THE EFFECT OF PHYSICAL ACTIVITY OVER THE LIFESPAN ON COGNITIVE FUNCTION

By

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A Thesis Submitted to The Honors College

In Partial Fulfillment of the Bachelors degree
With Honors in

Psychology

THE UNIVERSITY OF ARIZONA

MAY 2012

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Title of Honors thesis: The Effect of Physical Activity over the Lifespan on Cognitive Function	
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RUNNING HEAD: Physical activity, aging and cognitive function

The Effect of Physical Activity Over the Lifespan on Cognitive Function

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Psychology 498H

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May 2, 2012

Abstract

A large body of research suggests that physical activity can help prevent cognitive decline in older adults by contributing to their cognitive reserve. The aim of this project was to develop a questionnaire to measure physical activity over the lifespan, in order to examine the effects of activity on cognition in older adults. We collected data on two participants concerning their physical activities in every decade of their lives, and the intensity levels of those activities, by means of the Physical Activity over the Lifespan Questionnaire (PALQ). The preliminary results of the data analysis suggest that higher levels of physical activity over the lifespan are related to higher episodic memory performance. Further research is needed to support these claims.

Introduction

MRI technology is a tool for imaging the brain. fMRI is a way to examine in realtime what areas of the brain are activated during many kinds of cognitive tasks, from speech processing to vision to memory tasks. MRI scans of the brain can aid in finding tumors, and subsequent volumetric analyses can determine pathological shrinkage and/or ventricular enlargement. Researchers can study healthy brains to create a baseline for a study of diseased or damaged brains. When we know what biomarkers we are looking for as precursors to dementia, and specifically Alzheimer's Disease, neuroimaging will be on the forefront for the early detection and diagnosis of these ailments. Currently this technology is used to study the effects of preventative and curative measures for cognitive impairment. These measures may include things that the brain does without our conscious help, as well as things that we do deliberately to improve our cognitive function.

One recent finding of fMRI research was that younger brains and older brains do not process things the same way on some tasks. Cabeza's HAROLD (Hemispheric Asymetry Reduction in Older Adults) model was created when it was discovered that some older adults were more likely to show bilateral activation of their prefrontal lobes while performing a memory task during an fMRI scan. This is in contrast to younger adults, who were more likely to show unilateral brain activation during an fMRI scan, while doing the same memory tasks (Cabeza, 2002).

Stern (2009) suggests that the concept of Cognitive Reserve (CR) underlies the ability of the brain to respond in such a way. He defines CR as "individual differences in how people process tasks" that "allow some to cope better than others with brain pathology." CR can involve brain structures and/or networks, and it can come from heredity factors, life experiences, education or exercise.

Cabeza theorized that CR permitted the aging brain to compensate for its lost or declining abilities, and this compensation was why older adults had bilateral activation. He proposes that some older adults are recruiting additional areas of the brain to help with the cognitive workload, which means that the brain is working harder to maintain cognitive function. Compensation could be why the older brain does not seem to be, in some cases, showing cognitive decline as the person ages (Cabeza, 2002). In a 2002 study done by Cabeza, Anderson, Locantore & McIntosh, they found that in addition to a difference in recall and source memory processing between older and younger adults, there was also a recall and source memory processing difference between older high-performing and older low-performing adults. The high-performing older adults' brains showed bilateral prefrontal activation, while the low-performing adults did not. The researchers thought that this lent more support to the idea of compensation for the aging brain.

In another study by Reuter-Lorenz et al. (2000), working memory was examined by positron emission tomography (PET). Similar bilateral activations were shown for older adults in the anterior areas of the brain during verbal and spatial tasks. This is in contrast to younger adults, who showed left frontal activations for verbal memory and right frontal activations for spatial memory. These researchers suggest that these results also support the idea of compensation for the neural networks and structures of the aging brain.

There are additional ways to protect the aging brain, and Barber, Clegg & Young (2012) argue that neuronal loss could be prevented through physical activity. Mild cognitive impairment (MCI), defined as “cognitive decline greater than expected for an individual’s age and level of education” (Barber at al., 2012), is one of the possible identifiers for people at high risk for developing dementia. Physical activity, which is “any bodily movement produced by skeletal muscle that requires energy expenditure” (Barber et al., 2012), is a possible intervention for MCI. Physical activity has been shown to increase the amount of neurotrophic growth factors, which in turn can promote processes like neurogenesis and synaptic plasticity. The hippocampus, crucial for memory formation, is one brain area that is positively affected by this.

More MRI research done on the hippocampus demonstrated that aerobic exercise had the effect of increasing the size of the participants’ hippocampi. The increases were small, only 2.12% for the left and 1.97% for the right hippocampus. However, for the control group that only did stretching exercises, there was a decrease in hippocampal volume, between 1.40-1.43%. At baseline, both groups started with the same hippocampal volume (Erickson, et al., 2010). According to these researchers, hippocampal shrinkage is normal with age, but vigorous exercise was able to reverse this trend, even though just slightly, over a 1-2 year period. Szabo, et al. (2011) also found that older adults with higher levels of fitness show greater preservation of hippocampal volume. In their study, larger hippocampal volume was correlated with more accurate and faster spatial memory and fewer episodes of forgetting.

In a longitudinal study, more than 5,000 older women were assessed over a period of 6-8 years for their exercise level and cognitive function. At baseline they had no observed cognitive impairment or physical limitation. Their main form of exercise was walking and/or climbing stairs, and they were evaluated with the Mini-Mental State Examination (MMSE). In this study, the researchers defined cognitive decline as a loss of 3 or more points on the MMSE. What they found was that the women who had higher levels of activity from the start were less likely to cognitively decline over time (Yaffe et al., 2001). In addition to the possibility of neurogenesis being stimulated by physical activity, which would help prevent cognitive decline, other positive outcomes from exercise include increasing cerebral blood flow, reducing the risk of cardiovascular and cerebrovascular disease, and reducing the risk of other disorders/diseases like obesity and diabetes. The neuronal part of the brain may be ultimately more influenced by learning, but Churchill et al. (2002) found that the contribution of blood vessels and blood supply to the brain's ability to function were impacted by exercise.

From a review of several articles, Kramer et al. (2005) suggest that aerobic exercise has a beneficial effect on the cognitive functioning of older adults. They also found that these effects were most noticeable for executive control processes like planning, working memory and task coordination. Executive processes typically decline as people age. According to the authors, the brain areas that were most likely to lose grey or white matter were the frontal, prefrontal and temporal regions. These areas serve executive processes. MRI scans done in conjunction with the studies that were reviewed showed that older adults who were more physically fit were less likely to lose tissue in these cortical areas, as well as in the parietal cortices. When aerobic exercise was combined with strength and flexibility training, the positive cognitive effects were increased even further. It may be that the positive effects come from the production of more insulin-like growth factor 1 (IGF-1), which has been shown to increase after strength training. IGF-1 is a factor involved in neuronal growth.

Lack of standardization in definitions used could easily account for some of the differing results achieved in research. There are also different methods used to assess cognitive function or dementia. In spite of that, longitudinal studies consistently show that "the risk of dementia, cognitive impairment, cognitive decline, and Alzheimer's disease is lower among persons engaging in high levels of physical activity, relative to those engaging in low levels of physical activity" (Rockwood & Middleton, 2007).

In the Mayo Clinic Study of Aging, nine different tests were used to assess four cognitive domains: memory, executive function, language and visuospatial skills. Results from this study show that even if exercise was not started until midlife, there was still a 39% reduced odds ratio for MCI. Exercise started in late life produced an odds ratio that was almost as high: 32% (Geda et al., 2010). This study suggests that activity later in life may be beneficial to the brain and cognition.

A recent study utilized broad definitions for "exercise", including movement around the house, postural allocation, and fidgeting. Almost 200 older adults were tested for two weeks to determine if any kind of energy expenditure would contribute to improved cognitive function. The doubly-labeled water method was used. This method uses water in which hydrogen and oxygen are partly or completely replaced for tracing purposes ("labeled") with an uncommon isotope of these elements. Urine samples with the isotopes are collected and analyzed to determine total energy expenditure. The authors of this study found that greater energy expenditure could be protective against cognitive impairment, although they were not able to separate out the effects of different intensities (eg. light or vigorous) of the "exercise" examined (Middleton et al., 2011).

One of the points made by Colbert et al. (2011) was that since the population of interest was older, and they are typically not as active as younger adults, it would be important to discover whether or not lower volumes/intensities of activity are sufficient to reap the benefits of reduced disease risk and reduced cognitive impairment. In Colbert's study, they used a pedometer, an Actigraph accelerometer and a Sensewear armband to detect the smallest amounts of movement. Their purpose was to compare these methods to the doubly-labeled water method. Their conclusion was that these methods gave significantly different means, but that objective devices were better for measuring energy expended.

The doubly-labeled water (DLW) method seems to be the "gold standard" used to evaluate energy expenditure as it relates to amounts of physical activity, but this method is expensive, invasive, and not longitudinal. Bonnefoy et al. (2001) compared it to ten other physical activity questionnaires to find a valid measure that was more cost-effective for older adults. Half of the surveys compared were created for older adults: the Yale Physical Activity Survey (YPAS), the Modified Baecke Questionnaire, the Modified Dallosso Questionnaire, the Physical Activity Scale for the Elderly (PASE), and the Questionaire d'Activite Physique Saint-Etienne (QAPSE). The other half were designed for the general population and they are: the Minnesota Leisure Time Physical Activity Questionnaire, the College Alumni Questionnaire, the Seven Day Recall, the Lipid Research Clinics Questionnaire and the Stanford Usual Activity Questionnaire. The surveys that had the most validity for the older male population being studied were the YPAS, the Modified Baecke and the QAPSE. The researchers noted that the least accuracy was obtained between the survey methods and the DLW method by very sedentary individuals, and those who were trying to lose weight. The surveys with the most validity had means that were the most similar to those found with the DLW method.

In much of the literature that concerns the topics of aging, cognitive impairment and physical activity, the researchers note the need for more longitudinal studies and not just cross-sectional research. They also mention the lack of a questionnaire that will measure different levels of activity. The Physical Activity over the Lifespan Questionnaire (PALQ) attempts to cover both of these areas. It can do this because it asks participants about every sport/hobby/activity they have participated in for every decade of their lives, as well as giving them three different intensity levels to rate their physical activities with. The development of the PALQ was based in part on the Paffenbarger Physical Activity Questionnaire among Healthy Adults (Simpson, 2011).

The aim of the present study is to examine whether or not exercise/physical activity over the lifespan of individuals will increase their cognitive reserve, and thereby delay cognitive decline as they age and enable their brains to continue to function. The hypotheses for this study are a) that greater physical activity levels over the lifespan will produce faster reaction times and increase result accuracy on episodic memory tasks, b) that a steady pattern of activity level intensity will produce faster reaction times and higher result accuracy than an activity level that diminishes over the years, and c) that a steady pattern of activity level intensity will produce faster reaction times and higher result accuracy than an activity level that increases and then diminishes over the years.

Methods

Participants

Two participants from the Tucson, AZ area were recruited after they finished word-pair memory tasks in the MRI scanner and at a computer. They were each between the ages of 64-90, and had been screened over the phone before the memory tasks to ensure that they had no history of stroke, epilepsy or substance abuse. They were both right-handed, native English speakers, and had also completed an MRI safety questionnaire. After the imaging, and the computer task, they each completed a set of neuropsychological tests, including the Mini Mental State Exam (MMSE), and the National Adult Reading Test (NART). Each participant then filled out the Physical Activity over the Lifespan Questionnaire (PALQ). Participant #1 had fourteen years of education and participant #2 had twelve years.

Materials

The PALQ, a three-page document, was developed in order to assess the amount of physical activity over a person's entire lifespan. The PALQ asks participants to list every sport, hobby and/or work-related activity that they had performed for at least 1 year in each of the decades of their lives between 20's-80's. For each decade they listed the number of years they performed the activity. The were given a list of potential activities to cue them for activities to include. They were then asked to rate the exertion level of each of these activities, for each of the decades, by using the letters L (for light), M (for moderate), or V (for vigorous). Definitions for each of those levels of intensity were given in the instructions on the questionnaire.

Each participant arrived at the University Medical Center (UMC) in Tucson, AZ and was escorted to the MRI lab. All participants provided informed consent. All MRI scanning and computer tasks, as well as the neuropsychological tests and the PALQ, were done at UMC. The MRI scanner was 3T, and each participant was scanned six times. Each scan lasted between five and seven minutes. The first scan was for structural purposes, to ensure that there were not any brain abnormalities. The next two scans were both judgment memory tasks with word pairs, where the participant was asked to decide if the two words in the pair were the same, opposite, or the participant did not know. The last three scans were memory tasks, also with word pairs. The participant was asked if the pair of words had been previously seen, or not. For all five judgment and memory tasks, the response of the participant was timed. The final test was done at a computer, and during it the participant was asked to decide if the second word in the word pair was a good synonym for the first word in the word pair, or not, or the participant did not know. The range of possible responses was given in a multiple-choice format, and this test was self-paced. Then the participant was escorted to a different room, and he or she completed the neuropsychological tests, and the PALQ.

The PALQ consists of three pages: 1) instructions that include definitions for light, moderate and vigorous activity, 2) a chart to be filled out, and 3) a list of activity and/or sport ideas to help jog participants' memories. The participants were encouraged to think beyond that list of activities, since it was only a list of suggestions and not meant to be exhaustive. The participants then read the page of instructions, and were questioned to see if they understood what to do. They then filled out the chart by listing each activity/sport they could think of that they had done from their 20's forward, for at least one year. Since there were only enough lines for ten activities to be listed, the participants were instructed to create additional lines at the bottom of the PALQ as needed. Then they estimated how many of the years of each decade they had done each activity/sport. The final step was to rate the intensity level of the activity/sport in each of the decades that they had done it in, with either L, M or V, according to the definitions provided.

Results

Although this study is ongoing and data is still being collected, some preliminary analysis has been done on accumulated data. The amount of years for each activity, for all intensity levels, was summed in order to give each participant a raw score. Then values obtained from each intensity level were weighted in order to acknowledge the positive benefit that heavier exercise provides (Kramer, 2005). For the weighted score, the number of years of vigorous exercise were kept the same, years of moderate activity were reduced by .33 and the number of years of light activity were reduced by .67. Those numbers were summed to give each participant a weighted score. These scores were then compared to the result accuracy for each participant on the cognitive tasks performed in the scanner. (Table 1.) Participant #1 had 135 for a raw score and 48.3 for a weighted score. Participant #2 had 193 for a raw score and 109 for a weighted score. Participant #2 was classified as having higher activity levels than participant #1. For the cognitive tasks, participant #1 scored 96% on the easy semantic task, 83% on the hard semantic task, 71% on the easy episodic task and 60% on the hard episodic task. Participant #2 scored 79% on the easy semantic task, 73% on the hard semantic task, 88% on the easy episodic task and 88% on the hard episodic task. On the semantic tasks participant #1 did better, and on the episodic tasks participant #2 did better.

Discussion

Since this study has only had two participants so far, it is too soon to proclaim a trend, but some striking findings did emerge. From Questionnaire results in Table 1, it is observed that Participant #1 had a lower raw score, which indicates that he/she exercised less years overall than Participant #2. Participant #1 also had an even proportionately lower weighted score, which means that he/she exercised less vigorously overall. When compared to the bar graph in Figure 1, Participant #1 did better on the semantic memory task than Participant #2, which was expected based on more years of education. However, both of them experienced a decrease in result accuracy as the task progressed from easy to hard. On the episodic memory task, Participant #2 not only had higher result accuracy than Participant #1 overall, but also had no decrease in accuracy as the task progressed from easy to hard. Therefore the participant with higher activity level demonstrated better performance compared to the participant with less activity For older adults, semantic memory is more likely to be retained, while episodic memory is more likely to degrade. These results are consistent with the initial hypothesis. In order to answer the other hypotheses, more data must be collected.

One limitation to this research is that PALQ is a self-report questionnaire that relies on the participant's memory. The normally aging brain is more susceptible to episodic memory loss than semantic memory loss. Currently there is no better way to collect this kind of information, but this could affect the accuracy of the data. It will be necessary to be cautious when we make conclusions.

This initial finding is consistent with prior research about the potential benefits of physical activity and exercise for cognitive function. Even though fitness training studies conducted over the past few decades have not produced consistent results, some studies have found a positive relationship between fitness training and cognition. Fitness training is more strenuous and organized that simply going for a walk, and may be therefore somewhat less enjoyable and/or even stress-producing. Exercise that produces too much stress could be counter-productive, cognitively speaking.

Since most elderly adults do not find themselves in the "vigorously exercising" category. perhaps more study needs to be devoted to the topics of fairly light exercise and its potential benefits. More research is needed.

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Physical Activity over the Lifespan Questionnaire

The 3 purposes of this questionnaire are to:

1) List the physical activities participated in your adult life.
2) List the number of years participated in each of these activities.
3) Describe the intensity level of each of these activities in each decade with the words light, moderate or vigorous.

In the table that follows, please include every activity you can remember that lasted at least 1 year. Write the number of years you participated in each of these activities for each of the decades of your life, even if that is zero. Decades are in the columns headed by “20’s”, “30’s” etc. In addition to that, please pick either light, moderate or vigorous to describe the level of intensity you exerted for each of these activities, in each of the decades. Write L, M or V in the column headed with “I”. You can get ideas of possible activities participated in from the list on a following page, and there are definitions for light, moderate and vigorous activity below.

Please refer to the following definitions and letter codes for light, moderate and vigorous activity.

L (Light) - This activity creates very little change in my heart rate and no sweat. (ex. light Housework, briefly Walking).

M (Moderate) - This activity noticeably increases my heart rate and breathing rate. I may sweat, but I am still able to carry on a conversation. I can talk, but I can’t sing. (ex. Ballroom Dancing, Walking on a Treadmill).

V (Vigorous) - This activity is hard enough that I work up a sweat, get my heart pumping and/or get out of breath. (ex. Running, Biking uphill).

Please refer to the list on the next page for suggestions of sports and activities.

Listed below are possible ideas of sports and/or activities that people do. While this list attempts to be exhaustive, it is by no means inclusive.

Activity Ideas

Any sport, intramurals
Archery
Baseball
Basketball
Biking/cycling
Billiards/pool
Boat Racing
Boxing
Broomball
Calisthenics
Canoeing
Camogie
Cardio
Cheerleading
Climbing Stairs
Colorguard
Construction Projects
Croquet
Cross-Country Running
Cross-Country Skiing
Dance Dance Revolution (DDR)
Dancing (Ballroom, Jazz, Square, Swing, Tap, etc.)
Dodgeball
Dog Walking
Downhill Skiing
Diving
Elliptical training
Farming
Football
Gardening
Golf
Gymnastics
Hang Gliding
Health Club
Hi-impact Aerobics

Hiking
Hockey
Horseback Riding
Horseshoes
Housework
Hurling
Jazzercise
Jet Skiing
Jogging
Kayaking
Kickball
Lacrosse
Low-impact Aerobics
Marching Band
Motorcycle Racing (offroad/dirt track racing)
Paintball
Pilates
Playing with Kids/Grandkids
Raquetball
Rappelling
Rock Climbing
Rollerblading
Rollerskating
Rugby
Running
Sailing
Shuffleboard
Snowboarding
Snowmobiling
Snowshoeing
Soccer

Softball
Spinning
Step Aerobics
Surfing
Swimming
Tae BoT
Team Sport not listed (ultimate Frisbee, European team handball
Tennis
Triathlon
Volleyball
Walking
Water Aerobics
Water Polo
Water Skiing
Weight Lifting
Workout at gym
Wrestling
Zumba

1) List all the activities you have participated in over your adult life. 2) In each one of the decade columns (marked as 20's, 30's, etc.), estimate the number of years you have participated in each activity that you list, even if that is zero for some of the decades. 3) In the intensity columns (marked as Int.), please rate the level of intensity of each activity listed, in each decade. To rate intensity please use the letter codes L (Light), M (Moderate) or V (Vigorous). Use zero for the level of intensity if the activity was not done in that decade.

Name of Sport or Activity	20's	Int.	30's	Int.	40's	Int.	50's	Int.	60's	Int.	70's	Int.	80's	Int.
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														

Table 1

Participant	Raw Score	Weighted Score
1	135	48.3
2	193	109

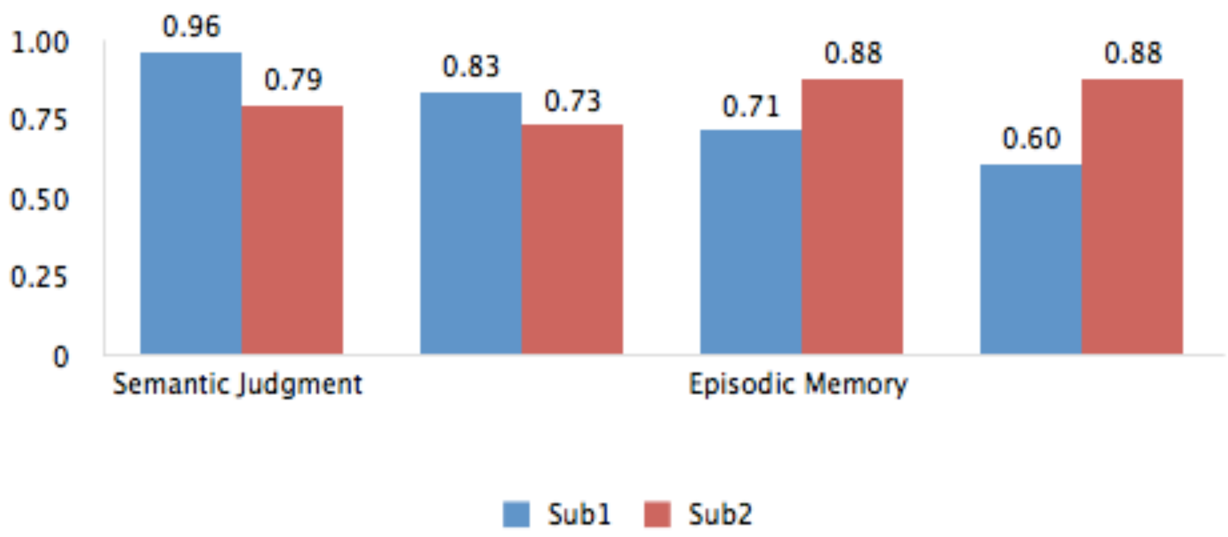

Figure 1