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The Relationship between Muscular Strength and Cognition in Older Adults

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### Abstract

Little is known about the correlation between resistance training, muscular strength, and cognition. This study aimed to evaluate the relationship between muscular strength and cognition in older adults. Data were collected for this cross sectional study at Butterfield Trail Village, a retirement community in Northwest Arkansas. Thirty participants, at least 65 years of age, without severe mental impairment were evaluated. Of the 30 participants, 23 females were included in the data analysis. The Stroop Color Test, Trail Making Test, and Dual Task Walking Test difference were used to measure executive cognition. Handgrip dynamometry was used as a valid, reliable measure of strength (Alencar, Dias, Figueiredo, & Dias, 2012). Three correlation analyses were performed to determine the effect of the independent variable, muscular strength, on the dependent variables, domains of executive cognition (represented in Stroop Color Word, Trail Making, and Dual Task evaluations). Statistical significance was set at 0.05 for each analysis. No significant correlation was found between handgrip strength and Trail Making Tests ( $r = -.21$ ) or Stroop Color Word ( $r = .01$ ); the results were not statistically significant ( $p = .34$  and  $p = .966$ ). Moderate correlation was found between handgrip strength and dual task difference ( $r = -.41$ ), with a trend for significance ( $p = .052$ ). Dependence on muscular coordination may account for the correlation between handgrip and dual task walking, a physical proxy-measure of cognition. Overall, there is moderate correlation between muscular strength and dual task walking in older community-dwelling women, but no correlation was found between muscular strength and other measures of cognition.

*Keywords:* Strength, cognition, older adults

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### **Introduction**

As nutritional knowledge grows and medicinal abilities expand, so too does the life expectancy of Americans. At the same time, though many people are living longer, they are not necessarily living a full, functional life. Naturally, with an increase in age comes a decrease in physical fitness, a decrease in muscle mass, and an increase in cognitive problems. The “baby boomers” are on the rise and the necessity of physical therapy has become prevalent. Several studies support the idea that aerobic and resistance training improve cognitive function in older adults, defined as persons 65 years of age or older. Resistance training improves physical fitness and quality of life (Cassilhas et al., 2007). While knowledge of the positive correlation between aerobic training and brain function grows, little is known about the correlation between resistance training, muscular strength, and cognition.

It is thought that cognition problems lead to a lack of functionality in older adults however it is also plausible that a lack of functionality exacerbates cognition problems. While this chicken-egg conundrum deserves clinical attention, most can agree that in many cases aging begins the cognitive decay. Age most strongly effects the following neuropsychological processes: processing speed, attention, episodic memory, language abilities, attention, and executive function (MacAulay, Brouillette, Foil, Bruce-Keller, & Keller, 2014). Executive function, responsible for goal-oriented actions, adaptations, and inhibitions, greatly influences the ability of one to interact socially and remain functional. While gray matter losses in the frontal lobe, where executive function stems from, are associated with aging, cognitive improvement is associated with exercise participation (Adolfsdottir et al., 2014).

Non invasive tests including the Stroop Color Word Test, Trail Making Test, and Timed Dual Tasking Walk Test are all reliable and valid measures of executive function. More specifically, Stroop Color Word assesses attention control, the Trail Making Test assesses mental processing and attention, and the DualTasking Walk assesses attention and overall executive function (Tangen, Engedal, Bergland, Moger, & Mengshoel, 2014). Grip strength is a widely used computation that reflects frailty and general muscular strength (Mirelman et al., 2012). This study aims to determine the relationship between muscular strength and cognition in older adults, and furthermore, identify the functional areas which may show correlation. This was accomplished by measuring the handgrip strength of older adults and comparing these values against the results of a timed dual tasking activity, Stroop Color Word test, and Trail-Making Test. Demographics including age, ethnicity, family history of illness, current medications, previous exercise activity, current exercise activity, education, work history, and profession were collected in an effort to better understand factors that may affect cognition on an individual basis. Subject recruitment and data collection primarily took place at Butterfield Trail Village in Fayetteville, Arkansas.

### **Review of Literature**

Executive functions, housed in one's frontal lobe, involve a compilation of several cognitive processes affecting one's ability to direct, manage, and guide psychological actions; the ability to problem solve and control behavioral and emotional cognitions in daily situations is also included within executive functioning (Riccio, Blankely, Yoon, & Reynolds, 2013). Furthermore, goal-oriented actions and adaptations are strongly influenced by executive cognition (Forte et al., 2013).

One of the core executive functions, inhibition, lends the ability to purposefully suppress dominant, principal responses which may be necessary for normal social interaction. This lack of inhibition may be linked to a loss of social functionality, as well as physical functionality.

European researchers explain that while executive function is quickly lost as one ages, these cognitive abilities also show positive sensitivity to aerobic exercise (Forte et al., 2013). Further studies have suggested that exercise most greatly affected the executive control processes of the brain; programs that combined aerobic exercise, flexibility exercises, and resistance training were more effective than singular faceted programs in improving cognition (Kramer, 2006). Resistance training, in combination with other exercise, may improve cognition.

The Stroop Color Test, involving naming either the shown word or the color of ink it is typed in, is a valid and reliable way to measure executive function and, more particularly, attention control (Hutchison, Balota, & Duchek, 2010). The Stroop Color Test activates both the lateral prefrontal cortex (IPFC) and anterior cingulate (ACC), parts of the brain that are responsible for task control and conflict detection, respectively. These abilities aid in daily processes as one decides which tasks to pursue and which activities should take precedence over others. Stroop paradigm has shown significant patterns of difference in aged brains and dementia-ridden brains. Compared to younger adults, older adults showed a larger Stroop interference in reaction times, while maintaining a relatively small rate of error. However in opposition, participants with mild or very mild dementia saw larger interference effects and larger error rates, compared to older adults without cognitive impairment. These data support the idea that individuals with dementia struggle with goal maintenance, which in this case would be stating the color of ink and ignoring the word and vice versa. More practically, goal maintenance

includes driving while speaking. Additionally, goal maintenance is necessary for an individual to walk from the living room to the kitchen to take daily medications without becoming distracted.

Though individuals with mild dementia showed a distinct impairment within the context of the Stroop Test, older adults who had aged healthy (without signs of dementia, or without having been diagnosed with dementia) also showed natural signs of a decline in cognition. While the older, healthy adults did not show a pattern of goal maintenance problems, they did show a lack of resolution in response competition, indicated by longer reaction times when viewing incongruent items (the word “blue” spelled in red ink) as opposed to neutral items (the word “blue” spelled in blue ink). Furthermore, healthy adults who were eventually diagnosed with dementia (of the alzheimer’s type) went on to show incongruent error rates 2.2 times higher than older adults who continued to be classified as healthy (Hutchison et al., 2010). The reliability and validity of this exam has allowed many to compare results of not only individuals of different age, but also individuals with developing health and cognition changes.

Moreover, the Trail Making Test is a commonly used exam that evaluates executive functions including visual tracking, psychomotor speed, and mental attention and flexibility. This test is composed of two trails: A and B. In order to complete trail A, participants are asked to draw a line connecting letter of the alphabet in ascending order. These encircled letters are spread randomly about a piece of paper. This exam measures attention and visual scanning performance. Trail B involves participants connecting both encircled letters and numbers in ascending, alternating order (i.e. A-1-B-2). This section of the exam assesses overall cognitive flexibility. While age and education may also impact the test results, overall, cognition negatively correlates with response time (Cangoz, Demirci, & Uluc, 2013).

What's more, Turkish researchers found that results from Trail A can separate healthy people from those with dementia while part B may detect subjects with early stages of Alzheimer's disease. Unlike other studies, this Turkish study analyzed time of test completion, and error frequencies. Every variation of TMT components including Time of Completion (TC) for Test A, TC for Test B, TC A+B, and TC B-A was evaluated and showed significance in distinguishing between healthy and dementia-ridden patients. With this in mind, it should be noted that validity studies have not been completed when errors and corrections have been made, as many speculate that time differences may be at the discrepancy of the mediator (Lamoth et al., 2011). However, any discrepancy of the mediator would remain consistent for all subjects and would not impact the results of an isolated study.

In continuation, dual tasking, performing two tasks simultaneously, is also a measure of cognition. While completing two tasks, an individual must not only have the ability to split their cognitive attention, but also to adapt to and change the attention deficits. Partaking in an additional activity, such as talking, while walking has been shown to be especially difficult for aged adults. More importantly, risk of falling increases with age and frailty; a reported one in every three community-dwelling adults age 65 of older falls no less than once every year (Lamoth et al. 2011). Further frightening evidence suggests that unintentional injury is the fifth leading cause of death in older adults. After falling and being admitted to the hospital, only about 50% will live an additional year (Rubenstein, 2006). Gait characteristics such as walking speed, step length, step time, and pattern, are often altered to provide more stability to individuals who have developed a fear of falling. In this way, walking becomes less of an autonomic task and

more of a cognitively taxing activity, making it harder for many to complete other activities while also walking.

A study in the Netherlands asked 26 older adults to walk for three minutes both with and without performing a secondary task (naming words that started with the letters “R” or “G”). Half of the adults were cognitively healthy and half were cognitively impaired, as defined by an MMSE score of greater than 26 less than 23, respectively (MMSE, or Mini Mental State Exam, is a quick exam comprised of eleven questions that measures cognition). It was found that though the number of words named did not differ significantly from dual or single task sessions, other variables did. Stride frequency and walking speed decreased while dual tasking while stride variability increased. Furthermore, while no statistically significant difference was recorded in words listed between the two groups of cognitive abilities, differences in trunk acceleration and mobility was observed in the cognitively impaired population while dual tasking. This variance may account for the increased fall rate in dementia-ridden patients. Gait variability increased in the cognitively impaired while dual tasking but did not correlate strongly with MMSE scores; however they did correlate strongly with verbal fluency and temporal orientation subtest scores. Overall, dual tasking presents a greater challenge to those who are cognitively impaired as opposed to those who are considered cognitively healthy, as reflected by the fact that gait differences were only seen between the two groups when dual tasking was performed (Lamoth et al., 2011).

Still, other studies support that executive functions are weakly associated with walking and gait pattern under a single task condition and become more influential under dual-task conditions. More pointedly, individuals without cognitive problems do not use executive

cognition when walking whereas persons with impaired gait patterns or cognition rely rather heavily on executive function to safely walk (Lamoth et al., 2011). In general, poor executive functioning exacerbates poor dual task performance and gait stability (MacAulay et al., 2014).

Memory problems, like muscle mass diminishment, increase with age. However, memory problems may start to reveal themselves in adults as young as 45. Loss of memory has been correlated with stressors in life, in addition to aging (Rickenbach, Almeida, Seeman, & Lachman, 2014). Loss of cognition may be attributed to a sedentary lifestyle however, while actions of those at a young age may not be undone as they grow older, studies have shown that it is possible to improve cognition in older adults (Grossman, 2014). One study explains that physical exercise decreases the chance of developing dementia. Once initial testing was performed and co-variables were adjusted, it was found that adults over the age of 65 who exercised fewer than three times a week had a higher incidence rate of Alzheimer's disease than those who exercised more than three times a week. Furthermore, genetic testing was also performed and included as a variable. Individuals that originally scored the lowest on their fitness testing saw the most improvement/ least risk of developing Alzheimer's after the follow up over 6 years later. In other words, subjects that were the least fit to start with showed the most improvement from the exercise plan. Additionally, inverse relationships have been found between cognitive function and objectively tested physical activity. The point has also been made that not all reported physical activity is in the form of exercise or leisure, but rather work, and thus the same benefits may not be seen. Those with a genetic risk for dementia saw an increase in cognition when performing at least 15 minutes of physical leisure activity twice per week. Put simply, a mere 30

minutes of exercise on a weekly basis can help prevent dementia in genetically predisposed persons (Kramer, 2006).

Sarcopenia indicates the loss of muscle mass associated with aging. Unlike cachexia, which is the degradation of muscle tissue in older adults as a result of ailments, sarcopenia has no specific cause. While lack of muscle usage, malnutrition, and sedentary lifestyles are thought to contribute to sarcopenia, no strong conclusions may be made. Though rather elusive in etiology, the prevalence of sarcopenia is well acknowledged. Loss of muscle mass may begin as early as 40 years old in some adults and continues to worsen as the body ages. In the United States, as many as 30% of adults aged more than 65 years are afflicted, while roughly 50% of the population of at least 80 years of age are experiencing the effects of sarcopenia (Greig, 2013).

With sarcopenia comes a loss of functionality and a possible loss of independence. However studies show that both resistance and endurance training may increase the muscle mass of older adults. While studies are inconclusive as to the optimal number of sets, as little as one set of 10 repetitions, 2-3 times per week for 12 weeks may increase muscle mass in those over 65. Furthermore, high-velocity training has also been shown to induce muscle hypertrophy in healthy elderly. In the same way, frail elderly showed marked increases in their one repetition maximum (defined as the maximum amount of weight that can be lifted in one repetition) after training 3 times per week using sets of 3 sets of 8-12 repetitions for 12 weeks. These men and women progressed from lifting 20% of their maximum ability to 80% and saw no significant negative side effects. In addition to muscle hypertrophy, weight training has been shown to improve power output and neuromuscular action. These combined training methods and effects improve the physical function of older adults (Cadore, Pinto, Bottaro, & Izquierdo, 2014).

Chemically, exercise induces the production of brain derived neurotrophic factor (BDNF), a chemical that is expressed in the hippocampus, the part of the brain that controls behavior, responses, and thus, memory (Kramer, 2006). Both young and aging brains respond to BDNF; neurotransmitters are also positively affected by exercise (Kramer, 2006). This neurotrophin aids in brain cell growth and has even been associated with psychomotor processing speed, cognition, and increased size of the hippocampus. While it is known that both young and aging brains respond to BDNF, the Institute of Exercise Physiology and Wellness at the University of Central Florida found that blood serum levels of BDNF did not significantly change after a 6-week resistance training program in older adults. It should be noted, however, that BDNF levels may be temporary and heavily influenced by exercise duration and intensity. Though levels of BDNF did not change significantly over a 6-week period, the participants showed an improved neurotracker threshold speed, visual reaction time, and physical reaction time. While long-term increased levels of BDNF may not be associated with any cognitive changes, it has been hypothesized that a short-term increase in BDNF, lasting as few as 20 minutes after exercise, may aid in neurological adaptations and improvements (Fragala et al., 2014).

Many diseases have also been shown to lead to problems with cognition. For example, as many as 80% of patients with congestive heart failure will subsequently experience cognitive impairment. In the same way that physical activity combats the effects of cardiac disease, so too does it improve cognitive function (Fulcher et al., 2014). Exercise may positively impact cognition, regardless of the reason for impairment (genetically accumulated dementia, congestive heart failure, etc.). For this reason, origin of cognitive decline will not be considered in this

study. The Summa Akron City Hospital in Ohio revealed that minutes spent in moderate to vigorous physical activity predicted overall cognitive function. Similarly, lower levels of physical activity correlated with poorer scores on cognitive tests. Activity levels are often simply measured by step count and walking, an aerobic activity, increases cardiovascular function. Therefore, one may conclude that there is an increase in oxygen to the brain during aerobic activity, resulting in an increase in cognitive ability. It should be noted that while this study found a significant correlation between activity level and cognitive function, no significant correlation was found between activity level and memory in older adults (Fulcher et al., 2014).

Further evidence of improvements in cognition and muscle mass as a result of exercise is apparent in a study published in the Journal of the American College of Sports Medicine throughout which 62 sedentary male subjects between the ages of 65-75 were evaluated. Tests including 1 RM tests, body composition, neuropsychological tests, quality of life and mood profiles, hemodynamic measures, blood viscosity, erythrocytes, hematocrit, and insulin-like growth factor-1 were performed. The men were then divided into various groups that participated in strength training at different relative intervals of overload with the control group participating in training, but not overload weight training. At the end of 24 weeks the men were re-assessed and it was found that for the group lifting at a higher intensity (80% of 1 repetition maximum) experienced a higher increase in lean muscle mass as compared to the moderately exercised group (50% of 1 repetition maximum) and the control group (no overload training). The 1 RM test scores increased significantly in the moderate and high intensity groups, as compared to the control group. The group that lifted with moderate overload increased its scores in three neuropsychological scores while the group that lifted with high overload increased in four

categories of neuropsychological scoring. The moderate group showed significant improvement in their quality of life scores while the high group showed improvement only in the quality of life scores that correlated to the general health domain. When re-evaluated using the depression tests, it was found that those who trained with moderate overload intensity positively increased their scores in 6 areas pertaining to depression; however, those who overloaded at a high intensity only statistically improved their scores in three areas. Increased amounts of IGF-1 was found in both the moderate exercise group and the high exercise group, as compared to the control. The impact of the gain in muscle was similar in both the moderate and high groups, though they trained at different capacities (Cassilhas et al., 2007). Overall, resistance training using an overloading stimulus yielded more favorable results than those derived from resistance training at an unchallenging level. Other studies show that the Central Nervous System is improved with moderate exercise, implying that the brain itself, including reaction time and nervous impulses, may see improvements rather than simply memory (Cassilhas et al., 2007).

Additional research on the effects of exercise on elderly adults diagnosed with dementia and other cognitive impairments include a pilot study conducted in the Netherlands. Eighteen adults of at least 70 years of age with diagnosed dementia participated in 6 weeks of both aerobic and resistance training. The results, based on a pre-test/post-test difference indicated that there were positive increases in Face Recognition, Picture Recognition, Visual Memory, Span Backward Test, incomplete figure test, and Stroop Tests. While part of the collective group attended exercise sessions 93% of the time, the other half only attended 86% of the sessions. Though each group averaged a different increase in performance for each test, there was no consistent pattern of improvement among the subjects. Overall, there was no statistically

significant improvement in cognitive function after 6 weeks of weight and aerobic training, with the exception of the Visual Memory Span Forward; results from this post-test showed a medium-sized improvement. Exercise had a positive effect on visual spatial cognitive processes, while having little to no effect on verbal functions. Keeping in mind that these older adults were already cognitively impaired, it was concluded that this exercise routine had little effect on the executive cognitive function of the subjects. Additionally, this study showed no correlation between physical function improvements and cognitive improvements but suggested that functional improvements did not occur at the same rate as improvements of cognition (Bossers et al., 2014).

While studies have examined the effects of exercise on the muscle mass and cognition of older adults, the actual measurement of strength has not been the focus. The handgrip dynamometer has been found to be valid and reliable in many populations. In pursuit of information regarding dementia patients and handgrip correlation, 76 adults age 65 or older, with varying degrees of diagnosed dementia were clinically evaluated. The subjects and their caregivers completed several questionnaires in order to determine the severity of the subjects' dementia. The subjects then used the JAMAR Hydraulic Hand Grip Dynamometer, as instructed. The test was repeated three times, while subjects rested one minute between each session. Another set of tests was conducted one week later using the same procedures. The subjects were divided into four groups based on their classifications of dementia development: borderline, mild, moderate, and severe. In three of the four groups (borderline, mild, moderate) it was found that the handgrip dynamometer re-test reliability was high. The fourth, severe group was not included in the analysis because several members of the group were unable to complete the test

due to cognitive impairment. Though it is important to make sure the participants understand the test and have a chance to practice with and examine the handgrip, people with severe mental impairment may not be able to comprehend the task and therefore, in these individuals, the handgrip strength test may not be a reliable or valid measure of strength. Overall, in those with moderate cognitive impairment, the handgrip dynamometer is a reliable measurement of strength (Alencar, Dias, Figueiredo, & Dias, 2012).

In comparison, while handgrip strength may be reliable, it may not be an indicator of lower body strength. A study in the Netherlands found that in a study of 764 adults, mean age 83, handgrip strength and quadriceps strength were “weakly” associated and, furthermore, independently correlated with health outcomes. Handgrip strength correlated with quality of life, while quadriceps strength did not aid in predicting measures of health (Chan, Houwelingen, Gussekloo, Blom, & Elzen, 2014). Contrastingly, researchers in Tennessee studied very old and oldest females (minimum age 75) and found that handgrip strength correlated moderately to overall body strength but was not a good indicator of functional capacity (Tietjen-Smith, et al., 2006). What’s more, in a study evaluating gait, balance, and dual tasking as it effects falls in the elderly, both grip strength and lower extremity strength were measured. Because lower extremity strength (quadriceps and tibialis anterior) were not associated with falling, grip strength was the only measure used in the study’s assessment; it was cited to be an understood measure of overall muscular strength (Mirelman et. al, 2012). Though a bit debatable, many clinicians and exercise physiologist agree that hand grip strength may be used as a quick, easy measure of overall body strength in older populations.

### **Research Methods**

A group of 30 adults at least 65 years old were selected, based on willingness to participate and fulfillment of the inclusion criteria (No severe cognitive impairment and in relatively good health. If the participant's doctor had ever said he/she should not participate in physical activity, then they were excluded from the study). A written informed consent was explained and signed by the participants before beginning this cross-sectional study. After signing the informed consent, participants took the MMSE and completed a demographic questionnaire. The aim was to gather a range of participants with varying degrees of muscular strength and cognitive impairment, however because of incapacities to consent, individuals that have been diagnosed with severe mental impairment were excluded from this study. It was decided to collect between 25 and 40 participants because of the comparative, correlational nature of the study. All participants were from the Northwest Arkansas area, coming from Butterfield Trails Village in Fayetteville, Arkansas.

Before any exams were administered, each participant took the Mini Mental State Exam to assesses whether he or she qualified to participate in the study. This exam involved 11 questions. The first section of this exam required the participants to respond verbally. It measured orientation, memory and attention. A maximum of 21 points could be obtained in this section. Part 2 evaluated the abilities to name, follow both written and verbal instructions, draw complex figures, and construct an unplanned sentence. A maximum of 9 points could be obtained in this section. "Normal" cognition for adults over the age of 65 is considered a score of between 26-30. In order to be eligible for this study, participants must have received a score of at least 23 out of

the possible 30 points, indicating a lack of severe mental impairment. This test is both a valid and reliable measure of cognition (Folstein, Folstein, & McHugh, 1975).

### **Muscular Strength**

Handgrip dynamometry is a valid, reliable measure of strength in many populations including individuals with borderline to moderate cognitive impairment (Alencar et al., 2012). More specifically, lean body mass has been known to correlate with maximum muscle contraction (Yamauchi, 2013). This indicates that muscle mass is directly correlated with strength. However, lean body mass is often hard to measure and furthermore, may not be an accurate representation of strength at a time when one's muscle mass is rapidly decaying due to sarcopenia . For these reasons, each subject performed a maximal-force handgrip strength test three times, each with a one minute rest period between. This short contraction does not significantly increase blood pressure or cause muscle fatigue (Trutshnigg et al., 2008). Subjects were seated in a chair, feet planted shoulder width apart with their non-testing hand resting comfortably. The participants's elbow rested on the arm of the chair, bent at a 90 degree angle, while his or her wrist remained at a neutral position of zero degrees, if possible. Participants were instructed to squeeze as hard as they could for three seconds (Trutshnigg et al., 2008). Participants completed this exercise three times on each hand. The strongest scores from each hand were then averaged and recorded.

### **Cognition**

One's frontal lobe, connected to both executive function and attention, is also associated with gait patterns and speed. In older adults, a slower gait speed correlates to a smaller frontal lobe volume. Studies show that walking while performing an additional task (dual tasking)

increases activation in the prefrontal cortex of the brain, especially in younger adults (Mirelman et al., 2014). Dual tasking may simply be described as performing two activities at once. One's attention must be split in order to simultaneously perform the given two tasks (Thomassin, Gonthier, Guerraz, & Roulin, 2014). For these reasons, the ability to perform two tasks at once is said to be a measurement of cognition and was used to assess functional cognition: attention and executive function. The individuals of this study were asked to walk 20 meters down the hallway while they were timed. Using the Brower Timing System, timers were placed 10 meters apart on the measured pathway. Cones and masking tape were used to mark 5 meters before and after the timing system. Participants began walking at one cone and finished walking at the other. In this way, acceleration and deceleration did affect walking speed or time for the middle 10 meters. After a rest period of a time determined by the individual based on need and preference, he or she was asked to walk the 20 meter length again. The second time was recorded; individuals repeated this process until two trials were less than or equal to 0.1 seconds different. These two trials were then be averaged and their score was recorded. Once this was achieved, the individuals were again instructed to walk the designated length but this time they were instructed to count back by three from a randomly selected number between 100 and 200 while they walked. Just as before, the individuals repeated this process until two trial times were within 0.1 seconds of each other. These two times were averaged and recorded. The difference between the dual task time and the single task time was also calculated and recorded.

A Trail Making Test was used to evaluate the speed of mental processing, attention, and executive function. Participants were given a piece of paper and asked to first connect circles in numerical order, and then upon obtainment of test two, connect the circles in order, alternating

between letter and numbers. The participants were given a maximum of 5 minutes to complete each task, however their timed score was categorized and recorded (Tangen et al., 2014).

Research from Texas A&M University found that while a more complex two-factor model shows greater validity for a younger population, this simple one-factor model including trails A and B is an adequate fit for older adults, 50 or more years of age, and is valid and reliable. Additionally, validation of the newly used two-factor model is still necessary for individuals with cognitive impairment because time to completion is the dominant measure of scoring (Riccio et al., 2013). For the purposes of this study, a single-factor model of the Trail Making Test was used.

In another effort to measure cognition, subjects were asked to perform the Stroop Color Word Test. He or she read a list of words (color names) as they were shown. Following the completion of this control trial, he or she was shown a new list and asked to announce which color ink the words were printed in, not the actual word itself. The nature of this exercise indicates an evaluation of cognitive inhibition and interference. Brain monitoring software shows several parts of the brain are activated during this test and therefore, this activity may be used as an additional measure of brain activity (Leung, Skudlarski, Gatenby, Peterson, & Gore, 2000). This activity has been deemed a valid and reliable measure of executive function and attention control in a variety of populations including both healthy older adults and older adults with budding cognition problems (Hutchison, Balota, & Duchek, 2010).

### **Data Analysis**

Three correlation analyses were performed to determine the effect of the independent variable, muscular strength, on the dependent variables, domains of executive cognition

(executive function, attention, mental processing, cognitive inhibition, and inference). Statistical significance was set at .05 for each analysis.

### Results

The sample consisted of 30 individuals between the ages of 66 and 89 with MMSE scores ranging from 23 to 30. Roughly 21% ( $n = 6$ ) of the sample were male. Two individuals chose to quit testing when asked to complete the dual task, and one individual was not able to complete the entire handgrip protocol due to arthritic pain. Furthermore, outliers in each correlation were determined using a box-plot; the participants falling outside of the box plot whiskers were considered outliers and taken out of their respective correlation analysis. One outlier was found in the Trail Making Test, one outlier was found in the Stroop Color Word Test, and three outliers were found in the Dual Task Walking Test. In addition, all male participants were excluded from data analysis, as they consistently produced more handgrip force than women, given the nature of the task. A total of 23 women were included in the analysis. Table 1 shows descriptive statistics of the sample.

Table 1

#### *Demographic Characteristics*

Females, n=23	
<u>Variable</u>	<u>Mean</u>
Age (years)	78.5 ± 5.9
Weight (kg)	67.0 ± 13.0
Height (cm)	161.6 ± 5.9
MMSE	27.8 ± 2.2

*Note.* MMSE= Mini Mental State Exam

No correlation was found between handgrip strength and Stroop Color Word performance, nor was there significant correlation between handgrip strength and Trail Making performance. A moderate correlation was found between handgrip strength and habitual dual task walking performance, however at  $p = .052$ , there is a trend for significance but the correlation cannot be deemed statistically significant. Table 2 shows correlation statistics between the independent variable, muscular strength, and the dependent measures of cognition. Overall, there is no statistically significant relationship between muscular strength and cognition in older adults.

Table 2

*Bivariate Correlations among Older Adults*

Correlation with Hand Grip Average		
<u>Variable</u>	<u>R value</u>	<u>P value</u>
CW Contrast Scaled 3v1	.01	.996
Trails Ratio	-.21	.34
DTD	-.40	.052

*Note.* CW Contrast Scaled 3v1= Stroop Color Word contrasted scaled scores condition 3 versus condition 1; DTD= Dual Task Difference; R value= correlation; P value = statistical significance when  $p < .05$

Figure 1 demonstrates the trend for moderate correlation between handgrip strength and dual task differences. As the difference of time between dual task and single task walking increases (meaning there was a greater difference in how long it took to do one task, as opposed

to two tasks), handgrip strength decreases. This indicates that the physically weaker individuals performed dual tasks more poorly than physically strong individuals.

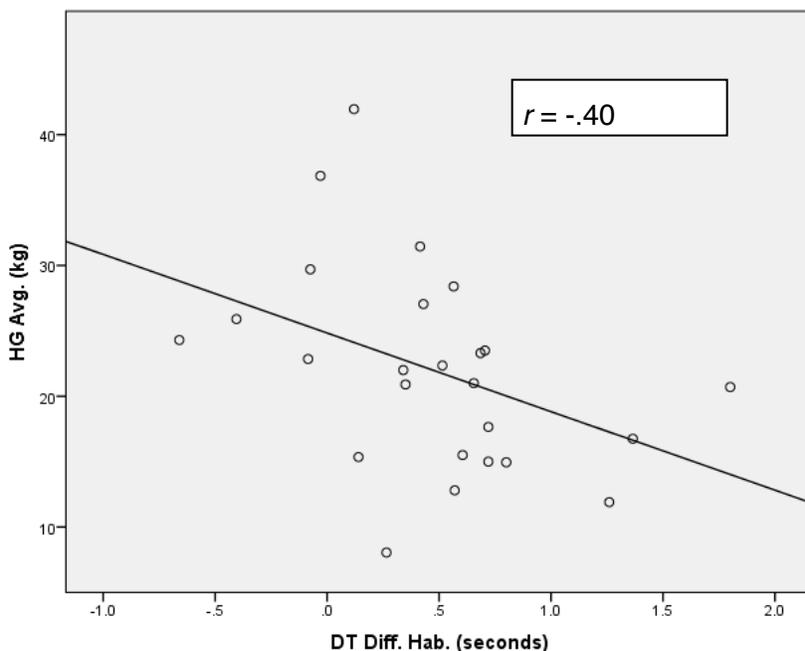


Figure 1. Bivariate Correlation between Habitual Dual Task Differences and Handgrip Averages in Older Adults

### Discussion

While handgrip strength may not correlate with direct measures of cognition, there was moderate correlation (with a trend for significance) between grip strength and dual task walking, a physical proxy measure of cognition. The overarching physicality of each test lends to the idea that while walking may use cognitive function, it is still a physical act that requires muscle mass and muscular coordination to complete. The dual-task nature of this exam should have accounted for this muscular dependency, as the times themselves were not compared, but merely the difference between walking normally and walking while attempting to complete a dual task. That

is to say, muscle mass or strength should not have affected the scores physically because the speed at which individuals walked was not taken as stand-alone score. Instead, the comparison of walking speeds when asked to perform one task versus two tasks was assessed. A single task time of eleven seconds and a dual task time of twelve seconds yields a time difference of one second, just as a single task time of twenty seconds and a dual task time of twenty-one seconds yields a time difference of one second. Each dual tasking score was relative to the individual. Nevertheless, it is logical that strength would correlate most highly with a physical proxy measure of cognition because both handgrip and walking require muscular coordination.

The moderate correlation found between handgrip, a measure of strength, and dual task walking, a measure of (executive) cognition, is supported by a study done in Japan. Multiple measures of strength were used and compared to both the MMSE and the Montreal Cognitive Assessment. It was found that hand grip strength was positively associated with cognitive assessment scores (Narazaki et al., 2014).

The lack of correlation ( $r = .01$ ) between handgrip strength and Stroop Color Word proficiency does not align with recent findings in South America. A study done in Sao Paulo, Brazil evaluated healthy, middle-aged women before and after they completed acute aerobic and strength exercises, composed of three 60-minute (aerobic) or 30-minute (anaerobic) sessions over the course of three weeks (Alves et al., 2012). Though the present study evaluated strength, and not exercise, it has been concluded that resistance training significantly increases muscle mass, in addition to muscular strength and power in middle-aged and older adults (Hunter, McCarthy & Bamman, 2004). The women who participated in aerobic exercises saw a “medium to large effect” on each of the three conditions of their Stroop performance, whereas individuals

who completed the acute strength training saw a similar beneficial improvement of their Stroop performance only in two out of the three Stroop conditions. These two conditions, non-color word and color word, were the two conditions tested in the present study and are said to be measures of executive function (Alves et al., 2012). The third condition, Stroop test “color,” is not a measure of executive function, was not tested in the present study, and showed no improvement after acute strength exercises in the previous study. What’s more, neither the aerobic exercisers nor the strength exercisers improved their Trail Making times. The findings of the present study corroborate the previous study as it relates to Trail Making tests, but defers from the previous study as it relates to the Stroop Color Word test. Individuals from the previous study with more strength scored better on the Stroop Color Word test but scored no differently in Trail Making. It should be noted, however, that the previous study highlights recent theories that the effects of acute exercise are task-dependent (Alves et al., 2012). The effect of strength on cognitive performance could also be task-dependent.

Trail Making tests have not often been used alongside measures of strength. A study completed in 2014 and published in the *Journal of Physical Therapy Science* evaluated the relationship between lower limb strength and cognitive decline in community-dwelling elderly in Japan and found no correlation. Trail Making part A was included in the assessment of cognition; its cognitive scores did not correspond with lower limb strength (Ohsugi et al., 2014). While the previous study evaluated only lower-limb strength, handgrip strength is more indicative of overall body strength and still correlates to lower body strength (Mirelman et. al, 2012). The study completed at Butterfield Trail Village evaluated total body strength on the basis of handgrip strength. Still, the lack of correlation found between Trail Making scores and strength

in the previous study corresponds to the low correlation ( $r = -.21$ ) between handgrip and Trail Making found in the present study. Ergo, the results of the present study support the results of the previous study. Findings from both past and present studies suggest that older adults are able to maintain physical strength, despite cognitive problems or inefficiencies.

Additionally, correlations of  $r = .01$  between hand grip and Stroop Color Word,  $r = -.21$  between handgrip and Trail Making, and  $r = -.41$  between handgrip and Dual Task Walking reflect very high variance among the measures. Future studies should evaluate a greater number of participants in an effort to develop a clearer trend in correlations.

In continuation, many participants complained that they were “not good with numbers.” In the future, the dual-task test may be completed using a different measure of duality, such as naming animals or listing the alphabet backwards. These tasks, while slightly less difficult and less common in scientific practice, may be a more accurate representation of functional dual tasking in an older adult’s life. The ease of understanding may lead to more willingness to complete the task and more accuracy in data collection.

### **Conclusion**

The results of this study suggest only a moderate correlation between strength and dual task walking, a physical proxy-measure of executive function, in older, community-dwelling women without severe cognitive impairment. However, statistical significance was not found for this correlation. Further studies should include a larger number of participants in an effort to improve the statistical significance of any correlations found; older adult men should be included in further studies and different measures of dual tasking should be used. Alternate measures of

muscular strength, such as lower limb strength, should also be considered when using dual task walking as a measure of executive cognition.

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