of older adults coupled with the increase of obesity among them, more knowledge on the extent to which each factor contributes to the obesity trend will help explain the reasons for the increase and help find effective strategies to handle the increasing obesity rates in older adults. In particular, knowing the contribution of individual lifestyle behaviors would be helpful to design more effective individualized weight management programs for older adults depending on their physiological and lifestyle characters. Such investigations of the role of lifestyle behaviors on the change of obesity could provide greatly needed evidence to help direct future healthy aging intervention programs and positively impact future obesity trends in older adults.

Hypothesis

The increase in obesity among older adults over the 2005-2018 year period is explained by changes in lifestyle behaviors and demographic factors. Specifically, the increased intakes of sugar, protein, saturated fatty acid, and FAFH are related to the increase of obesity prevalence. The decreased of fiber intake, PA, alcohol intake, smoking, sleep duration and quality, and intentional weight loss are related to the increase of obesity prevalence.

3.3 METHODOLOGY

3.3.1 Data

This study used public-use data from the National Health and Nutrition Examination Survey (NHANES) (NHANES Questionnaires, Datasets, and Related Documentation, n.d.). The NHANES is a nationally-representative cross-sectional study, repeated in two-year cycles by the National Center for Health Statistics (NCHS) at the Centers for Disease Control and Prevention to assess the health and nutritional status of the American population. The NHANES uses structured interviews to obtain demographic, socioeconomic, dietary, and health-related information; physical examination for medical, dental, physiological information; and laboratory tests. The NHANES uses the Automated Multiple Pass Method (AMPM) to collect accurate data on dietary intake by five steps (quick list, forgotten foods, time & occasion, detail cycle, and final probe) and calculates nutrient intakes based on a two-day dietary interview (NHA, 2020).

This study used data from the 2005-2006 cycle and the 2017-2018 cycle. These cycles were selected because they provided continuity in the variables and questions this study was most interested in.

Overall, steps of this study are illustrated below.

3.3.2 Subjects

The study sample consisted of older adults defined as individuals of ages equal to or greater than 65 years old at the time of screening. There were 1,189 older adults in the cycle of 2005-2006 and 1,500 older adults in the cycle of 2017-2018. The 1,228 subjects who answered "do not know", refused to answer questions, or had missing data on any of the key variables of this study were excluded from the sample. This resulted in a sample size of 1,461.

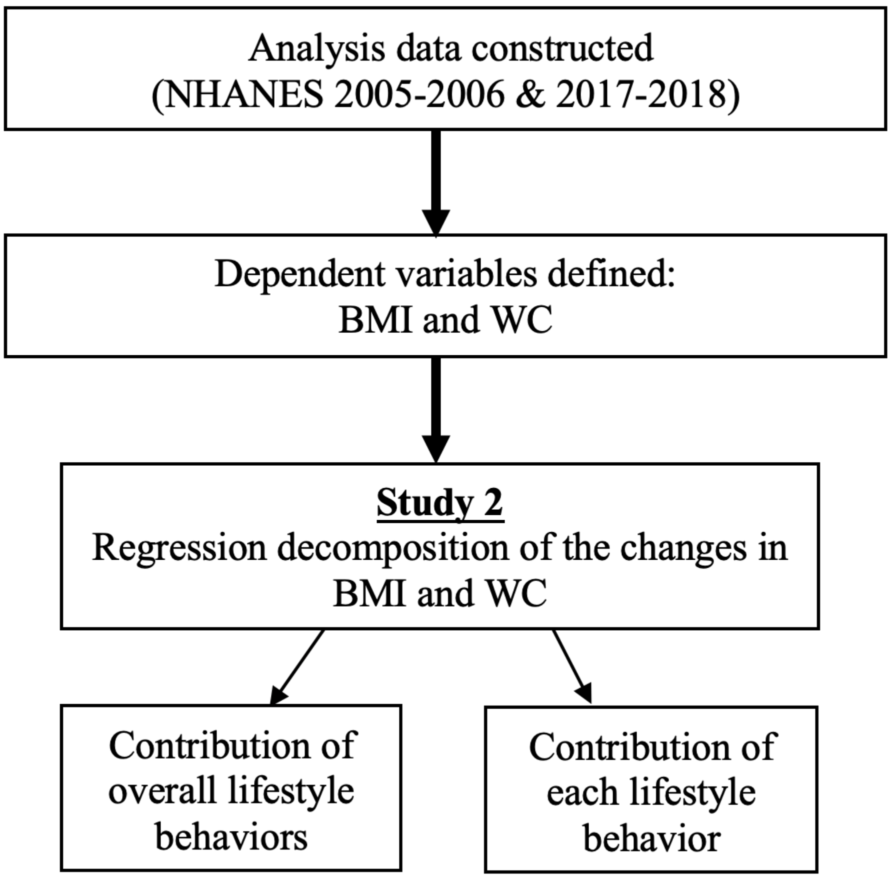

Figure 3.1. Research steps in Study 2

3.3.3 Variables

3.3.3.1 Dependent variable (body mass index and waist circumference)

Body mass index (BMI) (kg/m^2) and WC (cm) were obtained from the Body Measures files in the NHANES Examination Data and used as dependent variables for regression decomposition. Other measures of body composition such as dual-energy X-ray absorptiometry (DXA) scan measures considered more relevant indicators of obesity for older adults were unavailable for the given age group in the NHANES data cycles being used.

A dichotomous variable of BMI-based obesity was defined with 1 if BMI $\geq$ 30 kg/m2 and 0 otherwise. A dichotomous variable of WC-based obesity was defined with 1 if WC $\geq$ 102cm and 0 if otherwise for men; 1 if WC $\geq$ 88cm and 0 if otherwise for women. Because BMI and WC yield different obesity measures, association analysis was conducted separately for the BMI-based obesity variable and the WC-based obesity variable.

3.3.3.2 Lifestyle behavior variables

The specific NHANES files from which lifestyle behavior variables were extracted are listed in Table 2.2. Contributing lifestyle behavior factors were classified into i) diet (total sugar intake, dietary fiber intake, protein intake, saturated fatty acids intake, and frequency of food away from home), ii) physical activity intensity, iii) other lifestyle factors (alcohol, smoking, sleep duration and sleep problem, and intentional weight loss).

Dietary consumption behavior (nutrient data) Daily amounts of energy intake, carbohydrate, total sugar, dietary fiber, total saturated fatty acids, protein, and alcohol were obtained from the NHANES dataset. Because dietary intakes were collected for two days for each individual, the averages of the first-day and second-day intakes were used. For the individuals with only first-day dietary data (0.9% of total data), first-day data was used. The test of collinearity for energy intake and carbohydrate yielded a variance inflation factor (VIF) greater than 10, which means collinearity did exist. So, the variables of energy intake and carbohydrate were dropped. Total intakes of sugar, protein, dietary fiber, and saturated fatty acids were measured in grams.

FAFH Frequencies of FAFH were obtained based on the dietary behavior questionnaires using the questions "During the past 7 days, how many meals did you get that were prepared away from home in places such as restaurants, fast food places, food stands, grocery stores, or from vending machines?" Respondents were instructed not to include meals provided as part of the community programs. The range of answers was from 0 to 21.

Intensities of physical activity The Physical Activity file of the NHANES questionnaire data included questions on whether or not the respondent engaged in moderate and vigorous physical activities in their leisure time. The questionnaire described the vigorous activity as "sports, fitness, or recreational activities that cause heavy sweating or large increases in breathing or heart rate." In the 2005-2006 cycle, running, lap swimming, aerobics class or fast bicycling were given as examples, while in the 2017-2018, running or basketball were the examples. The moderate activity was described as "sports, fitness, or recreational activities that cause a small increase in breathing or heart rate." Examples provided in the 2005-2006 cycle were brisk walking, bicycling for pleasure, golf, and dancing, while in the 2017-2018, brisk walking, bicycling, swimming, or volleyball were given as examples. The exact questions were phrased as "Over the past 30 days, did you do [...] activities for at least 10 minutes [...]?" (2005-2006) and "In a typical week, do you do [...] activities for at least 10 minutes [...]?" (2017-2018). For each of the questions for moderate and vigorous-intensity activities, respondents provided "yes" or "no" answers. In this analysis, four categories of intensity were created based on those two questions: moderate-intensity if the answer of moderate-intensity PA question was "Yes" but the answer of vigorous-intensity PA question was "No"; vigorous-intensity if the answer of vigorous-intensity PA question was "Yes" but the answer of moderate-intensity PA question was "No"; moderate combined with vigorous-intensity if both answers were "Yes"; low-intensity or none if the answer was "No" in both questions. In the regression, compared to vigorous-intensity PA, moderate-intensity PA, and moderate combined with vigorous-intensity PA groups, group of low-intensity or none PA was set as the reference group.

Other lifestyle factors

Alcohol consumption behavior Alcohol status was defined using the average value of two-day Dietary Intake data of NHANES. Respondents were categorized on the basis of alcohol intake (g/day) into three levels including none/light, moderate, and heavy, based on (Maher et al., 2013). None/light alcohol intake was defined as alcohol intake $< 28g/day$ for men and $< 14g/day$ for women. A moderate alcohol intake was defined as alcohol intake between 28 and 56 g/day for men, and between 14 and 28 g/day for women. A heavy alcohol intake was defined as alcohol intake $\geq 56g/day$ for men, and $\geq 28g/day$ for women. In the regression, the none/ light alcohol group was set as the reference group compared to the moderate/ heavy alcohol group.

Smoking status Smoking status was categorized based on serum-cotinine levels (ng/mL) into four levels following the literature (Maher et al., 2013). Compared to the self-report measures in the Cigarette Use questionnaire of NHANES, using biomarkers such as the level of serum-cotinine provided a more objective measure. In addition, serum-cotinine levels can reflect second-smoking which might be a lifestyle factor.

A non-smoker was defined as serum-cotinine levels $< 0.1ng/mL$. A light smoker was defined as serum-cotinine levels between 0.1 and 1 ng/mL. A moderate smoker was defined as serum-cotinine levels between 1 and 3 ng/mL. A heavy smoker was defined as serum-cotinine levels $\geq 3ng/mL$. The non-smoker was set as the reference group compared to light, moderate, and heavy smokers.

Sleep patterns Two variables representing the sleep patterns were created based on the NHANES Sleep Disorder questionnaire file. Sleep duration was "how much sleep do you get (hours/day)", and units were hours. Sleep quality was defined based on the questionnaire item (sleep problems), "Trouble sleeping or sleeping too much over the last two weeks". Answers were a choice from "not at all", "several days", "more than half the days", and "nearly every day". In regressions, the reference group was the "not at all" group.

Intentional weight loss The question in intentional weight loss was "During the past 12 months, have you tried to lose weight?". Answers were "Yes" and "No". The answer of "No" (Did not try to lose weight) was set as the reference group in regressions.

3.3.3.3 Demographic characteristics

The participants' demographic characteristics were obtained from the Demographic Variables Sample Weights file.

Gender In regressions, women were set as the reference group.

Age The "Age in years at screening" were used for analysis. The range of age was from 65 to 80 years old, as the NHANES top-codes the age at 80. Dichotomous variables representing four categories of age were created: 65-69 years old, 70-74 years old, 75-79 years old, and 80 years old and over. The reference group in regression models is 65-69 years old.

Ethnicity Dichotomous variables indicating Non-Hispanic White, Mexican Americans, other Hispanic, Non-Hispanic Black, and other race were used. In regressions, non-Hispanic White was set as the reference category.

Education level The demographic questionnaire of NHANES included a question "What is the highest grade or level of school completed or the highest degree received". Five dichotomous variables were created indicating less than 9th grade, 9-11th grade, high school, some college or associate (AA) degree, and college graduate or above. In regressions, less than 9th grade was used as the reference category.

Marital status Marital status was combined into four categories: never married, married or living with a partner, widowed, and divorced or separated. The reference group in regression models was married or living with a partner.

Annual family income Dichotomous variables representing six categories of annual family income (gross) were created: under $20,000, $20,000-34,999, $35,000-44,999, $45,000-54,999, $55,000-64,999 and $65,000 and over. The reference group in regression models was the under 20,000 group.

3.3.4 Statistical analyses

Data were analyzed using Stata software (Version 15.1, StataCorp, LP). In this study, two waves of the NHANES, which were 2005-2006 and 2017-2018 cycles, were used. The multi-year sample weight was computed by dividing the two-year sample weights by the number of two-year cycles, following the formulas provided in the website of the CDC (https://wwwn.cdc.gov/nchs/nhanes/tutorials/module3.aspx). The two-fold Oaxaca- Blinder regression decomposition for linear models using 2005-2006 cycle as the reference, described by Ben Jann (2008), was used to assess the explanatory effects of the independent variables. Three groups of independent variables were included. They were: lifestyle behaviors: diet [i.e., total sugar intake, dietary fiber intake, saturated fatty acids intake, protein intake, and FAFH], physical activity, and other lifestyle factors [i.e., alcohol intake, smoking, sleep duration and quality, and intentional weight loss]; and demographic factors: [i.e., age, gender, ethnicity, education level, marital status, and annual family income]. In this study, it was expected that all factors of lifestyle behaviors had contributions to the increase of BMI and WC between the two cycles that are twelve years apart. Specifically, we predicted that the increased intakes of sugar, protein, saturated fatty acid, and FAFH will be related to the increase of BMI and WC. We also predicted that the decreased of fiber intake, PA, alcohol intake, smoking, sleep duration and quality, and intentional weight loss will be related to the increase of BMI and WC. An alpha level of 0.05 was set to determine statistical significance.

3.4 RESULTS

In the current study, the Oaxaca-Blinder regression decomposition was applied to detect how much change of obesity could be explained by lifestyle behaviors from 2005-2006 to 2017-2018. Altogether, contributors explained almost one-third of overall obesity change between 2005-2006 and 2017-2018 (29.38% in BMI increase and 29.09% in WC increase). In the 2005-2006 and 2017-2018 cycles of the NHANES combined, there were 1,502 participants aged 65 or older who had information on their BMI, and 1,482 participants aged 65 or older who had information on their WC. Of those, 1,461 participants had both BMI and WC information to determine the obesity status based on both criteria, which was the sample for this study.

This study primarily focused on the portion of the change in obesity that could be explained. Altogether, contributors explained almost one-third of overall obesity change between 2005-2006 and 2017-2018 (29.38% in BMI increase and 29.09% in WC increase). Findings suggest that more than half of the changes in obesity over the 12 year study period were explained by lifestyle behaviors (54.86% in the increase of BMI and 53.12% in the increase of WC) if other factors stayed the same levels as 2005-2006. In regards to the contributions to BMI difference, other factors of lifestyle behaviors, including alcohol, smoking, sleeping and intentional weight loss, marked the largest impact (25.98%) on BMI difference, followed by diet (19.87%) and PA (9.00%). The order of contributions for WC increase was the same as that in the increase of BMI. The first three contributors in diet were protein intake, SFA intake, and FAFH, and the first three contributors in other factors were intentional weight loss, smoking and sleep duration.

3.4.1 Descriptive Statistics

3.4.1.1 Changes of obesity

The weighted means and percentages of variables for the sample were shown in Table 2.11. Between 2005-2006 and 2017-2018, the BMI value significantly increased ($p < 0.001$), and so did the WC value ($p < 0.001$). In addition, the prevalence of obesity based on the BMI standard significantly increased by 10.46 percentage points (from 27.54% in 2005-2006 to 38.01% in 2017-2018) ($p < 0.001$). When obesity was defined by the WC standard, the prevalence of obesity increased by 5.39 percentage points (from 65.35% in 2005-2006 to 70.74% in 2017-2018) ($p = 0.02$). These results showed the increase of obesity, both in generalized, BMI-based obesity and abdominal, WC-based obesity.

3.4.1.2 Changes of lifestyle behaviors

From 2005-2006 to 2017-2018, in overall diet, the intakes of protein and saturated fatty acids increased, while the intake of total sugar decreased. Of those, the decrease in the intake of sugar ($p < 0.001$) and the increase in the intake of saturated fatty acids ($p < 0.001$) were statistically significant. Compared to the cycle of 2005-2006, the intake of protein increased by about 5 percentage points in both BMI and WC groups in 2017-2018. The increased intake of protein from 2005-2006 to 2017-2018 contributed to 5.64% and 4.40% of the increase of BMI and WC groups, separately. This result was supported by the report that protein intake protected against weight loss among the healthy older adults (Gray-Donald et al., 2014). A higher consumption of protein is often linked with a higher consumption of carbohydrates and fat. Given this, excessive protein intake could promote an unwanted increase of body weight in some individuals.

In this study, through OB regression decomposition, the decreased intake of total sugar among older adults contributed to about 1% of BMI and WC increase. The main providers for energy were total fats and carbohydrates (Song et al., 2012). Thus, total sugar intake was not the main reason for the increase obesity in this study.

The number of meals prepared outside of home per week increased significantly ($p < 0.001$). From 2005-2006 to 2017-2018, meals of non-home prepared increased by 34.89 percentage points in BMI group and increased by 35.46 percentage points in WC group among American older adults. The analysis of regression decomposition shows that the increased meals of non-home prepared promote the increase of BMI and WC from 2005-2006 to 2017-2018, which contribute to 7% for obesity change. Frequently visiting fast-food restaurants contributed to the increase of body weight and waist circumference (Li et al., 2009).

Participation in PA in vigorous, moderate, and moderate combined with vigorous intensities decreased between these two periods, and the decrease in moderate intensity and moderate combined with vigorous intensity were significant ($p < 0.001$). From 2005-2006 to 2017-2018, the low participation in PA among older adults, those who took part in all three intensities of PAs decreased. Specifically, the number of participating in vigorous PA decreased by 4 percentage points in both obesity groups over 12 years. The number of participating in moderate PA decreased by 15.97 percentage points in BMI group and decreased by 11.21 percentage points in WC group over 12 years. And the largest decrease among three PA intensities was vigorous combined moderate PA group, which decreased 30.18 percentage points in BMI group and decreased by 28.4 percentage points in WC group over 12 years. The decrease of participation in overall PA contributed to 9-10% of the increase of BMI and WC between 2005-2006 and 2017-2018.

In this study when assessing the intake of alcohol, the moderate alcohol intake significantly decreased ($p < 0.001$), but heavy alcohol intake increased, although the latter was not statistically significant.

All light, moderate, and heavy smoking decreased over 12 years, with a significant decrease in light smoking ($p < 0.001$). The finding of this study shows that heavy smoking decreased by 7.52 percentage points in the increase of BMI and decreased by 4.22 percentage points in the increase of WC from 2005-2006 to 2017-2018. The contributions of the decline in smoking between 2005-2006 to 2017-2018 was 5.53% in the increase of BMI and 3.97% in the increase of WC through the analysis of OB regression decomposition. A similar result was found in one study among 25,318 Cuban urban adults that smoking contributed up to 42% in BMI increase and 10% in WC increase from 2001 to 2010 (Nie et al., 2018).

In 2017-2018, the number of older adults suffering sleep problems nearly every day increased by 10.09 percentage points in BMI group and increased by 14.12 percentage points in WC group compared to 2005-2006 cycle. Both the duration of sleep ($p < 0.001$) and the intention to lose weight ($p < 0.001$) significantly increased. For sleep quality, the number of sleep problems on several days in the two weeks decreased, but the number of people having sleep problems on half of the days or nearly every day increased, and the number of people having sleep problems on half of the days significantly increased ($p < 0.001$). These results indicated that sleep problems were more serious in 2017-2018 compared to 2005-2006. The current result of regression decomposition analysis suggested that the increase of sleep problems (nearly every day) promoted the increase of BMI and WC. While, the opposite results were found in sleeping problems on several days and on more than half days.

In contrast to the expectations at the outset of this study, intentional weight loss was not associated with decreased risk of obesity, but it was associated with an increased obesity trend. The results suggested that almost one-third of older adults thought they had weight problems and wanted to lose weight. Even though intentional awareness of weight loss increased by 27.13 percentage points in BMI group and increased by 32.10 percentage points in WC group over 12 years, it did not result in the decline of obesity but promoted the increase of BMI and WC. At the same time, the increase of intentional weight loss was a main contributor to the increase of obesity (26.40% in BMI group and 24.48% in WC group).

3.4.1.3 Changes in obesity related to demographic factors

Among demographic factors, the proportions of Mexican Americans, other Hispanic populations, and other race populations significantly increased from 2005-2006 to 2017-2018 ($p < 0.05$), while the proportion of White populations significantly decreased ($p <$

0.001). The proportion of people with an educational attainment of 9th-11th grade, some college education, and college degree or above all significantly increased ($p < 0.05$), and proportion of people with an educational attainment of less than 9th grade significantly decreased ($p < 0.001$). The proportion of those who were divorced or separated significantly increase ($p < 0.001$), while the proportion of widowed participants significantly decreased ($p < 0.001$). In annual family income, the proportion of participants with an annual family income under \$20,000 and in the \$20,000 to \$34,999 range significantly decreased ($p < 0.001$), and those with an annual family income over \$65,000 significantly increased ($p < 0.001$) between 2005-2006 and 2017-2018. Consequently, the changes in ethnicities, educational attainment, marital status, and annual family income from 2005-2006 to 2017-2018 might have played an important role in the changes of obesity across these years.

3.4.2 Regression Decomposition

Regardless of BMI-based obesity or WC-based obesity, obesity increased from 2005-2006 to 2017-2018. The method of OB-regression decomposition was performed to detect the proportion of each factor for explaining the change of obesity from 2005-2006 to 2017-2018. In the analysis of both BMI-based and WC-based obesity, there was a positive contribution to the increase of obesity in overall lifestyle behaviors, which included the changes of sugar intake, protein intake, saturated fatty acids intake, FAFH, all three intensities of PA, all kinds of smoking, moderate alcohol intake, sleep problems happening nearly every day, and intentional weight loss. Positive contribution means that the changes of all these contributors listed above promoted the increase of BMI and WC between these two periods. In other words, if removing these contributors or if these contributors stay the same levels between two cycles, the differences of BMI and WC decrease. In addition, the contributors that played a negative role on the increase of BMI and WC were overall demographic factors, the intake of fiber, the intake of heavy alcohol, sleep duration, and overall sleep quality (including sleep problems happening on several days and half of the days). If these negative contributors were removed, the gap of BMI and WC between 2005-2006 and 2017-2018 would increase. The value of BMI in 2017-2018 might be larger than that in 2005-2006 if the negative contributors were removed. So, the negative factors mitigated the increase of BMI and WC and could be considered as protective factors against obesity epidemic among older adults.

3.4.2.1 Regression Decomposition of BMI

Changes in lifestyle behaviors and demographic factors together explained 0.39-units increase (95% CI: -0.17, 0.95) of the 1.34-units increase in BMI, which equals 29.38% of total BMI increase. Lifestyle behaviors explained 54.86% of the BMI increase. This implies that 54.86% of the increase in BMI could have been reduced if the lifestyle behaviors stayed at the same as in the 2005-2006 cycle. Changes in demographics contributed -25.48% of the increase of BMI, which means demographic factors detracted 0.34-units from the explained gap and the change of BMI would have increased by 25.48% if the demographic factors remained at the same level of 2005-2006. Specifically, changes in the intake of diet contributed 19.87% of the increase, PA contributed 9.00% of the increase, and other lifestyle behavior factors contributed 25.98% of the increase of BMI from 2005-2006 to 2017-2018. The total increase of BMI was largely driven by the increase in intentional weight loss (which contributed 26.40% to explain the increase of BMI), the decrease in PA (which contributed 9.00% to explain the increase of BMI), and the increase in the number of meals prepared outside of home per week (which contributed 6.82% to explain the increase of BMI). The statistically significant determinants of BMI increase in this study were overall demographic factors (including ethnicity significantly contributed -8.93% of BMI increase), overall lifestyle behaviors, diet intake, and intentional weight loss ($p < 0.05$).

3.4.2.2 Regression Decomposition of WC

In the sample for the analysis of WC-based obesity, changes in lifestyle behaviors and demographic factors together explained 1.09-units increase (95% CI: -0.39, 2.57) of the 3.75-units increase in WC among older adults from 2005-2006 to 2017-2018, which equals

29.09% of the total WC increase. There was a little bit less of an explained percentage (0.29 percentage points) in the sample for the analysis of WC-based obesity than in the BMI-based obesity, which demonstrated lifestyle behaviors included in this study explained less change of obesity in the WC-based group than in the BMI-based group. In terms of the over-time change decomposition, most of the over-time increase of WC was due to total lifestyle behaviors, which contributed to 53.12% of WC increase. This means that 53.12% of WC increase could be reduced if total lifestyle behaviors stayed at the same as in 2005-2006. The negative contributor, demographic factors, contributed to -24.03% of the increase of WC, which suggests that demographic factors mitigate the increase of WC, because the change of WC would have increased by 24.03% if the demographic factors remained at the same level of 2005-2006. The bulk of the overall increase in WC resulted from the increase of intentional weight loss (which contributed 24.48% of the increase in WC), the decrease of PA (which contributed 10.01% of the increase in WC), and the increasing number of meals prepared outside of home per week (which contributed 6.71% of the increase in WC). These contributors were the same as those in the BMI-based obesity group. The contributions of PA intensities changes on the increase of WC were more than that in the increase of BMI, which shows that the decrease of PA facilitates the increase of central obesity. Moreover, the contributions of intentional weight loss and FAFH were less in the change of WC than that in BMI change. So, changes in intentional weight loss and FAFH were more strongly associated with generalized obesity. The statistically significant factors in the analysis of WC were the changes of overall lifestyle behaviors, diet intake, PA, intentional weight loss, and ethnicity (specifically proportion in other race populations). In this group, changes of PA were added as a key factor in the increase of abdominal obesity. From the results of this study, future interventions to decrease potential obesity in older adults should include recommending increased PA and consumption of more frequent home-prepared meals.

Table 3.1. Obesity, lifestyle behaviors, and demographics in the NHANES 2005-2006 and NHANES 2017-2018, weighted means and percentage (n=1,461)

Variables		2005-2006 (n=690)	2017-2018 (n=771)	t	p
Obesity					
BMI (kg/m^2)		27.70	29.04	3.71	0.00*
WC (cm)		99.10	102.85	3.57	0.00*
BMI-based obesity%		27.54	38.01	3.81	0.00*
WC-based obesity %		65.35	70.74	2.31	0.02*
Lifestyle Behavior					
Total sugar (g)		98.38	95.33	-4.53	0.00*
Protein (g)		133.27	139.29	1.47	0.14
Dietary fiber (g)		16.08	16.11	0.94	0.35
Saturated fatty acids (g)		21.87	25.35	3.32	0.00*
FAFH (meals/week)		1.94	2.64	4.20	0.00*
PA	low/none	42.11	50.32	5.99	0.00*
	vigorous	3.24	3.13	-0.52	0.61
	moderate	41.04	36.97	-3.93	0.00*
	vigorous & moderate	13.62	9.58	-4.18	0.00*
Alcohol	none/light	87.33	89.07	2.21	0.03*
	moderate	9.28	6.58	-3.19	0.00*
	heavy	3.39	4.35	0.62	0.53
Smoking	non-smoker	71.37	81.09	3.07	0.00*
	light	11.94	4.58	-3.37	0.00*
	moderate	2.64	0.82	-1.91	0.06
	heavy	14.05	13.51	-0.26	0.80
Sleep duration (hours)		7.16	8.12	11.55	0.00*
Sleep problem	not at all	66.76	61.61	-2.56	0.01*
	several days	22.71	21.17	-0.25	0.80
	more than half the day	2.94	8.69	3.82	0.00*
	nearly every day	7.58	8.52	1.55	0.12
Intentional weight loss	No	67.23	57.17	-3.68	0.00*
weight loss	Yes	32.77	42.83	2.58	0.01*
Demographics					
Age	65-69	31.34	36.48	1.88	0.06
	70-74	28.68	28.35	-0.12	0.91
	75-79	19.06	17.08	-0.31	0.76
	80 and over	20.92	18.09	-1.59	0.11

Table 3.2. Obesity, lifestyle behaviors, and demographics in the NHANES 2005-2006 and NHANES 2017-2018, weighted means and percentage (n=1,461) (continued)

Variables		2005-2006 (n=690)	2017-2018 (n=771)	t	p
Obesity					
BMI (kg/m^2)		27.70	29.04	3.71	0.00*
WC (cm)		99.10	102.85	3.57	0.00*
BMI-based obesity %		27.54	38.01	3.81	0.00*
WC-based obesity %		65.35	70.74	2.31	0.02*
Lifestyle Behavior					
Total sugar (g)		98.38	95.33	-4.53	0.00*
Protein (g)		133.27	139.29	1.47	0.14
Dietary fiber (g)		16.08	16.11	0.94	0.35
Saturated fatty acids (g)		21.87	25.35	3.32	0.00*
FAFH (meals/week)		1.94	2.64	4.20	0.00*
PA	low/none	42.11	50.32	5.99	0.00*
	vigorous	3.24	3.13	-0.52	0.61
	moderate	41.04	36.97	-3.93	0.00*
	vigorous & moderate	13.62	9.58	-4.18	0.00*
Alcohol	none/light	87.33	89.07	2.21	0.03*
	moderate	9.28	6.58	-3.19	0.00*
	heavy	3.39	4.35	0.62	0.53
Smoking	non-smoker	71.37	81.09	3.07	0.00*
	light	11.94	4.58	-3.37	0.00*
	moderate	2.64	0.82	-1.91	0.06
	heavy	14.05	13.51	-0.26	0.80
Sleep duration (hours)		7.16	8.12	11.55	0.00*
Sleep problem	not at all	66.76	61.61	-2.56	0.01*
	several days	22.71	21.17	-0.25	0.80
	more than half the day	2.94	8.69	3.82	0.00*
	nearly every day	7.58	8.52	1.55	0.12
Intentional weight loss	No	67.23	57.17	-3.68	0.00*
weight loss	Yes	32.77	42.83	2.58	0.01*
Demographics					
Age	65-69	31.34	36.48	1.88	0.06
	70-74	28.68	28.35	-0.12	0.91
	75-79	19.06	17.08	-0.31	0.76
	80 and over	20.92	18.09	-1.59	0.11

* Two-tail test from two-sample t-test, adjusting for sampling weights ($*p < 0.05$)

Table 3.3. Regression decomposition of the BMI change between NHANES 2005-2006 and 2017-2018 by changes in lifestyle behaviors and demographics over the same period (n=1,461)

				Coefficient	95%CI		Contribution
Overall							
2017-2018				29.04	(28.48	29.59)	
2005-2006				27.70	(27.23	28.17)	
difference				1.34	(0.61	2.07)	
explained				0.39	(-0.17	0.95)	29.38
unexplained				0.94	(0.18	1.71)	70.62
Explained							
Lifestyle Behaviors				0.73	(0.26	1.21)	54.86*
	Diet			0.27	(0.05	0.48)	19.87*
		Sugar (g)		0.01	(-0.03	0.06)	1.10
		Protein (g)		0.08	(-0.03	0.18)	5.64
		Fiber (g)		0.00	(-0.09	0.08)	-0.26
		SFA (g)		0.09	(-0.07	0.25)	6.57
		FAFH (meals/per)		0.09	(-0.01	0.20)	6.82
	PA			0.12	(0.00	0.24)	9.00
		none/low (reference)					
		vigorous		0.00	(-0.02	0.02)	0.07
		moderate		0.05	(-0.04	0.15)	4.10
		vigorous & moderate		0.06	(-0.03	0.16)	4.83
	Other factors			0.35	(-0.05	0.75)	25.98
		Alcohol		0.04	(-0.06	0.13)	2.93
			none/light (reference)				
			moderate	0.05	(-0.03	0.14)	3.98
			heavy	-0.01	(-0.06	0.03)	-1.04

Table 3.4. Regression decomposition of the BMI change between NHANES 2005-2006 and 2017-2018 by changes in lifestyle behaviors and demographics over the same period (n=1,461) (continued)

			Coefficient	95%CI		Contribution
Explained						
	Smoking		0.07	(-0.07	0.22)	5.53
		none (reference group)				
		light	0.05	(-0.04	0.14)	3.48
		moderate	0.02	(-0.03	0.06)	1.14
		heavy	0.01	(-0.10	0.12)	0.91
	Sleep duration (hours)		-0.10	(-0.32	0.12)	-7.50
	Sleep problem		-0.02	(-0.10	0.06)	-1.38
		not at all (reference)				
		several days	0.00	(-0.03	0.02)	-0.36
		more than half days	-0.02	(-0.09	0.05)	-1.55
		nearly every day	0.01	(-0.02	0.04)	0.53
	Intentional weight loss					
		no (reference)				
		yes	0.35	(0.10	0.61)	26.40*
Demographics			-0.34	(-0.65	-0.04)	-25.48*
	Age		0.07	(-0.02	0.17)	5.44
		65-69 (reference)				
		70-74	0.00	(-0.03	0.03)	0.11
		75-79	0.02	(-0.04	0.08)	1.69
		80 and over	0.05	(-0.03	0.13)	3.64
	Gender					
		female (reference)				
		male	0.01	(-0.04	0.06)	0.43

Table 3.5. Regression decomposition of BMI changes between NHANES 2005-2006 and 2017-2018 by changes in lifestyle behaviors and demographics over the same period (n=1,461) (continued)

		Coefficient	95%CI		Contribution
Explained					
Ethnicity		-0.12	(-0.19	-0.05)	-8.93*
	Non-Hispanic White (reference)				
	Mexican American	0.00	(0.00	0.00)	0.00
	other Hispanic	-0.02	(-0.04	0.01)	-1.22
	other race	-0.10	(-0.16	-0.04)	-7.23*
	Non-Hispanic Black	-0.01	(-0.03	0.01)	-0.48
Education level		-0.08	(-0.24	0.08)	-5.88
	less than 9th (reference)				
	college graduate or above	-0.12	(-0.31	0.07)	-8.67
	9-11 grade	0.04	(-0.03	0.11)	2.83
	high school	0.01	(-0.03	0.05)	0.84
	some college or AA degree	-0.01	(-0.05	0.03)	-0.88
Marital status		-0.10	(-0.21	0.00)	-7.74
	married & living with partner (reference)				
	divorced & separated	-0.01	(-0.05	0.03)	-0.67
	widowed	-0.09	(-0.20	0.01)	-7.00
	never married	0.00	(-0.01	0.01)	-0.07
Annual family income		-0.12	(-0.40	0.17)	-8.80
	under $20,000 (reference)				
	$20,000 – $34,999	0.07	(-0.08	0.22)	5.48
	$35,000 – $44,999	-0.01	(-0.05	0.03)	-0.72
	$45,000 – $54,999	0.03	(-0.04	0.09)	1.97
	$55,000 – $64,999	0.00	(-0.02	0.02)	-0.13
	$65,000 and over	-0.21	(-0.55	0.14)	-15.36
	$20,000 and over	0.00	(-0.02	0.02)	-0.04

Table 3.6. Regression decomposition of WC changes between NHANES 2005-2006 and 2017-2018 by changes in lifestyle behaviors and demographics over the same period (n=1,461)

				Coefficient	95%CI		Contribution
Overall							
2017-2018				102.85	(101.41	104.29)	
2005-2006				99.10	(97.85	100.35)	
difference				3.75	(1.84	5.65)	
explained				1.09	(-0.39	2.57)	29.09
unexplained				2.66	(0.78	4.54)	70.91
Explained							
Lifestyle Behaviors				1.99	(0.84	3.14)	53.12*
	Diet			0.65	(0.12	1.17)	17.24*
		Sugar (g)		0.03	(-0.06	0.13)	0.83
		Protein (g)		0.16	(-0.07	0.40)	4.40
		Fiber (g)		-0.01	(-0.22	0.20)	-0.22
		SFA (g)		0.21	(-0.18	0.59)	5.52
		FAFH (meals/per)		0.25	(-0.04	0.54)	6.71
	PA			0.38	(0.02	0.73)	10.01*
		none/low (reference)					
		vigorous		0.00	(-0.09	0.10)	0.11
		moderate		0.17	(-0.13	0.47)	4.49
		vigorous & moderate		0.20	(-0.08	0.49)	5.41
	Other factors			0.97	(-0.02	1.96)	25.86
		Alcohol		0.12	(-0.10	0.34)	3.25
			none/light (reference)				
			moderate	0.13	(-0.09	0.35)	3.47
			heavy	-0.01	(-0.05	0.03)	-0.22

Table 3.7. Regression decomposition of WC changes between NHANES 2005-2006 and 2017-2018 by changes in lifestyle behaviors and demographics over the same period (n=1,461) (continued)

	Coefficient	95%CI		Contribution
Explained				
Smoking	0.15	(-0.13	0.43)	3.97
none (reference group)				
light	0.07	(-0.13	0.27)	1.87
moderate	0.06	(-0.05	0.17)	1.62
heavy	0.02	(-0.14	0.18)	0.49
Sleep duration (hours)	-0.17	(-0.75	0.41)	-4.61
Sleep problem	-0.05	(-0.28	0.19)	-1.23
not at all (reference)				
several days	-0.02	(-0.11	0.07)	-0.56
more than half days	-0.05	(-0.25	0.15)	-1.41
nearly every day	0.03	(-0.08	0.13)	0.73
Intentional weight loss				
no (reference)				
yes	0.92	(0.26	1.58)	24.48*
Demographics	-0.90	(-1.87	0.07)	-24.03
Age	0.05	(-0.08	0.18)	1.27
65-69 (reference)				
70-74	0.00	(-0.02	0.02)	0.03
75-79	0.01	(-0.05	0.07)	0.28
80 and over	0.04	(-0.06	0.13)	0.97
Gender				
female (reference)				
male	0.08	(-0.59	0.75)	2.08

Table 3.8. Regression decomposition of WC changes between NHANES 2005-2006 and 2017-2018 by changes in lifestyle behaviors and demographics over the same period (n=1,461) (continued)

		Coefficient	95%CI		Contribution
Explained					
Ethnicity		-0.31	(-0.50	-0.11)	-8.22*
	Non-Hispanic White (reference)				
	Mexican American	0.00	(-0.01	0.01)	-0.01
	other Hispanic	-0.06	(-0.15	0.02)	-1.72
	other race	-0.24	(-0.40	-0.07)	-6.30*
	Non-Hispanic Black	-0.01	(-0.03	0.02)	-0.19
Education level		0.05	(-0.36	0.45)	1.23
	less than 9th (reference)				
	college graduate or above	-0.07	(-0.53	0.38)	-1.99
	9-11 grade	0.10	(-0.07	0.28)	2.72
	high school	0.04	(-0.08	0.15)	0.98
	some college or AA degree	-0.02	(-0.10	0.06)	-0.48
Marital status		-0.21	(-0.45	0.03)	-5.61
	married & living with partner (reference)				
	divorced & separated	-0.01	(-0.11	0.09)	-0.22
	widowed	-0.20	(-0.44	0.04)	-5.29
	never married	0.00	(-0.03	0.02)	-0.10
Annual family income		-0.55	(-1.30	0.19)	-14.78
	under $20,000 (reference)				
	$20,000 – $34,999	0.14	(-0.23	0.50)	3.66
	$35,000 – $44,999	-0.02	(-0.11	0.08)	-0.40
	$45,000 – $54,999	0.09	(-0.08	0.26)	2.44
	$55,000 – $64,999	-0.01	(-0.06	0.05)	-0.17
	$65,000 and over	-0.76	(-1.62	0.10)	-20.30
	$20,000 and over	0.00	(-0.02	0.02)	-0.01

PA, alcohol, smoking, sleep problem, and intentional weight loss were dichotomous variables.

3.5 DISCUSSION

This study focused on documenting the contribution of specific lifestyle behaviors and demographic variables that could explain the change in obesity in older adults over a 12 year span. Findings suggested that more than half of the changes in obesity over 12 years could be explained by lifestyle behaviors (54.86% in the increase of BMI and 53.12% in the increase of WC), and demographic factors detracted more than twenty percentage points from the explained part (-25.48% in the increase of BMI and -24.03% in the increase of WC), if other variables stayed the same levels as 2005-2006. The contributors measured explained almost one-third of overall change in obesity between 2005-2006 and 2017-2018 (29.38% in BMI increase and 29.09% in WC increase). This result of the explained part increase in obesity in the BMI-based obesity group (29.38%) was less than that in Nie's previous research, in which age, gender, ethnicity, marital status, education, smoking, drinking and province explained 51% of the increase of BMI in Cuba from 2001 to 2010. But the result of the explained part increase in WC-based obesity (29.09%) was more than that in Nie's research (20%) (Nie et al., 2018). It is possible that the difference of selected contributors, participants, and test year period lead to the difference of results between researches.

Several limitations should be noted when study results are considered. First, in this study, obesity is defined by BMI or by WC. Although body composition examined by DXA may be more accurate for measuring obesity in older adults, data on fat mass cannot be obtained from the NHANES dataset because older adults were not tested for body fat through DXA. It is suggested that an accurate anthropometric measure of fat mass, such as DXA, can be used for future obesity research in older adults. Since this was a prospective review the BMI for longitudinal studies is considered appropriate to use until enough DXA measurements are collected by NHANES to constitute enough waves needed for an informative trend analysis.

This study analyzed the changes of obesity in two cycles, which were 2005-2006 and

2017-2018, depending on the availability and consistency of data in the NHANES website. We did not analyze the variables among these 12 years, missing the process of changes in these variables. Meanwhile, this study applied two-fold OB regression decomposition model with limited explanations for the increase of BMI and WC. Future research may use three-fold model to provide additional explanations on the change of obesity.

This NHANES study is the cross-sectional study with measurement at one point in time. Some variables may not represent the subjects' usual behavior. For example, alcohol consumption was analyzed based on the day of diet recall due to considering the consistency of data and the references from other researchers. Subjects were classified as light/ none drinkers if they did not drink on the test day, even though they might be drinkers (moderate or heavy) all the time. So, further research could combine the report on the test day and the questionnaire during a longer time in order to define the status of drinkers accurately. This limitation could impact other variables as well.

Finally, due to limited lifestyle behaviors in the NHANES dataset, several factors possibly related to obesity are omitted, such as PA duration and frequency, sedentary activities (screen time), and physical function. Future data is needed to explore associations between other lifestyle behaviors not mentioned in this study and obesity among older adults since theses can also be contributors to obesity patterns.

Baed on the study findings the selected lifestyle behavior contributors assessed appear to play an essential role in explaining the change of obesity. The major contributors in diet were protein intake, SFA intake, and FAFH, and the major contributors in other lifestyle behavior factors were smoking, sleeping, and intentional weight loss.

The increase of protein intake contributed to the increase of BMI and WC in this study. This result was supported by the report that protein intake protected against weight loss among the healthy older adults (Gray-Donald et al., 2014). A higher consumption of protein is often linked with a higher consumption of carbohydrates and fat. Thus, excessive protein intake may promote the increase of obesity in some individuals. Second, the increased intake of SFA is positively associated with the increase of BMI and WC. It was reported that the overweight and obese had a high dietary intake of fat, especially SFA (Dooley and Ryan, 2019). The increased intake of SFA was positively associated with the increase of BMI and WC. High intakes of SFAs are being discouraged and older adults are encouraged to replace with unsaturated fats due to findings that SFA intake plays an important role in the obesity prevalence and multiple chronic disease states. Last, FAFH is often thought as consumption of foods with high calories and high fat, leads to more energy intake. Frequently visiting fast-food restaurants contributed to the increase of body weight and WC (Li et al., 2009). Due to FAFH being a risk factor of obesity, older adults should be encouraged to eat food prepared at home and limit the level of consumption of FAFH. This has to be balanced with the need for socialization needs as well.

PA represents the expenditure of energy and it is thought as the most productive method to prevent obesity in the general population. Undoubtedly, in this study, the decreased participation in all intensities PA promoted the increase of BMI and WC. Therefore, PA has enormous potential to reduce obesity and should be considered a major component of healthy lifestyles among older adults. Considering the necessity of PA, older adults should be encouraged to increase their PAs.

The current study showed that the decrease of smoking (heavy) contributed to the increase of BMI and WC. Similar result was found in one study among 25,318 Cuban urban adults that smoking contributed up to 42% in BMI increase and 10% in WC increase from 2001 to 2010 (Nie et al., 2018). This finding must be interpreted with caution and given rationale thought. While smoking cessation programs should continue to be encouraged due to the wealth of research on the negative health consequences smoking can produce, it is important for interventionists who work in this area to address the potential for unwanted weight gain due to a natural behavior of replacement of smoking with increased consumption of food or beverages which can increase weight. Education on this undesirable consequence should be included in their program protocols.

The findings on sleep problems were very interesting. A national poll recently documented that more than half of older adults did not realize the significance of their sleep problems, and had just considered it to be a normal phenomenon with aging (Malani et al., 2017). Thus, the real number of older adults suffering from sleep problems seems likely higher than the reported one. Poor sleep quality limits the PA of older adults, leading to less energy expended and body weight gain as a result. Sleep problems also had a harmful impact on carbohydrate metabolism, which resulted in more food intake (Nedeltcheva and Scheer, 2014). Poor sleep quality also increased the risk of physiological stress, which caused body weight gain through disordered eating behaviors (high calorie intake) (Norton et al., 2018). In addition, sleep problems can affect a regular lifestyle by interrupting regular mealtimes and causing less opportunities to exercise (Patel et al., 2014). Given that sleep problems were associated with obesity in older adults, poor sleep quality, especially sleep problems happening frequently (every day), should be addressed and given more attention when assessing weight management.

Despite the fact that older adults have intentional weight loss goals, the prevalence of obesity was still increasing significantly. Health promotion practitioners can provide effective guidance to help the obese control body weight. This should be especially targeted to older obese adults, offering specific strategies on weight management that includes increased resistance training, and limited high-calories diets options for a healthy lifestyle should be developed depending on their physiological characteristics and individualized to meet their individual preferences, functional ability, access to resources needed for compliance and cultural preferences.

Most of the results previously mentioned as contributors were positively associated with obesity change, however, some lifestyle behaviors contributed negatively to the difference of BMI and WC, such as sleep duration. The current results showed that sleep hours increased from 2005-2006 to 2017-2018. The increase of sleep hours detracts from the explained part, and the change (increase) of BMI and WC will decrease if sleep duration does not change between 2005-2006 and 2017-2018. In other words, if older adults had the same sleep duration in 2017-2018 compared to 2015-2016, the value of BMI and WC in 2017-2018 was larger than what observed in this study. So, the increase of sleep duration (within what is considered the normal range of 7-8 hours per night) might mitigate BMI and WC increase. In this case, the increase of sleep hours could be considered as a protective factor against obesity prevalence. The previous research found that normal sleep, which is 7-8 hours, reduced the risk of obesity (Buxton and Marcelli, 2010). Combined with the result of the current study, sleep duration within the normal ranges in older adults is felt to be an important component of a healthy lifestyle.

After accounting for the roles of demographic shifts and changes in lifestyle behaviors, 73.15% of the BMI increase and 70.63% of the WC increase remained unexplained. (Sen, 2014) analysis from a previous study proposed some reasons that might account for the unexplained part in this study as well. First, other factors were omitted from the model, and these omitted variables could have affected some outcomes. As mentioned above, obesity was a multifactorial caused disease. Besides lifestyle behaviors and demographic factors analyzed in this study, genetic factors played a role in obesity. Meanwhile, the secondary data in this study was collected over 7 two-year cycles from the NHANES dataset, so for the sake of variable consistency, we had to omit some important variables, such as factors of sedentary activity. Also, a measurement error in variables might lead to the unexplained portion. The OB regression decomposition analyzed contributors to the difference levels of obesity from 2005-2006 to 2017-2018. The gap between study cycles was 12 years. With the development of technology and science, test equipment and trained persons' skills had improved, which might have resulted in measurement error over these years.

In summary, in the current study, OB decomposition regression was applied to detect the role of lifestyle behaviors on the increase of BMI and WC from 2005-2006 to 2017-2018. The functionality of this model not only explained the change of obesity, but also described the contributions of the changes in individual variable and grouped variables over 12 years.

Use of the OB regression decomposition method of analysis was useful to reveal that total lifestyle behaviors explained more than half change of obesity, followed by other factors (alcohol consumption, smoking, sleeping and intentional weight loss), diet, and PA. Future studies should consider using a three-fold method to add to the knowledge from this study and help provide expanded explanation for changes in obesity over time. Analyzing more cycles over an extended time frame might also help identify key cultural, industrial and/ or demographic factors that could also be key contributors to be investigated. New assessment measures hold promise but require repeated measures over time to truly validate longitudinal findings. Given the population projection of longer lifespans and increased numbers of older adults, more research is needed to drive future development of evidence based interventions specific to the needs of older adults.

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