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# Obesity Indices and Cognitive Function in Veterans

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**Abstract**

Obesity is linked to many chronic health conditions and middle-aged obesity is associated with later-life dementia. Obesity rates in veterans are higher than in the civilian population. Research examining body mass index (BMI) and cognitive function has demonstrated that young to middle-aged obese adults consistently demonstrate deficits in memory and executive function. Waist circumference (WC) is another measure of obesity that has been investigated as it relates to cognitive function; however, a clear pattern of deficit has not yet emerged. This study's purpose was to investigate the relationship among BMI, WC, and cognitive function in male veterans aged 18-55. One hundred and seventeen veterans participated in this one-session study. Participants had their height and weight measured, completed questionnaires that assessed demographic information and other health-related variables, and completed a battery of cognitive tests. A chart review of each participant's medical record was conducted, and relevant diagnoses and medications were extracted. A factor analysis (FA) of the cognitive outcome variables was conducted for data reduction purposes and FA results were used to create the following factors: Speeded Measures, Verbal Fluency, Memory, and Executive Function. Then, four-step hierarchical regression analyses were conducted with BMI and WC entered as the main predictor variables. Results revealed no significant relationship between obesity indices and cognitive function after controlling for relevant variables. Post hoc analyses were then conducted. Composite scores were created based on the conceptual basis of the neuropsychological outcome measures: Memory, Executive Function, Verbal Fluency, Attention, and Psychomotor Speed. Regression analyses were rerun using these scores. Results revealed no significant relationship between any index of obesity and cognitive function. Implications of these findings are discussed.

# OBESITY INDICES AND COGNITIVE FUNCTION IN VETERANS

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**Obesity Indices and Cognitive Function in Veterans**

Obesity is a growing problem in the United States and around the world. Despite widespread knowledge regarding the adverse effects of obesity on health outcomes as well as the implementation of numerous medical and public health interventions, obesity rates continue to rise (Olshansky, 2005). The World Health Organization (WHO) reported that, in 2005, approximately 1.6 billion adults around the world were overweight, and at least 400 million were obese (WHO, 2010). Should this global trend continue, by 2015 there will be upwards of 2.3 billion and 700 million overweight and obese people, respectively. In many European countries, prevalence rates of obesity have tripled since 1980, resulting in increased mortality and health care costs (WHO, 2010).

Increases in U.S. obesity trends have been shown to be unrelated to gender, socioeconomic status, or geographic region (Olshansky, 2005). It has been projected that there are 9.3 million more obese American adults (ages 20-74) in 2010 than there were in the year 2000 (Wang, Colditz, & Kuntz, 2007). The implication of these epidemiological data is that, as the population ages, both in the US and around the world, life expectancy will decline. Furthermore, an aging population, coupled with an increase in obesity-related health problems, has the potential to create an immense burden on the health care system (Lee et al., 2009).

Obesity is of particular concern to veterans utilizing Veteran's Affairs (VA) medical centers. According to national data from the year 2000, the prevalence of overweight and obesity in veterans using VA facilities was higher than the general population (Das, Kinsinger, Yancy, et. al, 2005; Koepsell, Forsberg, & Littman, 2009). Furthermore, veterans who use the VA have the highest rates of obesity compared to veterans who do not use the VA and non-veterans, according to a national sample (Nelson, 2006). Specifically, only 27.8% of veterans who receive

VA healthcare are of normal weight, compared to 42.6% in the general population (Nelson, 2006). In another national sample looking at gender differences in obesity among VA-using veterans, approximately 66% of women are at least in the overweight range, as compared to 62% in the general population. Among male VA users, over 70% were at least overweight, compared to 67% in the general population (Flegal, Carroll, Ogden, & Johnson, 2002). These high rates of obesity could be a partial contributor to the higher rates of illness in VA patients as compared to non-VA samples (Agha, Lofgren, VanRuiswyk, & Layde, 2000).

**Body Mass Index**

Overweight and obesity are defined as excess adipose tissue and are most commonly measured by body mass index (BMI). BMI is calculated by way of a person's height and weight (weight in kilograms/height in centimeters squared), and does not take into account demographic variables such as age or gender. Overweight is categorized as a BMI between 25 and 29.9, while obese is categorized as a BMI over 30 ("What is obesity?"; 2010); health risk increases when moving from normal weight, to overweight, to obese (Must et al., 1999).

The health implications of obesity are well-documented (CDC, 2010; WHO, 2010). It has been linked to many chronic health conditions such as hypertension, type 2 diabetes, and cardiovascular disease, which is the leading cause of death worldwide. Furthermore, research has also shown that middle-aged people who are obese are more likely to develop dementia in late-life than normal weight, middle-aged people (Fitzpatrick et al., 2009; Laitala, et al., 2011; Naderali, Ratcliffe, & Dale, 2009). Specifically, people who are obese in mid-life are three times more likely and five times more likely than normal-weight people to develop Alzheimer's disease and vascular dementia respectively (Whitmer, Gunderson, Quesenberry Jr., Zhou, & Yaffe, 2007). One hypothesis about the mechanism behind this relationship is that it is mediated

through obesity-related diseases like hypertension and diabetes (Lee et al., 2009). Sub-clinical cognitive deficits have been demonstrated in persons with such diseases (Brady, Spiro III, & Gaziano, 2005; M. B. Cohen & Mather, 2007; R. A. Cohen et al., 2009; Stewart & Liolitsa, 1999; Waldstein, 1995; Whitmer, 2007), prior to the onset of clinical dementia. Consequently, researchers have investigated whether cognitive changes can be detected in the presence of obesity, independent of its related conditions (e.g. Elias, Elias, Sullivan, Wolf, & D'Agostino, 2005; Gunstad et al., 2007; Waldstein & Katzel, 2006).

**BMI and Cognitive Function**

**Older Adults.** Research in the area of BMI and cognitive function in older adults (over age 65) has yielded mixed results. A significant relationship between BMI and cognitive function across a variety of domains including working memory, verbal and nonverbal memory, verbal fluency, attention, executive function, and learning has been found (Elias, Elias, Sullivan, Wolf, & D'Agostino, 2005), such that a higher BMI predicted worse performance on these measures. In the domain of executive function, this finding has been replicated in a sample of elderly women only (Walthier, Birdsill, Glisky, & Ryan, 2010). Others have also found a negative relationship between BMI and global cognitive function in older adults (Kilander, Nyman, Bobbrg, & Lithell, 1997; Sturman et al., 2008).

Null findings also have been shown in older adults across a number of domains, including working memory, verbal memory, attention, and executive function (Nilsson & Nilsson, 2009; Kuo et al., 2006; Sweat et al., 2008; Waldstein & Katzel, 2006), as well as confrontation naming (naming pictures of objects presented to the participant), and psychomotor speed (Kim et al., 2008). Inconsistencies in findings could be explained by a significant difference in sample sizes across studies, as well as other confounding variables (e.g., education

level of participants; Waldstein & Katzel, 2006). A number of additional studies have investigated the BMI-cognitive function relationship by way of a screening measure for cognitive disorders (e.g. Mini-Mental State Exam; MMSE; Folstein, Folstein, McHugh, & Fanjiang, 1975), and have found no relationship between BMI and performance on this measure (Kim et al., 2008; Nagai, Hoshide, Ishikawa, Shimada, & Kairo, 2008; Psaltopoulou et al., 2008; Sakakura et al., 2008). Because the MMSE was designed to identify patients with dementia (Strauss, Sherman, & Spreen, 2006), it does not provide a wide range of scores in cognitively intact populations. This lack of variability could explain the nonsignificant relationship between BMI and performance on cognitive screening measures.

However, some studies of the elderly have actually found a positive relationship between BMI and cognitive function in the domains of episodic memory, visuospatial skills, and reasoning skills (Kuo et al., 2006; Nilsson & Nilsson, 2009). These results tend to be found in the oldest old (over 75 years of age). It has been hypothesized that these results may be due to the fact that BMI may not be an appropriate measure of body composition in the old. In addition, it is also possible that those individuals who were obese in middle age have already suffered and died from complications related to obesity prior to being old enough to participate in such studies. Lastly, it is also possible that low BMI in the oldest old is a consequence of cognitive decline and neurodegeneration associated with it (Smith, Hay, Campbell, & Trollor, 2011).

It is clear from the state of the current literature that the relationship between BMI and cognitive function in the elderly population is complicated. Thus, it is essential to study this relationship earlier on in the disease process before these obesity-related, chronic illnesses can take their toll on brain structure and function. Younger people are less likely to have cerebrovascular sequelae associated with obesity-related chronic diseases (Smith, Hay,

Campbell, & Trollor, 2011) and as such, provide a better avenue to examine obesity's independent contribution to cognitive function. Studies of this relationship in younger adults also help to determine whether the pattern of deficit is similar in younger versus older individuals or if it changes with the development and persistence of other chronic conditions. Furthermore, examining patterns of cognitive deficit can be informative as to what areas of the brain are most closely related to obesity. With this information, future studies may be designed to clarify the mechanism driving the obesity-dementia relationship and consequently develop early interventions to help prevent or reduce the incidence of dementia later in life.

**Middle-Aged and Younger Adults**. A number of studies have looked at the BMI-cognitive function relationship in both middle-aged (under age 60) and younger adults (e.g. Cserjesi, Luminet, Poncelet, & Lenard, 2009; Gunstad et al., 2007; Lassek & Gaulin, 2008; Wolf et al., 2007). These studies have also shown fairly inconsistent findings. A negative relationship between BMI and cognitive function has been shown in middle-aged adults in the domains of verbal memory (Gunstad, Paul, Cohen, Tate, & Gordon, 2006), attention, executive function (Cserjesi, Luminet, Poncelet, & Lenard, 2009; Gunstad et al., 2007), and visuospatial abilities (Nilsson & Nilsson, 2009). Furthermore, morbidly obese individuals seeking bariatric surgery have demonstrated deficits in executive function when compared to normative data (Boeka & Lokken; 2008; Lokken, Boeka, Yellumahanthi, Wesley, & Clements, 2010). However, non-significant findings have been found by others in the domains of working memory and attention (Lassek & Gaulin, 2008), as well as verbal and nonverbal memory, visuospatial skills, and executive function (Wolf et al., 2007). Ward and colleagues (2005) also found no significant relationship between BMI and cognitive function (learning, working memory, and processing speed) despite a significant negative relationship between BMI and whole brain volume.

Finally, there is limited research on the BMI-cognitive function relationship in younger adults only (ages 18-45). Studies have shown a significant negative association between BMI and decision making (Davis, Levitan, Muglia, Bewell, & Kennedy, 2004), and between BMI and psychomotor speed (MacGregor, Fonken, Robottom, Hyunh, & Jorgensen, 2009) in young individuals. This association was not found for the domains of memory, executive function, attention, or verbal fluency (MacGregor, Fonken, Robottom, Hyunh, & Jorgensen, 2009). These non-significant findings could potentially be explained by small samples with limited variability in test scores. Taken together, results from cross-sectional studies of BMI and cognitive function, though mixed, have shown the most consistent findings in the areas of executive function and memory (Boeka & Lokken; 2008; Cserjesi, Luminet, Poncelet, & Lenard, 2009; Elias, Elias, Sullivan, Wolf, & D'Agostino, 2005; Gunstad et al., 2007; Gunstad, Paul, Cohen, Tate, & Gordon, 2006; Lokken, Boeka, Yellumahanthi, Wesley, & Clements, 2010; Walthier, Birdsill, Glisky, & Ryan, 2010). However, given the limited data especially in younger individuals, further investigation is needed to clarify the pattern of deficit related to obesity in a younger sample.

Three known studies have begun to examine BMI and cognitive function prospectively and have demonstrated similar results when compared to studies utilizing a cross-sectional design. Sabia and colleagues (2009) examined BMI and cognitive function across the adult lifespan beginning at age 25 to see how later life cognition (age 61) is affected by obesity earlier in life. Results indicated that long-term overweight status was associated with lower scores on the MMSE, and tests of memory and executive function later in life compared to normal-weight individuals. Cournot et al. (2006) also used a prospective design over a five year period to examine BMI and cognitive function in healthy, middle-aged adults (aged 32 to 62), and found

that higher BMI at baseline predicted greater cognitive decline on measures of attention, learning, and memory after a five year period. Driscoll and colleagues (2011) prospectively followed elderly (age 65-79) women over an approximately five year period, and found that those who remained stable or gained weight over time demonstrated no significant cognitive change on measures of global cognition, verbal fluency, verbal knowledge, visuospatial and verbal memory, attention, visuospatial skills, and motor speed.

**Central Obesity**

In addition to BMI, waist circumference (WC) has been used as an index of obesity and a measure of cardiovascular risk. Specifically, central obesity is defined as having a WC greater than 40 inches and 35 inches in men and women, respectively (AHA, 2010), and is the most prominent feature of the metabolic syndrome (Bjorntrop, 1992; DeFronzo & Ferrannini, 1991). It is associated with a number of CVD risk factors such as glucose intolerance, hypertension, and high cholesterol (Bjorntrop, 1992; DeFronzo & Ferrannini, 1991). Furthermore, central obesity has been found to have the highest level of CVD risk when compared to all other overweight and obese groups (e.g. peripheral obesity; Cikim, Ozbey, & Orhan, 2004), and may be a better predictor of CVD risk than BMI (Friedl, 2009). In fact, a high WC is related to risk of developing a number of obesity-related diseases such as hypertension, diabetes, dislipidemia, and metabolic syndrome, independent of BMI (Janssen, Katzmarzyk, & Ross, 2002; 2004). In other words, normal-weight individuals with high WC have the same health risk as those who are overweight (Friedl, 2009). Moreover, WC may actually serve as a better measure of obesity than BMI (Jacobs et al., 2010). For example, men who are tall and very muscular tend to have a BMI in the overweight to obese categories, but low body fat (Janssen, Katzmarzyk, & Ross, 2004),

whereas WC may be an appropriate proxy measurement of visceral fat (Janssen, Katzmarzyk, & Ross, 2002).

**Central Obesity and Cognitive Function**

Similar to BMI, central obesity has been researched as a potential risk factor for cognitive decline, though the literature is sparse and inconsistent. In addition, many of these studies have examined how WC predicts cognitive function in the presence of other disorders such as hypertension (Waldstein & Katzel, 2006) and diabetes (Kim et al., 2008). Higher WC has been found to be associated with poorer performance on measures of psychomotor speed, executive function, and attention in older adults with (Kim et al., 2008) and without diabetes (Wolf et al., 2007). Although null findings have been shown in verbal memory (Wolf et al., 2007), naming (Kim et al., 2008), and on a screening measure of cognitive dysfunction (Jeong, Nam, Son, Son, & Cho, 2005). One prospective study of this relationship in elderly women also did not report a relationship between change in WC and change in cognitive performance over time (Driscoll et al., 2011). Interestingly, unlike BMI, no known studies have found a positive relationship between WC and cognitive function, suggesting a differential relationship between these two obesity indices as they relate to cognitive performance in the elderly.

When looking at middle-aged and older adults together, Dore and colleagues (2008) found a significant, negative relationship between WC and cognitive function on measures of executive function across the lifespan (age 23-98) even after adjusting for age and other risk factors (e.g., CVD, depression). Waldstein and Katzel (2006) found a relationship between WC and cognitive function such that high WC was associated with poor performance on measures of gross motor speed, manual dexterity, and executive function. However, this finding was qualified by a significant interaction between blood pressure (BP) and WC such that people with

both high BP and high WC had worse scores than those with either high BP or high WC (Waldstein & Katzel, 2006). One additional study found no relationship between WC in the context of metabolic syndrome and cognitive function in the domains of verbal learning, semantic memory, or performance on a screening measure for cognitive disorders (Gatto et al., 2008).

When looking at both BMI and WC as they relate to cognitive function, one study found a negative relationship between total body composition and cognitive function in the domains of global cognitive function, memory, and language, with no clear pattern of deficit emerging when looking at BMI and WC separately (Gunstad et al., 2010). However, it has been more consistently found that central obesity, not total obesity, has predicted cognitive deficit in middle-aged and older adults on measures of semantic memory (Gatto et al., 2008), attention, executive function, visuomotor speed, visual memory, organization (Wolf et al., 2007) and global cognitive function as measured by the MMSE (Jeong, Nam, Son, Son, & Cho, 2005). Similarly, Fergenbaum and colleagues (2009) used odds ratios to examine whether BMI and/or WC classification predicted decreased executive performance. Results indicated that obese individuals were at four times increased odds for lowered executive performance. Those who were centrally obese were at five times the risk of lowered executive performance as compared to non-centrally obese participants. Nilsson and Nilsson (2009) also found a differential relationship between BMI and central obesity as measured by waist-to-hip ratio (WHR) such that there was a negative relationship between WHR and visuospatial functioning, and WHR and semantic memory in women. However, they did not find a relationship between BMI and cognitive function. Only one known study examined the interaction between BMI and WC predicting cognitive performance such that those with both high BMI and high WC have worse

performance than all other participants (Jeong, Nam, Son, Son, & Cho, 2005). Taken together, these cross-sectional results suggest that central obesity presents more of a risk for poor cognitive performance than obesity as measured by BMI. Though studies of BMI have generally found a relationship between this index and memory and executive function, the pattern of cognitive deficit as it relates to WC is still inconsistent. In addition, the significant interaction between BMI and WC (Jeong, Nam, Son, Son, & Cho, 2005) warrants further investigation.

Three known studies have also begun to examine this relationship using a prospective design (Gunstad et al., 2010; Han et al., 2009; Kanaya et al., 2009) with a less consistent pattern emerging between BMI and central obesity as it relates to cognitive function. One study of adults across the lifespan found that higher body composition was associated with more rapid decline on measures of global cognitive functioning, executive function, and memory over time; however, no clear pattern of deficit emerged when looking at BMI and WC separately (Gunstad et al., 2010). Kanaya and colleagues (2009) examined a large sample (N = 3,054) of elderly individuals (age 70-79). They measured both BMI and WC in this sample, as well as other body composition indices (e.g., total fat mass, visceral fat as measured by CT scan). They examined obesity indices as they predict performance on a cognitive screening measure over time. They found that higher BMI, WC and other measures of obesity were associated with decline on this measure over seven years in men, but not women. Lastly, Han and colleagues (2009) prospectively examined change in BMI, WC, WHR, and percent body fat as they relate to change in cognitive function in a sample of 721 elderly Korean individuals. Cognitive function was measured by way of a composite score of measures of confrontation naming, verbal and visual memory, visual construction, as well as a cognitive screening measure. They found that BMI and percent body fat at baseline actually predicted improved cognitive performance over

two years. However, when looking at gender differences in this relationship, they found that, for men who were obese at baseline, an increase in BMI, WC, and WHR predicted better cognitive performance over time. In women who were obese at baseline, a decrease in WHR predicted a decrease in cognitive performance over time. Furthermore, in women who were not obese at baseline, a decrease in WC predicted worse cognitive performance over time.

In sum, it is clear from the current state of the literature that further investigation into the complicated relationship between obesity and cognitive function is warranted. Though a fairly consistent pattern of deficit has emerged in cross-sectional studies of BMI and cognitive function in the domains of executive function and memory in young to middle-aged individuals, there is a less consistent pattern of deficit when looking at WC. In addition, the interplay between BMI and WC as they relate to cognitive function has yet to be investigated fully. Lastly, no known study has utilized a veteran sample when investigating this relationship. This omission is of particular concern given the higher rates of obesity and chronic disease in this population (e.g., Das, Kinsinger, Yancy, et. al, 2005; Larson & Welch, 2007). Given the documented relationship between middle-aged obesity and later-life dementia, and the potential cross-sectional relationship between obesity and cognitive function, veterans are at particularly high risk for cognitive deficits both in middle age and later in life. As such, study of the obesity-cognitive function relationship is necessary both to simply describe the pattern of cognitive deficit in obese veterans and to investigate whether this relationship is similar to or different from civilian samples.

**Purpose and Hypotheses**

This study's purpose was to investigate the relationship between indices of obesity (as defined by high BMI and WC) and cognitive function in a young to middle-aged veteran sample.

Specifically, this study examined whether BMI is a better predictor of cognitive performance than WC and whether these two obesity indices interact, such that veterans with high BMI and high WC show worse cognitive performance than those with just one obesity index. This is a unique approach to this type of study, as only one other study (Jeong, Nam, Son, Son, & Cho, 2005) has examined whether people who are both centrally and peripherally obese have exponentially worse cognitive function than those with just one obesity index. In addition, this study builds upon the work of Jeong and colleagues (2005) in that we are examining cognitive function through multiple domains as opposed to using a screening measure only. Furthermore, as it is still unclear which cognitive domains are specifically related to obesity, particularly central obesity, in a young and middle-aged population, this study utilized measures of a number of cognitive domains, including memory, executive function, attention, verbal fluency, and psychomotor speed to explore possible patterns of deficit.

Based on the literature as a whole, it was hypothesized that (1) WC would better predict poorer cognitive test performance across domains than BMI. Specifically, it was hypothesized that WC would produce higher effect sizes in the analyses than BMI. Though this effect has yet to be demonstrated in the obesity-cognitive literature, it was hypothesized that WC would better predict cognitive function than BMI because WC has recently been shown to be a better predictor of disease risk (Friedl, 2009), likely due to the fact that it is a better proxy measure of visceral fat (Janssen, Katzmarzyk, & Ross, 2002). As such, the implication is that WC is a better measure of obesity than BMI, and would likely better predict cognitive function. Secondly, given that one study has shown an interaction between BMI and WC predicting cognitive function (Jeong, Nam, Son, Son, & Cho, 2005), it was hypothesized that (2) BMI and WC would interact to predict cognitive performance such that those with both high BMI and high WC would have

worse cognitive performance than those who have only one obesity index. Domains that seem to be most consistently related to obesity indices (particularly BMI) are executive function and memory; therefore, it was hypothesized that (3) measures of these domains would yield the highest effect sizes. There is no evidence to suggest that the results of this study would reveal notable differences in results between this veteran sample and other non-veteran samples used in the literature.

## Method

### Power Analysis

A power analysis was conducted using G*Power 3.1 (Faul, Erdfelder, Lang, & Buchner, 2007) to determine the necessary sample size for this study. The statistical test utilized in this power analysis was a linear multiple regression wherein change in $R^2$ will be calculated. A meta-analysis of all published data up until 2009 investigating the BMI-cognitive function relationship was conducted (MacGregor, unpublished data), and effect sizes across cognitive domains were combined, yielding an overall effect size of 0.1. This effect size was used in all power calculations. Because a hierarchical linear regression will be conducted, it was necessary to calculate the number of predictors or covariates entered for each particular step. The highest number of predictors should be used when calculating sample size (Colcombe et al., 2003). The number of predictors entered in the power analysis was eight, given that this is the highest number of covariates in the model (see Statistical Analysis Plan for specific covariates), and the number of predictors to be tested was three (i.e., BMI, WC, and their interaction). Power was set at 0.8 and alpha was set at 0.05, yielding a necessary sample size of 114.

### Participants

To ensure the current study reached an N of 114, 120 participants between the ages of 18 and 55 were recruited to participate in this study. Participants had BMIs in the normal (18.5 to 24.9), overweight (25 to 29.9), and obese (over 30) categories. Those participants with BMIs in the underweight category (below 18.5) were excluded due to data suggesting that underweight individuals also experience cognitive deficits as compared to normal weight people (e.g. Sabia, 2009). Participants were also native English speakers as many of the neuropsychological measures were verbal in nature and may not have reflected accurate performance had the participant not possessed adequate verbal fluency. Other selection criteria included the following: veterans were required to be free of any neurological disorder that would likely have affected their cognitive performance (e.g. multiple sclerosis, Parkinson's disease, brain tumor, stroke, moderate to severe head injury) or any type of dementia (e.g. vascular dementia, Alzheimer's disease) in order to be eligible for participation. Only males were recruited to participate in this study because females are still an underrepresented population in the VA system (Department of Veteran's Affairs, 2011), and gender is related to both obesity (Flegal, Carroll, Ogden, & Johnson, 2002) and cognitive function (Lezak, Howieson, & Loring, 2004). Thus, it was unlikely that a sufficient number of females would be able to be recruited to allow for gender comparison.

**Recruitment Methods**

The main method of recruitment for this study consisted of a medical record database search of all veterans using primary care clinics at the Syracuse Veterans Administration Medical Center (VAMC) and the Rochester Outpatient Clinic (ROPC). Patients were identified as potentially eligible to participate if their medical chart indicated that they had a BMI greater than or equal to 18.5, if they were between the ages of 18 and 55, if they were veterans, if they

currently used a primary care clinic at the VAMC or the ROPC, and if they were male. Patients that met these criteria were separated into BMI categories (normal weight, overweight, and obese) based upon the most recent height and weight measurements indicated in their medical records. To ensure equal representation of patients from each category, 30 patients at a time from each of the three BMI categories were randomly selected from the list of eligible participants using a random numbers generator. Each of the patients' primary care providers was asked whether or not their patients were eligible/appropriate for the research study, and whether the provider would grant permission for the participant to be contacted regarding the study. If the provider indicated that the patient was ineligible or if the provider did not give permission for the patient to be contacted, he was removed from the contact list. If the provider granted permission for the patient to be contacted, he was sent a letter from his provider introducing the study (Appendix A). A contact number for research staff was included in the letter. If the participant had not already initiated contact one to two weeks after the letter was sent, the participant was called to inquire whether or not he was interested in participating in the study. Those patients expressing interest on the phone were scheduled for an in-person research session at the VAMC or ROPC. Batches of 90 letters were sent once per month until an N of 120 participants was reached. As recruitment progressed, there were more normal-weight individuals than the other two groups who were participating in the study. As a result, letters were sent to only overweight and obese individuals in order to ensure equal distribution of participants among normal-weight, overweight, and obese groups.

**Sample**

One hundred and twenty veterans consented to participate in the study. Each veteran received $30 compensation upon completion of the study, and had a choice between a gift card

to a local supermarket or a check sent to his house. Three participants were excluded from the analyses: one was not a veteran but the spouse of a veteran, and one had had a recent stroke prior to participation. In addition, the third participant excluded from analyses was legally blind and could not complete any of the visual measures in the cognitive battery. Thus, the final sample consisted of 117 male veterans.

**Procedures**

At the beginning of the session, participants provided written informed consent for all procedures. Additionally, a HIPAA waiver was obtained in order to gather relevant medical information (i.e. diagnoses and medications) from each veteran's electronic medical chart.

Following the informed consent procedure, the participant was asked to remove his shoes then had his height (in inches) and weight (in pounds) measured and recorded. Height was measured by way of a stadiometer, a device used for measuring height consisting of a ruler and a horizontal headpiece that sits on the top of the patient's head and indicates his height. Weight was measured using a Seca digital scale, model 872. The same stadiometer and Seca scale were used for each patient in order to ensure consistency across measurements. Then, using a tape measure, WC (in inches) was measured. Two measurements were taken, and the mean recorded, in order to ensure the most accurate measurement. These two measurements did not differ by more than one inch for any participant.

**Questionnaires**

Following the obesity assessment, participants completed the following questionnaires to assess demographics, and a number of psychological and health-related variables.

**Demographic Questionnaire** (Appendix B). This questionnaire assessed basic demographic information such as age, education level, race, and marital status as well as military history.

**Patient Health Questionnaire – 9-item** (PHQ-9; Kroenke, Spitzer, & Williams). The PHQ-9 is a nine-item measure of frequency of depressive symptoms over the past two weeks. Items ranged from zero, indicating the participant was not experiencing the symptom at all, to three, indicating he was experiencing the symptom nearly every day. Items were summed to yield a total score with higher scores reflecting more presence of and higher frequency of depressive symptoms. Depressive symptoms as measured by this questionnaire served as a potential covariate in the analyses because depression is related to both obesity (Strine et al., 2008) and cognitive function (McDermott & Ebmeier, 2009). The PHQ-9 was chosen because of its brevity and ease of administration. In addition, it has been shown to be a valid screening measure for the severity of depressive symptoms (Kroenke, Spitzer, & Williams, 2001), and is recommended for use with primary care patients (Nease & Malovin, 2003).

**Alcohol Use Disorders Identification Test** (AUDIT; Saunders, Aasland, Babor, de la Fuente, & Grant, 1993). The AUDIT is a 10-item questionnaire designed to screen for symptoms of alcohol use disorders. Higher scores on this measure indicate greater consumption of alcohol and/or frequency of negative consequences related to drinking. The AUDIT was chosen because of its strong criterion validity for both alcohol dependence and hazardous drinking (Reinert & Allen, 2007). Studies of alcohol consumption and cognitive function have produced mixed results (Britton, Singh-Manoux, & Marmot, 2004; Sher, Martin, Wood, & Rutledge, 1997). Additionally, a review of the literature between obesity and alcohol consumption indicated that alcohol is related to weight gain differently depending on level of consumption as well as type of

diet (Suter, 2005). Because of the unclear relationship between alcohol, obesity, and cognitive function, the AUDIT score served as a potential covariate in the analyses.

**Primary Care – Post Traumatic Stress Disorder** (PC-PTSD; Prins et al., 2003). This measure is a 4-item questionnaire designed to screen for the presence of post-traumatic stress symptoms (i.e. re-experiencing, avoidance, hypervigilance, emotional numbing) in the past month. It also assesses the nature of the traumatic event. This measure was chosen because of its strong diagnostic efficiency (Prins, et al., 2003), particularly in veterans (Bliese, et al., 2008). A PTSD measure was included because of the high prevalence of PTSD in veterans (Seal, Bertenthal, Miner, Sen, & Marmar, 2007; Weiss et al., 1992), and because PTSD has been shown to be related to deficits in a number of cognitive domains including memory and executive function (LaGarde, Doyon, & Brunet, 2010). Because of the demonstrated relationship between PTSD and cognitive function, this measure served as a potential covariate in the analyses.

**Insomnia Severity Index** (ISI; Morin, 1993). The ISI is a 5-item measure that assesses the presence and severity of insomnia as well as how sleep problems affect daily functioning. This measure was chosen because it has been found to adequately assess the diagnostic criteria for insomnia (Bastien, Vallieres, & Morin, 2001), and included as a potential covariate because research has shown that sleep disorders (e.g. sleep apnea, insomnia) are associated with both obesity (Crummy, Piper, & Naughton, 2008; Vgontzas, 2008) and cognitive function (Engleman, Kingshott, Martin, & Douglas, 2000; Haimov, Hanuka, & Horowitz, 2008). Higher scores on this measure are indicative of greater sleep disturbance (Morin, 1993).

**Cognitive Measures**

Following the completion of the questionnaires, a brief neuropsychological battery was administered to test the following cognitive domains: verbal memory and recognition, attention,

psychomotor speed, executive function, and verbal fluency. A global cognitive battery was chosen for a number of reasons. First, though memory and executive function are the most consistently related to BMI (Boeka & Lokken; 2008; Cserjesi, Luminet, Poncelet, & Lenard, 2009; Elias, Elias, Sullivan, Wolf, & D'Agostino, 2005; Gunstad et al., 2007; Gunstad, Paul, Cohen, Tate, & Gordon, 2006; Lokken, Boeka, Yellumahanthi, Wesley, & Clements, 2010; Walthier, Birdsill, Glisky, & Ryan, 2010), it is still unclear which cognitive domains are most related to WC. As such, a global cognitive battery was chosen to further clarify the pattern of deficit associated with obesity indices. Furthermore, as no study has utilized veterans when examining obesity and cognitive function, a global battery was chosen to examine the possible pattern of deficit in veterans.

The following measures were administered in a fixed order so as to avoid the clustering of tests assessing the same neuropsychological domain, which could occur by randomizing the order of administration. All measures were administered according to standardized instructions.

**Hopkins Verbal Learning Test-Revised** (HVLT-R; Brandt & Benedict, 2001). The HVLT-R is a list-learning task that was used to assess different aspects of memory (i.e., immediate recall, delayed recall, and recognition; Lezak, Howieson, & Loring, 2004). This task was chosen because of its brevity, ease of administration and its strong convergent validity with other, longer tests of verbal memory (e.g. California Verbal Learning Test; Strauss, Sherman, & Spreen, 2006).

For this task, participants were read a list of 12 words with four words from each of three different semantic categories (i.e. animals, precious stones, and human dwellings). The list was presented to the participant three times and the participant was asked to list all of the words remembered, in any order after each of the three trials. After a 20-minute delay (wherein non-

verbal neuropsychological tests were given), participants were asked to recall the words from the original list, and were then presented a 24-word recognition list (12 target, and 12 non-target words). The participant was required to indicate whether or not each word was on the target list (Strauss, Sherman, & Spreen, 2006). Outcome measures for this task were total number of words learned across three learning trials (immediate recall), number of words remembered after 20 minutes (delayed recall) and number of words correctly identified in the recognition list minus number of false positive errors (recognition).

**Trail Making Test-A** (TMT-A; Boll, 1981). TMT-A is a common, easily administered measure of psychomotor speed (Strauss, Sherman, & Spreen, 2006). In this task, participants were asked to draw a line connecting numbers in order beginning at number one. Participants were to draw the line as quickly as possible, connecting the numbers in succession until they reached the end. Time to completion rounded to the nearest second was the outcome variable with higher scores denoting worse performance.

**Trail Making Test-B** (TMT-B; Boll, 1981). TMT-B was used to assess mental flexibility (i.e., executive function) via speeded mental set shifting. For this task, participants were asked to draw a line connecting numbers and letters, alternating between the two sequences. Participants were to begin at number one and draw a line as quickly as possible from a number to a letter to a number and so on, in order, until the end is reached. If an error was made, it was immediately corrected without stopping the timer. As with TMT-A, time to completion rounded to the nearest second served as the outcome variable with higher scores denoting worse performance.

**Symbol Search subtest from the Wechsler Adult Intelligence Scale-III** (WAIS-III; Wechsler, 1997). The Symbol Search task is a pencil-and-paper Performance IQ subtest of the WAIS-III. It is a measure of psychomotor speed. The test consists of two "target symbols" as

well as a group of "search symbols". The participant was instructed to decide whether either of the two target symbols was also included in the group of search symbols and mark the "yes" or "no" box accordingly. The participant was told to work as quickly as possible without making any mistakes, as he may not go back and change an incorrect response. The participant had 120 seconds to complete as many items as possible. The number of correct items served as the outcome variable.

**Ruff Figural Fluency Test** (RFFT; R. Ruff, 1998). The RFFT is a measure of executive function, specifically, visual-motor fluency and response suppression (Strauss, Sherman, & Spreen, 2006). This task consists of five trials, with each trial consisting of 35, five-dot matrices. Each trial has a different five-dot pattern. Only the first three trials of the RFFT were given, however, because research has shown no significant difference in scores across the five trials (R. M. Ruff, Light, & Evans, 1987). For each trial, the participant was asked to connect at least two dots with a straight line to create unique designs. The participant was given one minute per trial. The outcome measure for this test was the number of unique designs generated across all three trials.

**Digit Symbol Coding from the WAIS-III** (Wechsler, 1997). The Digit Symbol Coding is another Performance IQ task from the WAIS-III. It is a measure of psychomotor speed. The test consists of nine symbols, each with a corresponding number. Symbols are represented in a random order, each with an empty box underneath. The participant was asked to decide which number corresponds with each symbol, and write that number in each of the empty boxes. The participant had 120 seconds to fill in as many numbers as possible. The number of items correctly completed served as the outcome variable for this task.

Following the Digit Symbol Coding measure, the delayed recall section of the HVLT-R was administered.

**Controlled Oral Word Association Test** (COWAT; Bechtoldt, Benton, & Fogel, 1962). This task is a widely used measure of phonemic verbal fluency. Participants were to spontaneously produce as many words as possible that begin with a specific letter of the alphabet (i.e. "F," "A," and "S"). Participants were instructed not to use proper names or variations of the same word (e.g. run, running). The time limit for each of the three trials is 60 seconds. The outcome variable was total number of correct words generated across three trials.

**Animal Naming** (Goodglass & Kaplan, 1983). The animal naming task was used to assess semantic verbal fluency. Participants were given 60 seconds and asked to name as many animals as possible. The number of animals correctly named (without repeating) served as the outcome variable.

**Category Switching from the Delis-Kaplan Executive Function Scale** (Delis, Kaplan, & Kramer, 2001). This test is a measure of verbal fluency and executive function (Delis, Kaplan, & Kramer, 2001) wherein the participant must switch between saying words of two different semantic categories – fruit and furniture. Participants were given 60 seconds to name as many fruits and pieces of furniture he could, switching back and forth between categories. Correct words (i.e., the verbal fluency outcome measure) and number of accurate category switches (i.e., the executive function measure) both served as outcome variables for this task.

**Hayling Test** (Burgess & Shallice, 1997). The Hayling test is a measure of executive function, specifically initiation speed and verbal response suppression (Strauss, Sherman, & Spreen, 2006). This task consists of two sets of 15 sentences with the last word missing from each sentence. In part one of this task, participants were read each sentence and asked to

complete the sentence with the appropriate word as quickly as possible. Part one is intended to measure response speed and attention of the participant, and is a primer for part two of the test (Strauss, Sherman, & Spreen, 2006). In part two, the participant was again read each sentence but this time was instructed to respond with a word that does not make sense – completely disconnected from the sentence in every way. This part of the task is intended to measure response inhibition of the participant (Strauss, Sherman, & Spreen, 2006). Time to complete trials A and B, as well as a total scaled score were used as the outcome variables for this task.

**Brief Test of Attention** (BTA; Schretlen, 1997). The BTA is a CD or audiotape-administered test of sustained and selective attention (Strauss, Sherman, & Spreen, 2006). This test was chosen because it was designed to reduce the influence of other factors present in tests of attention such as memory and motor scanning (Schretlen, Bobholz, & Brandt, 1996). In this task, the participants were presented with strings of letters and numbers by way of an audio CD. The lists increase in length with each trial; list length starts at four and ends at 18 characters. The task consists of two parts – in the first part, the participant was asked to disregard the letters and count the numbers presented in each list. In the second part, the same lists are presented, but the participant was instead asked to count the number of letters presented in each list. The number of correct responses served as the outcome variable for this measure; scores range from zero to 20 (Strauss, Sherman, & Spreen, 2006).

The entire research session lasted approximately 1.5 hours. When requested, participants were allowed a break from testing. All research sessions were lead by either this writer or a trained research assistant. Research assistants were trained in protocol administration by this writer. They were given the opportunity to practice this protocol extensively by way of multiple role plays with this writer. Specifically, they were able to practice measuring height, weight, and

waist circumference until they were able to reliably obtain these measurements. In addition, they role played administrating the neuropsychological protocol with this writer as well as each other until they felt comfortable with the protocol and were prepared to deal with any issues that may arise during the research session. Lastly, this writer provided consultation to the research assistants as needed when issues arose. This writer completed all data scoring.

**Chart Review**

Upon completion of the research session, a chart review of each participant's medical chart was conducted (for the chart review form, see Appendix C). This writer conducted all chart reviews. Diagnoses collected included the following: hypertension, heart disease, heart failure, hyperlipidemia, diabetes, sleep apnea, any other sleep disorder (e.g., insomnia), chronic pain, any mental health disorder, or any substance use disorder. In addition, each of these disorders' corresponding medications were also collected. Lastly, other medications that are related to cognitive performance (e.g., ADHD medications) were collected.

Heart diseases and their related risk factors (i.e., hypertension and hyperlipidemia) as well as diabetes were included because obesity is a risk factor for each of these disorders (CDC, 2010; WHO, 2010), and have also been shown to be related to declines in cognitive function (e.g., (Brady, Spiro III, & Gaziano, 2005; M. B. Cohen & Mather, 2007; R. A. Cohen et al., 2009; Stewart & Liolitsa, 1999; Waldstein, 1995; Whitmer, 2007). No known study has found a relationship between heart medications (e.g., beta blockers) and cognitive function, so the inclusion of these medications was done so for exploratory purposes. In addition, while there is no known evidence to suggest an effect of oral medications for diabetes (e.g., metformin) on cognitive function, some studies have recently investigated insulin taken intranasally as a potential treatment for mild cognitive impairment and Alzheimer's Disease (e.g., Craft et al.,

2012). Thus, while oral medications for diabetes were included for exploratory purposes, insulin was included given the potential protective properties against cognitive decline. Further, sleep disorders such as sleep apnea and insomnia are also related to both obesity (Crummy, Piper, & Naughton, 2008; Vgontzas, 2008) and cognitive deficits (Engleman, Kingshott, Martin, & Douglas, 2000; Haimov, Hanuka, & Horowitz, 2008) and thus included in the chart review as potential covariates. As there is no known literature on the effect of sleep medication on cognitive function, this information was collected for exploratory purposes. Chronic pain diagnosis was extracted from patients' charts because it is also related to obesity such that those who are obese have more pressure on their lower joints and tend to experience new onset or an exacerbation of preexisting musculoskeletal conditions (e.g., Tukker, Visscher, & Picavet, 2009). In addition, chronic pain is also related to cognitive deficit (Brown, Zuelsdorff, & Fleming, 2006; Hart, Martelli, & Zasler, 2000). Many patients with chronic pain take opiate medications for pain relief, and the relationship between opiate pain medication and cognitive function is unclear. While some researchers have found a negative relationship between opiate overuse mainly in the domain of executive function (e.g., Gruber, Silveri, Yurgelun-Todd, 2007) in patients without chronic pain, others have found that chronic pain patients actually improved in psychomotor performance before and after being prescribed an opiate pain medication (Jamison et al., 2003). Thus, opiate use was included as a potential covariate for exploratory purposes. As there is no known evidence to suggest a relationship between non-opiate pain medication (e.g., NSAIDs) and cognitive function, these medications were coded separately from opiate medications, and included as an exploratory variable.

Similar to chronic health conditions, mental health conditions such as depression, anxiety, and PTSD were included in the chart review because they have been shown to be related

to both obesity (e.g., LaGarde, Doyon, & Brunet, 2010; Strine et al., 2008) and performance on cognitive measures. Specifically, depression has been shown to be related to deficits in attention and memory (e.g., McDermott & Ebmeier, 2009), while PTSD has been shown to be related to deficits in memory and executive function in the general population (e.g., LaGarde, Doyon, & Brunet, 2010) and memory and attention in veterans (Gilbertson, Gurvits, Lasko, Orr, & Pitman, 2001). Anxiety reportedly has an inverse relationship to cognitive function in the domains of visuospatial skills and memory (Stillman, Rowe, Arndt, & Moser, 2012). Psychotropic medication use was also included because there is evidence to suggest improvement in cognitive function with the successful use of these medications (e.g., Gualtieri, Johnson, & Benedict, 2006).

Lastly, substance use disorders were extracted from patients' medical charts because of their relationship to both obesity and cognitive function. Specifically, epidemiological data suggest that those who are obese are less likely to be diagnosed with a substance use disorder (Simon et al., 2006). In addition, substance use disorders have shown differential relationship to cognitive function. In particular, alcohol use disorders have been shown to be related to decreased performance in visuospatial skills and motor speed in otherwise healthy adults (Sher, Martin, Wood, & Rutledge, 1997). Cannabis abuse and dependence diagnoses have also demonstrated cognitive deficit, particularly in the areas of attention and executive function (e.g., Bolla, Brown, Edlreth, Tate, & Cadet, 2002; Pope & Yurgelun-Todd, 1996). Mild cognitive deficits have also been demonstrated in those with a cocaine use disorder (Woicik et al., 2009) and an opiate use disorder (e.g., heroin; Gruber, Silveri, Yurgelun-Todd, 2007) as compared to healthy controls.

**Statistical Analysis Plan**

First, to assess the generalizability of the sample, t-tests and chi-square statistics were used to compare the demographic traits and BMI status between eligible individuals who participated in the study and those who declined participation. Then, data were summarized from the self-administered questionnaires using descriptive statistics to identify the overall characteristics of those patients who participated in the study. Variables were checked for normality using the skewness and kurtosis tests. All variables were normally distributed; no transformations needed to be performed. Given that data were collected at two different sites, t-tests and chi-square statistics were then conducted to examine differences between sites on demographic variables. Summary statistics were then calculated for all questionnaires and cognitive measures.

Because there are multiple outcome measures in this study and there is no neuropsychological test that purely measures one cognitive domain (Lezak, Howieson, & Loring, 2004; Strauss, Sherman, & Spreen, 2006), an exploratory factor analysis was conducted using all the aforementioned outcome variables for each of the neuropsychological tests. This factor analysis was conducted for data reduction purposes in order to limit the probability of type I error by limiting the number of statistical tests. A Principal components analysis with a Varimax rotation was conducted. Factors were investigated for interpretability using a scree plot and Kaiser's (1960) *eigenvalues-greater-than-one* rule. The outcome variables that were shown to load on the same factor (i.e., factor loadings greater than 0.4) were combined by first computing z-scores for each of the outcomes, and then averaging across all z-scores in each of the factors to form a composite score for each domain. These composite scores then served as the outcome variables in all subsequent analyses.

Next, all categorical variables were dummy coded for ease of interpretation (e.g., for medical diagnoses, zero indicated lack of diagnosis, whereas one indicated presence of the diagnosis). In addition, race was dummy coded into non-white (zero) and white (one), again for ease of interpretation. Then, correlation analyses were conducted to examine the relationship between the predictors, covariates, and the outcome variables derived from the factor analysis. Correlations were computed in order to determine which variables it was necessary to include as covariates in the subsequent regression analyses. To limit the number of covariates entered, only those significantly associated with the outcome variables were included in the following regression equation. BMI and WC were centered, and a five-step hierarchical regression was conducted. In step one, demographic variables significantly correlated with the outcome variables were entered. In step two, identified health variables were entered (i.e., relevant diagnoses/medications). In step three, identified questionnaires and psychological diagnoses were entered. In step four, the main predictor variables were entered – BMI and WC. In step five, the interaction between BMI and WC was entered.

## Results

### Participants

Three thousand six hundred and ninety-eight participants were initially identified by chart review as eligible to participate (2291 from the Syracuse VAMC and 1407 from the ROPC). Five hundred and twenty-four participants were randomly selected to be contacted, 241 from Syracuse and 283 from Rochester. Of those patients, 122 were excluded because their PCP did not give permission for the patient to be contacted, or because their PCP's were unable to be reached (6 from Rochester and 116 from Syracuse). Though this information was not formally collected, anecdotally, PCP's tended to not give permission for patients to be contacted because they did

not meet inclusion criteria. Other reasons included participants traveling to Florida for the winter or moving away. PCP's did not make determinations based on subjective ratings of the patients (e.g., the patient was "difficult" or would not make a "good" participant). Thus, 402 letters were sent to potential participants. Of those veterans, 90 declined participation (17 from Syracuse and 73 from Rochester) and 131 were unable to be contacted. There were 60 additional participants who initially agreed to participate and then either could not find a time to come in for an appointment, or made an appointment and then no-showed and was unable to be contacted again, or expressed interest in the study after recruitment was over. A total of 120 veterans agreed to participate in the study. See Figure 1 for a flow chart of recruitment data. There was no significant difference between those patients who declined participation and those who participated in race, age, or BMI. These were the only three variables that were analyzed in terms of difference between decliners and participants because this was the only available information extracted from potential participants' charts.

Of the patients that participated, 19 veterans were from the Syracuse VAMC and 99 of them were from ROPC. Data were collected at the Syracuse VAMC for four months and at the ROPC for eight months, which resulted in the large difference in number of participants between the two sites. T-tests revealed no significant differences between sites on age, education level, total months in the military, BMI, or WC. Chi-squared statistics revealed no significant differences between sites in martial status, race distribution, branch of the military, whether patients were on active duty, or employment status.

Participants had an average age of 42.5 (*SD* = 10.2). Average BMI was 28.6 (*SD* = 5.7). In terms of the percentage of the sample, all BMI classes were well represented at 35.0%, 29.9%, and 35.0% at normal, overweight, and obese categories respectively. Average WC was 39.6 (*SD*

= 5.6), with similar representation between those who were centrally obese (41.8%) and those who were not (58.1%). For additional descriptive information regarding demographic and questionnaire data, see Table 1. For descriptive information regarding active diagnoses and medications, see Table 2. As noted in Table 2, chronic pain was the most prevalent diagnosis found in the patients' charts with 53.0% of the sample diagnosed with a chronic pain condition.

**Missing Data**

A total of 6 participants had missing data on one or more of the neuropsychological outcome measures. Given the low number of missing data points, missing data were imputed using overall mean scores for each of the variables. Ten total data points were imputed. Overall means and standard deviations for the neuropsychological outcome measures are presented in Table 3. It is of note that the following analyses were conducted both with imputed values and with participants with missing data excluded. No differences were observed in the results of the analyses, thus data from the dataset with imputed values are reported in the following analyses. Imputed values were used in order to retain the all available participants in each of the analyses.

**Factor Analysis**

In order to determine whether the data were appropriate for a factor analysis, correlations were conducted to examine the inter-relatedness among the neuropsychological outcome variables listed above. The correlation matrix of these variables is presented in Table 4. As there are a substantial number of correlations above 0.30, it was appropriate to proceed with the factor analysis.

A principal components analysis was conducted with a Varimax rotation. Though the underlying neuropsychological processes are likely correlated suggesting the use of an oblique, rather than an orthogonal rotation, a Varimax rotation was used for a number of reasons.

Primarily, this factor analysis was conducted utilizing both an orthogonal and oblique rotation, and the solution using an orthogonal rotation was the most interpretable solution. In addition, other studies using factor analysis on neuropsychological outcomes for data reduction purposes have utilized an orthogonal, specifically Varimax rotation (e.g., Kim et al., 1997; Ris, Dietrich, Succop, Berger, & Bornschein, 2004).

To determine the number of factors to retain, Kaiser's (1960) *eigenvalues-greater-than-one* rule was applied and a scree test conducted. Kaiser's rule suggested a 5-factor pattern, while the scree plot (see Figure 2) suggested a 4-factor pattern. Both a 4-factor and a 5-factor pattern were subjected to a Varimax rotation and tested for interpretability. The 4-factor pattern was determined to be the most interpretable, accounting for 60.2% of the variance (see Table 5 for the rotated factor solution). One of the outcome variables (Brief Test of Attention) was dropped from the solution because it did not correlate with any of the factors above 0.4. In addition, the COWAT cross-loaded on factors 2 and 3 (see Table 5). However, the COWAT most highly correlated with Factor 2 ($r = 0.49$), which created an interpretable factor, and was thus retained in the factor solution.

Factors were named then combined by first computing z-scores for each of the outcome variables, then averaging across factors. Factor 1, named "Speeded Measures," comprised of both subtests of the TMT, the digit symbol coding and symbol search subtests of the WAIS-III, and the RFFT. Factor 2, named "Verbal Fluency," consisted of the COWAT, Animal naming test, and the correctly identified words as well as the switching accuracy of the Category Test from the D-KEFS. Factor 3, named "Memory" consisted of the immediate and delayed recall as well as the recognition trials of the HVLT. And Factor 4, named "Executive Function" consisted of the A and B subtests of the Hayling Test as well as the total scaled score. It is of note that the

subsets of the TMT as well as the subtests of the Hayling tests are measured in seconds, meaning that higher scores on these measures denote worse performance. Combining these measures with tests wherein higher scores denote better performance would render the factors uninterpretable. Therefore, after z-scores were computed for both the TMT and Hayling subtests, their signs were flipped so that higher scores now denote better performance according to the z-score. As a result, the Speeded Measures and Executive Function factor scores may be interpreted such that higher scores denote better performance on these factors.

**Correlation Analyses**

Correlation analyses were conducted examining the four factors created by the factor analysis as well as the potential covariates (i.e. age, education, race, questionnaire data, and chart review data). Those variables that correlated with any of the four factors were retained (see Table 6 for correlations). Variables that significantly correlated with any of the factors included age, years of education, race (white or non-white), ISI total score, hyperlipidemia, heart disease, diabetes, whether the participant was on insulin or any other diabetic medication, chronic pain condition, PTSD, and current or remote cannabis abuse. These variables were retained as covariates in the following analyses, with the exception of cannabis abuse as only two participants had this diagnosis and thus this correlation could not be interpreted.

**Regression Analyses**

BMI and WC variables were centered, and then the following hierarchical regression models were conducted for each of the four factor outcomes. In step one, age, education, and race were entered. In step two, diabetes, insulin, other diabetic medication, and pain diagnoses were entered. In step three, ISI total score and PTSD were entered. In step four, centered BMI and WC variables were entered, and in step five, their interaction was entered. Given the strong

correlation between BMI and WC ($r = 0.93, p < 0.0001$), diabetes and insulin ($r = 0.90, p < 0.0001$) and diabetes and any other diabetic medication ($r = 0.78, p < 0.0001$), the variance inflation factor (VIF) was used to examine multicollinearity in the above model. It has been suggested that VIF values greater than 10 indicate signs of significant multicollinearity (Cody & Smith, 2006). VIFs for diabetes, insulin, and other diabetic medications were 11.22, 6.93, and 3.61 respectively (all other VIFs were around 1.00). It is likely that these inflated VIFs are due to the fact that these three variables are measuring essentially the same construct (i.e., whether the patient has diabetes). Thus, only diagnosis of diabetes was examined in the final model. In addition, VIFs for BMI and WC in this sample were 10.22 and 10.28 respectively. The near perfect correlation between BMI and WC, as well as the very high VIF values argue against testing the interaction between BMI and WC in the following models. These data suggest that, in this case, BMI and WC are proxies for one another, and measuring essentially the same construct, thus rendering the interaction between these two variables uninterpretable. As a result, the interaction between BMI and WC was not tested in the following models. Furthermore, due to the multicollinearity in the regression model because of the high correlation between BMI and WC, these two indices were tested in separate models.

**Speeded Measures.** Results from the hierarchical regression models examining BMI and WC as they predicted performance on the Speeded Measures factor are presented in Table 7. After adjusting for the number of covariates, step four of both the BMI and WC regression model accounted for 44% of the variance. Notably, after controlling for age, education, race, ISI total score, hyperlipidemia, diabetes, chronic pain, and PTSD, neither BMI nor WC predicted performance on Speeded Measures. In step four of both models, the only significant predictors of performance on Speeded Measures were age, education, and race. Results indicated that those

participants who were younger performed better on this measure, as did those with higher education. Results also indicated that white participants outperformed non-white participants.

**Verbal Fluency.** Results examining BMI and WC as they predicted Verbal Fluency are presented in Table 8. These models predicted only 12% of the variance after adjusting for number of independent variables. Neither of the obesity indices predicted performance on Verbal Fluency in step four of the models. Significant predictors of Verbal Fluency in both models included chronic pain and PTSD. Surprisingly, those with chronic pain and PTSD performed better on these measures than those without these diagnoses.

**Memory.** Results examining BMI and WC as they predicted Memory are presented in Table 9. Step four of these models predicted 25% of the variance after adjusting for number of independent variables. Neither of the obesity indices predicted performance on Memory measures. Significant predictors of memory in both models included age, years of education, and ISI total score. Those who were younger performed better on memory measures, as did those with more years of education. People with more sleep problems as measured by the higher scores on the ISI performed worse than those with less sleep difficulty.

**Executive Function.** When examining the relationship between BMI and WC, and Executive Function, neither obesity index predicted performance on this factor. Results are presented in Table 10. These models predicted only 11% of the variance after adjusting for number of independent variables. In the BMI model, the only significant predictor of Executive Function performance was race such that white participants performed better than non-white participants. When examining WC as it predicted Executive Function, race and age significantly predicted performance in step four of the model such that younger individuals and white individuals performed better on this measure than older and/or non-white individuals.

**Post Hoc Analyses – Conceptual Scores**

While the principal components analysis produced four interpretable factors for the above analysis, outcome measures would have been combined differently based on the conceptual basis of each measure (Lezak, Howieson, & Loring, 2004; Strauss, Sherman, & Spreen, 2006). For example, while TMT-A, TMT-B, Digit Symbol Coding, Symbol Search, and RFFT are all speeded measures, conceptually they are thought to measure different constructs (e.g., TMT-A is thought to measure basic psychomotor speed, while TMT-B is thought to measure executive function; Lezak, Howieson, & Loring, 2004). Thus, given the generally non-significant findings when using the four factor scores, measures were then combined based on the a priori, conceptual basis of the measure and the regression analyses were rerun. Five composite scores were combined using the same procedure as above to form the following composite variables: Memory, Executive Function, Verbal Fluency, Attention, and Psychomotor Speed. The Memory composite variable consisted of immediate and delayed recall and the recognition trial of the HVLT (which was the same as the Memory factor score). The Executive Function composite score was made up of TMT-B, subtest B and total scaled score from the Hayling Test, RFFT total score, and number of accurate switches from the Category Test. The Verbal Fluency factor was made up of the COWAT, Animal naming tests, and number of correct words from the Category Test. The Attention factor was made up of subtest A from the Hayling Test and number of correct responses on the BTA. And lastly, the Psychomotor Speed factor was made up of TMT-A and the Digit-Symbol Coding and Symbol Search subtests of the WAIS-III.

Correlation analyses were then conducted to determine which covariates should be included in the hierarchical regression model. The correlation matrix can be found in Table 11. As in the above analyses, the variables that significantly correlated with any of the outcome

variables included the following: age, education, race, ISI total score, hyperlipidemia, heart disease, diabetes, taking insulin, taking another diabetic medication, chronic pain, PTSD, and cannabis abuse. In addition, taking a cholesterol medication, and taking a psychotropic medication also correlated significantly with one or more of the outcome measures (see Table 11). As in the above models, cannabis diagnosis was not included because only two participants had this disorder.

The VIF was used to check for multicollinearity in the following hierarchical regression model. In step one, age, education, and race were entered. In step two, heart disease, hyperlipidemia, statin use (cholesterol medication), diabetes, insulin use, other diabetic medication use, and chronic pain were entered. In step 3, PTSD, ISI total score, and psychotropic medication use was entered. And in step 4, the obesity index was entered (i.e., BMI or WC). As in the regression model employing factor scores, VIFs for diabetes, insulin, and other diabetic medications were inflated, and thus only diagnosis of diabetes was examined in the final model. No other variables showed an inflated (above 10) VIF.

**Memory.** When examining the relationship between BMI and WC as they predicted Memory, neither of these indices significantly predicted Memory performance in these models. These models explained 23% of the variance after adjusting for number of covariates. As with the Memory factor score models, significant predictors of Memory included age, education, and ISI total score such that younger individuals outperformed older individuals on these measures, and participants with more years of education performed better than those with less years. Those with more sleep problems performed worse on these measures than those with less sleep difficulty as measured by the ISI. Results are presented in Table 12.

**Executive Function.** In the models examining the relationship between obesity indices and Executive Function, neither BMI nor WC predicted performance on these measures. The BMI and WC models accounted for 23% and 24% of the variance respectively, after adjusting for number of independent variables. In step four of each of the models, significant predictors of Executive Function included age, education, and race. Results indicated that younger, more educated, and white outperformed their counterparts on these measures. Results from these models are presented in Table 13.

**Verbal Fluency.** Results from the models examining obesity indices and Verbal Fluency performance are presented in Table 14. After adjusting for number of independent variables, these models accounted for 15% of the variance. Neither obesity index predicted performance on the Verbal Fluency composite score. Significant predictors of Verbal Fluency in step four of these models included chronic pain and PTSD diagnoses such that those with either chronic pain or PTSD outperformed those that did not have these diagnoses on measures of Verbal Fluency. In addition, patients taking psychotropic medications (e.g., SSRIs) also performed better on these measures than those not taking these medications.

**Attention.** Results from the models examining obesity indices and Attention are presented in Table 15. Only 6% of the variance was explained by the BMI model, and 5% was explained by the WC model, after adjusting for number of independent variables. Neither BMI nor WC predicted performance on Attention. In step four of these models, significant predictors of attention included age and psychotropic medication use such that younger participants and those taking a psychotropic medication performed better than older participants or participants not taking these medications.

**Psychomotor Speed.** Lastly, results from models examining obesity indices and Psychomotor Speed are presented in Table 16. Both models explained 42% of the variance after adjusting for number of independent variables. Neither of the obesity indices predicted Psychomotor Speed performance. Significant predictors of Psychomotor Speed in these models included age and years of education. In these models, there was a negative relationship between age and Psychomotor Speed, and a positive relationship between years of education and Psychomotor Speed.

**Post Hoc Analysis – Correlations**

Given the unexpected relationship between a number of the covariates and neuropsychological function in the above analyses, correlations were conducted to examine the interrelatedness among covariates, predictors, and outcomes. Correlations between the obesity indices and the individual neuropsychological outcome measures are presented in Table 17. Results showed that BMI and WC significantly negatively correlated with only the Symbol Search subtest of the WAIS-III, while WC significantly negatively correlated with performance on the Digit Symbol Coding subtest of the WAIS. In addition, correlations between obesity indices and demographic variables, medical diagnoses, medications, and questionnaire data are presented in Table 18. Only covariates included in either of the aforementioned regression models are included in the correlation matrix. Most notably, both obesity indices were positively correlated with heart disease, hyperlipidemia, diabetes, and statin use such that those who were obese were more likely to have these diagnoses. In addition, BMI, but not WC was correlated with chronic pain wherein those with a higher BMI were more likely to have chronic pain. Correlations between demographic variables and medical diagnoses, medications, and questionnaire data are presented in Table 19. Of note, age was associated with heart disease,

hyperlipidemia, diabetes, and PTSD. Those who were older were more likely to have heart disease, hyperlipidemia, and diabetes, while younger individuals were more likely to have PTSD. Lastly, correlations between health variables and neuropsychological variables are presented in Table 20.

**Post Hoc Analysis – Age**

Given that age significantly predicted a majority of the neuropsychological factor scores and was significantly correlated with both BMI and WC, exploratory analyses were conducted to investigate whether age "mediates" the relationship between obesity and cognitive function. It is of note that, because obesity cannot "precede" or cause age, the term "mediation" here means statistical mediation. To test for mediation, as outlined by Baron and Kenny (1986), it must first be determined that obesity predicts neuropsychological function, without covarying for any other variable. Regression models were conducted with BMI or WC as the predictor variable and each of the 4 initial factor scores as the outcomes. (Because the results of the regression models utilizing the factor scores versus the conceptual composite scores did not differ significantly, only the factor outcome scores were used in this analysis.) In these models, WC significantly predicted performance on Speeded Measures ($B$ = -0.04, $SE$ = 0.01, $p$ = 0.003). No other analyses were significant. The second step was to determine whether WC predicted age. A regression model was run and determined that WC significantly predicted age ($B$ = 0.60, $SE$ = 0.16, $p$ = 0.0003). The third step was to demonstrate that age significantly predicted Speeded Measures, which it did ($B$ = -0.05, $SE$ = 0.01, $p < 0.0001$). Lastly, a regression analysis was run with WC as the predictor, Speeded Measures as the outcome, controlling for age. When adding age to the model, the relationship between WC and Speeded Measures disappeared ($B$ = -0.01, $SE$ = 0.01, $p$ = 0.21), while the relationship between age and Speeded Measures remained

significant ($B$ = -0.04, $SE$ = 0.01, $p < 0.0001$). Because the relationship between WC and Speeded Measures did not decrease to zero, these results imply partial statistical mediation (Baron & Kenny, 1986).

## Discussion

This study examined the relationship between obesity indices (WC and BMI) and cognitive function in young to middle-aged, male veterans in primary care. Specifically, this study aimed to elucidate whether WC is a better predictor of cognitive function than BMI, and whether these indices interact to predict cognitive performance. Lastly, this study aimed to describe the pattern of deficit as it relates to obesity in a veteran sample. Hypotheses for this study included the following: (1) WC would better predict poorer cognitive test performance across domains than BMI, (2) BMI and WC would interact to predict cognitive performance, and (3) domains of executive function and memory would yield the highest effect sizes.

Hypothesis one, WC would better predict poorer cognitive performance than BMI, was not supported by these data. Neither BMI nor WC was related to cognitive function in any domain after covarying for relevant demographic, health, and psychological factors. As such, hypothesis three, domains of executive function and memory would yield the highest effect sizes, was also not supported by the data. While the lack of findings is inconsistent with the literature suggesting a relationship between obesity and executive function and memory, particularly in younger adults (Boeka & Lokken; 2008; Cserjesi, Luminet, Poncelet, & Lenard, 2009; Elias, Elias, Sullivan, Wolf, & D'Agostino, 2005; Gunstad et al., 2007; Gunstad, Paul, Cohen, Tate, & Gordon, 2006; Lokken, Boeka, Yellumahanthi, Wesley, & Clements, 2010; Walthier, Birdsill, Glisky, & Ryan, 2010; Wolf et al., 2007), this finding is consistent with other reports of null results. For example, studies examining the relationship between BMI and

cognitive function have reported no relationship in the domains of attention (Lassek & Gaulin, 2008), memory, visuospatial skills, executive function (Wolf et al., 2007), and processing speed (Ward, Carlsson, Trivedi, Sager, & Johnson, 2005), which is consistent with the current study.

There are a number of explanations as to why no significant main effects were found for BMI or WC. Primarily, while there is a growing literature reporting a significant relationship between obesity and cognitive function, a meta-analysis conducted by this author in 2009 on the BMI-cognitive function relationship suggested a small effect size of 0.1 across studies (MacGregor, unpublished data). While the current study's power analysis suggested that this study's sample size provided ample power to detect an effect of this magnitude, it is possible that the file-drawer effect is contributing to an over-inflation of this already small effect size. This explanation is supported in the literature. Many of the studies reporting significant findings did so with sizable samples [e.g., N=1814 and 1423 in two studies reporting results from the Framingham Heart Study data (Elias, Elias, Sullivan, Wolf, & D'Agnostino, 2003; Wolf et al., 2007) and N=408 in another study reporting significant findings (Gunstad et al., 2007)]. Thus, it is possible that the effect of the relationship between these obesity indices and cognitive function is so small that the current study is underpowered to detect such a relationship.

In addition, simple correlations examining the interplay between obesity, neuropsychological variables, and covariates revealed a complicated relationship. For example, BMI and WC were significantly correlated with age such that older people were more likely to have a higher BMI/WC. In addition, age was a significant predictor of cognitive function in nearly all of the regression models tested in this study such that younger people outperformed older people on most measures. Furthermore, post hoc analyses revealed a significant relationship between waist circumference and cognitive function, specifically performance on

speeded measures, in this study, and that the addition of age to the model created a "mediation," or confounding effect (MacKinnon, Krull, & Lockwood, 2000). In other words, the addition of age to the model obscured the obesity – cognitive function relationship. This is the first known study of its kind to investigate the "mediation" effect of age on cognitive function. This complex relationship is worth further study.

Other explanations for these findings include the fact that the sample used male veterans only, and the potential for range restriction in neuropsychological outcome data given the young, relatively healthy sample. However, these explanations are not supported by the current data or the current literature. While the use of a male veteran sample may limit the generalizability of the findings, this does not likely explain the null results of this study. Specifically, most of the studies examining obesity and cognitive function report results from samples of both men and women. All published studies examined gender as a covariate, and only two known studies reported differential findings between men and women (Han et al., 2009; Kanaya et al., 2009), which were prospective, not cross-sectional in nature. The lack of reported findings as it relates to gender in this literature would suggest that the results of the current study would not have been significantly different had women been included. However, it is impossible to say this with certainty as there are no known studies examining obesity and cognitive function in female veterans, and generalizing non-veteran studies to a study that utilized a veteran sample may be inappropriate.

Similarly, this is the only study of its kind that employed a sample of veterans only. It is possible, though unlikely, that the unique sample used in this study contributed to the null findings. Veterans are specifically unique because they are generally more obese (Das, Kinsinger, Yancy, et. al, 2005; Koepsell, Forsberg, & Littman, 2009) and overall more medically

and psychiatrically compromised than the general population (Agha, Lofgren, VanRuiswyk, & Layde, 2000). It has even been suggested that, as veterans are so different from the general population, studies looking at the general population should not be generalized to veterans using VA medical centers (Agha, Lofgren, VanRuiswyk, & Layde, 2000). However, given that veterans are sicker than the general population, it seems logical that the current study would have found a relationship between, if not obesity, then other chronic health conditions known to be related to obesity, and cognitive function. Though relationships were found between diagnoses related to obesity (e.g., heart disease, hyperlipidemia) and cognitive function, they were in the opposite direction than suggested by the literature (i.e., people with these diagnoses outperformed their healthy counterparts). Thus, it is possible, if not likely, that the fact that this sample consists of veterans only does not account for the null findings shown here.

In addition, it could be argued that, as in any study of cognitive function in a healthy population, this study suffers from a range restriction problem in its neuropsychological outcome variables, making it less likely to find any effect. However, there is no evidence of range restriction in any of the neuropsychological outcome variables in this study. As can be observed in Table 3, all neuropsychological outcome measures demonstrated a range of at least four standard deviations, two above and two below the mean, suggesting a sufficient enough range to find any effect, had one existed (Cohen, Cohen, West, & Aiken, 2003). Lastly, this study took into account many psychological, medical, and self-reported questionnaire data when examining the obesity and cognitive function relationship. While most studies covary for at least a handful of these variables (e.g., Gunstad et al., 2007; Nilsson & Nilsson, 2009; Lokken, Boeka, Yellumahanthi, Wesley & Clements, 2010), none employ such an extensive list as was used in the current study. While this list is certainly not exhaustive, it is possible that, when partialling

out the variance for all other related covariates, there is no significant relationship between obesity indices and cognitive function. On the other hand, it was demonstrated in the post hoc analysis suggesting that WC does predict performance on speeded measures, but that age confounds this effect. Similarly, it is possible that covarying for so many other variables may have caused a confounding effect leading to the null findings between obesity and cognitive function (MacKinnon, Krull, & Lockwood, 2000).

Hypothesis two, BMI and WC will interact to predict cognitive performance, was unable to be tested in these analyses. Given the near perfect correlation between BMI and WC, it appears that these two indices are measuring essentially the same construct and are therefore proxies for one another. As such, the interaction is uninterpretable as a variable cannot interact with itself. This explanation may account for the lack of studies examining the interaction between these two indices – they are far too highly correlated. And interestingly, of the seven studies examing both BMI and WC as they relate to cognitive function (Fergenbaum et al., 2009; Gatto et al., 2008; Gunstad, Lhotsky, Wendell, Ferrucci, & Zonderman, 2010; Han et al., 2009; Jeong, Nam, Son, Son, & Cho, 2005; Kanaya et al., 2009; Nilsson & Nilsson, 2009), none of these studies reported the correlation between BMI and WC. Only one of the aforementioned studies examined the interaction between BMI and WC. In this study, it was reported that participants with both high BMI and high WC evidenced the worst performance on a cognitive screening measure when compared to all other participants (Jeong, Nam, Son, Son, & Cho, 2005). Though this study did not report the correlation between BMI and WC, they did report the distribution of normal, overweight, and obese BMIs versus normal and centrally obese WC. In that study, 3.9% of the sample was at least overweight according to their BMI, but had a normal waist circumference. It is of note, however, that there were 467 participants in this sample, and

only 10 of these participants were overweight but had a normal waist circumference. As such, particularly in smaller samples, it is not surprising that BMI and WC are studied separately because of the high correlation demonstrated in this study, and the low number of people who are overweight with a normal waist circumference as demonstrated in the Jeong (2005) study.

There are a number of additional findings from this study that warrant further discussion. Primarily, demographic factors, both age and education level in particular, were the most consistent predictors of cognitive performance in this study, and consistently explained the most variance in the regression models. Specifically, these demographic factors predicted performance on the Speeded Measures, Memory, and Executive Function factor scores, as well as the Psychomotor Speed, Memory, Executive Function, and Attention conceptually-based composite scores. These data indicated that younger people and those with more years of education outperformed their older and less educated counterparts. These findings are consistent with the wealth of literature discussing the psychometric properties of neuropsychological tests (e.g., Lezak, Howieson, & Loring, 2004; Strauss, Sherman, & Spreen, 2006). In fact, most normative data for neuropsychological measures employ age-, and usually education-corrected scores (e.g., Heaton, Grant, & Matthews, 1991; Wechsler, 1997). Race was another demographic variable that predicted cognitive performance on a number of factors including Speeded Measures and Executive Function (both factor and composite score). Similar to age and education, a number of neuropsychological normative data employ scores correcting for race given the consistent discrepancies in performance between races on a number of neuropsychological tests (Heaton, Grant, & Matthews, 1991). Thus, findings from this study are consistent with relevant, normative neuropsychological data.

Secondarily, there were a number of diagnoses that also predicted cognitive performance in this study. These diagnoses included PTSD and chronic pain, both of which predicted Verbal Fluency (both the factor and conceptual composite score). Interestingly, both diagnoses consistently predicted better performance on these factors. These findings are inconsistent with what has been reported in the literature. Studies examining PTSD as it predicts cognitive function have reported worse cognitive performance on measures of memory and executive function in non-veterans (LaGarde, Doyon, & Brunet, 2010), and memory and attention in veterans (Gilbertson, Gurvits, Lasko, Orr, & Pitman, 2001). This inconsistency could potentially be explained by the way in which data from the current study were collected. Diagnoses for the current study were collected by way of a chart review. Specifically, if patients had a diagnosis of PTSD in the problem list of their electronic medical chart, they were classified as having PTSD. However, in the VA, any provider can add a diagnosis to a patient's problem list (e.g., a physican, psychologist, social worker, etc.). Thus, there is no way to know from the chart what criteria, if any, were used to diagnose this disorder. Furthermore, there is also no way to know whether this diagnosis is current or in remission. Conversely, many of the published studies examining PTSD and its related cognitive function used structured clinical interviews to properly diagnose current PTSD symptoms (e.g., Brown, Zuelsdorff, & Fleming, 2006; LaGarde, Doyon, & Brunet, 2010). This methodological difference could explain the inconsistent finding. In addition, PTSD significantly correlated with age in this sample, and age significantly correlated with cognitive function. Specifically, those with PTSD were younger, and younger individuals outperformed older individuals on the cognitive measures. Thus, it is possible that the positively significant PTSD – cognitive function relationship is really reflecting an age effect in this sample. Lastly, there were only 10 participants who were diagnosed with PTSD in this sample. It

is possible that this small number of participants is not providing an accurate representation of the PTSD-cognitive function relationship. Furthermore, it is possible that there is something unique about these 10 participants (other than age) that would account for this relationship.

Similarly, a published review of the chronic pain and cognitive function literature suggested that those with chronic pain consistently evidence worse performance on measures of attention, processing, and psychomotor speed (Hart, Martelli, & Zasler, 2000). The results from the current study are inconsistent with the findings of this review given that the current study found a positive relationship between chronic pain and cognitive function such that those with chronic pain conditions outperformed their healthy counterpats. However, this review also suggested that concomitant symptoms of chronic pain (e.g., sleep disturbance) may play a more important role in the cognitive sequelae demonstrated in patients with chronic pain. In addition, the review points out the heterogeneous nature of chronic pain conditions (e.g., musculoskeletal conditions versus head and neck injury), and the differential effects of these conditions on cognitive function (Hart, Martelli, & Zasler, 2000). In the current study, all chronic pain conditions (e.g., arthritis, spinal stenosis, migraine) were pooled together to create one chronic pain variable. These methodological issues could at least partially explain the unexpected positive relationship that emerged between chronic pain and cognitive function in this study. Furthermore, there are no obvious statistical reasons as to why pain would positively predict neuropsychological functioning in this study (e.g., confounding). In the simple correlations, pain was positively associated with scores on the verbal fluency measures such that people with pain did better than those without pain on these measures. It is possible that another, unknown variable is contributing to this unusual outcome.

This study also found a positive relationship between psychotropic medication use and the Verbal Fluency and Attention conceptual composite scores. From the literature, there is evidence to suggest that the successful use of psychotropic medications (i.e., medication use resulting in symptom reduction) results in an improvement in the cognitive deficit you would likely see in psychiatric conditions. However, these deficits have not been shown to improve to intact levels of functioning (Gualtieri, Johnson, & Benedict, 2006). Therefore, it does not appear as though this finding is generally consistent with the literature on psychotropic medication use and cognitive function. However, this literature is sparse, mostly concentrated in schizophrenic patients. As such, it is possible that psychotropic medications, if used successfully, have a neuroprotective effect, which may account for the positive relationship observed in this study. More research is needed in this area to clarify this finding.

Lastly, this study observed a negative relationship between ISI score and Memory, both the factor and conceptual composite scores. This finding is consistent with other studies of sleep disturbance including insomnia and obstructive sleep apnea as it relates to cognitive function. Specifically, it has been shown that older adults with chronic insomnia have difficulties with memory, attention, and executive function (Haimov, Hanuka, & Horowitz, 2008). Moreover, as in patients with insomnia, those with chronic obstructive sleep apnea evidence deficits in memory, attention, and executive function, which worsen with disease severity (Engleman, Kingshott, Martin, & Douglas, 2000). The ISI is designed to measure both sleep disturbance as well as this disturbance's impact on quality of life. Both insomnia and obstructive sleep apnea demonstrate sleep disturbance as well as difficulty with daytime functioning (D'Ambrosio, Bowman, Mohsenin, 1999; Zammit, Weiner, Damato, Sillup, & McMillan, 1999). As such, it makes sense that the ISI would predict deficits similar to those observed in diagnosed sleep

problems. Interestingly, it was the ISI and not diagnosis of sleep disorders that predicted performance in this study. This result implies that current sleep problems better predict cognitive function than simply carrying a sleep disorder diagnosis.

This study has several important limitations that warrant further discussion. Primarily, as discussed above, because this study consisted of males only, generalizability of this study's findings is reduced. Though the veteran population is predominantly male (Department of Veteran's Affairs, 2011), a study examining the obesity-cognitive function relationship in female veterans is warranted. Though most of the obesity and cognitive function literature has reported no significant gender effects, a handful of studies of this relationship have examined and reported significant results in female-only samples (e.g., Nilsson & Nilsson, 2009). Thus, it is possible that obesity and cognitive function have a different relationship in female veterans as compared to male, and warrants further study. Furthermore, as females are becoming more and more prevalent in the military (Department of Veteran's Affairs, 2011), examining this relationship in women is becoming more and more important, and, logistically speaking, more and more feasible. Secondly, the main recruitment method used in this study consisted of sending a letter from the PCP to a random, BMI-stratified sample of primary care patients. This method of recruitment could have unknowingly created sampling bias in this study. Because this study was concerned with weight, and this information was included in the recruitment letter (Appendix A), it is possible that veterans who are sensitive about their weight may have felt stigmatized that they were selected for a study concerning weight, and therefore self-selected out. However, given the constraints on recruitment methods implemented by the Institutional Review Board at the VA, this method of recruitment is the only one that they deem ethically appropriate. Thus, it is unlikely that a similar study could be conducted within the VA using

different recruitment methods. Third, as discussed previously, information regarding diagnoses was obtained by chart review only, making it impossible to know whether symptoms of these diagnoses were current or remote, potentially influencing the results of this study. Asking the patient to confirm current diagnoses may help to alleviate this problem in future studies. Fourth, there is data to suggest a relationship between a high fat diet and cognitive function. More specifically, a recent review suggested that type of diet, not obesity, may be responsible for the cognitive deficits observed in obese individuals (Smith, Hay, Campbell, & Troller, 2011). This study did not employ a measure of diet or food intake, potentially eliminating an important predictor in this relationship. However, as high fat diets and obesity are highly related (Golay & Bobbioni, 1997), this limitation does not likely explain the null results of the current study.

Lastly, and arguably most importantly, this study was cross-sectional as opposed to prospective in nature. Despite the generally inconsistent relationship between obesity, particularly central obesity, and cognitive function in the cross-sectional data of the literature, it is generally agreed upon that middle-aged obesity predicts higher incidence of dementia, both Alzheimer's and vascular, in later life (Fitzpatrick et al., 2009; Laitala, et al., 2011; Naderali, Ratcliffe, & Dale, 2009; Whitmer, Gunderson, Quesenberry Jr., Zhou, & Yaffe, 2007). In addition, there is evidence implying an inverse relationship between obesity and cognitive function in children (Burkhalter & Hillman, 2011). Furthermore, some have suggested that poor cognitive function in children actually predicts future increase in BMI over time (Smith, Hay, Campbell, & Taylor, 2011). These findings highlight the public health need to continue to examine the obesity and cognitive function relationship across the lifespan, beginning in childhood. This need is further amplified by the rising rates of obesity in children, who are at

likely risk for dementia in older adulthood. Future research should continue to investigate obesity and cognitive function prospectively, ideally beginning in childhood.

In sum, results from this study suggest that, while there is an epidemiological implication for the posited relationship between obesity and cognitive function, the effect of this relationship is likely small enough that there is little clinical implication. In other words, it is important to understand, on the population level, how obesity and cognitive function are related. However, if an obese veteran is referred for a neuropsychological evaluation, it is unlikely that obesity will be clinically relevant in the conceptualization of his cognitive deficits. Furthermore, it appears from these data that age and education are still the best predictors of performance on cognitive measures in young, generally healthy people. However, given the relationship between midlife obesity and dementia, and the potential relationship between childhood cognitive function and obesity, further prospective research should continue to be conducted in this area, ideally utilizing large enough samples to detect these effects. Lastly, results from this study suggest that veterans and non-veterans, as it relates to the BMI-cognitive function relationship, are more similar than different.

# Appendix A

Date:

Dear

The Veterans Affairs Healthcare Network of Upstate New York is working on ways to enhance our services and improve the health of our veterans. We are interested in the relationship between health indicators like body mass index, waist circumference, blood pressure, and brain function. Therefore, I would like to call to your attention a **new** research study that is being conducted by «GreetingLine» at the Syracuse VA Medical Center.

The goal of this study is to investigate the relationship between health indicators and different types of brain function. Participation in the study is completely voluntary. If you do decide to participate, you will be a great help to the research study and future development of weight-loss and health improvement programs.

To find out if you are interested in participating, Ms. MacGregor will call you. During this brief call, you will be asked about your age and current health status to determine if you are eligible for the study. If you are eligible and choose to participate, Ms. MacGregor will go over what your participation would involve. If you do not participate, your healthcare will not be affected. If you would not like to be called by research staff about this project please call (315-425-4400 X53519) or email (Kristin.macgregor@va.gov) Ms. MacGregor to opt out.

If you have questions before you receive a call about the study, feel free to call the primary investigator of the study, Ms. Kristin MacGregor at 315-425-4400, extension 53519.

Sincerely,

Primary Care Provider
Veterans Affairs Healthcare Network of Upstate New York

Appendix B

# Demographic Questionnaire

*Please answer the following questions.*

What is your age? _____

What is your gender? (*circle one*) Male Female

How many years of education have you completed? _____

What racial group best describes you? (*check one*)
_____ Black or African-American
_____ Asian
_____ Caucasian
_____ American Indian/Alaskan Native
_____ Pacific Islander
_____ Mixed Race (more than 1)
_____ Other: (*please describe)* _____

What ethnic category best describes you? (*check one*)
_____ Hispanic/Latino
_____ Not Hispanic/Latino

What is your marital status? (*check one*)
_____ Single, Never Married
_____ Married
_____ Divorced/Separated
_____ Widowed
_____ Civil Union
_____ Other: (*please describe*) _____

What is your current employment status? (*check one*)
_____ Employed full-time
_____ Employed part-time
_____ Retired
_____ Partially Disabled, Temporary
_____ Partially Disabled, Permanent
_____ Totally Disabled, Temporary
_____ Totally Disabled, Permanent
_____ Unemployed
_____ Student
_____ Homemaker

_____ Other: (*please describe*) _____

How long were you in the military?

_____ Years _____ Months

What branch of military service were you involved in? (*check all that apply*)

_____ Navy
_____ Marines
_____ Army
_____ Air Force
_____ Reserves
_____ National Guard
_____ Coast Guard
_____ Other: (*please describe*)

Are you still on active duty? (*circle one*) Yes No

Appendix C

# Medical Records Review Form

**Date of Research Session: _____ ID# _____**

**Active Medical Diagnoses: (circle yes or no)**

Hypertension: YES NO

Medicated? YES NO

Well controlled? YES NO

If yes, specify medication: _____

Heart Disease: YES NO

If yes, specify type: _____

Medicated? YES NO

If yes, specify medication: _____

Heart Failure: YES NO

Medicated? YES NO

If yes, specify medication: _____

Hyperlipidemia: YES NO

Medicated? YES NO

Well controlled? YES NO

If yes, specify medication: _____

Diabetes: YES NO

Medicated? YES NO

Well controlled? YES NO

If yes, specify medication: _____

Sleep Apnea: YES NO

If yes, specify treatment, if any: _____

Other sleep disorder: YES NO

Medicated? YES NO

If yes, specify medication: _____

Chronic Pain: YES NO

Medicated? YES NO

If yes, specify medication: _____

Mental Health Diagnosis: YES NO

If yes, specify: _____

Medicated? YES NO

If yes, specify medication: _____

Substance Use Disorder: YES NO

If yes, specify: _____

Medicated? YES NO

If yes, specify medication: _____

Other Medications that could affect cognitive performance:

YES NO

If yes, specify medication: _____

Table 1.

*Sample Descriptives (N = 117)*

| Variable | Mean (*SD*) | N (%) |
|---|---|---|
| Age | 42.5 (10.2) | -- |
| Race | | |
| Black or African American | -- | 24 (20.5%) |
| Caucasian | | 82 (70.1%) |
| American Indian/Pacific Islander | | 4 (3.42%) |
| Other | | 7 (5.98%) |
| Education (in years) | 13.8 (2.01) | -- |
| Military Service (in months) | 104.5 (89.2) | -- |
| Branch of Military | | |
| Navy | -- | 23 (19.8%) |
| Marines | | 19 (16.4%) |
| Army | | 46 (39.7%) |
| Air Force | | 7 (6.03%) |
| Reserves/National Guard | | 1 (0.86%) |
| Multiple Branches | | 20 (17.2%) |
| Active Duty | -- | 4 (3.45%) |
| Marital Status | | |
| Single, Never Married | -- | 31 (26.5%) |
| Married | | 53 (45.3%) |
| Divorced/Separated | | 32 (27.3%) |
| Civil Union | | 1 (0.85%) |
| Employment Status | | |
| Employed | -- | 75 (64.1%) |
| Retired | | 2 (1.71%) |
| Disabled | | 23 (19.6%) |
| Unemployed | | 9 (7.69%) |
| Student | | 10 (8.55%) |
| Body Mass Index | 28.6 (5.70) | -- |
| Waist Circumference | 39.6 (5.64) | -- |
| AUDIT Score | 4.39 (5.00) | |
| PHQ-9 Score | 4.96 (4.99) | |
| ISI Score | 9.34 (7.41) | |
| PC-PTSD Score | 1.40 (1.63) | |

Table 2.

*Chart Review Descriptives*

| Variable | n (%) |
|---|---|
| Health Diagnoses | |
| Hypertension | 30 (25.6%) |
| Heart Disease | 12 (10.3%) |
| Hyperlipidemia | 43 (36.7%) |
| Diabetes | 11 (9.4%) |
| Sleep Apnea | 8 (6.8%) |
| Insomnia | 15 (12.8%) |
| Chronic Pain | 62 (53.0%) |
| Mental Health Diagnoses | |
| Depression | 7 (6.0%) |
| Anxiety | 21 (18.0%) |
| PTSD | 10 (8.5%) |
| Other Mental Health Diagnosis | 24 (20.5%) |
| Substance Use Disorders (Current or in Remission) | |
| Alcohol Abuse | 11 (9.4%) |
| Alcohol Dependence | 9 (7.7%) |
| Cocaine Abuse | 5 (4.3%) |
| Cocaine Dependence | 9 (7.7%) |
| Cannabis Abuse | 2 (1.7%) |
| Cannabis Dependence | 1 (0.8%) |
| Opioid Dependence | 1 (0.8%) |
| Medications | |
| Anti-hypertensives | 25 (21.4%) |
| Medication for heart disease | 8 (66.7%) |
| Cholesterol lowering medications | 22 (18.8%) |
| Insulin | 9 (7.7%) |
| Other diabetic medications | 7 (6.0%) |
| Sleep medication | 15 (12.8%) |
| Opiates | 32 (27.3%) |
| Other pain medication | 53 (45.3%) |
| Psychotropic medication | 28 (23.9%) |
| Medication to treat a substance use disorder | 12 (10.2%) |

*Heart Failure was also extracted from the chart; no participants suffered from heart failure

Table 3.

*Neuropsychological Outcome Scores*

| Variable | Mean (SD) | Range |
|---|---|---|
| Hopkins Verbal Learning Test – Revised | | |
| Immediate Recall | 24.6 (4.65) | 14-39 |
| Delayed Recall | 8.78 (2.07) | 3-12 |
| Recognition | 10.5 (1.43) | 6-12 |
| Trail Making Test – Part A (in seconds) | 28.6 (11.4) | 15-83 |
| Trail making Test – Part B (in seconds) | 75.2 (35.5) | 20-213 |
| Symbol Search Subtest from the WAIS-III | 33.5 (7.39) | 19-50 |
| Digit Symbol Coding from the WAIS-III | 67.6 (15.4) | 7-107 |
| Ruff Figural Fluency Test | 51.1 (14.0) | 23-81 |
| Controlled Oral Word Association Test | 37.7 (10.5) | 15-66 |
| Animal Naming Test | 21.2 (5.09) | 10-36 |
| Category Switching Test from the D-KEFS | | |
| Total Correct Words | 13.1 (2.58) | 7-19 |
| Total Accurate Switches | 11.7 (2.87) | 3-18 |
| Hayling Test | | |
| Part A (in seconds) | 5.61 (4.42) | 0-28 |
| Part B (in seconds) | 30.5 (28.4) | 0-156 |
| Total Scaled Score | 18.0 (2.29) | 9-22 |
| Brief Test of Attention | 16.4 (2.88) | 6-20 |

Table 4.

*Correlation Matrix of Neuropsychological Outcome Measures*

| | HVLT | HVLT Delay | HVLT Rec | Trails A | Trails B | Sym Search | Digit Symbol | RFFT | COWAT | Animal | Category | Category Switch | Hayling A | Hayling B | Hayling Scaled | BTA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HVLT | 1.00 | **0.70*** | **0.37*** | -0.25* | -0.38* | **0.40*** | **0.46*** | **0.34*** | **0.47*** | 0.27* | 0.29* | 0.29* | -0.11 | **-0.36*** | **0.34*** | 0.22* |
| HVLT Delay | -- | 1.00 | **0.43*** | -0.16 | **-0.32*** | **0.32*** | **0.38*** | 0.28* | **0.46*** | **0.31*** | 0.26* | 0.28* | -0.10 | **-0.46*** | **0.40*** | 0.22* |
| HVLT Rec | -- | -- | 1.00 | -0.16 | -0.21* | 0.20* | 0.22* | 0.21* | 0.11 | 0.12 | 0.17 | 0.22* | 0.01 | -0.25* | **0.30*** | 0.21* |
| Trails A | -- | -- | -- | 1.00 | **0.41*** | **-0.44*** | **-0.35*** | -0.22* | -0.15 | -0.13 | -0.15 | -0.17 | 0.11 | 0.18 | -0.13 | -0.12 |
| Trails B | -- | -- | -- | -- | 1.00 | **-0.50*** | **-0.41*** | **-0.34*** | -0.12 | -0.08 | -0.18 | -0.22* | 0.14 | 0.26* | **-0.32*** | -0.25* |
| Sym Search | -- | -- | -- | -- | -- | 1.00 | **0.62*** | **0.40*** | **-0.39*** | 0.21* | **-0.34*** | **0.36*** | -0.18* | **-0.36*** | **0.30*** | **0.38*** |
| Digit Symbol | -- | -- | -- | -- | -- | -- | 1.00 | **0.39*** | 0.21* | 0.27* | 0.26* | 0.27* | -0.24* | -0.28* | 0.26* | 0.24* |
| RFFT | -- | -- | -- | -- | -- | -- | -- | 1.00 | 0.28* | 0.19* | 0.17 | 0.09 | -0.20* | **0.37*** | **0.37*** | 0.10 |
| COWAT | -- | -- | -- | -- | -- | -- | -- | -- | 1.00 | **0.39*** | **0.40*** | **0.31*** | -0.17 | **-0.32*** | 0.24* | 0.14 |
| Animal | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1.00 | **0.42*** | **0.32*** | -0.20* | **-0.30*** | 0.20* | 0.06 |
| Category | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1.00 | **0.91*** | -0.19* | **-0.37*** | 0.18* | 0.13 |
| Category Switch | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1.00 | -0.14 | **-0.36*** | 0.20* | 0.13 |
| Hayling A | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1.00 | **0.36*** | **-0.35*** | -0.17 |
| Hayling B | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1.00 | **-0.75*** | -0.22* |
| Hayling Scaled | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1.00 | 0.22* |
| BTA | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1.00 |

HVLT = Hopkins Verbal Learning Test – Revised; Sym Search = Symbol Search Subtest from the WAIS-III; Digit Symbol = Digit Symbol Coding Subtest from the WAIS-III; RFFT = Ruff Figural Fluency Test; COWAT = Controlled Oral Word Association Test; Animal = Animal Naming test; Category = Correctly named words on the Category Test from the D-KEFS; Category Switch = Number of correct switches from the Category Test from the D-KEFS; Hayling A = Number of total seconds on the Hayling Test, Subtest A; Hayling B = Number of total seconds on the Hayling Test, Subtest B; Hayling Scaled = Total Scaled Score on the Hayling Test; BTA = Brief Test of Attention

* $p < 0.05$

**Bold font indicates $r \geq 0.30$

Table 5.

*Principal components analysis with a Varimax Rotation – Rotated Factor Solution*

| Variable | Factor 1 | Factor 2 | Factor 3 | Factor 4 |
|---|---|---|---|---|
| HVLT | 0.34 | 0.23 | **0.73** | -0.09 |
| HVLT Delay | 0.18 | 0.22 | **0.81** | -0.18 |
| HVLT Rec | 0.14 | 0.04 | **0.66** | -0.03 |
| Trails A | **-0.70** | -0.10 | -0.01 | -0.05 |
| Trails B | **-0.72** | -0.02 | -0.18 | 0.12 |
| Sym Search | **0.70** | -0.02 | 0.14 | -0.14 |
| Digit Symbol | **0.70** | 0.19 | 0.20 | -0.13 |
| RFFT | **0.46** | 0.002 | 0.26 | -0.31 |
| COWAT | 0.12 | **0.49** | 0.41 | -0.15 |
| Animal | 0.04 | **0.57** | 0.20 | -0.20 |
| Category | 0.14 | **0.93** | 0.05 | -0.08 |
| Category Switch | 0.17 | **0.88** | 0.06 | -0.04 |
| Hayling A | -0.17 | -0.16 | 0.22 | **0.72** |
| Hayling B | -0.13 | -0.29 | -0.30 | **0.74** |
| Hayling Scaled | 0.15 | 0.04 | 0.35 | **-0.80** |
| BTA* | 0.38 | 0.01 | 0.15 | -0.22 |

HVLT = Hopkins Verbal Learning Test – Revised; Sym Search = Symbol Search Subtest from the WAIS-III; Digit Symbol = Digit Symbol Coding Subtest from the WAIS-III; RFFT = Ruff Figural Fluency Test; COWAT = Controlled Oral Word Association Test; Animal = Animal Naming test; Category = Correctly named words on the Category Test from the D-KEFS; Category Switch = Number of correct switches from the Category Test from the D-KEFS; Hayling A = Number of total seconds on the Hayling Test, Subtest A; Hayling B = Number of total seconds on the Hayling Test, Subtest B; Hayling Scaled = Total Scaled Score on the Hayling Test; BTA = Brief Test of Attention

*BTA not included in factor scores as it did not correlate with any factor ≥ 0.40

Table 6.

*Correlations between Factor Scores and Potential Covariates*

| | Factor 1 | Factor 2 | Factor 3 | Factor 4 |
|---|---|---|---|---|
| Demographics | | | | |
| Age | -0.52*** | -0.25*** | -0.38*** | -0.26** |
| Education | 0.42*** | 0.11 | 0.30** | 0.17 |
| Race (White vs. Non-White) | 0.43*** | 0.13 | 0.29** | 0.32*** |
| Questionnaires | | | | |
| PHQ-9 total score | -0.03 | 0.09 | -0.03 | -0.0003 |
| AUDIT total score | -0.05 | -0.04 | -0.03 | 0.11 |
| PC-PTSD total score | -0.03 | 0.09 | -0.05 | -0.08 |
| ISI total score | -0.10 | -0.01 | -0.18* | -0.12 |
| Medical Diagnoses | | | | |
| Hypertension | -0.09 | -0.04 | -0.005 | -0.03 |
| Heart Disease | -0.21* | -0.09 | -0.05 | 0.01 |
| Hyperlipidemia | -0.23* | -0.15 | -0.15 | -0.02 |
| Diabetes | -0.21* | -0.08 | -0.22 | -0.19* |
| Sleep Apnea | 0.02 | 0.07 | 0.08 | 0.05 |
| Insomnia | -0.05 | -0.10 | -0.05 | -0.02 |
| Chronic Pain | -0.04 | 0.21* | 0.10 | 0.003 |
| Mental Health Diagnoses | | | | |
| Depression | -0.07 | 0.10 | 0.08 | -0.14 |
| Anxiety | 0.13 | 0.03 | 0.08 | 0.01 |
| PTSD | 0.12 | 0.29** | 0.18 | 0.09 |
| Substance Use Disorders | | | | |
| Alcohol Abuse | 0.07 | 0.17 | 0.02 | 0.15 |
| Alcohol Dependence | -0.11 | 0.001 | -0.05 | -0.04 |
| Cocaine Abuse | -0.01 | 0.16 | 0.002 | -0.08 |
| Cocaine Dependence | -0.01 | 0.13 | -0.01 | 0.05 |
| Cannabis Abuse | 0.18* | 0.17 | 0.11 | 0.001 |
| Cannabis Dependence | -0.15 | -0.04 | -0.09 | 0.02 |
| Opiate Dependence | -0.02 | -0.13 | 0.06 | -0.05 |
| Medications | | | | |
| Antihypertensives | -0.06 | -0.06 | -0.04 | -0.05 |
| Statins | -0.16 | -0.14 | -0.13 | 0.001 |
| Insulin | -0.12 | -0.08 | -0.21* | -0.09 |
| Other Diabetic Medication | -0.20* | -0.06 | -0.16 | -0.20* |
| Sleep Medication | 0.003 | 0.03 | 0.01 | -0.03 |
| Opiate Pain Medication | -0.10 | 0.04 | -0.03 | -0.13 |
| Other Pain Medication | 0.03 | 0.13 | 0.06 | -0.14 |
| Psychotropic Medication | -0.03 | 0.18 | -0.03 | 0.11 |
| Substance Use Disorder Med | -0.01 | 0.04 | -0.01 | -0.01 |

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 7.

*Hierarchical Regression: Obesity indices predicting Speeded Measures Factor Score*

| | Age | Education | Race | Lipid | Diabetes | Pain | Heart Disease | ISI Score | PTSD | Obesity Index | Adj. $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Step 1* | | | | | | | | | | | 0.46 |
| Beta | -0.03*** | 0.12*** | 0.42*** | | | | | | | | |
| Standard Error | 0.005 | 0.02 | 0.11 | | | | | | | | |
| *Step 2* | | | | | | | | | | | 0.45 |
| Beta | -0.03*** | 0.12*** | 0.41*** | 0.01 | -0.04 | -0.005 | -0.24 | | | | |
| Standard Error | 0.006 | 0.02 | 0.12 | 0.12 | 0.18 | 0.10 | 0.17 | | | | |
| *Step 3* | | | | | | | | | | | 0.44 |
| Beta | -0.03*** | 0.12*** | 0.40** | -0.02 | -0.03 | 0.01 | -0.25 | -0.01 | 0.04 | | |
| Standard Error | 0.006 | 0.02 | 0.12 | 0.12 | 0.18 | 0.10 | 0.17 | 0.01 | 0.19 | | |
| *Step 4 - BMI* | | | | | | | | | | BMI | 0.44 |
| Beta | -0.03*** | 0.12*** | 0.40** | 0.01 | -0.04 | 0.01 | -0.25 | -0.01 | 0.04 | 0.002 | |
| Standard Error | 0.006 | 0.02 | 0.12 | 0.12 | 0.18 | 0.10 | 0.17 | 0.01 | 0.19 | 0.01 | |
| *Step 4 - WC* | | | | | | | | | | WC | 0.44 |
| Beta | -0.03*** | 0.12*** | 0.41*** | -0.0003 | -0.06 | 0.001 | -0.26 | -0.01 | 0.04 | 0.01 | |
| Standard Error | 0.006 | 0.02 | 0.12 | 0.12 | 0.18 | 0.10 | 0.17 | 0.01 | 0.19 | 0.01 | |

** $p < 0.01$; *** $p < 0.001$

Table 8.

*Hierarchical Regression: Obesity indices predicting Verbal Fluency Factor Score*

| | Age | Education | Race | Lipid | Diabetes | Pain | Heart Disease | ISI Score | PTSD | Obesity Index | Adj. $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Step 1* | | | | | | | | | | | 0.05 |
| Beta | -0.02* | 0.03 | 0.08 | | | | | | | | |
| Standard Error | 0.01 | 0.03 | 0.16 | | | | | | | | |
| *Step 2* | | | | | | | | | | | 0.07 |
| Beta | -0.01 | 0.03 | 0.10 | -0.13 | 0.01 | 0.36* | -0.06 | | | | |
| Standard Error | 0.01 | 0.03 | 0.16 | 0.16 | 0.24 | 0.14 | 0.24 | | | | |
| *Step 3* | | | | | | | | | | | 0.13 |
| Beta | -0.01 | 0.03 | 0.13 | -0.14 | 0.04 | 0.38** | -0.09 | -0.005 | 0.71** | | |
| Standard Error | 0.01 | 0.03 | 0.16 | 0.16 | 0.24 | 0.14 | 0.23 | 0.01 | 0.25 | | |
| *Step 4 - BMI* | | | | | | | | | | BMI | 0.12 |
| Beta | -0.01 | 0.03 | 0.14 | -0.16 | 0.02 | 0.37** | -0.10 | -0.005 | 0.71** | 0.01 | |
| Standard Error | 0.01 | 0.03 | 0.16 | 0.16 | 0.24 | 0.14 | 0.23 | 0.01 | 0.25 | 0.01 | |
| *Step 4 - WC* | | | | | | | | | | WC | 0.12 |
| Beta | -0.01 | 0.03 | 0.15 | -0.17 | 0.001 | 0.36** | -0.12 | -0.005 | 0.70** | 0.01 | |
| Standard Error | 0.01 | 0.03 | 0.16 | 0.16 | 0.24 | 0.14 | 0.23 | 0.01 | 0.25 | 0.01 | |

* $p < 0.05$; ** $p < 0.01$, *** $p<0.001$

Table 9.

*Hierarchical Regression: Obesity indices predicting Memory Factor Score*

| | Age | Education | Race | Lipid | Diabetes | Pain | Heart Disease | ISI Score | PTSD | Obesity Index | Adj. $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Step 1* | | | | | | | | | | | 0.22 |
| Beta | -0.02*** | 0.10** | 0.30 | | | | | | | | |
| Standard Error | 0.01 | 0.03 | 0.15 | | | | | | | | |
| *Step 2* | | | | | | | | | | | 0.22 |
| Beta | -0.02** | 0.09** | 0.30 | -0.04 | -0.26 | 0.21 | 0.12 | | | | |
| Standard Error | 0.01 | 0.03 | 0.15 | 0.16 | 0.24 | 0.13 | 0.23 | | | | |
| *Step 3* | | | | | | | | | | | 0.25 |
| Beta | -0.02** | 0.10** | 0.28 | -0.01 | -0.24 | 0.26 | 0.08 | -0.02* | 0.32 | | |
| Standard Error | 0.01 | 0.03 | 0.15 | 0.15 | 0.23 | 0.13 | 0.23 | 0.01 | 0.24 | | |
| *Step 4 - BMI* | | | | | | | | | | BMI | 0.25 |
| Beta | -0.02** | 0.09** | 0.30 | -0.04 | -0.27 | 0.25 | 0.06 | -0.02* | 0.32 | 0.01 | |
| Standard Error | 0.01 | 0.03 | 0.15 | 0.16 | 0.24 | 0.14 | 0.23 | 0.01 | 0.24 | 0.01 | |
| *Step 4 - WC* | | | | | | | | | | WC | 0.25 |
| Beta | -0.02** | 0.10** | 0.30 | -0.05 | -0.30 | 0.24 | 0.05 | -0.02* | 0.31 | 0.01 | |
| Standard Error | 0.01 | 0.03 | 0.15 | 0.16 | 0.24 | 0.13 | 0.23 | 0.01 | 0.24 | 0.01 | |

* $p < 0.05$; ** $p < 0.01$, *** $p<0.001$

Table 10.

*Hierarchical Regression: Obesity indices predicting Executive Function Factor Score*

| | Age | Education | Race | Lipid | Diabetes | Pain | Heart Disease | ISI Score | PTSD | Obesity Index | Adj. $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Step 1* | | | | | | | | | | | 0.12 |
| Beta | -0.01 | 0.04 | 0.44** | | | | | | | | |
| Standard Error | 0.01 | 0.03 | 0.16 | | | | | | | | |
| *Step 2* | | | | | | | | | | | 0.11 |
| Beta | -0.01* | 0.04 | 0.45** | 0.18 | -0.27 | 0.03 | 0.15 | | | | |
| Standard Error | 0.01 | 0.03 | 0.16 | 0.16 | 0.25 | 0.14 | 0.24 | | | | |
| *Step 3* | | | | | | | | | | | 0.11 |
| Beta | -0.01 | 0.04 | 0.44** | 0.20 | -0.26 | 0.06 | 0.13 | -0.01 | 0.14 | | |
| Standard Error | 0.01 | 0.04 | 0.16 | 0.17 | 0.25 | 0.14 | 0.24 | 0.01 | 0.26 | | |
| *Step 4 - BMI* | | | | | | | | | | BMI | 0.11 |
| Beta | -0.01 | 0.04 | 0.46** | 0.15 | -0.30 | 0.04 | 0.10 | -0.01 | 0.13 | 0.01 | |
| Standard Error | 0.01 | 0.04 | 0.17 | 0.17 | 0.26 | 0.15 | 0.25 | 0.01 | 0.26 | 0.01 | |
| *Step 4 - WC* | | | | | | | | | | WC | 0.11 |
| Beta | -0.02* | 0.04 | 0.46** | 0.15 | -0.32 | 0.04 | 0.09 | -0.01 | 0.13 | 0.02 | |
| Standard Error | 0.01 | 0.03 | 0.17 | 0.17 | 0.26 | 0.15 | 0.25 | 0.01 | 0.26 | 0.01 | |

* $p < 0.05$; ** $p < 0.01$, *** $p<0.001$

Table 11.

*Correlations between Conceptually-Based Composite Scores and Potential Covariates*

| | Memory | Executive Function | Verbal Fluency | Attention | Psychomotor Speed |
|---|---|---|---|---|---|
| Demographics | | | | | |
| Age | -0.38*** | -0.36*** | -0.23*** | -0.33** | -0.57*** |
| Education | 0.30** | 0.35*** | 0.10 | 0.19* | 0.38*** |
| Race (White vs. Non-White) | 0.29** | 0.43*** | 0.07 | 0.33*** | 0.38*** |
| Questionnaires | | | | | |
| PHQ-9 total score | -0.03 | 0.01 | 0.12 | -0.03 | -0.09 |
| AUDIT total score | -0.03 | 0.02 | -0.05 | 0.13 | -0.02 |
| PC-PTSD total score | -0.05 | 0.01 | 0.06 | -0.12 | -0.02 |
| ISI total score | -0.18* | -0.11 | -0.01 | -0.12 | -0.02 |
| Medical Diagnoses | | | | | |
| Hypertension | -0.005 | -0.05 | -0.03 | -0.08 | -0.14 |
| Heart Disease | -0.05 | -0.10 | -0.07 | 0.04 | -0.24** |
| Hyperlipidemia | -0.15 | -0.13 | -0.17 | -0.07 | -0.27** |
| Diabetes | -0.22* | -0.22* | -0.03 | -0.15 | -0.21* |
| Sleep Apnea | 0.08 | 0.05 | 0.06 | -0.04 | -0.02 |
| Insomnia | -0.05 | -0.04 | -0.11 | 0.05 | -0.15 |
| Chronic Pain | 0.10 | 0.04 | 0.21* | 0.01 | -0.06 |
| Mental Health Diagnoses | | | | | |
| Depression | 0.08 | -0.03 | 0.09 | -0.09 | -0.06 |
| Anxiety | 0.08 | 0.07 | -0.004 | 0.06 | 0.16 |
| PTSD | 0.18 | 0.15 | 0.30*** | 0.09 | 0.14 |
| Substance Use Disorders | | | | | |
| Alcohol Abuse | 0.02 | 0.10 | 0.18 | 0.04 | 0.13 |
| Alcohol Dependence | -0.05 | -0.03 | 0.003 | 0.07 | -0.15 |
| Cocaine Abuse | 0.002 | 0.12 | 0.14 | 0.01 | -0.01 |
| Cocaine Dependence | -0.01 | 0.02 | 0.15 | 0.01 | -0.01 |
| Cannabis Abuse | 0.12 | 0.20* | 0.15 | 0.12 | 0.15 |
| Cannabis Dependence | -0.08 | -0.09 | -0.005 | -0.04 | -0.16 |
| Opiate Dependence | 0.06 | -0.10 | -0.14 | 0.03 | 0.04 |
| Medications | | | | | |
| Antihypertensives | -0.04 | -0.04 | -0.05 | -0.09 | -0.11 |
| Statins | -0.13 | -0.09 | -0.13 | -0.07 | -0.20* |
| Insulin | -0.21* | -0.18 | -0.02 | -0.05 | -0.16 |
| Other Diabetic Medication | -0.16 | -0.19* | -0.04 | -0.17 | -0.16 |
| Sleep Medication | 0.01 | 0.09 | 0.03 | -0.01 | -0.15 |
| Opiate Pain Medication | -0.03 | -0.16 | 0.08 | -0.03 | -0.11 |
| Other Pain Medication | 0.06 | 0.03 | 0.12 | 0.05 | 0.03 |
| Psychotropic Medication | -0.03 | 0.03 | 0.20* | 0.12 | 0.03 |
| Substance Use Disorder Med | -0.01 | 0.003 | 0.05 | 0.01 | 0.01 |

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 12.

*Hierarchical Regression: Obesity indices predicting Memory Conceptual Composite Score*

| | Age | Education | Race | Heart Disease | Hyper-lipidemia | Statin Use | Diabetes | Pain | ISI Score | PTSD | Psycho-tropic | Obesity Index | Adj. $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Step 1* | | | | | | | | | | | | | 0.22 |
| Beta | -0.03*** | 0.10** | 0.09 | | | | | | | | | | |
| Standard Error | 0.01 | 0.03 | 0.05 | | | | | | | | | | |
| *Step 2* | | | | | | | | | | | | | 0.20 |
| Beta | -0.02** | 0.10** | 0.07 | 0.09 | -0.05 | -0.03 | 0.17 | | | | | | |
| Standard Error | 0.01 | 0.03 | 0.05 | 0.25 | 0.19 | 0.24 | 0.14 | | | | | | |
| *Step 3* | | | | | | | | | | | | | 0.23 |
| Beta | -0.02** | 0.10** | 0.09 | 0.01 | -0.07 | 0.07 | -0.20 | 0.22 | -0.02* | 0.33 | 0.07 | | |
| Standard Error | 0.01 | 0.03 | 0.05 | 0.24 | 0.19 | 0.24 | 0.25 | 0.14 | 0.01 | 0.26 | 0.17 | | |
| *Step 4 - BMI* | | | | | | | | | | | | BMI | 0.23 |
| Beta | -0.02** | 0.10** | 0.09 | 0.001 | -0.09 | 0.07 | -0.21 | 0.21 | -0.02* | 0.32 | 0.07 | 0.005 | |
| Standard Error | 0.01 | 0.34 | 0.05 | 0.25 | 0.19 | 0.25 | 0.25 | 0.14 | 0.01 | 0.26 | 0.17 | 0.01 | |
| *Step 4 - WC* | | | | | | | | | | | | WC | 0.23 |
| Beta | -0.02** | 0.10** | 0.09 | -0.01 | -0.10 | 0.07 | -0.24 | 0.20 | -0.02* | 0.32 | 0.07 | 0.01 | |
| Standard Error | 0.01 | 0.03 | 0.05 | 0.25 | 0.19 | 0.25 | 0.25 | 0.14 | 0.01 | 0.26 | 0.17 | 0.01 | |

* $p < 0.05$; ** $p < 0.01$, *** $p<0.001$

Table 13.

*Hierarchical Regression: Obesity indices predicting Executive Function Conceptual Composite Score*

| | Age | Education | Race | Heart Disease | Hyper-lipidemia | Statin Use | Diabetes | Pain | ISI Score | PTSD | Psycho-tropic | Obesity Index | Adj. $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Step 1* | | | | | | | | | | | | | 0.24 |
| Beta | -0.02*** | 0.10*** | 0.09 | | | | | | | | | | |
| Standard Error | 0.005 | 0.03 | 0.04 | | | | | | | | | | |
| *Step 2* | | | | | | | | | | | | | 0.22 |
| Beta | -0.02** | 0.10** | 0.08* | -0.13 | -0.05 | 0.11 | -0.19 | 0.04 | | | | | |
| Standard Error | 0.01 | 0.03 | 0.04 | 0.20 | 0.15 | 0.20 | 0.20 | 0.11 | | | | | |
| *Step 3* | | | | | | | | | | | | | 0.24 |
| Beta | -0.02** | 0.10*** | 0.09* | -0.16 | -0.10 | 0.20 | -0.14 | 0.07 | -0.01 | 0.14 | 0.20 | | |
| Standard Error | 0.01 | 0.03 | 0.04 | 0.20 | 0.15 | 0.20 | 0.20 | 0.11 | 0.01 | 0.21 | 0.14 | | |
| *Step 4 - BMI* | | | | | | | | | | | | BMI | 0.23 |
| Beta | -0.02** | 0.10*** | 0.09* | -0.17 | -0.12 | 0.20 | -0.15 | 0.06 | -0.01 | 0.14 | 0.20 | 0.005 | |
| Standard Error | 0.01 | 0.03 | 0.04 | 0.20 | 0.16 | 0.20 | 0.20 | 0.11 | 0.01 | 0.21 | 0.14 | 0.01 | |
| *Step 4 - WC* | | | | | | | | | | | | WC | 0.24 |
| Beta | -0.02** | 0.11*** | 0.09* | -0.18 | -0.13 | 0.20 | -0.18 | 0.05 | -0.01 | 0.13 | 0.21 | 0.01 | |
| Standard Error | 0.01 | 0.03 | 0.04 | 0.20 | 0.16 | 0.20 | 0.20 | 0.11 | 0.01 | 0.21 | 0.14 | 0.01 | |

* $p < 0.05$; ** $p < 0.01$, *** $p<0.001$

Table 14.

*Hierarchical Regression: Obesity indices predicting Verbal Fluency Conceptual Composite Score*

| | Age | Education | Race | Heart Disease | Hyper-lipidemia | Statin Use | Diabetes | Pain | ISI Score | PTSD | Psycho-tropic | Obesity Index | Adj. $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Step 1* | | | | | | | | | | | | | 0.04 |
| Beta | -0.02* | 0.03 | -0.04 | | | | | | | | | | |
| Standard Error | 0.01 | 0.03 | 0.05 | | | | | | | | | | |
| *Step 2* | | | | | | | | | | | | | 0.06 |
| Beta | -0.01 | 0.04 | -0.05 | 0.10 | -0.15 | -0.16 | 0.06 | 0.38** | | | | | |
| Standard Error | 0.01 | 0.03 | 0.05 | 0.25 | 0.19 | 0.25 | 0.25 | 0.14 | | | | | |
| *Step 3* | | | | | | | | | | | | | 0.15 |
| Beta | -0.01 | 0.05 | -0.03 | 0.10 | -0.23 | -0.12 | 0.20 | 0.38** | -0.004 | 0.59* | 0.38* | | |
| Standard Error | 0.01 | 0.03 | 0.05 | 0.24 | 0.19 | 0.24 | 0.25 | 0.14 | 0.01 | 0.26 | 0.17 | | |
| *Step 4 - BMI* | | | | | | | | | | | | BMI | 0.15 |
| Beta | -0.01 | 0.05 | -0.03 | 0.08 | -0.27 | -0.12 | 0.17 | 0.36* | -0.005 | 0.58* | 0.38* | 0.01 | |
| Standard Error | 0.01 | 0.03 | 0.03 | 0.25 | 0.19 | 0.25 | 0.25 | 0.14 | 0.01 | 0.26 | 0.17 | 0.01 | |
| *Step 4 - WC* | | | | | | | | | | | | WC | 0.15 |
| Beta | -0.01 | 0.05 | -0.03 | 0.07 | -0.28 | -0.11 | 0.15 | 0.36* | -0.005 | 0.58* | 0.38 | 0.01 | |
| Standard Error | 0.01 | 0.03 | 0.05 | 0.25 | 0.19 | 0.25 | 0.25 | 0.14 | 0.01 | 0.26 | 0.17 | 0.01 | |

* $p < 0.05$; ** $p < 0.01$, *** $p<0.001$

Table 15.

*Hierarchical Regression: Obesity indices predicting Attention Conceptual Composite Score*

| | Age | Education | Race | Heart Disease | Hyper-lipidemia | Statin Use | Diabetes | Pain | ISI Score | PTSD | Psycho-tropic | Obesity Index | Adj. $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Step 1* | | | | | | | | | | | | | 0.07 |
| Beta | -0.03* | 0.08 | 0.18 | | | | | | | | | | |
| Standard Error | 0.01 | 0.07 | 0.10 | | | | | | | | | | |
| *Step 2* | | | | | | | | | | | | | 0.03 |
| Beta | -0.03* | 0.07 | 0.17 | 0.02 | 0.11 | 0.12 | -0.25 | -0.02 | | | | | |
| Standard Error | 0.02 | 0.07 | 0.11 | 0.54 | 0.41 | 0.53 | 0.54 | 0.30 | | | | | |
| *Step 3* | | | | | | | | | | | | | 0.06 |
| Beta | -0.04* | 0.11 | 0.19 | 0.08 | -0.11 | 0.33 | -0.04 | -0.04 | -0.01 | -0.19 | 0.98* | | |
| Standard Error | 0.02 | 0.07 | 0.11 | 0.53 | 0.41 | 0.53 | 0.53 | 0.30 | 0.02 | 0.56 | 0.37 | | |
| *Step 4 - BMI* | | | | | | | | | | | | BMI | 0.06 |
| Beta | -0.04** | 0.11 | 0.19 | 0.14 | -0.01 | 0.33 | 0.03 | 0.01 | -0.01 | -0.17 | 0.97* | -0.03 | |
| Standard Error | 0.02 | 0.07 | 0.11 | 0.54 | 0.42 | 0.53 | 0.54 | 0.30 | 0.02 | 0.56 | 0.37 | 0.03 | |
| *Step 4 - WC* | | | | | | | | | | | | WC | 0.05 |
| Beta | -0.04* | 0.11 | 0.19 | 0.09 | -0.10 | 0.33 | -0.03 | -0.03 | -0.01 | -0.19 | 0.98 | -0.001 | |
| Standard Error | 0.02 | 0.07 | 0.11 | 0.54 | 0.42 | 0.53 | 0.55 | 0.30 | 0.02 | 0.57 | 0.38 | 0.03 | |

* $p < 0.05$; ** $p < 0.01$, *** $p<0.001$

Table 16.

*Hierarchical Regression: Obesity indices predicting Psychomotor Conceptual Composite Score*

| | Age | Education | Race | Heart Disease | Hyper-lipidemia | Statin Use | Diabetes | Pain | ISI Score | PTSD | Psycho-tropic | Obesity Index | Adj. $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Step 1* | | | | | | | | | | | | | 0.44 |
| Beta | -0.04*** | 0.12*** | 0.01 | | | | | | | | | | |
| Standard Error | 0.005 | 0.03 | 0.04 | | | | | | | | | | |
| *Step 2* | | | | | | | | | | | | | 0.42 |
| Beta | -0.04*** | 0.12*** | 0.02 | -0.30 | -0.05 | 0.09 | -0.06 | -0.05 | | | | | |
| Standard Error | 0.01 | 0.03 | 0.04 | 0.21 | 0.16 | 0.20 | 0.21 | 0.11 | | | | | |
| *Step 3* | | | | | | | | | | | | | 0.42 |
| Beta | -0.04*** | 0.13*** | 0.02 | -0.33 | -0.08 | 0.17 | -0.04 | -0.03 | -0.01 | -0.06 | 0.14 | | |
| Standard Error | 0.01 | 0.03 | 0.04 | 0.21 | 0.16 | 0.21 | 0.21 | 0.12 | 0.01 | 0.22 | 0.15 | | |
| *Step 4 - BMI* | | | | | | | | | | | | BMI | 0.42 |
| Beta | -0.04*** | 0.13*** | 0.02 | -0.30 | -0.04 | 0.18 | -0.004 | -0.01 | -0.01 | -0.05 | 0.14 | -0.01 | |
| Standard Error | 0.01 | 0.03 | 0.04 | 0.21 | 0.16 | 0.21 | 0.21 | 0.12 | 0.01 | 0.22 | 0.15 | 0.01 | |
| *Step 4 - WC* | | | | | | | | | | | | WC | 0.42 |
| Beta | -0.04*** | 0.13*** | 0.02 | -0.31 | -0.07 | 0.17 | -0.02 | -0.02 | -0.01 | -0.05 | 0.14 | -0.005 | |
| Standard Error | 0.01 | 0.03 | 0.04 | 0.21 | 0.16 | 0.21 | 0.21 | 0.12 | 0.01 | 0.22 | 0.15 | 0.01 | |

* $p < 0.05$; ** $p < 0.01$, *** $p<0.001$

Table 17.

*Correlations between Obesity Indices and Neuropsychological Outcome Variables*

| | BMI | WC |
|---|---|---|
| Hopkins Verbal Learning Test – Revised | | |
| Immediate Recall | -0.04 | -0.11 |
| Delayed Recall | -0.08 | -0.12 |
| Recognition | -0.01 | -0.005 |
| Trail Making Test – Part A (in seconds) | 0.09 | 0.10 |
| Trail making Test – Part B (in seconds) | 0.04 | 0.06 |
| Symbol Search Subtest from the WAIS-III | -0.26** | -0.32*** |
| Digit Symbol Coding from the WAIS-III | -0.18 | -0.23* |
| Ruff Figural Fluency Test | -0.03 | -0.08 |
| Controlled Oral Word Association Test | -0.04 | -0.06 |
| Animal Naming Test | 0.17 | 0.14 |
| Category Switching Test from the D-KEFS | | |
| Total Correct Words | -0.07 | -0.07 |
| Total Accurate Switches | -0.08 | -0.06 |
| Hayling Test | | |
| Part A (in seconds) | -0.02 | -0.04 |
| Part B (in seconds) | -0.01 | 0.04 |
| Total Scaled Score | -0.04 | -0.08 |
| Brief Test of Attention | -0.13 | -0.10 |
| Speeded Measures Factor Score | -0.17 | -0.22* |
| Verbal Fluency Factor Score | -0.01 | -0.02 |
| Memory Factor Score | -0.06 | -0.09 |
| Executive Function Factor Score | -0.002 | -0.03 |

* $p<0.05$; ** $p<0.01$; *** $p<0.001$

Table 18.

*Correlations between Obesity Indices, Diagnoses, Medications, and Questionnaires*

| Variable | BMI | WC |
|---|---|---|
| Demographics | | |
| Age | 0.21* | 0.33*** |
| Education | 0.0002 | -0.08 |
| Race (White vs. Non-White) | -0.25** | -0.27** |
| Health Diagnoses | | |
| Heart Disease | 0.22* | 0.24** |
| Hyperlipidemia | 0.40*** | 0.41*** |
| Diabetes | 0.21* | 0.28** |
| Chronic Pain | 0.20* | 0.18 |
| Mental Health Diagnoses | | |
| PTSD | -0.005 | -0.03 |
| Medications | | |
| Cholesterol lowering medications | 0.34*** | 0.34*** |
| Psychotropic medication | 0.03 | 0.04 |
| Questionnaires | | |
| ISI-Total Score | 0.16 | 0.11 |

* $p<0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 19.

*Correlations between Demographic Variables, Diagnoses, Medications, and Quetionnaires*

| Variable | Age | Education | Race |
|---|---|---|---|
| Obesity Indices | | | |
| BMI | 0.21* | 0.002 | -0.25** |
| WC | 0.33*** | -0.08 | -0.27*** |
| Health Diagnoses | | | |
| Heart Disease | 0.20* | -0.02 | -0.09 |
| Hyperlipidemia | 0.40*** | 0.002 | -0.20* |
| Diabetes | 0.24* | -0.13 | -0.17 |
| Chronic Pain | 0.01 | -0.02 | -0.09 |
| Mental Health Diagnoses | | | |
| PTSD | -0.23* | 0.04 | -0.0005 |
| Medications | | | |
| Cholesterol lowering medications | 0.33*** | 0.02 | -0.16 |
| Psychotropic medication | 0.08 | -0.18 | -0.07 |
| Questionnaires | | | |
| ISI-Total Score | 0.04 | 0.02 | -0.12 |

* $p<0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 20.

*Correlations between Obesity Indices and Neuropsychological Outcome Variables*

| | Heart Disease | Hyper-lipidemia | Diabetes | Pain | PTSD | Statin Use | Psycho-tropic | ISI score |
|---|---|---|---|---|---|---|---|---|
| HVLT – Imm | -0.09 | -0.16 | -0.17 | 0.14 | 0.20* | -0.11 | -0.02 | -0.10 |
| HVLT – Delay | -0.07 | -0.26** | -0.22* | 0.05 | 0.12 | -0.19* | 0.02 | -0.21* |
| HVLT - Recog | 0.04 | 0.04 | -0.15 | 0.05 | 0.11 | -0.01 | -0.07 | -0.14 |
| TMT – A | 0.09 | 0.12 | 0.11 | -0.01 | -0.07 | 0.13 | 0.17 | -0.01 |
| TMT – B | 0.12 | 0.13 | 0.24** | 0.09 | 0.04 | 0.13 | -0.04 | 0.10 |
| Symbol Search | -0.14 | -0.19* | -0.24** | -0.05 | 0.11 | -0.12 | 0.07 | -0.08 |
| Coding | -0.29** | -0.30** | -0.14 | -0.05 | 0.14 | -0.24* | -0.01 | -0.19* |
| RFFT | -0.12 | -0.10 | -0.01 | 0.04 | 0.15 | 0.01 | -0.04 | -0.01 |
| COWAT | -0.03 | -0.15 | -0.04 | 0.23* | 0.27** | -0.10 | 0.20 | 0.05 |
| Animals | -0.02 | -0.14 | 0.09 | 0.07 | 0.20* | -0.05 | 0.18 | -0.05 |
| Category Total | -0.10 | -0.12 | -0.13 | 0.18* | 0.23* | -0.15 | 0.10 | 0.02 |
| Cat Switch | -0.13 | -0.06 | -0.15 | 0.17 | 0.18 | -0.12 | 0.07 | -0.05 |
| Hayling – A | 0.16 | -0.005 | 0.13 | -0.05 | -0.08 | -0.002 | -0.15 | 0.05 |
| Hayling – B | -0.02 | 0.07 | 0.19* | 0.001 | -0.11 | 0.02 | -0.02 | 0.12 |
| Hayling Scaled | 0.09 | 0.02 | -0.13 | -0.05 | 0.03 | 0.02 | 0.09 | -0.11 |
| BTA | 0.04 | -0.05 | -0.10 | -0.01 | 0.06 | -0.04 | 0.15 | 0.0005 |

HVLT = Hopkins Verbal Learning Test – Revised; TMT = Trail Making Test; Symbol Search = Symbol Search Subtest from the WAIS-III; Coding = Digit Symbol Coding Subtest from the WAIS-III; RFFT = Ruff Figural Fluency Test; COWAT = Controlled Oral Word Association Test; Animals = Animal Naming test; Category = Correctly named words on the Category Test from the D-KEFS; Cat Switch = Number of correct switches from the Category Test from the D-KEFS; Hayling A = Number of total seconds on the Hayling Test, Subtest A; Hayling B = Number of total seconds on the Hayling Test, Subtest B; Hayling Scaled = Total Scaled Score on the Hayling Test; BTA = Brief Test of Attention

* $p<0.05$; ** $p<0.01$; *** $p<0.001$

Figure 1.

*Flow Chart of Participant Recruitment*

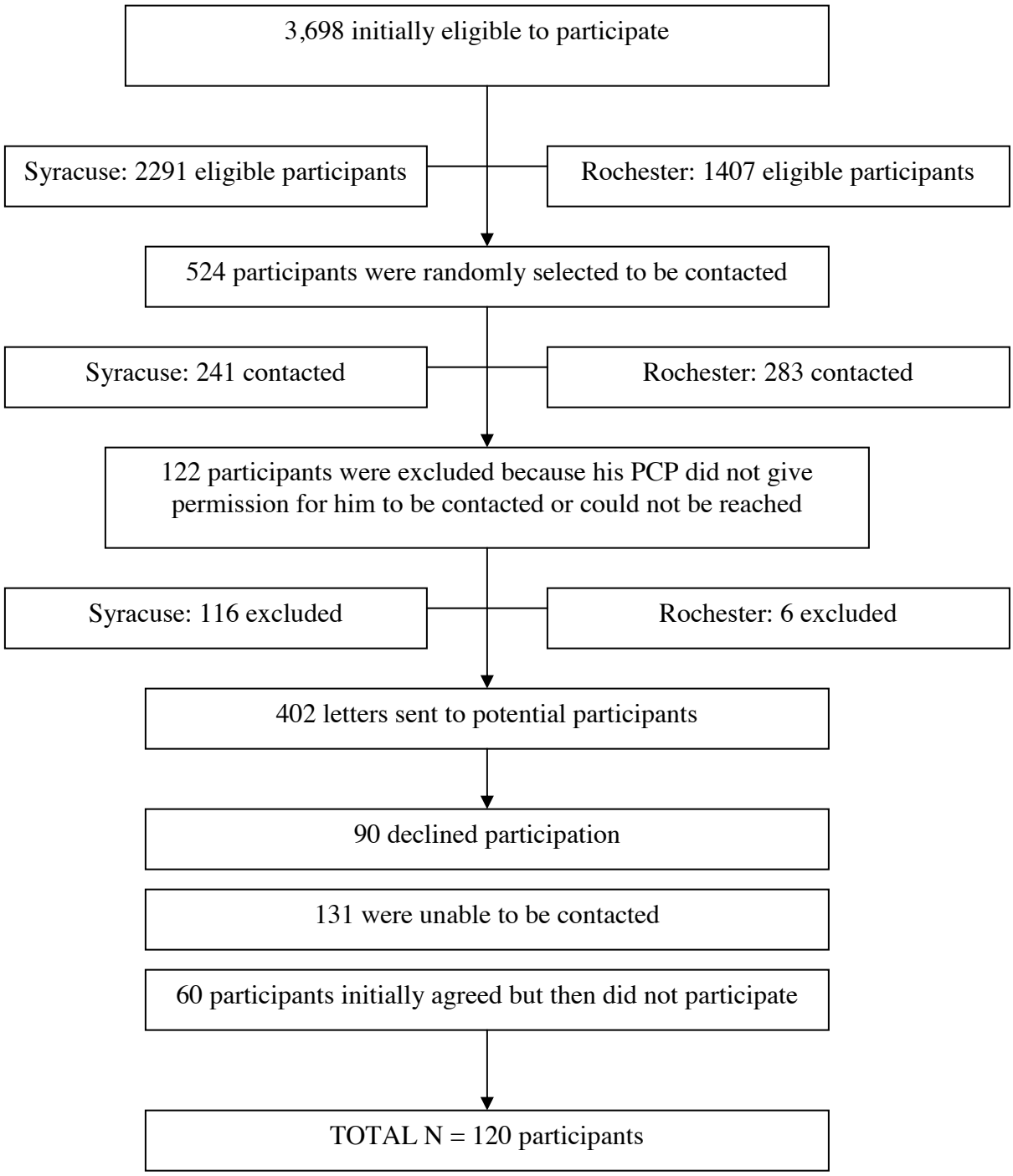
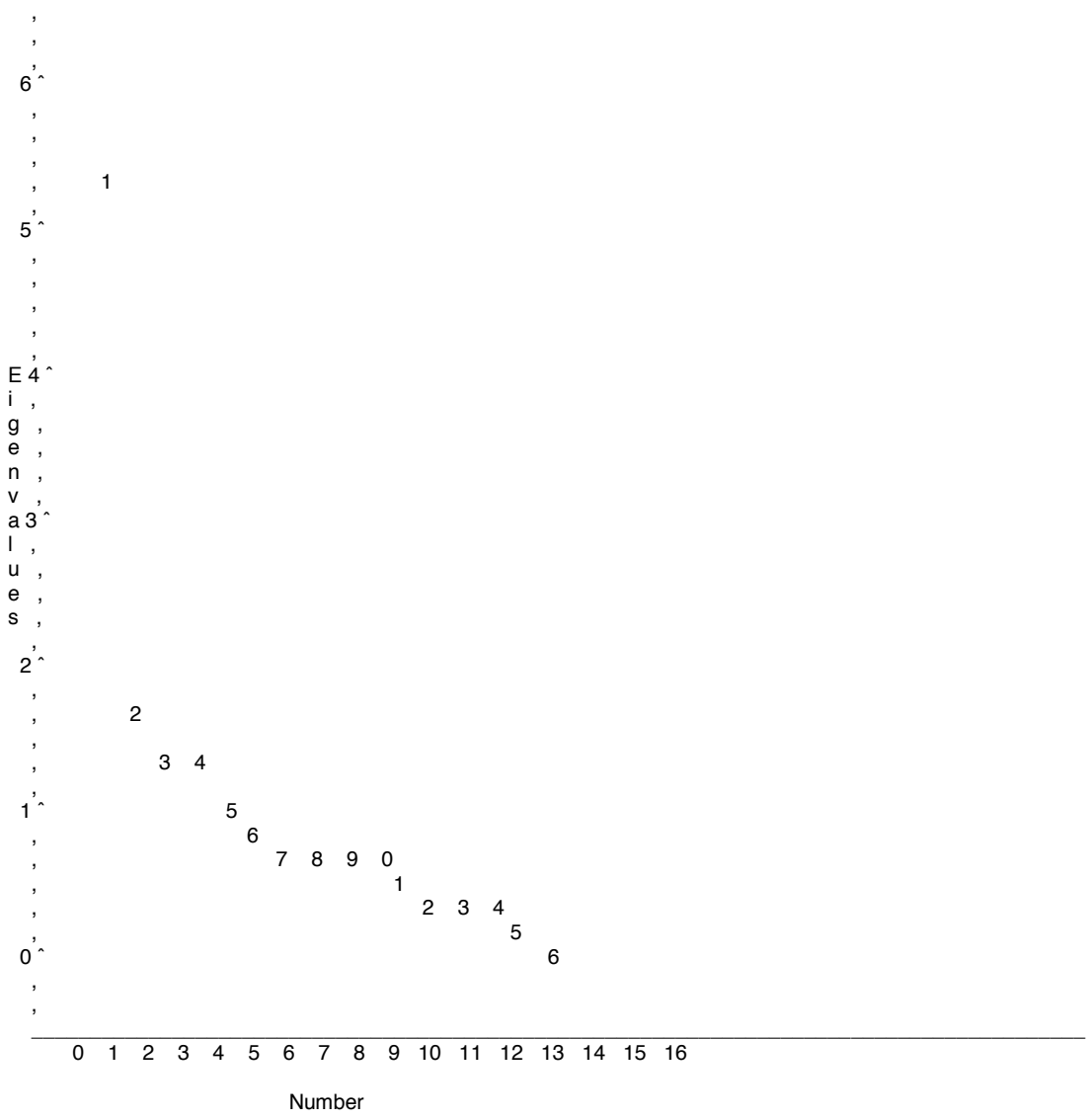


Figure 2.

*Scree Plot of Eigenvalues*



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