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Examining the relationship between neurocognitive performance and functional fitness levels among older adults

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Introduction

By 2050, 20% of the United States population will be age 65 years or older (U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, 2012). As the elderly population increases, so too will incidences of age-related neurological disorders. Contrary to the idiom we have all either heard or used, growing old is not always graceful. As we age, overall neurocognitive function becomes less efficient (O'Brien, 1999; Park et al., 2002). Neurocognitive functions are the mental processing abilities the brain needs to carry out tasks in the central nervous system. This is how we learn, remember, solve problems, and pay attention. Limited studies have examined the relationship between neurocognitive performance, physical activity, and functional fitness in elderly populations.

As we age, it is essential to more fully understand the correlation between physical activity, functional fitness, and neurocognitive performance levels. Typically, neuropsychologists or psychometrists administer standardized paper-pencil tests to measure psychological function. However, these tests are both time consuming and costly (Lovell, 2006). Internet-mediated neuropsychological tests are gaining popularity. These tests, given by trained test administrators, are comprehensive in nature and offer cost- and time-saving benefits (Butcher, Perry, & Hahn, 2004). Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) is one such test. ImPACT is a computerized neuropsychological test battery developed specifically for sports concussion evaluation (Schatz, Pardini, Lovell, Collins, & Podell, 2006). Considering its effectiveness amongst young athletes, a geriatric version of ImPACT is being implemented. It is important to determine if ImPACT is a more efficient and a more useful tool than traditional neurocognitive tests for making cognitive assessments in elderly populations.

Aging is accompanied by general slowing of motor skills, perceptual abilities, and cognitive speed (O'Brien, 1999). This slowing can be found throughout the central nervous system and in all types of human activities as synaptic transmissions of neurons in the brain become less efficient. The simplest response slows down by milliseconds each year from age 20 throughout adulthood (Tun & Wingfield, 2000). For example, if a person is asked to press a key on a computer as rapidly as possible every time a light flashes on the screen, this simple response, which takes someone in their 20s an average of 0.25 seconds, may require 0.35 seconds for someone in their 70s.

The aging process affects not only cognitive abilities, but functional fitness as well (Milanović et al., 2013). Functional fitness is defined as the ability to safely and effectively meet ordinary and unexpected demands of daily life. It encompasses strength, speed, endurance, and the ability to perform functional activities, such as, standing from a seated position, placing things overhead, pulling oneself up, and throwing and picking up things. Functional fitness is important to prolong independence, and it is a predictor of the quality of life one can expect to experience in the later stages of life. More than one-third of community-dwelling adults are at risk for mobility problems, which leads to increased dependency (Rikli & Jones, 1999).

Neuropsychological (NP) tests assess behavioral and cognitive changes resulting from central nervous system disease or personal injury (Douglas, Letts, Eva, & Richardson, 2012). Neuropsychological evaluations involve an interview and the administration of tests. The tests encompass both quantitative and qualitative assessments covering a number of cognitive domains including: verbal memory, visual memory, processing speed, reaction time, and impulse control. Tests are administered in either standardized paper-pencil or computerized formats. Studies have not examined the benefits of using ImPACT for cognitive testing in the elderly.

ImPACT is a multidisciplinary concussion evaluation and management tool administered on a computer or an iPad. Unlike traditional paper-pencil tests, ImPACT evaluates multiple variables at one time. ImPACT is the most scientifically researched tool used for concussion management in athletes (ImPACT Applications, Inc., 2014). It is both reliable and accurate as established by a number of research studies. ImPACT's website boasts of a large database of clinical research containing more than 190 and 125 peer reviewed and independent studies, respectively. To date, no significant studies have been conducted regarding ImPACT's usefulness in older adults. This study may be determined useful for assessing neurocognitive function in the elderly using ImPACT technology.

The aims of this study were to investigate the relationship between neurocognitive performance and functional fitness levels in older adults. It was hypothesized that there was a direct relationship between physical activity and functional fitness levels in older adults. More specifically, it was presupposed that physically active older adults are more functionally fit and have greater neurocognitive capacity than their less active counterparts.

The inherent limitations of this study warrant additional research of this subject matter. Limitations of this study included, but were not limited to:

1. This was a cross-sectional study. Therefore, results of these findings may not be representative of the population taken as a whole.
2. The sample was small and restricted to those at least 65 years of age and capable of participating in normal physical activity. For this reason, the resulting findings cannot be generalized to the community-at-large based on this study alone.
3. Subject's tablet-technology anxiety may have cause systemic errors. As a result, the outcomes generated may not have been indicative of actual performance levels.
4. Other factors including the subject's mental or physical fatigue, the time of the day of the day, or the day of the week the tests were administered may have also skewed tests results.
5. Self-reported demographic information was not validated for accuracy, which could have led to ineligible subjects participating in the study.

People are living longer in the United States, and as we age, our cognitive systems undergo normal, gradual but inexorable slowing. Understanding the correlation between neurocognitive performance and functional fitness is important because it allows researchers and other medical professionals to identify those considered at risk for diseases, injuries, and disabilities in their later years. Early indications of functional fitness risk factors could provide invaluable insight for managing functional fitness decline and guide interventions aimed at improving the quality of life. Presently, primarily paper-pencil neuropsychological tests are used to measure cognitive performance. However, if proven reliable and accurate for measuring cognitive performance in elderly adults, ImPACT could enhance effectiveness and efficiency of neuropsychological services. A cross-sectional study of ImPACT's usefulness for measuring the cognitive abilities in the elderly has not been conducted; therefore, further study is warranted.

Literature Review

Background

The geriatric population is the fastest growing demographic in the United States (USDHHS, CDC & Prevention, 2012). By 2030, the older population is expected to double. Therefore, it is imperative to understand, now, the relationship between physical activity and functional fitness as it relates to neurocognitive preservation. Primarily, paper-pencil neuropsychological tests are used to measure cognition (Lovell, 2006). Using a more comprehensive computerized tool such as ImPACT could help guide interventions designed to prevent serious injuries and disabilities in the later stages of life.

For the purposes of this project, a number of online databases were consulted including, but not limited to, EBSCO, a collection of Elsevier journals, Google Scholar, ImPACT technical manual, the Merriam-Webster online dictionary, PubMed, and the University of Arkansas Interlibrary Loan services. Key word searches included, but were not limited to: aging, cognition, functional fitness, geriatric neuropsychological tests, health-related quality of life, ImPACT, neurocognitive performance, physical activity, and other related searches. The following governmental publications were also explored: “General Information about the Older Adult Population” and “2008 Physical Activity Guidelines for Americans” from the U.S. Department of Health and Human Services, Centers for Disease Control and Prevention.

A total of 78 full-length articles were found and reviewed. Of those, 46 were collected and read. The review of literature was divided into the following major sections: 1) aging and neurocognitive performance; 2) aging, neurocognitive performance, and physical activity; 3) aging and functional fitness; and 4) neuropsychological tests.

Aging and Neurocognitive Performance

With the cumulative health effects associated with aging and pathological disease, adults typically experience a normal decline in cognitive function termed age-associated memory impairment (AAMI) (Kramer, Colcombe, McAuley, Scalf, & Erickson, 2005; O’Brien, 1999). AAMI is believed to be a non-progressive disorder. Mild cognitive impairment (MCI), on the other hand, is a slightly more aggressive and permanent form of memory loss affecting 27% of adults age 65 and older (Bischkopf, Busse, & Angermeyer, 2002). Although more aggressive than AAMI, changes caused by MCI are rarely severe enough to interfere with daily life activities.

There are two types of mild cognitive impairments, amnestic and nonamnestic (Bischkopf et al., 2002). Amnestic MCI affects episodic and semantic memory causing someone to forget important information that he or she would have otherwise easily recalled, such as, appointments, conversations, or recent events. Nonamnestic MCI primarily affects thinking skills unrelated to memory such as processing speed and reaction time. Nonamnestic MCI makes it difficult to make sound decisions or judge the time and sequence needed to complete tasks.

Studies show, mild cognitive impairment is an early indicator of more severe forms of cognitive decline. In the United States, individuals age 65 and older with MCI progress to Alzheimer's at an alarming rate of 12% annually, as compared to, older adults, without MCI, who develop Alzheimer's at a rate of 1% annually (USDHHS, CDC & Prevention, 2011). Studies confirm persons presenting with mild cognitive impairment are at greater risk for developing Alzheimer's disease than those who do not have MCI.

Age-related cognition deficits are caused by neuronal declines, neurotransmitter synthesis and signaling deterioration, and changes in density and plasticity (Deary et al., 2009). In other words, the brain's physical structure deteriorates over time. Shrinkage and loss of brain volume along with the death of neurons contribute to reductions of as much as 0.5% - 1.0% in cortical thickness and sub-cortical volume in some areas of the brain, annually. Studies further suggest that significant declines in brain capacity generally do not present until about age 75. Word and story recall decline by 1 standard deviation and 0.5 standard deviations, respectively. Additionally, episodic memory declines by 1 standard deviation and semantic memory declines by 0.23 standard deviations prior to age 75 and more than 0.5 standard deviations per decade after age 75. Processing speed has been shown to slow at a rate of 0.75 standard deviations per decade after 75, and reaction time declines at a rate of 1.5 standard deviations greater than the standard deviation of the response times for normal subjects (Ratcliff, Thapar, &

McKoon, 2001; Salthouse & Babcock, 1991). Studies consistently demonstrate this gradual yet progressive slowing of the brain's functioning as older adults age.

Aging, Neurocognitive Performance, and Physical Activity

Given that there is a natural age-related deterioration in the structural integrity of the brain, studies have shown, physical activity can slow the rate of deterioration and decrease the risks associated with cognitive impairments bolstering the idea that physical activity is a protective factor against the effects of aging (Bherer et al., 2013). Physical activity refers to any bodily movement that works muscles and requires more energy than at rest. It is one of the single most important steps Americans of all ages can take to improve their health (Bherer et al., 2013). However, numerous studies report, there is an unfortunate decline in physical activity levels as older adults age (Crombie et al., 2004). Generally speaking, these declines stem from a lack of interest, health issues, and a lack of knowledge regarding the benefits of physical activity. Adults age 65 and older should be participating in at least 150 minutes of moderate-intensity (5-6 on a scale of 1-10 for physical exertion) exercises or 75 minutes of vigorous-intensity (7-8 on a scale of 1-10 for physical exertion) exercises each week (American College of Sports Medicine, 2013). The activities should be spread out over a minimum of three days to prevent overexertion of muscles. The most significant decreases (42%) in the risk of cognitive impairment have been seen amongst older adults who participated in the recommended levels of activity (Kramer & Erickson, 2007a, 2007b).

Aging and Functional Fitness

The relationship between functional fitness and aging is understudied. There is far more evidence readily available pertaining to physical fitness than functional fitness. Although the terms are used interchangeably, the two are not synonymous. Functional fitness is the physical capacity needed to independently perform everyday activities, without the early onset of fatigue. Physical fitness, on the other hand, refers to an individual's ability to tackle both functional and skill-related tasks. It is a measurement of muscle strength and endurance, cardiovascular fitness, flexibility, power, and speed. Functional fitness is concerned with muscle integration while physical fitness emphasizes muscle isolation.

There is a correlation between physical activity and functional fitness. During the aging process, as physical activity decreases so do levels of functional fitness. Elderly adults who are not physically active expose themselves to a higher risk of losing muscle mass and reducing joint motion by up to 40%, depending on the body part in question. Loss of muscle mass ultimately leads to a decline in muscle strength. Studies further suggest that the average reduction in muscle strength for both men and women over 65 is approximately 1% annually, and after the age of 75, muscle-strength decreases by a total of 3.4% annually for physically inactive adults (Milanović et al., 2013).

Neuropsychological Assessments

Neuropsychological tests are useful for assessing behavior and cognitive changes resulting from normal aging, central nervous system disease, or personal injury (Douglas et al., 2012). Oftentimes, the evaluations involve an interview and test administration that encompasses both quantitative and qualitative assessments covering a number of cognitive domains including: verbal memory, visual memory, processing speed, reaction time, and impulse control. The tests can be administered in a standardized paper and pencil format or a computerized fashion. Even though traditional paper-pencil tests have been scientifically validated, computerized neuropsychological tests are gaining in popularity. Paper-pencil tests generally require administration by a neuropsychologist or other similarly trained professionals; whereas, computerized tests can be administered by non-technical people in a group setting. Additionally, computerized tests are considered more standardized than paper-pencil type tests. They offer better randomization of stimuli, are simpler to score, and are believed to be equally, if not more, accurate - all contributing factors to their increasing popularity. This study features five neuropsychological tests that have been independently studied with great precision. There is one computerized test (Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT)) and four paper-pencil tests (Stroop test, Mini-Mental State Examination, Trail-Making Test, and Symbol Digit Modalities Test).

Developed in the early 1990's by Drs. Mark Lovell and Joseph Maroon, ImPACT is considered the most scientifically researched concussion management tool available, utilizing battery of verbal memory, visual memory, processing speed, reaction time, and impulse control assessments (ImPACT Applications, Inc., 2014). It is both reliable and accurate having undergone 190 peer reviews and 125 independent regulatory tests administered by independent researchers. ImPACT was originally designed to assess concussion symptoms in athletes; however, the symptoms presented by concussed athletes are similar to older adults suffering from cognitive declines suggesting that

ImPACT may be useful in the geriatric population as well.

The Stroop Color-Word Test was originally designed by John Ridley Stroop to demonstrate the difference in reaction time of naming colors, reading names of color, and naming colors of words printed in different ink. It also aims to measure cognitive ability and impulse control. Since Stroop's original experiment, there have been many variations made to test different populations. For example, the California Older Adult Stroop Test has been designed to incorporate older adult-friendly features such as easily distinguishable colors, larger print, and fewer testing items in hopes of eliminating false positives for cognitive deficits (Pachana, Thompson, Marcopulos, & Yoash-Gantz, 2004).

Additionally, the Mini-Mental State Examination (MMSE) is a widely used screening tool that measures variables such as orientation, short-term memory, and immediate recall. It was originally designed for psychiatric patients but was later found useful for detecting and tracking cognitive impairments. The multidimensional MMSE not only screens for cognitive impairments but it determines the severity of any impairment and allows test administrators to monitor change by conducting follow-up tests. This examination solely focuses on the patients' cognitive function excluding all mood, thought, and judgment related content (Spencer & Folstein, 1985).

Lastly, the Trail-Making Test (TMT) and Symbol Digit Modalities Test (SDMT), created in similar fashions, are used interchangeably to assess visual memory and processing speed (Sheridan et al., 2006). The TMT is similar to "connect-the-dots" in which individuals connect a set of 25 dots as quickly as possible, and the SDMT features symbols that subjects must match to a given key also in the least amount of time as possible. Both of these tasks require a great deal of executive functioning such as memory, going back and forth between tasks, planning, and execution. Therefore, the multi-faceted TMT and SDMT are excellent tools for assessing these functions.

Methodology

Recruitment and Participation

For this study, the population of interest were the residents of a Continuing Care Retirement Community (CCRC) namely Butterfield Trail Village (BTV) located in the college town of Fayetteville, Arkansas. A CCRC is a particular type of retirement community, also known as a life community, offering aging care needs ranging from independent and assisted living, to special and skilled nursing home care. CCRCs offer a tiered approach to the aging process, accommodating residents' ever-changing needs in a single residential area.

Study Procedures and Experimental Design

The study began upon the Thesis Committee's and the Institutional Review Board's approval of the proposed procedures and experiments. Subjects were recruited from an existing database of potential research volunteers, by telephone recruitment, and by door-to-door contact. Eligibility criteria included: (1) of age 65 or older, and (2) capable of participating in normal physical activity (i.e. no physical, mental, or medical health restrictions). Subjects who failed to meet the stated criteria were excluded from participation. Testing ceased when all 41 subjects completed the assessments in their entirety.

Subjects voluntarily consented to participating in writing or were otherwise excluded from the study. Participants also completed a questionnaire designed to collect basic demographic information such as height, weight, sex, occupation (former or current), race and ethnicity, marital status, highest educational level achieved, and average annual household income. Additionally, participants were asked to provide general information about current medical and mental conditions, physical fitness abilities and/or limitations, as well as, answer questions about vision, hand preference, drug, alcohol, and caffeine usage, and the previous night's sleep. Subjects who presented with physical or mental impairments restricting them from participating in normal physical activities such as unassisted walking, standing, or lifting were excluded from the study. Additionally, participants completed a short, self-reporting questionnaire designed to assess Internet-mediated technology anxiety. The questionnaire's purpose was to evaluate, if and how much, training would be offered prior to and during testing administration to eliminate or substantially reduce the likelihood of systematic errors.

Subjects completed a series of fitness tests, namely the Senior Fitness Test (SFT), designed to objectively measure physical function. Properly trained personnel administered the SFT utilizing uniform testing procedures. Individual performance was initially recorded on personalized score sheets, but were later be converted to an electronic format for further analysis. Study participants were also administered ImPACT, a more comprehensive measure of the variables singularly assessed in traditional neuropsychological tests.

Measures

Physical Activity Scale for the Elderly (PASE). PASE is a researcher-guided interview process that measures physical activity levels of older adults in which participants are asked a series of questions concerning 12-types of activities performed over the previous seven days (Logan, Gottlieb, Maitland, Meegan, & Spriet, 2013). The time required to complete the interview process was typically 5 to 15 minutes. PASE scores were calculated from weights and frequency values for the 12 the activities evaluated. PASE has been deemed a useful tool for measuring physical activity levels with sufficient validity and reliability values. When compared to an accelerometer and a general physical activity questionnaire, PASE presented an intraclass correlation coefficient of r = 0.65 (Hagiwara, Ito, Sawai, & Kazuma, 2008).

The Late Life Function and Disability Instrument (LL-FDI) Test. The LL-FDI is a self-administered paper-pencil survey. It is a reliable and accurate method for assessing one's ability to perform activities of daily routines, achieving high intraclass correlations of r = 0.91 - 0.98 (Jette et al., 2002). Subjects were presented with a list of 32 "How much difficulty do you have…?" activities including, going up and down a flight of stairs while using a handrail, using a step stool to reach into a high cabinet, or washing dishes and utensils by hand while standing at the sink. Valid responses were (1) none, (2) a little, (3) some, (4) quite a lot, and (5) cannot. The time required to complete this assessment was approximately 5 minutes.

The Senior Fitness Test (SFT). The Senior Fitness Test is a comprehensive test comprised of six exercises measuring physical function (Rikli & Jones, 2001). The validity and reliability of the SFT have been established. Normative data were collected in a nation-wide study conducted with more than 7,000 participants. Performance was initially recorded on personalized scorecards and then later converted to an electronic format for further analysis. For two participants, it took about 30 minutes to administer the complete battery of tests. The test was administered in a group setting at BTV. The Senior Fitness Test targeted different aspects of functional fitness as delineated in Table 1 below.

Table 1

The Senior Fitness Test Exercises and Functional Targets

Senior Fitness Test Exercises	**Functional Targets**
6-Minute Walk	Aerobic Endurance
Chair Stand	Lower-Body Strength
Chair Sit and Reach	Lower-Body Flexibility
Arm Curl	Upper-Body Strength
Back Scratch	Upper-Body Flexibility
8-Foot Up-and-Go	Agility

6-Minute Walk Test. The 6-minute walk test measured aerobic endurance. The assessment took place on a designated walking course at BTV facilities. Research staff and I measured the distance subjects comfortably walked, without transitioning into running, during a 6-minute period. When participants began to feel unable to maintain their walking pace they were advised to continue at a slower rate. Both male and female participants unable to walk at least 350 yards are considered at risk for an inability to perform ADLs at some point in their elder years. The greater the distance walked, the greater the aerobic endurance. The 6-minute walk test was previously validated using the

Balke Protocol Submax Treadmill Test achieving an overall validity correlation of r = 0.78 and an overall reliability correlation of r = 0.94 (Rikli & Jones, 2001).

Chair Stand Test. The chair stand test examined lower body strength. Researchers measured, in a 30-second window, how many sit-stand cycles participants were able to complete. Participants were instructed to sit with arms crossed on their chest after which they were prompted to begin standing repetitions. Participants were required to completely stand and sit for a repetition to count. Participants unable to complete at least eight unassisted chair stands were considered at risk for lower physical function at some point in their later years. A higher score on this test represented greater lower-body strength. This test showed a moderately high correlation (r = 0.79) to a leg press assessment, suggesting it is a valid measure of body strength. Studies also determined the chair stand to be a reliable measure of body strength (r = 0.89) (Rikli & Jones, 2001).

Sit-and-Reach Test. The sit-and-reach test measured the distance subjects could reach towards or past their toes with a straightened knee. Participants were instructed to sit on the edge of a chair, with one leg bent and the other leg straightened as they reached toward the foot of their straightened leg with both hands. Those able to reach past their toes scores were recorded in positive centimeters while those who were unable to reach past their toes received negative scores. Those reaching just to the toe scored a “0.” Each participant was encouraged to complete two trials of this test but only the best reach was used. The higher the score, the higher the lower-body flexibility. Although no prior studies had been published investigating the validity of the sit-and-reach test, it displayed a moderately high criterion-related correlation (r = 0.83) when compared to goniometermeasured hamstring flexibility suggesting its validity. Further studies also suggest it is a reliable measurement of lower body flexibility (*r* = 0.95) (Rikli & Jones, 2001).

Arm Curl Test. The arm curl test assessed upper-body strength by measuring the number of bicep arm curls participants completed in a 30-second period. Men and women were asked to curl an 8 and a 5-pound dumbbell, respectively. The more arm curls completed represented a greater level of upper-body strength. This test shows a moderately high criterion-related correlation (*r* = 0.84 for men and *r* = 0.79 for women) as well as a reliability correlation (*r* = 0.81) to an upper-body strength assessment created by the makers of the Senior Fitness Test (Rikli & Jones, 2001).

Back Scratch Test. The back scratch test measured upper-body flexibility based on the degree to which individuals can reach behind their backs. Participants used their most flexible arm to reach overhead and down the middle of their backs while the other arm reached behind and up their backs to connect the two. The distance between participants' fingertips was measured. Participants whose fingertips did not touch were measured in negative inches, fingertips that touched were considered "0" inches, and fingertips that reached past one another were measured in positive inches. Again, each participant was encouraged to complete two trials of this exercise; only the best reach was recorded. Men with a score of 4 inches or less and women with a score of 2 inches or less were considered at risk for lower physical functioning later in life. The higher the score, the higher the lower-body flexibility. There were no empirical criterion-related or construct-related comparison values available to validate this test. However, current content-related evidence supports this is the best measure of shoulder flexibility (reliability, *r* = 0.96) (Rikli & Jones, 2001).

8-Foot Up-and-Go. The 8-foot up-and-go test assessed the functional agility of participants. Individuals were instructed to begin the test seated exactly 8 feet away from a marker. Participants were instructed to rise from a chair, walk as quickly as possible around either side of a cone, and then return to a seated position in a chair. Upon completion of two trials, only the fastest time was recorded. Individuals unable to complete the test in fewer than 8 seconds were considered at risk for lower functionality. The lower the score, the greater lower-body agility assumed. Past studies validate the 8-foot up-and-go test is significantly related to the Berg Balance Scale (r = 0.78). Studies also suggest the 8-foot up-and-go test is a reliable measurement of functional agility (0.95) (Rikli & Jones, 2001).

Geriatric Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT). ImPACT is a widely recognized comprehensive concussion management software program. All testing occurred before 12pm on weekdays in a secluded office at the BTV fitness center with just the researcher and the participant. There was one session of familiarization work with the iPad in order to reduce any potential anxiety. Practice sessions were administered before testing to allow participants to experience and understand the touch screen, how to type information into the demographic fields, and how to position the iPad to avoid screen glare. It took approximately 30 minutes to administer this test on an iPad. Participants took six neurocognitive tests (Shopping List, Design Rotation, Traffic Light, Color Match, Picture Match, and Clock Speed). Upon completion of this assessment, results were categorized into five components and displayed graphically for participants to view.

Table 2

Cognitive Process Tested vs. ImPACT Composite vs. Paper-pencil Tests

Cognitive Process	**ImPACT Composite**	**Paper-pencil Tests**
Verbal Memory	Shopping List, Picture Match	Mini-Mental State Examination (MMSE)
Visual Memory	Design Rotation	Symbol Digit Modalities Test (SDMT) and Trail Making Test (TMT)
Processing Speed	Clock Speed	Symbol Digit Modalities Test (SDMT) and Stroop test
Reaction Time	Traffic Light, Color Match	Stroop test
Impulse Control	Color Match	Stroop test

Statistical Analysis

To determine the relationship between neurocognitive performance and functional fitness, a bivariate correlation was performed. The independent variable was cognition and the dependent variables included agility, aerobic endurance, lower-body strength and flexibility, and upper-body strength and flexibility. Neurocognitive performance was defined by ImPACT, and functional fitness was defined by the results from the Senior Fitness Test (6-minute walk, chair stand, chair sit and reach, arm curl, back scratch, and 8-foot-up-and-go) and LL-FDI. Statistical significance was set at $\alpha = .05$. Table 3 provides an interpretation of Pearson's *r* correlations.

Table 3

Interpreting Strengths of Correlations

Value of the Correlation Coefficient	Strength of Correlation
.70 or higher	Very Strong Positive
.40 –.69	Strong Positive
.30 –.39	Moderate Positive
	Weak Positive
.20 –.29	No Relationship
.01 –.19	
0	0
-.10–(-.19)	No Relationship
-.20–(-.29)	Weak Negative
-.30–(-.39)	Moderate Negative
-.40–(-.69)	Strong Negative
-.70 or higher	Very Strong Negative

Note. Table 3 is an interpretation of Pearson's *r* correlations that are referenced throughout this analysis (Explorable," 2009).

Results

Demographics

This study consisted of 41 Caucasian men and women ranging from ages 65 to 90 years old. The average heights for men and women were 162 centimeters and 174 centimeters, respectively. The average weights were 68.0 kilograms and 84.8 kilograms, respectively. Of the 41 participants, 65.9% held at least a bachelor's degree, and 31.7% had a master's degree or higher. Descriptive statistics are presented in Table 4.

Table 4

Demographic Characteristics

Variable	Female *n* = 30	Male *n* = 11
Age (years)	76.5 ± 6.67	74.4 ± 5.55
Weight (kg)	68.0 ± 11.9	84.8 ± 12.1
Height (cm)	162 ± 5.33	174 ± 8.31
Bachelor's degree (#)	22	5
Master's degree or higher (#)	10	3

Note. Table 4 presents descriptive demographic statistics for the 41 participants of this study.

Instrument Descriptive Data

Tables 5 and 6 are referenced throughout the remaining analysis. They provide descriptive characteristics of functional fitness. Table 5 is a description of the Late Life Function and Disability Instrument (LL-FDI) function component item listings, and Table 6 describes the Senior Fitness Test and its functional targets.

Table 5

LL-FDI Function Component – Item Listings

Upper Extremity Functioning	**Basic Lower Extremity**	**Advanced Lower Extremity**
Unscrewing the lid off a previously unopened jar	Going up and down a flight of stairs, using a handrail	Running ½ mile or more
Putting on and taking off long pants	Reaching overhead while standing	Walking 1 mile, taking rests as necessary
Using common utensils for preparing meals	Sitting down in and standing up from a low soft couch	Going up & down a flight of stairs, without a handrail
Holding a full glass of water	Putting on and taking off a coat	Running a short distance, such as to catch a bus
Reaching behind your back	Stepping up and down from a curb	Hiking a couple of miles
Ripping open package of snack food	Opening a heavy outside door	Going up and down 3 flights, with handrail
Pouring from a large pitcher	Getting into and out of a car	Carrying something in both arms while climbing stairs
	Picking up a kitchen chair	Getting up from the floor
	Using a step stool	Walking several blocks
	Making a bed	Taking a 1 mile brisk walk without stopping
	Bending over from a standing position	Walking on a slippery surface outdoors
	Walking around one floor of home	
	Washing dishes, pots, and utensils while standing	
	Stepping on and off a bus	

Table 6

The Senior Fitness Test Exercises and Functional Targets

Senior Fitness Test Exercises	**Functional Targets**
6-Minute Walk	Aerobic Endurance
Chair Stand	Lower-Body Strength
Chair Sit and Reach	Lower-Body Flexibility
Arm Curl	Upper-Body Strength
Back Scratch	Upper-Body Flexibility
8-Foot Up-and-Go	Agility

Neurocognitive Performance and Functional Fitness

The geriatric Immediate Post-Concussion Assessment and Cognitive Test (ImPACT) along with the Senior Fitness Test (SFT; 6-minute walk, 8-foot up-and-go, arm curl, chair stand, back scratch, and sit-and-reach) and Late Life Function and Disability Instrument (LL-FDI) were used to examine the relationship between neurocognitive performance and functional fitness levels among older adults. With the exception of the 6-minute walk and arm curl, the findings in this study suggest that there is a positive correlation between functional fitness and neurocognitive performance. Table 3 provides an interpretation of the strengths of various correlations found. Tables 7–9 provide a statistical summary of these correlations.

6-minute walk. The 6-minute walk is not significantly correlated to any of the measures of neurocognitive performance as measured by ImPACT. It is, however, related to measured functional fitness as determined by the Senior Fitness Test. The 6-

minute walk displays a strong positive relationship to total functioning (*r* = .48), upper extremity functioning (*r* = .43), basic lower extremity functioning (*r* = .43), and advanced lower extremity functioning (*r* = .45).

8-foot Up-and-Go. The 8-foot up-and-go has a strong negative correlation to self-reported total functioning (*r* = -.47), advanced lower extremity functioning (*r* = -.51), and ImPACT's design rotation (*r* = -.51) and number of correct recognitions on the shopping list (*r* = -.61). The 8-foot up-and-go has a moderate negative correlation to self-reported basic lower extremity functioning (*r* = -.39), and a very strong negative correlation to ImPACT's number of correct hits on the traffic light portion (*r* = -.80).

Arm Curl. There is no observed association between the arm curl, self-reported functional fitness, or any of the measures of neurocognitive performance as measured by ImPACT.

Chair Stand. The chair stand has a moderate positive correlation to self-reported total functioning (*r* = .39) and upper extremity functioning (*r* = .32) as determined by the LL-FDI. It has a strong negative correlation to the average number of times answered correctly on ImPACT's color match (*r* = -.58) as well as average times on the clock speed portion (*r* = -.51). Lastly, the chair stand has a strong positive correlation to self-reported advanced lower extremity functioning (*r* = .49) and the number of correct recognitions on the shopping list (*r* = .52).

Table 7

Neurocognitive Performance and Functional Fitness – ImPACT vs. Senior Fitness Test

	6-minute Walk	Chair Stand	Chair Sit and Reach	Arm Curl	8-foot Up-and-Go
Shopping List	-.21	.52**	.12	.29	-.61**
Design Rotation	-.11	.03	.11	.06	-.51**
Traffic Light	-.25	-.12	.20	-.16	-.80**
Picture Match	-.18	-.20	-.15	-.02	.34
Color Match	-.34	-.58**	.32	-.12	.29
Clock Speed	-.10	-.51**	-.24	-.17	.46

Note. Table 7 presents a statistical summary of ImPACT scores vs. Senior Fitness Test scores. Pearson's correlations were used to determine relationships between variable. An alpha level of ≤ .05 was accepted as statistically significant. **Indicates statistically significant ≤ .05 correlations.

Table 8

Neurocognitive Performance and Functional Fitness – ImPACT vs. LL-FDI

	Shopping List	Design Rotation	Traffic Light	Picture Match	Color Match	Clock Speed
Total Function	.48**	.39**	.36	-.07	-.32	-.20
Upper Extremity	.43**	.32**	.10	.29	-.18	-.01
Basic Lower Extremity	.04	.14	.47	.28	-.14	-.06
Advanced Lower Extremity	.51**	.20	.49**	-.02	-.28	-.07

Note. Table 8 presents a statistical summary of ImPACT scores vs. LL-FDI scores. Pearson's correlations were used to determine relationships between variable. An alpha level of ≤ .05 was accepted as statistically significant. **Indicates statistically significant ≤ .05 correlations.

Table 9

Neurocognitive Performance and Functional Fitness – SFT vs. LL-FDI

	6-minute Walk	Chair Stand	Chair Sit and Reach	Arm Curl	8-foot Up-and-Go
Total Function	.48**	.39**	.10	.07	-.47**
Upper Extremity	.43**	.32**	-.31	.13	-.24
Basic Lower Extremity	.43**	.19	.01	-.05	-.39**
Advanced Lower Extremity	.45**	.49**	.142	.13	-.51**

Note. Table 9 presents a statistical summary of SFT scores vs. LL-FDI scores. Pearson's correlations were used to determine relationships between variable. An alpha level of ≤ .05 was accepted as statistically significant. **Indicates statistically significant ≤ .05 correlations.

Physical Activity and Functional Fitness

This study further establishes that there is a direct relationship between self-reported physical activity and functional fitness levels as determined by the Physical Activity Scale for the Elderly (PASE) and the LL-FDI. PASE has a moderate positive correlation to self-reported total functioning (r = .38), and a strong positive correlation to advanced lower extremity functioning (r = .51) as determined by the LL-FDI. Descriptive statistics are provided in Table 10.

Table 10

Physical Activity and Functional Fitness – PASE vs. LL-FDI

	Total Function	Upper Extremity	Basic Lower Extremity	Advanced Lower Extremity
PASE	.38**	.24	.27	.51**

Note. Table 10 presents a statistical summary of PASE scores vs. LL-FDI scores. Pearson's correlations were used to determine relationships between variable. An alpha level of ≤ .05 was accepted as statistically significant. **Indicates statistically significant ≤ .05 correlations.

Physical Activity and Neurocognitive Performance

As determined by PASE and ImPACT, there is a significant correlation between participation in physical activity and neurocognitive performance. ImPACT's design rotation and PASE have a strong positive correlation (*r* = .55) while ImPACT's traffic light and PASE have a strong negative correlation (*r* = -.46). Correlation statistics are provided in Table 11.

Table 11

Neurocognitive Performance and Physical Activity – ImPACT vs. PASE

	Shopping List	Design Rotation	Traffic Light	Picture Match	Color Match	Clock Speed
PASE	.19	.55**	-.46**	-.07	-.12	-.25

Note. Table 11 presents a statistical summary of ImPACT scores vs. PASE scores. Pearson's correlations were used to determine relationships between variable. An alpha level of ≤ .05 was accepted as statistically significant. **Indicates statistically significant ≤ .05 correlations.

Discussion

Neurocognitive functions are the mental processing abilities the brain needs to carry out tasks in the central nervous system. However, as we age, these cognitive abilities along with the capacity to safely and effectively perform everyday tasks decline (O'Brien, 1999; Park et al., 2002; Milanović et al., 2013). Previous studies suggest that there is a direct correlation between functional fitness and neurocognitive performance in older adults; therefore, the findings in this study were intended to indicate that relationship. Furthermore, the aims of this study were to demonstrate a direct relationship between physical activity and functional fitness levels in older adults. More specifically, it was intended to support the hypothesis that physically active older adults are more functionally fit and have greater neurocognitive capacity than their less active counterparts.

Neurocognitive Performance and Functional Fitness

High physical function plays an important role in maintaining memory function and delaying the progression of structural brain changes in older adults (Makizako et al., 2013). Studies have shown there is a direct correlation between aerobic capacity and cognition, particularly, between the 6-minute walk and cognition (Makizako et al., 2013 and Van Boxtel et al., 1997). An analysis conducted by Van Boxtel et al. (1997) consisted of 132 subjects between the ages of 24 and 76. Unlike the investigation done for this project, Van Boxtel et al.'s (1997) subjects were broken down into twelve different age groups and assigned various cognitive tasks that assessed memory, psychomotor speed, and information processing speed. Those scores were then compared to scores from a bicycle ergometer protocol. Ultimately, the study concluded that aerobic capacity and cognitive processes are directly correlated. Subjects with greater aerobic capacity performed better on cognitive tasks when compared to their less functionally fit counterparts. Makizakio et al.'s investigation, on the other hand, was slightly more specific. It only compared the 6-minute walk to neurocognitive performance. There were 91 participants and each of them completed the 6-minute walk test, structural magnetic resonance imaging scanning, and memory tests. With that, results concluded memory tests were positively correlated with the 6-minute walk. These findings suggested that a better 6-minute walking distance performance could be related to more efficient memory functioning in older adults.

In the analysis for this project, each domain of the Senior Fitness Test (6-minute walk, 8-foot up-and-go, arm curl, chair stand, back scratch, and sit-and-reach) was statistically compared to the LL-FDI and ImPACT. LL-FDI is a self-reporting measurement of functional fitness as delineated in Table 2. Furthermore, ImPACT is a measurement of verbal memory, visual memory, reaction time, and impulse control. Results from this study illustrated a positive correlation between ImPACT, LL-FDI, and the chair stand, as well as, a negative correlation between ImPACT, LL-FDI, and the 8-foot up-and-go. There were no observed associations between ImPACT, LL-FDI, 6-minute walk, or the arm curl. These findings are particularly interesting because, theoretically, the 6-minute walk should have displayed the strongest correlation between cognition and functional fitness. As previously stated, Makizako et al. (2013) indicated a direct correlation between cognition and functional fitness. Results showed a positive correlation with cognition and the 6-minute walk; however, in the investigation of this project, the 6-minute walk demonstrated no correlation. With the exception of the 6-minute walk, these findings still support the claim that there is a relationship between neurocognitive performance and functional fitness levels in older adults. This error could have been due to failure to provide clear instructions, improper test administration, inaccurate measurements, or lack of motivation on the participants' part.

Physical Activity and Functional Fitness

Regular aerobic activity is related to a reduced risk of functional limitations and disabilities in older adults (Paterson and Warburton, 2010). In a systematic review of 66 studies, Paterson and Warburton (2010) concluded that moderate and high levels of physical activity foreshadowed higher functional status. Similar findings were also reported in a longitudinal study performed by Miller, Rejeski, Reboussin, Ten Have, and Ettinger (2000). Their study assessed participants over a six year time period using interviews, and concluded that physical activity can reduce the progression of functional disability in older adults. Although methodically different from the previously mentioned analyses, the investigation used for this project also suggested there is a correlation between participation in physical activity and functional fitness. This study demonstrated a positive correlation between PASE and LL-FDI. There was a moderate positive correlation between PASE and total functioning, and a strong positive correlation between PASE and advanced lower extremity functioning. It is interesting, however, no correlations were found between PASE and the Senior Fitness Test. Considering that the Senior Fitness Test is another form of assessing functional fitness, it was predicted to have a positive correlation with PASE. This error could have been due to administrative or measurement discrepancies by researchers or the natural age-related decline in motivation by participants.

Physical Activity and Neurocognitive Performance

The final aim of this study was to support the notion that physical activity preserves neurocognitive performance. There is a natural age-related deterioration in the structural integrity of the brain. However, studies have indicated that physical activity can slow the rate of deterioration and decrease the risks associated with cognitive impairments; bolstering the idea that physical activity is a protective factor against the effects of aging (Bherer et al., 2013). The findings of this study, as determined by PASE and ImPACT, support that hypothesis. There was a statistically positive correlation between participation in physical activity and performance on neurocognitive tasks.

Limitations

As with any study, there were limitations in how research was conducted. With respect to the participants, the most limiting factor was the amount of effort and motivation given by each subject. A natural decrease in motivation due to age was expected (Hess, 2014). Therefore, without full effort on the part of the participant, a decrease in performance was expected. Additionally, motivation could have been further influenced by time of day. Attempts were made to test subjects at their convenience; unfortunately, due to researcher and subject availability this was not always possible.

Environmental influences on the subject may have also played a significant role in test performance. Efforts were made to reduce the effects of the environment by choosing a quiet area to minimize noise and distractions. However, because some participants were tested alongside someone else due to scheduling or if they chose to be tested with their significant other it is possible that they may have performed differently. Participants tested with more than one other person in the room could have become distracted by questions asked by someone else during the PASE and LL-FDI. Participants could have also been more inclined to amp up their performance during the Senior Fitness Test due to their competitive nature. Subjects tested alone versus subjects tested with a partner appeared more lackadaisical about testing.

Additional limitations of this study include sample size and demographic characteristics. Although attempts were made to secure at least 60 participants, researchers were only able to test 41 people due to dropouts and inclement weather. Furthermore, the majority of participants came from Butterfield Trail Village, a local retirement community. Of the 41 participants, all of them were Caucasian, 65.9% held at least a bachelor's degree, and 31.7% had a master's degree or higher. Therefore, results of these findings may not be representative of the population taken as a whole. It is recommended for future studies that researchers select a more ethnically and educationally diverse population to ensure a fair representation of the population. It is further recommended that subjects be tested one at a time to prevent distractions and competitive advantages. Lastly, it is recommended that researchers make all attempts to reduce systematic errors with uniform testing administration and precise measurements.

Conclusion

Outcomes of this study warrant attention from medical providers, the creators of ImPACT, and other researchers as they attempt to identify individuals considered at risk for diseases, injuries, and disabilities in their later years. The findings in this study demonstrate that there is a statistically significant relationship between neurocognitive performance, functional fitness, and physical activity levels in older adults. More specifically, individuals who scored higher on the PASE also had higher scores on the LL-FDI, and performed better on the Senior Fitness Test and ImPACT. With this, researchers and other medical professionals will be able to provide valuable insight for managing neurocognitive and functional fitness declines and guide interventions aimed at improving the quality of life.

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