The Relationship Between Hypertension and Cognition in Older Adults Living in a Retirement Community: By Maheen Islam

Maheen Islam
Abstract

Hypertension affects over 70 million American adults, with only half of these adults managing to keep it under control. Risk factors for hypertension include an unhealthy diet, lack of physical activity, and advanced age. As individuals age, their risk of hypertension dramatically increases. Hypertension impacts many of the body’s organs, including the brain. Furthermore, it has been suggested that both age and hypertension are linked to declines in cognition. Therefore, deciphering the mechanisms through which hypertension may cause cognitive decline in older adults is of great importance. The objective of this study was to investigate the relationship between hypertension and cognitive impairment in older adults. To examine this, 78 participants were recruited from retirement communities located in Tallahassee, FL. We assessed participants for resting blood pressure and global cognition, which assesses several cognitive domains such as memory, recall, and attention, as measured via the Montreal Cognitive Assessment (MoCA). The sample contained 48 non-hypertensive and 30 hypertensive participants. Results showed a positive relationship between both systolic and diastolic blood pressure and total MoCA score. However, when controlling for age and sex, this relationship only existed between diastolic blood pressure and total MoCA score. This finding contradicts previous findings of an association between hypertension and cognitive decline. No relationship was found between diastolic blood pressure and total MoCA score. Future research must examine whether a limited degree of high blood pressure can be optimal for protecting against cognitive decline.
THE RELATIONSHIP BETWEEN HYPERTENSION AND COGNITION IN OLDER ADULTS LIVING IN A RETIREMENT COMMUNITY

By

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Introduction

To sustain life and maintain healthy tissues in all parts of our body, tissues and organs must receive blood that is rich with oxygen and nutrients. The heart is a muscle that provides the body with oxygen and nutrients by pumping blood to the entirety of the body. On average, an adult has anywhere from four to five liters of blood, which is continuously circulated throughout the body to deliver oxygen and nutrients to the body. Blood also removes carbon dioxide and other wastes from the tissues. The heart is the main organ responsible for blood circulation. It beats continuously about 115,000 times per day to maintain this circulation and to ensure that a rich supply of oxygen is provided to the tissues.

Once oxygen is delivered to the tissues, blood returns to the right atrium of the heart through the superior and inferior vena cava. It then travels to the right ventricle through the tricuspid valve, after which it is sent to the pulmonary arteries through the pulmonary semilunar valve. After going through the pulmonary arteries, it is taken to the lungs, where a new supply of oxygen is received. The blood is then returned to the heart through the pulmonary vein, from which it flows to the left atrium. Next, it goes through the bicuspid, or mitral, valve to the left ventricle. From there, blood goes through the aortic semilunar valve to the aorta. This blood then enters a network of blood vessels that ultimately delivers blood to all the tissues of the body. At first it goes through arteries, then arterioles, then capillaries, where blood and carbon dioxide are exchanged at the tissues. From the capillaries, blood travels the venules, which then converge into the veins, and then it goes back to the heart. This continuous cycle pumps about 2,000 gallons of blood per day (Klabunde, 2005).
The Cardiac Cycle

The cardiac cycle (Figure 1) is one complete beat of the heart, and it includes systole and diastole. The diastole is the period of time when ventricles are relaxed and blood is filling up into the ventricles. Systole refers to the period of time when the ventricles contract and eject blood. The left ventricle ejects blood into the aorta and the right ventricle ejects blood into the pulmonary artery. The cardiac cycle begins with blood filling up the atria. The first phase occurs when the atria contract. Prior to contraction, blood that is returning to the heart moves into the atria and continues through the atrioventricular (AV) valves into the ventricles. The atria contract once they are stimulated by the electrical current of the heart that originates in the SA node. After the atria contract, the remaining blood that is in the atria moves through the atrioventricular (AV) valves and “tops off” the ventricles. Atrial pressure then gradually decreases. The semilunar valves (aortic and pulmonic valves) are closed during this phase. Phase two consists of Isovolumetric Contraction, when the ventricles begin to contract. Once the pressure in the ventricles exceeds that in the atria, the AV valves close. At this point both the AV and semilunar valves are closed, so contraction is therefore isovolumetric, meaning there is no change in volume in the ventricles. Phase three begins with rapid ejection of the blood into the aorta from the left ventricle and the pulmonary arteries from the right ventricle. This occurs when the pressure in the ventricles exceeds the pressure in the aorta and pulmonary artery, causing the semilunar valves to open. The AV valves are still closed at this time. After rapid ejection, the rate of ejection slows in phase four (Reduced Ejection). The right atrial pressure rises from the systemic circulation and the left atrial pressure rises from the persistent venous return from the lungs (Klabunde, 2005). Phase five begins when the semilunar valves close and Isovolumetric Relaxation begins. Pressure decreases in the ventricles, but the volume does not change. The
amount of blood that remains in a ventricle is called the end-systolic volume. The pressure in the left atrium continues to rise at this point. The pressure in the ventricles ultimately falls below the pressure in the atria, causing the AV valves to open quickly, marking Rapid Filling of the ventricles (phase six). Once the ventricles completely relax, their pressure rises slightly as they fill up with blood. In phase seven, Reduced Filling, the ventricles continue to fill up with blood and increase in volume, so they become stiffer and less compliant. This causes the pressure in the ventricles to continue to rise (Klabunde, 2005).

![Cardiac Cycle Phases](http://www.cvphysiology.com/Heart%20Disease/HD002.htm)

**Figure 1.** [Untitled image of The Cardiac Cycle]. Retrieved from [http://www.cvphysiology.com/Heart%20Disease/HD002.htm](http://www.cvphysiology.com/Heart%20Disease/HD002.htm)

**Blood Pressure**

Blood pressure is the pressure that the blood exerts against the sides of the blood vessels measured in millimeters of mercury (mmHg) (Klabunde, 2005). In order to ensure adequate flow of blood to the tissues, blood pressure must be maintained and regulated. Blood pressure is the
product of cardiac output and vascular resistance (Heymans, 1950). Cardiac output is the amount of blood pumped by the heart per minute in milliliters. It is the function of heart rate and stroke volume (Klabunde, 2005). Stroke volume is the amount of blood pumped out of the heart with each beat in millimeters. The equation is as follows:

\[
\text{Cardiac output} = \left( \frac{\text{beats}}{\text{minute}} \right) \times \left( \frac{\text{mL blood}}{\text{beat}} \right) = \left( \frac{\text{mL blood}}{\text{minute}} \right)
\]

Vascular resistance is the total resistance of blood flow that must be overcome to push blood through the circulatory system. It can vary based on how dilated or constricted a blood vessel is. Blood pressure levels are determined by vascular resistance (Klabunde, 2005). The higher the vascular resistance, the higher the blood pressure. Blood flow also determines blood pressure levels. Blood flow is the difference in pressure of the blood leaving the heart from the blood returning to the heart per resistance. It is dependent on cardiac output and the volume of blood that is circulating in the body (Tarjus, Amador, Michea, & Jaisser, 2015). Thus, a higher blood pressure results from a higher cardiac output and a higher vascular resistance.

**Blood Pressure Regulation**

Blood pressure is regulated through the parasympathetic and sympathetic nervous systems. There are two types of regulation for blood pressure: short term and long term. In short term regulation, baroreceptors in the arteries detect changes in blood pressure. If blood pressure increases in the aorta or the carotid sinus, the walls of the arteries stretch. This stimulates baroreceptors. The stretching of the artery contributes to a higher depolarization of the baroreceptors, and therefore a higher rate of action potentials, which allows for baroreceptors to relay this information to the central nervous system, including the brain. The central nervous system responds by activating the parasympathetic nervous system, which decreases the heart rate and stroke volume, and decreases the cardiac output. Vascular resistance decreases due to
vasodilation of the veins and arterioles via decreases in sympathetic activity. The dilation due to decreased sympathetic activity ensures that blood pressure is reduced as blood flows through a wider vessel. If blood pressure is low, the opposite occurs. Baroreceptor firing decreases as the sympathetic nervous system becomes activated, thus cardiac output and vasoconstriction increase. Epinephrine acts on alpha receptors that are on the blood vessel to cause vasoconstriction. Due to the vessels constricting, the pressure of the blood increases.

Acute local blood regulation occurs when the spontaneous movement of blood vessels is controlled by metabolites of nearby cells. For instance, during running, the metabolic needs of the leg skeletal muscles increase significantly (Mancia, 2012). The efferent limbs, the legs, produce more sympathetic flow to the heart and blood vessels. This process increases heart rate and stroke volume, which produces an increase in cardiac output. Arterial vasodilation occurs at the exercising muscles so that the increase in cardiac output ensures that oxygen and nutrients are delivered to the correct exercising muscles, in this case the legs, overriding any sympathetic vasoconstriction effects (Klabunde, 2005). The constriction that normally occurs due to the sympathetic activity during exercise is inhibited in arterioles that must receive oxygen. This process is known as functional sympatholysis (Hansen, Thomas, Harris, Parsons, & Victor, 1996).

Long term regulation involves the regulation of blood volume by decreasing normal salt and water balance. When blood volume, and therefore blood pressure, is low, juxtaglomerular cells in the kidneys produce renin, which stimulates production of angiotensin I. Angiotensin I then gets cleaved by Angiotensin Converting Enzyme (ACE) and is converted to angiotensin II. This causes multiple processes to occur: aldosterone is secreted by the adrenal cortex, which is located above the kidneys, and it causes the kidneys to resorb Na+ and Cl- ions while excreting
K+ ions; antidiuretic hormone (ADH) is secreted by the posterior pituitary gland, which allows for the collecting duct to increase water absorption. Finally, sympathetic activity increases, causing vasoconstriction of arteries to occur and blood pressure to rise. The tubules of the kidneys thus increase their resorption of sodium and water back into the blood. These actions increase blood volume, and ultimately blood pressure (Mancia, 2012).

Blood pressure can vary in an individual, especially with increasing age and it is essential to measure this change. Compliance is the inclination of the arteries and veins to stretch in response to blood pressure change. Compliance decreases at a higher pressure and a higher volume as the blood vessels become stiff (Klabunde, 2005). A decrease in arterial compliance, which occurs increasingly with age, can cause high blood pressure, or hypertension. Compliance is reduced by half between the ages of 25 and 75 years because as individuals age, the arterial walls’ components, elastin and collagen, become frayed and unraveled, respectively (Gates & Seals, 2006). The lower the ratio of elastin to collagen, the stiffer an artery will be, resulting in an increase in arterial stiffness (Arnett, Evans, & Riley, 1994).

**Blood Pressure and Hypertension**

Numerically, the categories of blood pressure are defined as (American Heart Association, 2015-a):

- **Normal**: systolic pressure < 120 mmHg; diastolic pressure < 80 mmHg
- **Prehypertension**: systolic pressure = 120-139 mmHg; diastolic pressure = 80-89 mmHg
- **Hypertension Stage 1**: systolic pressure = 140-159 mmHg; diastolic pressure = 90-99 mmHg
- **Hypertension Stage 2**: systolic pressure ≥ 160 mmHg; diastolic pressure ≥ 100 mmHg
- **Hypertensive Crisis**: systolic pressure ≥ 180 mmHg; diastolic pressure ≥ 110 mmHg
Hypertension can lead to many negative outcomes. It can cause damage to the arteries, heart, brain, and kidneys, to name a few. Hypertension may lead to many diseases such as cardiovascular disease, heart attack, stroke, and even death.

Prehypertension affects 59 million Americans. Hypertension affects over 70 million American adults, with only half of these adults keeping it under control (Centers for Disease Control and Prevention [CDC], 2015).

As individuals age, their risk of hypertension dramatically increases. About 64% of men and 69% of women who are 65 and older are hypertensive as opposed to the 25% of men and 19% of women who are hypertensive in their late 30s and early 40s (CDC, 2015). About 70% of those with hypertension are treating it using medication (CDC, 2015). In 2011, the total cost related to hypertension in America was around $46 billion, which included healthcare services and medication (CDC, 2015).

**Hypertension Risk Factors**

There are several risk factors for hypertension. Behavioral risk factors for hypertension include an unhealthy diet, and/or physical inactivity. An unhealthy diet high in trans-fats and saturated fats leads to an increase in triglycerides and cholesterol in the blood (American Heart Association, 2015-b). These substances build up as plaque in arterial walls and arteries harden to compensate, which leads to atherosclerosis.

Atherosclerosis is the narrowing of the arteries due to a buildup of plaque. Hypertension is one of the causes of atherosclerosis. High blood pressure puts a lot of added force against the artery walls and makes them stiff. Gradually, this pressure can damage and injure the endothelium of the arteries. The injury renders the endothelial cells in the arteries to release chemotactic agents and growth factors. Growth factors are substances necessary for the
stimulation of growth in cells. Chemotactic agents induce substances to move in response to a chemical stimulus. The endothelial cells also transport and alter lipids that are picked up from the blood, including low-density lipoproteins (LDL) that provide tissue cells with cholesterol. When the LDL cholesterol builds up in the blood stream, they oxidize because the environment is inflammatory, which damages the neighboring cells. LDL cholesterol acts as a chemotactic agent to solicit macrophages. As inflammation increases, macrophages aggregate in the endothelium and conjoin with LDL’s to form foam cells. An accumulation of foam cells is called a fatty streak. Smooth muscle cells from the tunica media, the middle layer of the artery, deposit elastic and collagen fibers, which thicken the layers of the artery. This results in the formation of plaques and they eventually block the lumen of the artery, causing atherosclerosis (Ross, 1999).

Arteries have two main functions, to act as a tube that connects the heart to the arterioles and to act as a cushion to allow for a steady blood flow (Safar, 2003). When arteries thicken through the formation of lesions and plaques in the walls, they have a higher resistance and stiffness (DPhil and Sear, 2004). Not only do arteries become thick, but so does the left ventricle. The left ventricle is the major pumping chamber in the heart. When blood pressure in the aorta is high, the left ventricle must squeeze that much harder to pump blood and open the aortic semilunar valve and ultimately through the aorta. As it works harder, it increases in muscle mass (hypertrophy) by abnormally increasing the accumulation of collagen by fibroblasts (Gosse, 2005). This may lead to the ventricle becoming stiffer and diastolic dysfunction. Diastole is the phase in which the heart is relaxed and is filling with blood that is returning from the body. When the left ventricle cannot be filled properly due to its thickness, it results in dysfunction of the diastole phase. Ultimately this is known as left ventricular hypertrophy (LVH) (Gosse, 2005). This leads to a decrease in the elasticity of the myocardium in the left ventricle.
Atherosclerosis and LVH combined are strong indicators of developing coronary artery disease (Gamble et al., 1998). Studies have shown that blood pressure is independently related to risks of coronary heart disease and that hypertensive patients who have been treated experience a higher risk of coronary heart disease than normotensives (Gamble et al., 1998). Over time, arteries are damaged and weakened.

**Cognition and Cognitive Tests**

Hypertension impacts many of the body’s organs, including the brain (Waldstein, 2003). It has been demonstrated that hypertensives show a decrease in blood flow and metabolism in particular brain regions. This decrease in blood flow is especially seen in hypertensives during cognitive memory tasks (Waldstein, 2003).

Cognition is defined as the mental processes that include obtaining, storing, changing, and using of knowledge while understanding based on one’s senses, thoughts and experiences (Matlin, 2009). Certain aspects of age-related cognitive decline can occur even in early adulthood. The magnitude of this decline accelerates from ages 60 and above (Salthouse, 2009).

Several tests are used to assess cognitive function. These tests measure various domains of cognition. The Mini Mental State Examination (MMSE) measures cognitive impairment, and is often used as a screening tool for mild cognitive impairment (MCI) and dementia (Pangman, Sloan, & Guse, 2000). The MMSE surveys several cognitive domains, such as registration, attention, memory, and orientation (Tuijl, Scholte, de Craen, & van der Mast, 2012). The tests for memory are the Auditory Verbal Learning Test (AVLT), Digit Span (Wechsler Memory Scale – Revised) (WMS-R), Digit Span Backward (DSB), and Rey-Osterrieth Complex Figure Test—recall (RCFT). In AVLT, individuals are given a list of words that are unrelated and are asked to repeat it. Afterwards, another list of words is provided, and individuals must repeat the
original list of words. Digit Span tests stimulate one’s verbal working memory by assessing the storage capacity of digits when participants are given an increasingly longer list of digits after each successful recall. RCFT assesses memory, attention, planning, etc. in that individuals are asked to copy a figure (by drawing it), and then draw it again from memory (Knecht et al., 2008; Knecht, Wersching, Lohmann, Berger, & Ringelstein, 2009).

The tests for attention and executive functions are the Stroop Test, Digit Symbol Substitution Test (DSST), Trail-Making-Test (TMT), Verbal Fluency Test (Category and Letter Fluency) (VF) test. The tests for intellectual functions are the Boston Naming Test (BNT) and RCFT. WASI Vocabulary test assesses verbal ability (Gifford et al., 2013). In the Stroop test, the name of a color is printed or written in a different color than the name. This test assesses interference of reading a word while identifying the color in which the word is printed. The DSST is a test that consists of pairs of symbols and digits given as a legend and below each digit, individuals must write the corresponding symbol as fast as they can. It specifically assesses processing speed. TMT asks for individuals to draw a trail that connects number to number (A) and a trail that connects number to letter (B). It assesses set shifting (executive functioning). Set shifting is the procedure that involves moving one’s attention between mental representations or processes. The VF test measures consist of category fluency and letter fluency and it assesses verbal ability. The BNT consists of word retrieval in that it contains drawings that are ranked in difficulty (del Toro et al., 2010). The WASI exam assesses comprehension of verbal skills and reasoning abilities (Gifford, 2013).

Effects of Hypertension on Cognition

A significant factor that may be affected by hypertension is cognition. There are many suggested mechanisms for diminished cognitive function due to hypertension. For instance,
Hypertensives may have limited cerebral blood flow and metabolism, specifically in the frontal lobes, temporal lobes, and subcortical regions. These effects appear to be worse in hypertensive individuals who are un-medicated (Waldstein, 2003). Furthermore, it has been found that hypertensive individuals show less cerebral blood flow than those with normal blood pressure during cognitive tasks related to memory (Waldstein, 2003). Hypertension can also lead to damage of the endothelium of the arteries leading to the brain. This injury can disrupt the blood-brain barrier. Brains of individuals with hypertension have shown atrophy as well (Waldstein, 2003).

Studies have primarily shown a negative correlation between hypertension and cognition (Brady, Spiro, and Gaziano, 2005; Gifford et al., 2013; Knecht et al., 2008; Vasilopoulos et al., 2011). Brady, Spiro, and Gaziano (2005) assessed 357 non-demented participants on category fluency, Digit Span Backward, and word list immediate and delayed recall. They found that older uncontrolled hypertensive participants, those who had a systolic blood pressure of 140 mmHg or higher, did worse on the category fluency and word list immediate recall tests than their normotensive counterparts. This pattern suggests that older uncontrolled hypertensives may display greater age differences on tests that require more rigorous retrieval processes. Thus, uncontrolled hypertension worsens age effects on retrieval processes (Brady, Spiro, and Gaziano, 2005).

Additionally, Gifford et al. (2013) conducted a meta-analysis of over 4,000 hypertensive participants that were assessed in global cognition, episodic memory, language, attention, executive functioning, information processing speed, and visuospatial skills. The analysis revealed a strong negative correlation between blood pressure and episodic memory ($r = .20$) along with blood pressure and global cognition in older adults ($r = .11$), as determined by the
Mini-Mental State Examination and several other cognitive exams. Attention was the only cognitive domain to show a positive correlation with blood pressure, as measured by the digit span forward. This is unexpected and it was suggested that it may be related to changes in the autonomic nervous system, such as heart rate, that enhance cognitive function. Another possibility may be that higher blood pressure may impact cerebral perfusion that has a positive influence on attention (Gifford et al., 2013).

The extent of the negative effects caused by hypertension is presented in a study by Knecht et al. (2008), in which non-demented and non-depressed participants from 40 to 85 years of age were assessed on cognitive domains such as learning and memory, attention and executive function, and intellectual functions. Results showed that there was an inverse relationship between systolic blood pressure and cognition. However, when participants were categorized by age, this association appeared to exist only in middle-aged adults and not adults older than 60 years of age (Knecht et al., 2008). This may be due to an increased systolic blood pressure required in the brain to maintain cerebral pressure for hypertensive individuals due to a greater atherosclerotic blood flow resistance.

Furthermore, in the study by Vasilopoulos et al. (2011), 1,237 male participants aged 51-60 were divided among three categories: non-hypertensive, medicated hypertensive, and unmedicated hypertensive. Participant cognition was measured through neuropsychological tests such as the Category Fluency test, and the Digit Span Backward test, etc. No differences were found among individuals across all of the categories, perhaps because the participants’ age range classified as middle aged. However, it was found that variance in a trait that is attributed to genetic factors (e.g. heritability of cognition) was lower among middle aged males (51-60 years of age) who had hypertension and were un-medicated, meaning that genetic factors had less of an
impact on cognitive function on this group of participants. These results suggest that high blood pressure can change genetic influences of cognitive domains prior to any changes observed in performance on cognitive tests; thus, lower cognitive performance may precede high blood pressure in individuals who are at risk for high blood pressure (Waldstein, 2003).

Hypertension is particularly problematic among older adults, as seen by the higher percentage of hypertensive individuals 65 or older than those who are in their 30s and 40s (CDC, 2015). The investigation of protective factors against the negative effects of hypertension must consider age as an important variable. What is protective among younger persons may not necessarily have the same effect, or the same magnitude of effect, among older adults.

With an increasing number of individuals with hypertension, treatment and prevention is of utmost importance. Research has looked primarily upon individuals who do not have any medical comorbidity to determine how hypertension affects cognition. While there may be a link between hypertension and cognition, more research is needed to understand the relationship between cognition and hypertension in older adults. An influential factor in doing this study is that there is a discrepancy between attention and other cognitive domains among hypertensives, according to Gifford et al. (2013). Furthermore, associations between hypertension and cognitive domains is weaker, or sometimes even reversed in older adults. Therefore, the purpose of this present study is to investigate the relationship between blood pressure and cognitive function in older adults. We hypothesize that older adults with higher blood pressure will have lower cognitive scores as assessed by the Montreal Cognitive Assessment.
Methods

Participants were recruited from Westminster Oaks and Westminster Gardens retirement communities located in Tallahassee, FL using flyers, announcements at town hall meetings, events, and fitness classes at Westminster Oaks.

This study was a cross sectional study. A sample of 78 participants (females = 60; males = 18) completed and signed an informed consent prior to the start of any testing. Physical measures, including height, weight, heart rate, and blood pressure were assessed by a nurse at the health center at Westminster Oaks. Participants had their height and weight measured while they were standing. Heart rate and blood pressure were assessed while participants were seated. These measurements were taken at various times of the day (anytime from 9 am to 4 pm) throughout the weekday, depending on the availability of the participants and nurses. Next, cognitive tests were conducted. Participants began with the Montreal Cognitive Assessment (MoCA). The MoCA assesses global cognitive functioning of an individual in comparison to demographically matched normative data. The domains it assesses are attention and concentration, executive functions, memory, language, visuoconstructive skills, conceptual thinking and orientation. A higher score indicates higher cognitive functioning. A score of 26/30 or above is considered normal, while a score below this value is considered a preliminary sign of cognitive impairment.

The MoCA consists of 11 parts. The first is alternating trail making, in which participants draw a line going from a number to a letter, following this sequence to create a trail. The second and third parts both test visuoconstructive skills. The second part asks participants to copy a drawing of a cube. The third part asks participants to draw an analog clock with a certain time on it. The fourth part consists of a naming task in which participants identify an animal shown in a picture. The animals pictured were a lion, a rhinoceros, and a camel (or dromedary). The fifth part was a memory task. We read participants a list of five words and asked them to recall as
many words as possible. This recall task was repeated one more time. The next part measures attention, concentration, and working memory. This consists of four subparts: the Forward Digit Span (participants verbally repeat a five numbered sequence after they hear it), the Backward Digit Span (participants verbally repeat a three numbered sequence backwards), Vigilance (participants were read a sequence of letters and every time they were read the letter A, they were asked to tap their hand once), and the Serial 7s (participants must count by subtracting seven from 100 until told to stop – 65 is the cut-off). The seventh part is sentence repetition, in which participants repeat two different sentences. Part eight measures verbal fluency. In this part, participants say aloud as many words as they can think of in one minute that begin with the letter F. Abstraction (part nine) involves asking participants how an orange and a banana are alike as a practice trial. In the next trial, they must answer how a train and a bicycle are alike and in the final trial, they must answer how a ruler and a watch are alike. The tenth part is called delayed recall. Participants are asked to recall the same set of words from the fifth task, with cues presented if they are not able to recall properly. The final part is Orientation and participants must say the date, month, year, day, place, and city in which they are taking the MoCA.

**Statistical Analysis**

Multiple analysis models were used to analyze the data. Pearson product moment correlations were used to analyze the relationship between age and both blood pressure and MoCA scores. Partial correlations, controlling for age and sex, were used to determine the association between blood pressure and total MoCA score. Independent t-tests were used to compare MoCA scores and blood pressure between males and females as well as the difference in MoCA scores between hypertensive and non-hypertensive participants. Non-hypertensive participants were categorized as having a systolic blood pressure below 140 mmHg and a
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diastolic blood pressure below 90 mmHg. Hypertensive participants were categorized as having a systolic blood pressure 140 mmHg or above and a diastolic blood pressure 90 mmHg or above. The program used for statistical analysis was SPSS. Significance was set at p < 0.05.

**Results**

Table 1 presents the descriptive statistics of physical measures including age, weight, blood pressure, and pulse. Total sample size was 78, with 60 females and 18 males. The mean age was 80.3 ± 6.9 years, with no difference in age between males and females (Table 3). Mean systolic blood pressure was 135.0 ± 16.9 mmHg and the mean diastolic blood pressure was 69.4 ± 8.7 mmHg. Females had a higher systolic blood pressure than men (females = 137.8 ± 16.9 mmHg; males 125.5 ± 13.0 mmHg) (Table 3). There were 48 non-hypertensive and 30 hypertensive participants. There was a positive correlation between systolic blood pressure and diastolic blood pressure (r = .447). There was no relationship between age and systolic or diastolic blood pressure.

Mean MoCA score was 26.2 ± 2.6 (Table 1), which is slightly above the cut-off score of 26 for normal cognitive function. Female participants performed better on the MoCA than males. Mean score for females (mean = 26.7 ± 2.6) was above the cut off score while males (mean = 24.7 ± 2.5) scored slightly below the cut off score (Table 3). As age increased, total MoCA score decreased (r = -.242).

There was a positive relationship between systolic blood pressure and total MoCA score (r = .225) as well as diastolic blood pressure and total MoCA score (r = 0.289) (Table 2). When controlling for age and gender, diastolic blood pressure remained positively correlated with total MoCA score (r = 0.239) while there was no longer a positive correlation between systolic blood...
pressure and total MoCA score. There was no difference in MoCA score among those participants who were hypertensive compared to those who were not.

**Table 1**
Baseline Physical Measures of Participants

<table>
<thead>
<tr>
<th>Variable</th>
<th>Physical Measures (n= 78)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>Min-Max</td>
</tr>
<tr>
<td>Age (years)</td>
<td>80.3 ± 6.9</td>
<td>67 – 95</td>
</tr>
<tr>
<td>Weight (lbs)</td>
<td>161.5 ± 32.9</td>
<td>105 – 246</td>
</tr>
<tr>
<td>Systolic (mmHg)</td>
<td>135.0± 16.9</td>
<td>100 – 178</td>
</tr>
<tr>
<td>Diastolic (mmHg)</td>
<td>69.4 ± 8.7</td>
<td>50 – 98</td>
</tr>
<tr>
<td>Pulse (BPM)</td>
<td>71 ± 10</td>
<td>48 – 92</td>
</tr>
<tr>
<td>Total MoCA Score</td>
<td>26.2 ± 2.6</td>
<td>21 – 30</td>
</tr>
</tbody>
</table>

Values are means ± standard deviations. BPM: beats per minute. MoCA: Montreal cognitive assessment.

**Table 2**
Correlations Between Blood Pressure and Total MoCA Score

<table>
<thead>
<tr>
<th>Blood Pressure</th>
<th>Total MoCA Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic BP</td>
<td>.225*</td>
</tr>
<tr>
<td>Diastolic BP</td>
<td>.289*</td>
</tr>
<tr>
<td>Systolic BP¹</td>
<td>.185</td>
</tr>
<tr>
<td>Diastolic BP¹</td>
<td>.239*</td>
</tr>
</tbody>
</table>

*p ≤ .05. BP: Blood Pressure
¹after adjusting for age and gender

**Table 3**
Blood pressure, Total MoCA Score, and Age differences among males and females

<table>
<thead>
<tr>
<th>Variable</th>
<th>Males Mean ± SD</th>
<th>Females Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic (mmHg)</td>
<td>125.5 ± 13.0</td>
<td>137.6 ± 16.9*</td>
</tr>
<tr>
<td>Diastolic (mmHg)</td>
<td>66.7 ± 6.8</td>
<td>70.2 ± 9.1</td>
</tr>
<tr>
<td>Total MoCA Score</td>
<td>24.7 ± 2.5</td>
<td>26.7 ± 2.4*</td>
</tr>
<tr>
<td>Age (years)</td>
<td>81.6 ± 8.2</td>
<td>79.9 ± 6.5</td>
</tr>
</tbody>
</table>

*p<0.05, significantly different between groups
Discussion:
The purpose of this study was to investigate whether there was an association between hypertension and cognition. We predicted a negative relationship between systolic blood pressure and total MoCA score based on past studies associating higher blood pressure with a lower cognitive score in older adults (Brady, Spiro, & Gaziano, 2005; Elias, Elias, Robbins, & Budge, 2004; Gifford et al., 2013).

Our results showed that there was a positive relationship between systolic blood pressure and total MoCA score as well as diastolic blood pressure and total MoCA score. Thus, older adults who had a higher systolic and diastolic blood pressure had higher cognitive scores as assessed by MoCA. While this association between systolic blood pressure and cognition disappeared when controlling for age and gender, there was still a positive relationship between diastolic blood pressure and total MoCA score. This finding did not support our hypothesis that higher blood pressures would lead to lower cognitive scores.

Medications play a part in determining how hypertension affects cognition. While medications have allowed for better control of hypertension, its management is nonetheless still difficult. Dilation and hardening of arteries occurs with advancing age, resulting in an increase in blood pressure that becomes more difficult to manage (McEniery, Wilkinson, & Avolio, 2007). Over half of men and women in America who are 55 years or older have hypertension (CDC, 2015). Most of the participants that were tested in this study had relatively healthy blood pressure readings. Only 38% of the participants were considered hypertensive. In the United States, 70% of those who have hypertension use medications to regulate blood pressure (CDC, 2015). In addition, there was no association between age and systolic and diastolic blood pressure. This may be due to the fact that participants were taking medications to keep their blood pressure under control. Participants were all residents of a continuing care community.
This community provides them with high quality care and on-site clinical staff and facilities, which would allow them the opportunity to better manage their blood pressure.

In our findings, females had a higher systolic blood pressure than males. Studies have shown that in the general population, men have higher blood pressure than females of the same age (Jung, Dawn, Teresa, Karlamangla, & Crimmins, 2006; Reckelhoff, 2011; Wiinber et al., 1995). However, after the onset of menopause in women, the prevalence of hypertension is higher in women than in men (Lopez-Ruiz, Sartori-Valinotti, Yanes, Iliescu, and Recklehoff, 2008). It has been suggested that a higher blood pressure in men than women during puberty is likely driven by an increase in androgens during puberty. Androgens are male sex hormones, such as testosterone. Androgen levels increase more in men than in women in this period of life. It is believed that androgens could upregulate a cytochrome. A cytochrome is a compound that is made up of heme bonded to a protein. Their main function is to transfer electrons in metabolic pathways such as cellular respiration. This increase in cytochrome would increase 20-hydroxy-5,8,11,14-eicosatetraenoic acid (20-HETE) levels and ultimately cause high blood pressure (Reckelhoff and Roman, 2011). 20-HETE has been known for its pro-hypertensive properties.

After menopause in women, hypertension is higher in women than in men. Mass and Franke (2009) demonstrate that there is a decline in estrogen levels during menopause. This decline stimulates production of factors that cause vasoconstriction. These factors are an increase in androgen levels, higher salt sensitivity, which activates the renin-angiotensin system to increase in renal sodium resorption and causes an increase in sympathetic activity. This increase in sympathetic activity leads to an increase in insulin resistance. The finding in the current study agreed with this information, as female participants, who were post-menopausal, had a higher blood pressure than males.
In addition, we found that females scored higher on the MoCA than their male counterparts. This is consistent with other findings in literature. Studies have shown that females tend to have higher visuomotor speed, object location memory, fine motor skills speed, and verbal, and language abilities than males (Heaton, Ryan, Grant, & Matthews, 1996; Kimura, 1999; Rosser, Ensing, Glider & Lane, 1984; Eals & Silverman, 1994; McBurney, Gaulin, Bevineni, & Adams, 1997; Hall & Kimura, 1995; Nicholson & Kimura, 1996). This may be due to declining estrogen levels in females as they approach menopause, according to Parsons, Rizzo, Zaag, McGee, and Buckwalter (2005). Not only is estrogen involved in hypertension differences between males and females, but it is also involved in cognitive differences between males and females as well. Estrogen regulates neural activity during performance of cognitive tasks (Shaywitz et al., 1999). Thus, during menopause, hormonal changes in women are linked to complaints in memory (Henderson, 2008). In our study, there was a negative relationship between age and total MoCA score. Although there was a negative correlation between age and total MoCA score, there was no difference in age between males and females.

Among all participants, a positive correlation was found between both systolic and diastolic blood pressure and total MoCA score. These findings contradict previous findings of an association between hypertension and cognitive decline among older adults (Brady, Gaziano, and Spiro, 2005; Elias et al., 2004; Gifford et al., 2013; Vasilopoulos et al., 2012). Although our findings contradict those found in some studies, Knecht et al. (2008) and Gifford et al. (2013) identified potential causes for these findings.

Knecht et al. (2008) conducted a cross sectional experiment examining over 300 older adults ranging from 44 to 82 years. Participants were examined with a comprehensive neuropsychological test that tested for working memory, verbal skills, etc. Although results
demonstrated a negative correlation between systolic blood pressure and cognition, when age groups were separated into midlife (<60 years) and late-life, the correlation only existed in the mid-life age group. They suggested that in late life, there is a higher atherosclerotic resistance to blood flow, which may necessitate higher systolic blood pressure to regulate cranial blood pressure, whereas normal systolic blood pressure would render inadequate blood supply to the brain. Perhaps it was the higher systolic blood pressure that impacted participants’ MoCA score and improved cognitive function.

In addition, a meta-analysis conducted by Gifford et al. (2013) showed a positive correlation between blood pressure and attention. This result could possibly be related to changes in the functioning of the autonomic nervous system such as heart rate that enhance cognitive function. Another possibility could be that higher blood pressure may impact cerebral perfusion that has a positive effect on attention.

Although this study provided insight into the relationship between hypertension and cognition in older adults, there were some limitations. For one, blood pressure was not taken at the same time of the day for each participant. It was taken any time between 9 am to 4 pm throughout the weekday, depending on the availability of the participants and nurses. Blood pressure has been shown to fluctuate throughout the day (Bevan et al., 1969; Littler et al., 1978, 1979; Mancia et al., 1983). Mancia et al. (1983) found that blood pressures dropped around midnight and increased to normal levels during the early hours in the morning, along with a slight drop in the afternoon. Another limitation was that, in our analyses, hypertension medications were not controlled for when running analysis on participants’ blood pressure. Perhaps hypertension medications may have played a part in our results by interfering with cognitive function, which ultimately could have affected MoCA scores.
In addition, the sample size in our study was relatively small (n = 78). A small sample size hinders generalizability, also known as low external validity. Moreover, over half of the sample consisted of females (females = 60; males = 18). Moreover, most of the participants’ education levels were postsecondary or higher. The sample we had was not representative of the population in terms of education level. Maurer (2011) suggested differences in levels of education among males and females are a significant factor in differences in cognitive functioning as aging occurs.

Finally, participants resided at an independent living in a retirement community that the participants resided at. Individuals working at these communities provide care to the residents, and keep them engaged in activities, as was the case with Westminster. This care may delay cognitive decline, possibly explaining why the average MoCA score was relatively high.

In conclusion, we found a positive relationship between both systolic and diastolic blood pressures and total MoCA score. Thus, older adults who had a higher systolic blood pressure and diastolic blood pressure tended to have better global cognitive functioning. While the relationship between systolic blood pressure and cognitive scores did not remain after controlling for age and gender, there was still a positive association between diastolic blood pressure and cognitive scores. Therefore, future research is needed to determine if a blood pressure that is higher than normal may have cognitive benefits in older adults and if these benefits outweigh the other risks associated with elevated blood pressure. Perhaps there is an optimal blood pressure that reaps benefits of both a higher cognition and a healthier body. Furthermore, future research should also control for hypertensive medications. In addition, cognition has multiple domains. Perhaps each of the domains of cognition can be tested separately so that their correlation with hypertension can be examined. Although this study may not be representative of the entire
population, it provides us with preliminary evidence about potential benefits of elevated blood pressure on cognition.
Literature Cited:


