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Does Physical Activity Improve Cognitive Functioning? A Synthesis of the Research Literature

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A Synthesis of the Research Literature

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Accepted by the Department of Kinesiology, Sport Studies, and Physical Education, The College at Brockport, State University of New York, in partial fulfillment of the requirements for the degree Master of Science in Education (Physical Education).

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Abstract

The purpose of this synthesis was to examine the effects of physical activity on cognitive function. A comprehensive literature review was conducted to study the effects of physical activity on cognitive function in adolescents and adults, what types of physical activity impact cognitive function, as well as to determine the effects that physical activity has on people with Parkinson's disease.

Scholarly peer-reviewed articles were found completely online through the SUNY Brockport Drake Memorial Library Research Guides. Key words were selected to find pertinent articles related to the research questions.

Past and current research suggests that physical activity could be an important, natural, and simple way to promote the well-being of an individual at any age, socio-economic group, or lifestyle. Regular high-vigorous physical activity, primarily aerobic, has a direct relationship with the improvement of cognitive function at all ages (Davis et al., 2007; Kvalo, Bru, Bronnick, & Dyrstad, 2017; and Linde and Alfermann; 2014). Alberts et al., (2016), DE Assis, DE Silva, & Silva Dantas (2017), Fiorelli et al., (2017), Fisher et al., (2008), Hazamy et al., (2017), and Loprinizi, Danzel, Ulanowski, & Paydo (2017), each agree that regular physical activity has a positive effect on individuals with Parkinson's disease both physically and cognitively.

Chapter 1

Introduction

Physical activity is defined as any bodily movements that require the use of energy (Khan and Hillman, 2014). There are many tasks that are encompassed within the term “physical activity”. Some prefer aerobic workouts such as running, swimming, biking, etc., while some prefer anaerobic physical activity such as weight lifting and resistance training. Some people even stay physically active through daily life activities such as walking their animals, gardening, lawn care, construction, parking further away from stores, taking the stairs, or other activities that require energy use.

Physical activity and proper nutrition contribute to keeping people healthy (Semeco, 2017). Research has determined that physical activity is good for overall physical health, for lowering the risk of premature death, and in the prevention of chronic disease such as cardiovascular disease, diabetes, hypertension, obesity, depression, osteoporosis, etc. (Warburton, Whitney Nicol, & Bredin, 2006 and Semeco, 2017). Physical activity can also make people feel happier/better by releasing endorphins, can help people lose weight, tone muscles and strengthen bones, can help to naturally increase energy levels, and help with relaxation and improvement of sleep quality (Semeco, 2017).

However, the effects of physical activity on other systems in the body has received less attention. There are a growing number of research studies done on the topic of physical activity and its positive effect on cognitive functioning (Macdonald, Abbott, Lisahunter, Hay, and McCuaig, 2014). Not only is physical activity important for children but it is also potentially important to slow cognitive degeneration later in life. According to Chaddock, Voss, and Kramer (2012), there is a positive association between school achievement and physical activity as well as a lowered risk for cognitive decline in aging. Besides the obvious physical health benefits of regular physical activity, there may be cognitive health benefits that can greatly impact an individual across a lifespan.

Some research has shown that there is a positive correlation between physical activity and cognitive functioning. For example Zoeller (2010) concluded that physical activity improves executive function in adolescents and the elderly. Similarly, executive function in children was found to be significantly improved by regular MVPA (moderate to vigorous physical activity) (Davis, Tomporowski, Boyle, Wailer, Miller, Naglieri, & Gregoski, 2007).

The push for improved academia and high stakes testing is leading to students feeling pressured to “succeed”, to do well throughout school and life, sometimes at the expense of their health and wellness (Zabell, 2018). Recent statistics show that only one in three children are physically active for 60 minutes each day, with roughly the same number of adults receiving the recommended amount of physical activity each week. More than 80% of adults do not meet guidelines for both aerobic and anaerobic activities and in an older population, only about 40% of adults 75 years or older and about 30% of adults 65-74 report being physically active at all (“Facts and Statistics”, 2017).

As technology has grown so has time devoted to using that technology. Children now spend more than seven and half hours per day in front of a screen - tv, computer, phone, tablet, etc., and about one third of high school students report playing video games for three or more hours per day (“Facts and Statistics”, 2017). Both have contributed to lack of time spent being physically active. Additionally, only six states, Illinois, Hawaii, Massachusetts, Mississippi, New York, and Vermont, have physical education requirements for each grade, kindergarten through senior year of high school (NASPE, 2019).

Research has also found that physical activity can positively improve brain function and fight age related brain tissue loss (Marmeleira, 2013 and Khan and Hillman, 2014). Specifically, some forms of physical activity have been shown to delay and even reverse some of the symptoms related to Parkinson’s disease (Alberts, Phillips, Lowe, Frankemolle, Thota, Beall, Feldman, Ahmed, & Ridgel, 2016). Symptoms such as bradykinesia (slowed movement), rigid muscles, impaired posture and balance, and loss of automatic movement are all symptoms that people with Parkinson’s Disease live with each and every day of their lives (“Parkinson’s Disease,” 2018). These symptoms are typically treated through medications but research has shown that physical activity can help stop, and sometimes reverse these symptoms, in a natural and holistic way (Alberts, Phillips, Lowe, Frankemolle, Thota, Beall, Feldman, Ahmed, & Ridgel, 2016)

In summary, increased classroom time may not be the only way to improve academic achievement in children and medications are not always the only cure for disease in the elderly. There may be promise in looking at a holistic approach to health and cognition, one that includes physical activity. This is potentially an affordable way for many socio-economic groups to enjoy a long and healthy life.

Purpose

The purpose of this synthesis will be to explore the impact that physical activity has on cognitive function at different ages. Secondary purposes of this synthesis are to determine what types of physical activity are most effective in improving cognitive function as well as determine whether physical activity and exercise can have a positive impact on people with Parkinson's disease. By examining research related to these topics, this synthesis will help clarify the cognitive benefits of physical activity.

Research Questions

1. How does physical activity impact cognitive function at different ages - youth/adults?
2. What types and how much physical activity are most effective in improving cognitive function?
3. What impact does physical activity have on cognitive function in Parkinson's disease, in particular?

Operational Definitions

It is important to have a good understanding of some of the keywords that will be used throughout this synthesis.

These terms include:

1. Anaerobic Exercise- a short term exercise carried out by metabolic pathways that do not use oxygen. (Khan and Hillman, 2014).
2. Aerobic Exercise- longer sustained exercises that stimulate and strengthen the heart and lungs, improving the body's utilization of oxygen (Khan and Hillman, 2014).
3. Cognitive Function - an intellectual process by which one becomes aware of, perceives, or comprehends ideas. It involves all aspects of perception, thinking, reasoning, and remembering (Segen's Medical Dictionary, 2011)
4. Executive Function - responsible for a number of skills, including: Paying attention. Organizing, planning and prioritizing. Starting tasks and staying focused on them to completion. (Zoeller, 2010).
5. Moderate to Vigorous Physical Activity (MVPA) - Physical activity that is 3-6 MET's, 50-70% of MHR for moderate intensity or greater than 6 MET's, 70-85% MHR, for vigorous intensity ("Physical Activity Basics," 2019).

Limitations

1. Low number of participants across some studies resulted in limited statistical power to determine significant results.
2. Studies included in this synthesis use many different tests to measure cognitive functioning, results may vary depending on tests used.

Delimitations

1. Research articles used for this synthesis were published in peer-reviewed

journals between 2007-2019.

2. Research focused on studies that addressed lengths of physical activity at different ages, particularly regarding cognitive benefits.
3. To answer research question 4, subjects included only people who were diagnosed with Parkinson's disease.

Assumptions

1. It is assumed that all data collection is valid and reliable.
2. It is assumed that all test subjects answered questions truthfully.

Chapter 2

Methods

The purpose of this chapter is to review the methods used for data collection regarding the impact of physical activity on cognitive function. Data collection for this synthesis project was done completely online using peer reviewed journal articles relevant to the study. The data collection for the current synthesis was done using the SUNY Brockport Drake Memorial Library Research Guides in Kinesiology, Sports Studies, Physical Education, Exercise Science, Psychology Related and Medical Related Resources. Databases included: SPORTDiscuss with Full Text, Academic Search Complete, the Physical Education Index, PsychInfo, and CINAHL Complete.

The process of data collection started with keywords relating to the topic. Keywords used for searches included, "*exercise or physical activity and cognitive development*", "*physical activity or exercise and cognitive development and adults*", "*physical activity or exercise and cognitive development and children*", "*physical activity or exercise and Parkinson's Disease*", "*physical activity or exercise and Parkinson's Disease and cognition*", and "*physical activity or exercise and brain function and Parkinson's Disease*". Each of these terms or phrases were entered into each database (SPORTDiscuss with Full Text, Academic Search Complete, the Physical Education Index, PsychInfo, and CINAHL Complete). For each search, parameters were set that each relevant article would be peer reviewed, published between the years 2007 and 2019, in academic journals, and would have full text PDF available; either included or linked to the article for full analysis.

For each of the following initial searches listed, articles were scanned for pertinent information through their titles and abstracts. If the article didn't completely fit this synthesis or answer any of the four research questions, the article was not used. If the article seemed to fit the synthesis and potentially answer the research questions, it was read fully and saved for later analysis. Once these searches were complete, the articles that were saved were then once again analyzed and twelve articles that were most relevant to the topic and research questions were included in the critical mass.

In the SPORTDiscuss database with Full Text, the term "*exercise or physical activity and cognitive development*" was searched, and yielded 316 articles. Out of the 316 articles, three articles were found that were relevant to and pertinent to the synthesis. To get from 316 articles to the three that were used for this synthesis, key words in the title of the paper, abstracts, and other pertinent information was scanned. If those articles did not clearly fit the purpose of the synthesis they were then excluded from further research.

Also in the SPORTDiscuss database with Full Text, the search "*physical activity or exercise and Parkinson's Disease*" yielded 126 hits. Of those hits, one was found to be useful in this synthesis. Also, "*physical activity or exercise and Parkinson's Disease and cognition*" yielded only 31 hits. Of those 31 articles, one article was useful and included in this synthesis. In the Academic Search Complete Keywords database, "*exercise or physical activity and cognitive development and adults*" was searched. This search yielded 379 results of which only one was used for this project. Again, key words in the title of the paper, abstracts, and other pertinent information were scanned.

If those articles did not clearly fit the purpose of the synthesis they were then excluded from further research in this synthesis.

In the Academic Search Complete Keywords database, *“physical activity and aerobic and cognitive”* was searched. This brought 231 results of which two articles were deemed appropriate to be included in this study. Key words in the title of the paper, abstracts, and other pertinent information were then scanned. If those articles did not clearly fit the purpose of the synthesis they were excluded from further research within this synthesis.

The Physical Education Index database was found through a joint search in which one article was found and used in this synthesis. This joint search included the Physical Education Index, Academic Search Complete, as well as SportDiscuss with Full Text and the term “*physical activity or exercise and cognitive function*” was searched and 82,793 articles were yielded. Clearly, 82,793 articles was too broad of a search. On the first page, articles were scanned for information pertaining to this synthesis. This article stood out as clearly fitting to the synthesis. As this was the only article that stood out, it was included in the synthesis before a new and more specific search was conducted.

In the PsychInfo database, a search of “*physical activity or exercise and cognition and Parkinson’s Disease”* was conducted. A total of 124 articles came through in that search and two articles were useful and included in the synthesis. Again, key words in the title of the paper, abstracts, and other pertinent information was scanned. If those articles did not clearly fit the purpose of the synthesis they were then excluded from further research in this synthesis.

In the Medical Related Database, CINAHL Complete, the search of "*physical activity or exercise and brain function and Parkinson's Disease"* resulted in 27 articles. Key words in the title, abstracts, and other pertinent information were then scanned. If those articles did not clearly fit the purpose of the synthesis they were excluded from further research within this synthesis. One of those 27 articles were included in this paper.

A total of 12 articles were selected to represent the critical mass of the synthesis. These searches included articles in the following journals; *Aging and Mental Health, Archives of Physical Medicine and Rehabilitation, The Journal of Physical Activity & Health, Research Quarterly for Exercise and Sport, PLoS ONE, Human Movement, Disability and Health Journal, Brain and Cognition, Scandinavian Journal of Medicine and Science in Sports,* and *Parkinsonism & Related Disorders.*

An article grid was used throughout the literature review to document and summarize the research articles used for this synthesis. The article grid required information from each article to be summarized based on the Purpose, Methods and Procedures, Analysis, Findings, as well as Recommendations for future research for each of the articles. This process aided in summarizing pertinent information to use for this synthesis.

The articles that were chosen to be part of this synthesis included one qualitative, nine quantitative, and two mixed qualitative and quantitative designs. A few supporting articles used for background and supplemental information were included in chapter 1.

Subjects included in the sample size for this synthesis were both male and female (number not designated in each article), children (992 subjects), adults and the elderly (20,168 subjects), as well as adults with mild to moderate Parkinson's Disease diagnosed within the last one to six years (137 participants) and were assessed both on and off medications (137 participants). The total number of participants in this synthesis is 21,297 across 21 different countries in the world. Participants age ranges are between seven and 80 years old.

Subjects within the research used for this synthesis were assessed in many different ways. These tests included BMI, waist circumference, the Cognitive Assessment System (CAS) for executive function, SHARE Questionnaires, 12 month recall Baecke PA questionnaire, The Senior Fitness Test Battery, The Unified Parkinson's Disease Rating Scale Motor Exam (UPDRSM-111), The Wechsler Adult Intelligence Scale, and accelerometry to measure physical exertion. The information collected through these tests were then assessed and analyzed through ANOVA, 2x2 repeated measures ANOVA, ANCOVA, Mixed ANCOVA, Tukey Test, Tukey Post Hoc Test, with SPSS Versions 21, 22, 9.1.1 and 13.0, mean, standard deviation, Metlab Software Tools, Chi-square difference tests, multivariable linear regression analysis, MRI, and Voxel Based Morphometry on SPM 12 to compare white and gray matter.

Chapter 3

Review of Literature

The purpose of this chapter is to review the literature selected as part of the critical mass for synthesis. Included in the critical mass were twelve articles that met the criteria. These articles each fell under one of three categories which were developed in the review of literature and on how they were related to the synthesis. Additionally, these categories were developed to address the research questions that were previously mentioned. The three categories were (1) Cognitive Effects of Physical Activity; (2) Amount and Types of Physical Activity on Cognition; and (3) Physical Activity and Parkinson's Disease. There were three articles that addressed physical and cognitive effects of physical activity, three others that examined amount and types of physical activity, and six that investigated physical activity and Parkinson's Disease. These categories will help develop a full understanding of the effect that physical activity may have on the body and brain.

Cognitive Effects of Physical Activity

Kvalo, Bru, Bronnick, & Dyrstad (2017) sought to explore whether increased physical activity in school would effect childrens' executive function and aerobic fitness level. This "Active School" study was a ten month randomized control trial. Participants were 449 children aged ten or eleven years old who had a parent permission slip and verbally agreed to participate in the study.

The authors examined a total of nine elementary schools; there were five intervention schools that had 325 minutes of physical activity per week and four control schools that had 135 minutes of physical activity per week. Interventions included 45 minute physically active classroom lessons twice per week, 10 minute physically active breaks five times per week, and a 10 minute physically active homework assignment five times per week on top of the already required twice weekly 45 minute physical education class and once weekly 45 minutes of physical activity. The control group only completed the required amount of physical activity which was 135 minutes per week while the intervention schools completed 325 minutes of physical activity per week.

Measurements on the children included weight, height, and waist circumference. BMI was then calculated from these measurements. Aerobic fitness was assessed using a 10 minute interval running test administered by adults in the school familiar with the test. Executive function was measured using four different cognitive tests: the Stroop Golden color-word test (selective attention, response inhibition, self-control, and mental speed), verbal fluency (initiation, efficient organization of verbal retrieval and recall, and self monitoring), Forward and Backward Digit Span (working memory function) , and Trail Making (attention, speed of psychomotor execution, and mental flexibility) (Kvalo, Bru, Bronnick, & Dyrstad, 2017).

SPSS 21 was used for all statistical analyses. Mixed ANCOVA repeated-measures were used to find changes in scores for aerobic fitness and executive function (dependent variables) both pre- and post- intervention (independent variable). Gender, BMI, and waist circumference were entered as covariates.

Analysis of data shows improvement in executive function, across both groups, with significant effect ($P < 0.001$). Aerobic fitness, however, did not have a significant change (P = .281). Three of the seven cognitive tests showed significant improvement from pretest to post-test. The tests that were improved were color naming, verbal fluency, and digit span forward. The other tests showed no significant change. The authors may conclude from this study that increased physical activity may increase children's executive function, although there were no significant changes in aerobic fitness.

Bourassa, Memel, Woolverton, and Sbarra (2015) sought to determine whether social participation predicts cognitive functioning based on individuals physical health status, depression, and physical activity levels. This study included a data set which had four waves of data, ranging from 2004-2012. Participants were selected from 19 European countries and Israel. The study participants included 19,832 aging adults who were 64 years old on average. Questionnaires were used as the main form of data collection. The SHARE Questionnaire included psychological states, physical health, and demographic variables such as age, gender, and household income. Cognitive functioning was measured by verbal fluency, immediate word recall, and delayed word recall. Executive function was measured using a category fluency task. Ten- Word Delayed Recall Test was used to measure memory function. Social participation was measured by the sum score of answers to four questions regarding participation in social events over the past month. It is important to note that social participation was categorized into four groups, one of the groups being a sport, social, or other type of club. A fitness group, fitness club, gym membership, yoga class, or any other type of physical activity promotion could be included in this category. Physical health was measured using participant's responses to a 5-point Likert-scale questionnaire. Scores were then coded for analysis. Finally, physical activity was measured using a single item self report questionnaire. The subjects' responses to this 4-point scale were then coded for later analysis as well.

Assessments were made using an estimated latent curve growth model for memory and executive function over time. The full SHARE sample was split into two random sub samples. The intercept and slope were estimated freely through the LCGM at time 0, time 1, and time 3. Time 2 was excluded as it did not include social or cognitive measures. Chi-square difference tests were then run to determine the best LCGM. Once the best LCGM was determined, the strength of associations were examined by comparing the standardized estimates of the within-occasion associations across all four time periods. Those values represent the amount of standard deviation change in the cognitive outcomes predicted by a 1SD change in the predictor. All models were run in MPlus v. 7.2.

Evidence in this study shows that social participation, health, and physical activity all significantly play a heavy role in positive promotion of memory, executive function, and successful aging of the brain. Adversely, low physical activity level at T0 was found to predict a faster decline in memory and executive function. These results were all replicated in the second random subsample of participants. The authors conclude that this study has demonstrated that increased amounts of social participation, higher amounts of self-reported physical activity participation, and lower self-reported levels of depression and mental health each play an important role in cognitive functioning and successful aging in older adults.

Linde & Alfermann (2014) is a research study in which the authors examined the short and long term effects of physical, cognitive, and combined physical plus cognitive training regimens on cognitive abilities. The study included a baseline test, 16-week intervention program, post-test, and then a 12-week wait period with a follow-up assessment. Participants chosen for the study were 70 healthy seniors, of which 63 returned for both the post assessment and follow-up assessment. Participants were between 60-75 years old. Test subjects were split into four intervention groups; an exercise training, cognitive training, combined exercise and cognitive training, or waiting control group. Each group participated in baseline cognitive standardized tests of short term memory (Word List Test), concentration (d2: Test of Attention), reasoning (Leistungs-Pruf-System 50+), processing speed (Trail Making Test Part A), cognitive speed (digit symbol substitution test), and spatial relations (LPS 50+) prior to the intervention program.

The intervention groups were as follows: 1. physical activity - moderate aerobic endurance training along with moderate strength training two times per week for 60 min each time; 2. cognitive training - one time per week for thirty minutes using a five minute warm up as group (info processing, attention, memory model, sensory memory, memory, short term memory, mnemonics, long term memory, and memory aids) followed by individual editing of worksheets; and 3. a combined physical activity and cognitive intervention twice per week with cognitive and physical activity training one time per week for ninety minutes and just physical activity once per week for sixty minutes. Intensity of activities was measured by PolarFS1c heart rate monitors for consistency in training between groups. Cardiovascular fitness was measured using a

2km walking test. The researchers administered an evaluation to each participant to subjectively assess overall satisfaction of the intervention program.

SPSS 19 was used for all statistical analysis in this study. Baseline differences were assessed through MANOVA (multivariate analyses of variance) for continuous variables and chi-square tests for categorical variables. A 2-way ANOVA with repeated measures was conducted to test cognitive performance of the intervention groups on the control group at the post-test and follow-up time periods.

Results of this study indicate that the combined intervention group performed better than the control group at both assessments, post-test and follow-up. In the cognitive intervention only group, results showed better performance at follow up for the combined intervention group than for the control group. An ANOVA revealed that all intervention groups performed better on concentration tasks than the control group at post assessment. The cognitive intervention enhanced cognitive speed and concentration immediately and at the follow-up. The physical intervention group improved concentration at the follow-up assessment and the combined intervention group improved cognitive speed and concentration both immediately and at the follow up assessment. Short-term memory, elementary information processing speed, spatial relation, and reasoning were all functions of the brain that were not affected by any of the interventions in this study.

The authors of this study concluded that physical and cognitive activities may lower the risk of age-related decline. Only participation in physical activity may lead to a persistent improvement of executive function (Linde & Alfermann, 2014). However, each of the three - physical, cognitive, and combined activities - may be seen as cognitive enriching behaviors in healthy older adults.

Amount and Types of Physical Activity on Cognitive Function

Davis et al., (2007) conducted a study that sought to address the effect of aerobic physical activity on executive function in overweight children. Ninety four overweight children with an average age of nine years were included in the study. The participants were randomly split into three groups: a control group with no physical activity; a low dose 20-minute physical activity group; and a high dose 40-minute physical activity group. Each group would work out at their respective doses five times per week for a total intervention time of fifteen weeks. The participants were evaluated with a pre and post test of the “CAS” or Cognitive Assessment System, BMI, and an aerobic fitness treadmill test. The CAS is a type of standardized test that measures children’s abilities in four interrelated cognitive processes including planning, attention, simultaneous, and successive (PASS).

Data was analyzed using ANCOVA, the Analysis of Covariance. It examined the differences between pre- and post- test scores of cognitive ability in various activity levels (Davis et al., 2007). SPSS 9.1.3 and SPSS 13.0 were used for statistical analysis. Results from ANCOVA showed that the control group had statistically lower posttest scores than the high dose group. Although there were not great statistical differences, the high dose group also had higher posttest scores than the low dose group did. The authors concluded that there is a direct relationship between high-vigorous physical activity and the improvement of children’s executive brain function (Davis et al., 2007).

Esmaeilzadeh, Hartman, Farzizadeh, Azevedo, Kalantari, Dziembowska, Kostencka, Narimani, & Abravesh (2018) examined different aspects of fitness, aerobic fitness, static strength, explosive strength, agility, and speed, on cognitive performance. Two hundred eleven university male students, aged 18-22 years old, were included in this study. This study was completed during regular physical education lessons. Mean age, height, weight, and fat% were taken at baseline. The 12 month recall Baecke PA questionnaire measured both physical activity level during leisure time and sport during leisure time on a 5-point Likert Scale. PA during leisure time was defined as any type of activity done out of the ordinary while sport during leisure time was defined as an organized and group type of sport activity. Speed, agility, physical fitness components, information processing, and inhibitory control (response to stimuli) assessments were also taken at different times throughout the study. Cognitive and fitness tests were taken after familiarization of participants to researchers while static strength (hand grip test), explosive strength (standing long jump), and aerobic fitness (1-mile run) were measured during the 1st week. Speed (40-meter sprint) and agility (4x9 meter shuttle run) were measured the following week.

There were four tests used to assess information processing speed and all tests were performed in the same sequence for all participants. The tests were clinical reaction time, simple visual reaction time, simple audio reaction time, and 4-choice reaction time. Each of these assessments was done on a computer in an empty room with the participant seated at rest. Inhibitory control was measured using the Simon Task and Stroop Task assessments.

Descriptive statistics were used for all variables. Initial Pearson Product Moment correlations were completed on composite cognitive scores, demographic variables, adiposity, physical activity level and fitness test scores. Multiple linear regression analyses using the ENTER method and adjusting for confounder were conducted between composite cognitive scores and fitness components. All statistical analyses were performed using SPSS v.21.0 software for Windows (Esmaeilzadeh et al., 2018).

Regression analysis revealed that aerobic fitness was positively associated with composite inhibitory control scores, meaning that higher aerobic fitness is associated with shorter inhibitory control. Aerobic fitness was also negatively associated with change in Simon Task score. This shows that participants with a higher aerobic fitness score presented a larger change in pre- and posttest Simon Task score. Explosive strength was found to be negatively associated with composite information processing scores as well as composite inhibitory control scores. Speed of movement, static strength, and agility were each found to have no impact and were not associated positively or negatively with any cognitive test used within this study.

The authors of this article can conclude, based on the findings of their study, that aerobic fitness and explosive strength may be indicators of positive cognitive functioning in this sample group (Esmaeilzadeh et al., 2018). Speed, agility, and static strength may then be ruled out as having a positive impact on cognitive function.

Rehfeld, Luders, Hokelmann, Lessmann, Kaufmann, Brigadski, Muller, & Muller (2018) was an article that looked to distinguish the specific effects of a dance training program vs. a sport based training program which incorporated primarily repetitive movements such as cycling, on the brain. Participants for this study included 52 seniors; split fairly evenly with 25 male subjects and 27 female subjects between the ages of 63 and 80 years old. Fourteen of the original subjects did not complete the experiment for different reasons, leaving a total of 38 complete data sets from which to draw conclusions.

This study included a six month intervention program where subjects were randomly assigned to an experimental dance group (DG) or a control sporting group (SG). Intervention for both groups occurred two times per week for 90 minutes. Intensity, frequency, and duration were matched by both groups during intervention. Heart rate was taken after warm up twice, during exercise and after cool down, to keep workload even among all participants.

A qualified dance instructor and qualified trainer supervised each DG and SG training session respectively. The DG intervention included a continuous learning of choreography; including movement patterns and coordination training. The DG intervention was split into three two month long sessions for different types of dance and music. The SG intervention program included endurance training performed on a stationary bike with intensity adjusted to match all participants as well as training which includes barbells, rubber bands, medicine balls, and gymnastics sticks. The SG repeated the same exercises of endurance, strength, and flexibility, over and over repeatedly.

Assessments were completed at baseline, before intervention, and after the completion of the six month intervention program. An MRI (magnetic resonance imagining) was performed on a 3 Tesla Siemens MAGNETOM Verio Scanner. To directly compare both groups' gray and white matter in the brain, the VBM method implemented on SPM 12 was used. Cognitive tests included assessments on the following: attention (alertness, Go/nogo, divided attention, flexibility), processing speed (trail making test), verbal word fluency, short term and working memory (digit span forward and backward of the Wechsler-Memory Scale), verbal episodic memory (verbal learning and memory task), and visuospatial memory (Rey-Osterrieth-Complex-Figure Test). The Physical Working Capacity 130 Test assessed endurance-related fitness for participants when on the stationary bike. This test measured heart rate and highly correlates with VO2 max.

T1-weighted images of baseline and post measures for each participant were taken to run pairwise longitudinal regression. At baseline, t-tests for independent samples compared volume changes in gray and white matter between the two groups and no significant differences were found. Gray and white matter were then compared after intervention using DARTEL (Diffeomorphic Anatomical Registration Through Exponentiated Lie Algebra), where normalized and smoothed images displayed volume changes in each. Cognitive and physical data was assessed using SPSS 22. Intervention effects were tested using repeated measurements ANOVAS with group as the between subject factor and time (pre-, post-) as the within subject factor.

After a six month intervention program, both groups increased their aerobic fitness. In regards to grey and white matter in the brain, the DG increased volume in the cingulate cortex, insula, corpus callosum, and sensorimotor cortex, in comparison to that of the CG. Regarding cognition, there were no significant group differences found however both groups did significantly improve areas of the brain in which are associated with higher attention and spatial memory (Rehfeld, 2018). The authors conclude that both a well planned and delivered dance program, as well as a repetitive aerobic based physical activity regimen can both increase cognitive processes which are related to regular age-related cognitive decline.

Physical Activity and Parkinson's Disease

Alberts, Phillips, Lowe, Frankemolle, Thota, Beall, Feldman, Ahmed, & Ridgel (2016) sought to compare acute effects of forced exercise with the effects of anti-Parkinsonian medication for the pattern of functional MRI activation and symptom improvement in people with Parkinson's Disease. A total of nine participants were used that had mild-moderate Parkinson's Disease (six male, three female, mean age 61). Subjects had been diagnosed with PD for one to six years before the study.

Data was collected at three different times. The first time was when patients were off medications, the second the patients were currently taking their prescribed medications, and the third measurement was taken when patients were off medications and an intervention of forced exercise (FE) was introduced. Guidelines for the study included the "off medication" group to have at least 12 hours since their last dosage of medication. The "on medication" group was to take their regular dose of medication one hour prior to evaluation. The intervention group (off medication plus FE) required participants to complete FE intervention session one hour prior to evaluation. The FE session included a 10 minute warm up, 40 minute FE set where the trainer augmented the patients efforts to achieve a higher stationary pedaling rate greater than what the patient could produce on their own, and a 10 min cool down.

SPSS Version 22 was used for all statistical analyses. Before the functional MRI (fMRI) evaluation session, PD symptoms were evaluated using the Unified Parkinson's Disease Rating Scale Motor Exam (UPDRSM-III). Data was then analyzed with a one-way ANOVA with condition for each of the three groups. Post-hoc pair-wise comparisons were performed using a Tukey Test when needed. Correlation analysis was run on calculated differences between UPDRSM-III scores.

In the UPDRS-III, all but one patient improved scores in the on medication group vs. the off medication group. All nine improved scores in the off medication plus FE group when compared to the OFF medication group. Medications only improved UPDRS-III ratings by 37% compared to off medication. UPDRS-III ratings improved 48% in the OFF medications +FE group vs. off medications only. Post -Hoc Tukey test demonstrated ratings were significantly improved ($P < 0.001$) when comparing on medication to off medication ($P = 0.002$) and when comparing off medication to off medication +FE ($P<0.001$). There was no statistical difference between the on medication group and off medication + FE group ($P = 0.43$).

Forced exercise and anti-Parkinsonian medication produce similar levels of improvement in PD symptoms. Both FE and medication produced significant improvements in PD symptoms without any reported side effects. Therefore, authors of this study conclude that forced exercise may be a useful, holistic, alternative to medication.

DE Assis, DE Silva, & Silva Dantas (2017) sought to evaluate the effects that aerobic exercise with dual-task has on the motor function in participants with Parkinson's disease. Participants included 20 patients with Parkinson's Disease, aged 59-73 years old, who were randomly divided into two groups; a control and experimental group. The control group remained in a sedentary routine for four weeks while the experimental group was enrolled in a four week aerobic exercise program with 30 minute sessions of water-walking. The water walking program consisted of a two week adaptation phase in a 120-cm deep pool with dimensions of 12/12.5 meters. Subjects wore a Colet Power EVA floater for safety. Heart rate and blood pressure were recorded before and after each session. During this phase, the Borg scale of perceived exertion was used for subjective control of intensity. At the completion of this period, the exercise phase started. This consisted of a 10 minute free standing warm-up, then subjects were to walk back and forth (25m) as many times as possible for 30 minutes. Subjects were also required to complete 15 different motor tasks for one minute each (15 minutes of motor task, 15 minute free standing). This session was ended with a 10 minute cool down of stretching exercises.

Prior to interventions, questionnaires were used for demographic and psychometric evaluation on executive function and fitness level. The Unified Parkinson's Disease Rating Scale Motor Exam (UPDRSM-III) was incorporated in this study as well as the Senior Fitness Test which assesses strength and agility. All physical tests were conducted four days before and after exercise sessions.

Independent t-tests were run to compare parametric variables and the Mann-Whitney-U test for nonparametric variables. ANOVA split-plot (2 x 2) with Bonferroni's post hoc were applied for inter- and intragroup comparisons. Statistical analyses were run through SPSS 22.0 software.

No significant differences were found for perceived effort in the sessions. The post hoc Bonferroni test showed a significant difference in executive motor function between pre- and post-intervention.

The results were exercise intensity dependent.The UPDRS III revealed that Parkinson's Disease patients had significant improvements in the pre- and posttest exercise of motor function with moderate effect ($P < 0.001$). Bradykinesia ($p < 0.001$), low limb agility ($p < 0.001$), and postural stability ($P < 0.05$) each exhibited significant changes as well. The authors of this study conclude that aerobic activity may play an important role in neuroplasticity and that it has proven to be an effective way to improve general motor function in patients with Parkinson's Disease. In other words, acute aerobic activity demonstrated an ability to better promote cognitive performance in attention auditory memory, visuomotor tracking and processing in people with Parkinson's Disease.

Fiorelli, Ciolac, Simieli, Silva, Fernandes, Christofoletti, & Barbieri (2019) aimed to investigate the acute effects of high-intensity interval training (HIIT) versus continuous moderate-intensity training (MICT) on cognitive function in people with PD. Participants included 14 individuals with Parkinson's Disease. Inclusion criteria included a Mini-Mental State Examination score which was greater than 24, no signs of dementia, no severe cardiovascular diseases, or other neurological disorders.

The individuals with PD performed cognitive tests both before and after three intervention sessions. Researchers used intervention sessions including a control group (a 30 min seated rest session), a HIIT group (four minute warm up, then 21 minutes of one minute intervals mixed with two minute moderate interval session), and a MICT group (a 30 min moderate exercise session). Each study participant was chosen to complete one of the three sessions. HIIT and MICT sessions were performed on a stationary bike. Participants completed these assessments on three different days within a seven day time frame.

Four tests from the Wechsler Adult Intelligence Scale-III were used to assess cognitive functioning in the study participants. These tests included the Associated Verbal Pairs, Symbol Search, Digital Span, and trail making test, parts A and B. The tests were used to evaluate attention, working memory, processing speed, executive functions and visuomotor skills. Cognitive measures were compared by a mixed-model analysis for repeated measures. Also, the Tukey post hoc test was used to identify the significant differences when a significant main effect was found.

Acute effects of exercise are as follows: MICT improved immediate auditory memory ($p < 0.001$); HIIT improved immediate auditory memory ($p<0.02$); attention ($p<0.001$) and sustained attention ($p<0.01$); and the study found that the control had no effect on cognitive functioning. Working memory was also not affected after any of the study groups. The authors of this study conclude that acute bouts of HIIT and MICT both improve cognitive functioning without medicine in people with Parkinson’s Disease, which may enhance the quality of everyday cognitive and motor tasks.

Fisher, Wu, Salem, Song, Lin, Yip, Cen, Gordon, Jakowec, & Petzinger (2008) sought information on the effects of high-intensity exercise on functional performance in people with PD in relation to low and no intensity exercise.This eight week randomized control trial included 30 participants with Parkinson's Disease. Each participant had been diagnosed with the disease within three years of the study.

The study used treadmill training only for each group. Groups included a high-intensity(HI) group (24 progressive exercise sessions), a low-intensity (LI) group (24 progressive exercise sessions), and a no intensity group (six education classes). For treadmill training, participants were hooked up to a harness system attached overhead for weight support. The goal at the end of the sessions was for participants to be able to continuously walk for a 45 minute time period. Data was collected before and immediately after intervention sessions. Baseline tests included age, duration of PD, UPDRS-III (Unified Parkinson's Disease Rating Scale Motor Exam) score, MMSE (Mini-Mental State Exam) score, and PD medications taken. A walking test, sit-to-stand test, and TMS (transcranial magnetic stimulation) were used as physical assessments.

Data were analyzed using the Matlab software tool. TMS trials were analyzed for CSP length, or the length of time between a TMS pulse and its first return on electromyographic activity of at least 50% strength. Each trial was completed ten times. If no pulse was returned, time was marked as zero milliseconds (ms). Mean and standard deviation were calculated pre- and post-test.

Results of this study show that the HI group portrayed postexercise increases in gait speed (4.4%), step length(5.8%), stride length (4.7%), as well as hip excursion (7.5%), and ankle joint excursion (4.6%). The LI and zero intensity groups didn't show improvements in gait or sit-to-stand measures. For CSPmax, the HI group had an increase in duration of 32ms on average while the LI and zero intensity groups showed an average decrease of 17ms.

The authors of this study conclude that dose-dependant physical activity (High Intensity) may benefit people with PD and that high intensity exercise can normalize excitability in early stages of PD.

Hazamy, Altmann, Stegemoller, Bowers, Keun Lee, Wilson, Okun, & Hass (2017) sought to examine the effects of cycling on cognitive performance in people with Parkinson's Disease (PD). A secondary purpose was to examine the effects of cycling on cognitive performance. This study included 39 individuals with Parkinson's Disease; including 21 healthy older adults (HOA). PD patients mean age was 66 years old and HOA mean age was 73.

Participants all took single and dual task cognitive tests consisting of twelve tasks. Tasks were of varied degree of difficulty, but given to each participant in the same order using MediaLab version 2006.2.40. Tasks measured processing speed (speed of articulation task, visual attention task, digit symbol substitution test), controlled processing (Stroop colors, a Stroop color-word task, and a visual 0-back task), working memory (Digit Span Forward, Digit Span Backward, visual 1-back task, visual 2-back task), and executive function (verbal operation span task, novel visual memory updating task). The participants were randomly chosen to perform single task sessions then dual task sessions or vice versa. Single task sessions were done in a quiet room at a desk and dual task was done on a stationary bike with a screen in front of them. Responses were voice activated in both.

A 2 x 2 repeated measures ANOVA was performed for each cognitive task separately. All statistical analyses were conducted using IBM SPSS statistics for Windows 21 version 21.0.

Both groups exhibited dual task facilitation of response times in visual tasks across cognitive domains and improved verbal recall during an executive function task. Analysis found that participants responded much faster during dual task cycling sessions for processing speed and executive function than they did during single task. No significant differences were found for controlled processing or working memory. As was expected, the PD group performed slower in all task sessions when comparing their performance to that of the HOA group. The authors conclude that pairing cognitive tasks with cycling may actually improve cognitive performance and may have a positive relationship with slowing cognitive decline associated with aging and PD pathology.

Loprinizi, Danzel, Ulanowski, & Paydo (2017) sought to evaluate the association between physical activity and older patients with Parkinson's Disease. Twenty five individuals with PD were included in this study with a mean age of 69 years old. The Montreal Cognitive Assessment (MoCA) was used for assessment and measured attention, concentration, executive function, memory, language, visuoconstructional skills, conceptual thinking, and recall. This test takes approximately ten minutes to administer and a total of 30 points can be scored, the higher the score the better.

Moderate to vigorous physical activity was assessed by an ActiGraph GT1M accelerometer over a one to two week period while the accelerometer was worn. This results in data that is an objective measure of physical activity intensity. All statistical analyses were run in Stata. A multivariable linear regression analysis was used to examine the relationship between MVPA and cognitive function.

Participants on average engaged in 10.6 minutes of MVPA per day. Results from this study show that for every one minute per day increase in MVPA, participants had a 0.09 unit increase in MoCA determined cognitive functioning ability. These results suggest there is a positive relationship between daily PA and cognitive function in adults with PD. Authors from this article conclude by stating that in patients with PD, the more MVPA engaged in per day the higher that person's cognitive functioning may be.

Chapter 4

Synthesis of Results

The purpose of this chapter is to synthesize the results of the literature review on the impact of physical activity on brain function in different populations. In order the address research questions, it was important to find similarities and differences within the research.

The purpose of this synthesis was to explore the impact that physical activity has on cognitive function in different populations. Secondary purposes of this synthesis were to determine what types of physical activity are most effective in improving cognitive function as well as determine whether physical activity can have a positive cognitive and physical impact on people with Parkinson's disease. By examining research related to these topics, this synthesis may help clarify the cognitive benefits of physical activity in these populations.

Research Question #1 - How does physical activity impact cognitive function at different ages - youth/adults?

The purpose of this section is to evaluate the connection between physical activity and brain function. The review was done to evaluate the relationship between the two; to increase learning in schools, create better overall health, decrease the symptoms of aging, and raise awareness on the topic. After completing the research, the findings show that there is in fact, a positive correlation between physical activity and the brain. At all ages, data from research proved this to be true.

In the youth population, research from the studies come to the same conclusions. In an article by Davis, et al., (2007) researchers found quantitative evidence to demonstrate that regular high-vigorous physical activity has a direct relationship with the improvement of children's executive brain function. However, no significant impacts were found in other areas of brain function such as attention or simultaneous functioning. This information by Davis, et al., (2007) was found to be dose dependent. This means that there was a direct correlation between dosage of physical activity and cognitive function.

Kvalo, Bru, Bronnick, & Dyrstad (2017) also describe dose dependency in results for a youth population indicating an improvement in post-intervention assessment for executive function (color naming, verbal fluency, and digit span forward) in a high-dose daily physical activity group. Interestingly enough, although cognitive functioning through physical activity in this population improved, aerobic fitness levels did not.

Aerobic fitness level, however, was found in another article, to have a direct relationship with cognitive function (Esmaeilzadeh et al., 2018). One difference is that in this article, the positive relationship was observed between aerobic fitness and composite inhibitory scores. Executive function was not tested within this study. In different cognitive assessments, each article supports the data which states that increased physical activity increases cognitive functioning in youth.

In the article by Bourassa, Memel, Woolverton, & Sbarra (2017), studying an adult population, evidence was provided that shows social participation plays a heavy role in cognitive functioning and successful aging. It must be noted that within the article, social participation included a sport, social, or other kind of club; including gym membership, fitness classes, and events that keep people physically active. The evidence in this article stated that low physical activity levels in the study predicted a faster decline in memory and executive function while a higher reported physical activity level throughout the study showed the opposite; a slower decline in memory and executive function (Bourassa, Memel, Woolverton, & Sbarra, 2017). These results were replicated in a second sub sample. Self-reported physical activity level, and physical health were all associated with higher levels of memory and executive function.

This data was supported through the recent research done by Linde and Alfermann (2014). Analyses in this study revealed that all intervention groups (exercise training only, cognitive training only, and combined exercise and cognitive training) performed better than did the control group (no exercise or cognitive training) at post assessment. There was also a large effect size for the combined group and physical group. In other words, both groups with exercise training in their intervention program greatly improved cognitive function in adults. It was concluded that physical activity lowered the risk of age related decline of cognitive abilities.

These research results, however, are challenged in a Rehfeld et al., (2018) study which showed that effects of physical activity on cognitive function were low and showed no significant differences in results. The authors stated that there is a strong potential for physical activity to induce more positive effects on brain volumes in this population, including working memory and attention, which are closely associated with age-related cognitive degeneration. Overall, there was more evidence and research found in this synthesis which supported the idea that physical activity positively impacts cognitive function in adults. Therefore, it may be concluded that there may be a direct positive relationship between the two.

Research Question #2 - What types and how much physical activity are most effective in improving cognitive function?

Throughout this research, articles were analyzed and common themes emerged in regard to this research question. These themes were aerobic physical activity, anaerobic physical activity, and dose dependency. Aerobic activities included repetitive activities which lasted at least thirty minutes in duration during intervention such as running and biking. Anaerobic physical activities included short bursts of high intensity energy such as speed training, agility, static strength, explosive strength, and even dance.

In a 2014 article by Linde and Alfermann, both aerobic and anaerobic physical activity regimens were analyzed. This research found that both types of physical activity had a positive impact on cognitive function through a higher post-assessment and follow-up assessment score than the control group had. These findings were then replicated throughout the rest of the research for this synthesis. Aerobic activity was further found to support these findings in other studies.

In the Davis et al., (2007) article, researchers found that high-vigorous aerobic activity has a direct positive relationship on executive function. Esmaeilzadeh et al., (2018) agreed, stating that a positive association was observed between aerobic fitness level and parts of cognitive functioning, inhibitory control scores, within their research. The research done by Kvalo, Bru, Bronnick, & Dyrstad (2017) also support these findings. Their research indicated an improvement in executive function for the low-dose and high-dose daily aerobic physical activity group.

However, the low-dose group had a lower significance than the high dose group did. In each of these articles, dose-dependency (direct correlation between dosage of physical activity and cognitive function) was found to be very important in results. Davis et al., (2007), Kvalo, Bru, Bronnick, & Dyrstad (2017), and Linde and Alfermann (2014), all agree that high-vigorous physical activity has a greater impact on cognitive function than does low or no physical activity.

In regard to types of physical activity different from aerobic activity, Rehfeld et al., (2018) as well as Esmaeilzadeh et al., (2018) each studied this but in different ways. Rehfeld et al., (2018) looked to compare a dance training program with a sport based program comprised of primarily a repetitive movement, stationary biking. Here, they discovered that both the dance program and sport-based program each have a strong potential to induce more positive effects on brain volumes including working memory and attention. They found no significant differences in cognitive function based upon training type.

Interestingly, Esmaeilzadeh et al., (2018), did find cognitive differences in anaerobic training type. Significant relationships were found between explosive strength and information processing and inhibitory control scores. Esmaeilzadeh et al., (2018) also found that there was no association between cognitive tasks and speed of movement, agility, or static strength.

Based upon the information found throughout this synthesis, a few results have become clear. Aerobic fitness and anaerobic fitness in any capacity have the potential to increase cognitive functioning. However, it has been demonstrated that high-vigorous aerobic physical activity has a greater impact on cognitive function, primarily executive function, than does low or no aerobic physical activity. Anaerobic physical activity still may impact the brain but in a lesser way. In this synthesis research showed that there is a direct relationship between the amount of physical activity and its impact on the brain with less significant importance on type of physical activity. In conclusion, increased physical activity, in any amount is positive for a healthy brain function and cognition.

Research Question #3 - What impact does physical activity have on cognitive function in Parkinson's disease, in particular?

This research question sought to bring awareness to Parkinson’s disease and analyze whether or not holistic type treatments, i.e., being physically active, could have a positive impact on individuals with Parkinson’s disease by slowing down the degeneration of the body and brain. After completing the research to answer this question, a few results became clear.

DE Assis, DE Silva, & Silva Dantas (2017), found that Parkinson’s Disease patients had significant improvements of motor function, specifically on Bradykinesia, low limb agility, and postural stability after just a four week intervention. Not only were physical effects found in this research but acute aerobic physical activity demonstrated an ability to better promote cognitive performance in attention auditory memory, visuomotor tracking and processing in this population as well.

In that study, the findings did not indicate that one type of acute aerobic exercise was better than another. Research done by Loprinizi, Danzel, Ulanowski, & Paydo (2017), agree by stating that the results in their study suggest there is a positive relationship between daily physical activity and cognitive function in adults with Parkinson's disease. However, because of the study design, there is no evidence to designate one type of physical activity better than another. Results were further supported by Hazamy et al., (2017) whose results suggest that pairing cognitive tasks with physical activity can actually improve cognitive performance. They add that physical activity does have a positive relationship with slowing cognitive decline associated with aging and Parkinson's disease pathology.

A few articles in this synthesis found improvements in this population based upon dose-dependency. Fisher et al., (2008) discovered a high-intensity group portrayed postexercise increases in gait speed, step and stride length, as well as hip and ankle joint excursion while a low intensity and zero intensity group didn't show improvements in gait speed or sit-to-stand measures. The research by Fiorelli et al., (2017) support the findings of Fisher et al., (2008). Fiorelli et al., (2017) found acute effects of exercise as follows: zero physical activity had no effects on cognitive function, moderate intensity training improved immediate auditory memory, and high intensity training improved immediate auditory memory, attention, and sustained attention. In this study, it was clear that memory was not affected in any of the study groups.

Fiorelli et al., (2017) added that these findings could be practical in use for cognitive function in people with Parkinson's disease without the use of medication. In a 2016 article by Alberts et al., findings support the previous findings and add to them by stating that there were no cognitive or physical differences between patients when they were on Parkinson’s disease medication and when they were off medication but were forced to participate in physical activity. Forced physical activity and anti-Parkinsonian medication both produce similar levels of improvement in Parkinson’s disease symptoms without any reported side effects. This is important because it may be a holistic and useful alternative to medication for this population.

Loprinizi, Danzel, Ulanowski, & Paydo (2017), do add to their research that muscle strengthening physical activities should be used with other types of physical activity to retain mobility or fight mobility issues in this population.

In conclusion, Alberts et al., (2016), DE Assis, DE Silva, & Silva Dantas (2017), Fiorelli et al., (2017), Fisher et al., (2008), Hazamy et al., (2017), and Loprinizi, Danzel, Ulanowski, & Paydo (2017), each agree that regular physical activity has a positive effect on individuals with Parkinson’s disease both physically and cognitively, especially on slowing down the rate of degeneration of the brain. They each also agree that physical activity may have a positive impact on age related declines throughout the body.

Chapter 5

Conclusion and Recommendations for Future Research

This synthesis set out to explore the effects of physical activity on the brain and cognition. Specifically, the purpose of this synthesis was to answer the three research questions earlier stated which include: (1) How does physical activity impact cognitive function at different ages - youth/adults? (2) What types and how much physical activity are most effective in improving cognitive function? (3) What impact does physical activity have on cognitive function in Parkinson's disease, in particular? After a thorough review of the literature, several categories emerged which helped to answer the research questions. These categories, based on the research questions, helped to then provide a basis for the following conclusions.

After completing the review, the overall findings indicate that there is in fact, a direct positive correlation between physical activity and brain cognition at all ages (Davis et al., (2007), Kvalo, Bru, Bronnick, & Dyrstad (2017), Bourassa, Memel, Woolverton, & Sbarra (2017), and Linde and Alfermann (2014). These findings indicate that regular physical activity is not only good for overall cognitive health but for other areas of positive cognitive health as well.

Aerobic physical activity, anaerobic physical activity, and explosive strength in any capacity has been found to have the potential to increase cognitive functioning, primarily executive function, inhibitory control, information processing, successful aging, as well as the previously stated overall improvement in cognitive functioning . Activities such as speed, agility, and static strength were not found to have a significant impact on cognition. (Davis et al., (2007), Kvalo, Bru, Bronnick, & Dyrstad (2017), Bourassa, Memel, Woolverton, & Sbarra (2017), and Linde and Alfermann (2014), Rehfeld et al., (2018), and Esmaeilzadeh et al., (2018).

It has now been demonstrated through numerous research studies that high-vigorous aerobic physical activity has a greater impact on cognitive function than does low or no aerobic physical activity. Research indicates that there is a direct relationship between the amount of physical activity and its impact on the brain with less importance on type of physical activity. Increased physical activity, in any amount, is positive for a healthy brain function and cognition.

A secondary goal of this synthesis included examining the effects of physical activity on people with Parkinson's disease. After researching information regarding this topic, conclusions became very clear. All of the articles included in this synthesis addressing this were all in agreement on their findings. Alberts et al., (2016), DE Assis, DE Silva, & Silva Dantas (2017), Fiorelli et al., (2017), Fisher et al., (2008), Hazamy et al., (2017), and Loprinizi, Danzel, Ulanowski, & Paydo (2017), agree that regular physical activity, of any type, has shown to have a positive effect on individuals with Parkinson's disease. These effects come both physically in regards to slowing/preventing muscle degeneration and within cognitive functioning. Results are clear that physical activity is especially important within slowing down the rate of degeneration of the brain. The researchers each also agree that physical activity may have a positive impact on regular age-related decline throughout the body.

Recommendations

In order to continue to address the effects of physical activity on cognition and on Parkinson's disease future research is necessary. While it seems that the research is clear on the positive effects of physical activity on the brain, many of the articles included in this synthesis were short in duration and only measured acute impacts within their study. To further investigate specific effects of physical activity, longitudinal study is recommended to assess variables not included at this point. Additionally, more study participants are recommended to increase the validity and reliability of the current findings. Additionally, future research would help to further clarify existing findings. Other research might examine benefits of long term versus short term physical activity.

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Voss, M.W., Nagamatsu, L.S., Liu-Ambrose, T., and Kramer, A.F. (2011). Exercise, brain, and cognition across the life span. *Journal of Applied Physiology. 111*(5). 1505-1513. Retrieved from https://brockport.idm.oclc.org/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=s3h&AN=67204291&site=ehost-live&scope=ci

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Appendix A

Article Grid

Author Title Source	**Purpose**	**Methods & Procedures**	**Analysis**	**Results & Conclusions**	**Limitations & Recommendations**
Alberts, Phillips, Lowe, Frankemolle, Thota, Beall, Feldman, Ahmed, & Ridgel (2016) erts, J. L.,Phillips, M., Lowe, M. J., Frankemolle, A., Thota, A., Beall, E. B., … Ridgel, A. L. (2016). Cortical and motor responses to acute forced exercise in Parkinson's disease. *Parkinsonism & Related Disorders*, *24*, 56–62. https://doi-org.brockport.idm.oclc.org/10.1016/j.parkreldis.2016.01.015 Cortical and motor responses to acute	The purpose of this study was to compare acute effects of forced exercise with the effects of antiparkinsonian medication on the pattern of functional MRI activation and symptom improvement in people with Parkinson's Disease.	Participants who had mild-moderate PD (6 male, 3 females, mean age 61). Subjects were diagnosed with PD for 1-6 years before the study. Data was collected 3 times - off meds, on meds, and off meds plus FE. Off - at least 12h since last meds. On meds - regular dose of meds 1h prior to evaluation. Off + FE - participants completed FE session 1 hour before evaluation. FE evaluation =	Before fMRI session, PD symptoms were evaluated with the Unified Parkinson's Disease Rating Scale Motor Exam (UPDRSM-III). Data was analyzed with one-way ANOVA with condition at each of the 3 levels. Post-hoc pair-wise comparisons were performed using Tukey Test when needed. Correlation analysis was run on calculated differences between UPDRS	In the UPDRS-III - all but one patient improved scores in on meds vs. off. All nine improved scores off + FE compared to OFF. medication improved ratings by 37% while ratings improved 48% in OFF meds +FE vs. Off meds. Post -Hoc Tukey test demonstrated ratings were significantly improved ($P < 0.001$) when comparing On meds to Off meds ($P = 0.002$) and when comparing off meds to off meds +FE ($P<0.001$). There was no statistical difference between the on meds and off meds + FE condition ($P = 0.43$). Forced exercise and anti-parkinsonian medication produce similar levels of	This study was done on acute effects; more research is needed on long term effects of FE on PD. A larger subject pool is needed to solidify results.

forced exercise in Parkinson's disease *Parkinsonism and Related Disorders*		10 min warm up, 40 min FE set, 10 min cool down.	Motor III score. SPSS Version 22 was used.	improvement in PD symptoms. Both FE and meds produced significant improvements in PD symptoms without any reported side effects. FE may be a useful alternative to medication.	
Author **Title** **Source**	**Purpose**	**Methods & Procedures**	**Analysis**	**Results & Conclusions**	**Limitations & Recommendations**
Bourassa, Memel, Woolverton, & Sbarra (2017) ırassa, K. J., Memel, M., Woolverton, C., & Sbarra, D.A. (2017). Social participation predicts cognitive functioning in aging adults over time: comparisons with physical health, depression, and physical activity. *Aging and Mental Health, 21*(2), 133-146. doi:10.1080/13607863.2015.1081152 Social participation	The primary goal of this analysis was to determine if social participation predicts cognitive functioning over physical health, depression, and PA.	Data set had four waves of data ranging from '04-'12. Participants selected from 19 European countries and Israel. 64 years old on average. 19,832 aging adult participants Questionnaires were used as a form of data collection for later analysis. SHARE Questionnaire	Estimated latent curve growth models for memory and executive function were used Two random sub samples were split from all participants Measured for memory and executive function at time0, time1, and time 3. *Time 2 was excluded as it did not include social or cognitive measures	Evidence is provided that shows social participation plays a heavy role in cognitive functioning and successful aging. Evidence above - low PA level at T0 predicted a faster decline in memory and executive function while a higher PA level throughout showed the opposite. Results were replicated in the second sub sample Self-reported mood, physical activity level, and physical health were all associated with higher levels of memory and executive function Interventions to cognition	Very large sample size adds strength to the study. Questionnaire - very subject to responses, lacks reliability.

predicts cognitive functioning in aging adults over time: comparisons with physical health, depression, and physical activity *Aging and Mental Health*		including psychological states, physical health, and cognition. Executive function was measured using category fluency task. Ten- Word Delayed Recall Test was used to measure memory function. Social participation was measured by the sum score of answers to 4 questions regarding participation. Physical Health was measured using participant's responses to a 5 point Likert-scale questionnaire. PA was measured using a single item self-report questionnaire.	Chi-square difference tests were run to determine the best LGCM Cognitive function measured by verbal fluency, immediate word recall, delayed word recall Executive function measured using a category fluency task	through social participation may be more valuable than by other ways to target cognitive decline. **Note that social participation included a sport, social, or other kind of club - gym membership, fitness classes etc.	

Author **Title** **Source**	**Purpose**	**Methods & Procedures**	**Analysis**	**Results & Conclusions**	**Limitations & Recommendations**
Davis, Tomporowski, Boyle, Waller, Miller, Naglieri, & Gregoski (2007) vis, C. L., Tomporowski, P. D., Boyle, C. A., Wailer, J. L., Miller, P. H., Naglieri, J. A., … Waller, J. L. (2007). Effects of aerobic exercise on overweight children's cognitive functioning: a randomized controlled trial. *Research Quarterly for Exercise & Sport*, *78*(5), 510–519. Retrieved from https://brockport.idm.oclc.org/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=s3h&AN=28718792&site=ehost-live Effects of aerobic	This article looked to address the concerns that systematic exercise training causes improvement in children's cognitive function, primarily overweight children.	94 overweight children (M=9.2 years) Groups exercised for 20 minutes (low dose), 40 minutes (high dose), or no exercise (control group) for 5 days/week. Intervention lasted 15 weeks. Body weight, height, were taken pre-intervention and post-intervention and converted into BMI scores. Fitness was measured with treadmill walking test Low dose group, control group,	The CAS Planning Scale was the main form of assessment in this study. (ANCOVA) or the Analysis of Covariance was used to examine the differences in pre and post test scores of cognitive ability in various activity levels. SPSS 9.1.3 and SPSS 13.0 were used to analyze BMI and the aerobic fitness treadmill test.	The study found that the control group had statistically lower posttest scores than the high-dose group. $p=.01$ Although not great statistical differences, the low dose group also had lower posttest scores than the high dose group. Control group and low dose group did not show statistical differences. Study provides quantitative evidence to prove that regular high-vigorous physical activity has a direct relationship with the improvement of children's executive brain function. ANCOVA analyses revealed no significant group differences in CAS attention, simultaneous or successive scales	In order to aid students in cognitive function in schools, greater than 20 minutes of moderate to vigorous PA could be helpful. Relatively small sample size. Measured acute effects - longer intervention time period needed to solidify data. More longitudinal studies should be done.

exercise on overweight children's cognitive functioning: A randomized controlled trial. *Research Quarterly for Exercise and Sport*		and high dose group were all evaluated with a pre-test and post-test of CAS (Cognitive Assessment System). CAS- measures planning, attention, simultaneous, successive			
Author **Title** **Source**	**Purpose**	**Methods & Procedures**	**Analysis**	**Results & Conclusions**	**Limitations & Recommendations**

DE Assis, DE Silva, & Silva Dantas (2017) Assis, G. G., DA Silva, T. A., & Silva Dantas, P. M. (2018). Dual-Task Exercise as a Therapy for Executive Motor Function in Parkinson's Disease. *Human Movement*, *19*(1), 57–63. Retrieved from https://brockport.idm.oclc.org/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=s3h&AN=131062973&site=ehost-live Dual-Task Exercise As A Therapy For Executive Motor Function In Parkinson's Disease *Human Movement*	To evaluate the effects that aerobic exercise with dual-task has on the motor function in participants with Parkinson's disease.	20 patients with PD were randomly divided into 2 groups - control and experimental. Control group remained sedentary for 4-weeks The water walking program consisted of a two week adaptation phase in a 120-cm deep pool with dimensions of 12/12.5 meters. Subjects wore a Colet Power EVA floater for safety. Heart rate and blood pressure were recorded before and after each session. During this phase, the Borg scale of perceived exertion was used for	Before interventions, questionnaires were used for demographic and psychometric evaluation on executive function and fitness level. The Unified Parkinson's Disease Rating Scale Motor Exam (UPDRSM-III) and Senior Fitness Test were used which assesses strength and agility. All physical tests were conducted four days before and after exercise sessions.	PD patients had significant improvements in the pre-test and post-test exercise of motor function with moderate effect ($P < 0.001$). Bradykinesia and low limb agility ($p < 0.001$) each exhibited significant changes individually. Postural stability showed significant effect as well ($P < 0.05$).	Regular exercise combined with executive challenge such as dual-task may counteract the advanced motor symptoms of PD neurodegeneration. Results were exercise intensity dependent. Findings did not guarantee that one type of acute aerobic exercise was better than another. However, they did suggest that aerobic exercises will bring positive results to cognition,

		subjective control of intensity. At the end of this period, the exercise phase started. This consisted of a 10 minute free standing warm-up, then subjects were to walk back and forth (25m) as many times as possible for 30 minutes. Subjects were also required to complete 15 different motor tasks for one minute each (15 minutes of motor task, 15 minute free standing). This session was ended with a 10 minute cool down of stretching exercises.			depending on exercise intensity. Small number of participants. Effect of learning the evaluations over time of intervention should be considered within results.
Author Title Source	**Purpose**	**Methods & Procedures**	**Analysis**	**Results & Conclusions**	**Limitations & Recommendations**

Esmaeilzadeh, Hartman, Farzizadeh, Azevedo, Kalantari, Dziembowska, Kostencka, Narimani, &Abravesh naeilzadeh, S., Hartman, E., Farzizadeh, R., Azevedo, L. B., Kalantari, H.-A., Dziembowska, I., … Abravesh, A. (2018). Association between physical fitness and cognitive performance in 19-24 year old males. *Biology of Sport*, *35*(4), 355–362. Retrieved from https://brockport.idm.oclc.org/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=s3h&AN=133165127&site=ehost-live Association between physical fitness and cognitive	The purpose of this study was to examine the association between physical fitness and cognitive performance in 19-24 year olds	211 male participants Participants aged 18-22 (University Students) Information processing speed and inhibitory control were measured along with aerobic fitness, static strength, explosive strength, explosive strength, agility and speed. Baseline tests were taken pre-intervention of age, weight, height, and body fat % 4 tests used to assess processing speed - Simple visual reaction time and 4-choice reaction time, simple auditory reaction	Kolmogorov-Smirnov test Initial pearson product moment correlations were conducted on composite cognitive scores, demographic variables, adiposity, PA, and fitness tests. Multiple linear regression analysis using the Enter method were conducted between composite cognitive score and fitness components. SPSS v.21.0 used	Significant relationships were found between explosive strength and and composite info processing scores, composite inhibitory control scores and aerobic fitness No association between cognitive tasks and speed of movements, agility, and static strength Positive association was observed between aerobic fitness and composite inhibitory control scores Significant relationship with greater explosive strength and info processing speed and inhibitory control. Speed, agility, static strength - no positive impact on cognitive function Aerobic fitness, explosive strength may have positive impact on cognitive function	This study only explored parts of cognitive function - other studies are needed to explore other parts of cognitive functioning - working memory, long term memory, etc. This study was only done on males - results cannot be generalized to women as well 211 participants is below the tarted sample for stable estimates of correlation

performance in 19-24 year old males *Biology of Sport*		time, clinical reaction time, stroop task, and inhibitory control Aerobic fitness - one mile run was used static strength - hand grip test explosive strength - standing long jump speed - 40 meter sprint agility - 4x9m shuttle run Measurements were taken during regular physical education classes (at University)			
Author Title Source	**Purpose**	**Methods & Procedures**	**Analysis**	**Results & Conclusions**	**Limitations & Recommendations**

Fiorelli, Ciolac, Simieli, Silva, Fernandes, Christofoletti, & Barbieri (2019) relli, C. M., Ciolac, E. G., Simieli, L., Silva, F. A., Fernandes, B., Christofoletti, G., & Barbieri, F. A. (2019). Differential Acute Effect of High-Intensity Interval or Continuous Moderate Exercise on Cognition in Individuals With Parkinson's Disease. *Journal of Physical Activity & Health*, *16*(2), 157–164. Retrieved from https://brockport.idm.oclc.org/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=s3h&AN=134277016&site=ehost-live Differential Acute Effect of High-Intensity Interval or Continuous	This study aimed to investigate the acute effects of high-intensity interval training (HIIT) versus continuous moderate-intensity training (MICT) on cognitive functions in people with PD.	14 individuals with PD Participants were split into different groups Participants performed cognitive tests, both before and after 3 sessions. Groups included a control session(30 min seated rest) HIIT session (25 min of 1min intervals mixed with 2 min moderate intervals) MICT session (30 min moderate exercise). HIIT and MICT sessions were performed on a stationary bike.	4 tests from the Wechsler Adult Intelligence Scale - III Associated Verbal Pairs, Symbol Search, Digital Span, and trail making test were used Tests were used to evaluate attention, working memory, processing speed, executive functions and visuomotor skills. Cognitive measures were compared by a mixed-model analysis for repeated measures. The Tukey Post Hoc Test was used to identify the significant differences when a significant main effect was found.	Acute effects of exercise are as follows - MICT improved immediate auditory memory ($p < 0.001$). HIIT improved immediate auditory memory ($p<0.02$), attention ($p<0.001$) and sustained attention ($p<0.01$). Control - no effects on cognitive function. Working memory was not affected after any of the study groups. Acute Aerobic Exercise was able to promote better cognitive performance in people with PD. The effects were exercise intensity dependant. These findings could be practical in use for cognitive function in people with PD without the use of medication.	Only 14 participants included Only 12 completed the entire study - more participants needed to support data More longitudinal data needed to solidify results

Moderate Exercise on Cognition in Individuals With Parkinson's Disease *Journal of Physical Activity & Health*					
Author **Title** **Source**	**Purpose**	**Methods & Procedures**	**Analysis**	**Results & Conclusions**	**Limitations & Recommendations**
Fisher, Wu, Salem, Song, Lin, Yip, Cen, Gordon, Jakowec, Petzinger (2008) ner, B. E., Wu, A. D., Salem, G. J., Song, J., Lin, C., Yip, J., Cen, S., Gordon, J., Jakowec, M., & Petzinger, G. (2008). The Effect of Exercise Training In Improving Motor Performance and Corticomotor Excitability in People With Early Parkinson's Disease. *Archives of Physical Medicine and Rehabilitation,*	The purpose of the article was to collect information on the effects of high-intensity exercise on functional performance in people with PD in relation to low and no intensity exercise.	Randomized control trial - 8 weeks 30 people with PD, within 3 years of diagnosis (age not specified) Used treadmill training - high-intensity group (24 progressive exercise sessions) low-intensity group (24 progressive exercise sessions)	Data were analyzed using Matlab software tool. TMS trials were analyzed for CSP length CSP length was time between TMS pulse and first return on electromyographic activity of at least 50%. Each was done 10 times. If no return time was marked as 0ms.	HI group portrayed postexercise increases in gait speed, step and stride length, as well as hip and ankle joint excursion. LI group didn't show improvements in gait or sit-to-stand measures. Zero intensity didn't show improvements in gait or sit-to-stand measures. These findings support dose-dependant benefits (High Intensity) on people with PD High intensity exercise can normalize excitability in early stages of PD	Very small sample size Large variability in disease severity and baseline motor performance. Further investigation is needed to support or deny these findings at a larger scale.

89(7), 1221-1229. Retrieved from https://www-sciencedirect-com.brockport.idm.oclc.org/science/article/pii/S0003999308002359 The Effect of Exercise Training in Improving Motor Performance and Corticomotor Excitability in People With Earl Parkinson's Disease *Archives of Physical Medicine and Rehabilitation*		no intensity group (6 education classes) Data collected before and immediately after intervention. Baseline tests included age, duration of PD, UPDRS score, MMSE score, and PD medications. Walking test, sit-to-stand test and TMS (transcranial magnetic stimulation) were used as assessments.	Mean and SD were calculated pre vs. post test.		
Author **Title** **Source**	**Purpose**	**Methods & Procedures**	**Analysis**	**Results & Conclusions**	**Limitations & Recommendations**

Hazamy, Altmann, Stegemoller, Bowers, Keun Lee, Wilson, Okun, & Hass (2017) azamy, A. A., Altmann, L. J. P., Stegemöller, E., Bowers, D., Lee, H. K., Wilson, J., … Hass, C. J. (2017). Improved cognition while cycling in Parkinson's disease patients and healthy adults. *Brain and Cognition*, *113*, 23–31. Improved cognition while cycling in Parkinson's disease patients and healthy adults. *Brain and Cognition*	The purpose of the study was to examine the effects of performing cycling on cognitive performance in people with PD. Also, to examine the effects of cycling on cognitive performance that hasn't previously been studied.	39 individuals with PD, 21 HOA (healthy older adults) HOA mean age 73 PD mean age 66 Participants all took single and dual task cognitive tests of 12 tasks. Varied degree of difficulty, but given in same order. Tasks measured processing speed, controlled processing, working memory and executive function. Participants were randomly chosen to perform single task sessions then dual task sessions or vice versa. Single task was done in a quiet	2 x 2 repeated measures ANOVA was performed for each cognitive task separately. All statistical analyses were conducted using IBM SPSS statistics for windows 21 version 21.0	Both groups exhibited dual task facilitation of response times in visual tasks across cognitive domains and improved verbal recall during an executive function task. Results suggest that pairing cognitive tasks with cycling may actually improve cognitive performance - may have a positive relationship with slowing cognitive decline associated with aging and PD pathology.	PD participants were only studied on medications. PD participants were mild to moderately impaired by the disease and had little evidence of cognitive impairment. Future studies should compare fixed and self-paced cycling on cognitive performance in both populations

		room at a desk. Dual task was done on a stationary bike with a screen. Responses were voice activated in both.			
Author Title Source	**Purpose**	**Methods & Procedures**	**Analysis**	**Results & Conclusions**	**Limitations & Recommendations**
Kvalo, Bru, Bronnick, & Dyrstad (2017) lø, S. E., Bru, E., Brønnick, K., & Dyrstad, S. M. (2017). Does increased physical activity in school affect children's executive function and aerobic fitness? *Scandinavian Journal of Medicine & Science in Sports*, *27*(12), 1833–1841. Retrieved from https://brockport.idm.oclc.org/login?url	This study looked to explore the relationship between increased PA in school and executive function and aerobic fitness in children.	"Active School" study - 10 month randomized control trial 449 children 10/11 yrs old 5 intervention (325 min PA)/ 4 control school (135 min PA) Weekly interventions - 2x45 min PA lessons, 5x10min PA break, 5x10 PA homework aerobic fitness	Mixed ANCOVA repeated measures were used to find changes in scores for aerobic fitness and executive function gender, BMI, and waist circumference were entered as covariates SPSS 21 used	Scores show improvement in both groups executive function was found to have a significant effect - P <0.001 Aerobic fitness did not have a significant effect - P = .281	shows that teachers can create lessons which are physically active in the classroom to promote executive function, not just health benefits. Low number of schools affected statistical power to determine significant evidence

=http://search.ebscohost.com/login.aspx?direct=true&db=s3h&AN=126462280&site=ehost-live Does increased physical activity in school affect children's executive function and aerobic fitness? *Scandinavian Journal of Medicine and Science in Sports*		measured using 10 min interval running test executive function measured using 4 cognitive tests - stroop, verbal fluency, digit span, and Trail Making			Short intervention time (10 months) did not give enough time to generate significant results.
Author **Title** **Source**	**Purpose**	**Methods & Procedures**	**Analysis**	**Results & Conclusions**	**Limitations & Recommendations**

Linde and Alfermann (2014) de, K., & Alfermann, D. (2014). Single Versus Combined Cognitive and Physical Activity Effects on Fluid Cognitive Abilities of Healthy Older Adults: A 4-Month Randomized Controlled Trial With Follow-Up. *Journal of Aging & Physical Activity*, *22*(3), 302–313. Retrieved from https://brockport.idm.oclc.org/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=s3h&AN=96938750&site=ehost-live Single Versus Combined Cognitive and Physical Activity Effects on Fluid Cognitive Abilities of Healthy older Adults: A 4-Month Randomized Controlled Trial	The purpose of the study is to examine the short and long term effects of physical, cognitive, and combined physical plus cognitive training regimens on cognitive abilities.	Baseline cognitive tests of short term memory, concentration, reasoning, processing speed, cognitive speed, and spatial relations. 3 intervention groups and a control group - exercise training cognitive training combined exercise and cognitive training waiting control group 16-week intervention program, test, 12-week wait, then follow up assessment 70 healthy seniors - 63 returned for post assessment and follow-up 60-75 years old	SPSS 19 was used for all statistical analysis Baseline differences assessed through MANOVA multivariate analyses of variance for continuous and chi-square tests for categorical variables 2 way ANOVA with repeated measures was conducted.	Combined intervention group performed better than control group at both assessments post and follow up cog group performed better at follow up no sig difference between physical intervention group and control group were found no differences found between 3 intervention groups at post assessment ANOVA revealed that all intervention groups performed better than did the control group at post assessment - large effect size for combined (d=0.64) and physical (d=0.51) only the physical intervention group performed better than the control group - d=0.46 It can be concluded that physical activity lowers the risk of age related decline of cognitive abilities	All interventions led to an improvement of cognitive performance in HOA physical intervention enhanced concentration and attention - sustainable and specific PA can be seen as the most promising intervention in terms of maintenance of interven effects Short term memory, information processing speed, spatial relation and reasoning were not changed by interventions

With Follow-Up *Journal of Aging and Physical Activity*		PA - Mod aerobic endurance with mod strength training - 2x/week, 60 min each Intensity was measured by PolarFS1c heart rate monitors cog training - 1x/week for 30 min - consisted of individual editing of worksheets w/ 5 min warm up as group (info processing, attention, memory model, sensory memory, memory, short term memory, mnemonics, long term memory, and memory aids. Combined - pa and cog intervention 2x/week. Cog + PA 90 min 1x week, and just PA 60 min 1x/			Social interaction between groups, except waiting control group, can threatens internal validity Small sample size and loss of data results in low power of test - 130 stated, 63 ended Participants were selected as highly educated, high cognitive functioning - results should be taken with generalization to this specific population

		week 6 standardized cog tests were used Cardio measured using 2km walking test A subjective evaluation to assess evaluation of intervention was given as well			
Author Title Source	**Purpose**	**Methods & Procedures**	**Analysis**	**Results & Conclusions**	**Limitations & Recommend ations**

Loprinizi, Danzel, Ulanowski, & Paydo (2017) rinzi, P. D., Danzl, M. M., Ulanowski, E., & Paydo, C. (2018). A pilot study evaluating the association between physical activity and cognition among individuals with Parkinson's disease. *Disability and Health Journal*, *11*(1), 165–168. https://doi-org.brockport.idm.oclc.org/10.1016/j.dhjo.2017.05.004 A pilot study evaluating the association between physical activity among individuals with Parkinson's disease *Disability and Health Journal*	Purpose of this article is to evaluate the association between physical activity among older patients with PD.	25 individuals with PD. mean age 69 57% men Montreal Cognitive Assessment (MoCA) was used for assessment. Mod-vig PA was assessed by accelerometry over a 1-2 week period while accelerometer was worn. *results were an objective measure of PA level because of the accelerometer	Multivariable linear regression analysis was used to examine the relationship between MVPA and cognitive function	Results show that for every 1min/day increase in MVPA, participants had a 0.09 unit increase in MoCA score (cognitive function). Results suggest there is a positive relationship between **DAILY** PA and cognitive function in adults with PD	small sample size measures that are objective, such as the accelerometer, does not provide context to type of physical activity - future research may use subjective and objective measures of PA. Promotion of muscle strengthening activities should be given to patients with PD that have mobility limitations.

Author Title Source	**Purpose**	**Methods & Procedures**	**Analysis**	**Results & Conclusions**	**Limitations & Recommendations**
Rehfeld, Luders, Hokelmann, Lessmann, Kaufmann, Brigadski, Muller, & Muller (2018) hfeld, K., Lüders, A., Hökelmann, A., Lessmann, V., Kaufmann, J., Brigadski, T., … Müller, N. G. (2018). Dance training is superior to repetitive physical exercise in inducing brain plasticity in the elderly. *PLoS ONE*, *13*(7), 1–15. https://doi-org.brockport.idm.oclc.org/10.1371/journal.pone.0196636 Dance Training is superior to repetitive physical exercise in inducing brain plasticity in	The purpose of this article is to distinguish the specific effects of a dance training program vs. a sport based training program which incorporated primarily repetitive movements such as cycling; on the brain.	52 seniors - 25 male, 27 females. 63-80 years randomly assigned to experimental dance group DG or control sporting group SG 14 did not complete the experiment - total of 38 complete data sets 6 month intervention program intensity, frequency, and duration were matched by both groups 2x weekly - 90 min duration	MRI was performed on 3 Tesla Siemens MAGNETOM Verio Scanner VBM method implemented on SPM 12 - used to directly compare both groups gray and white matter in the brain cognitive tests: Attention, processing speed, verbal word fluency , short term and working memory and visuospatial memory were all tested T1-weighted images of baseline and post measures for each participant were taken to run pairwise	No significant difference between groups or values of gray and white matter at baseline after intervention: Gray Matter - DG showed significantly larger volumes in frontal and temporal cortical areas than SG SG showed greater volume increased in occipital and cerebellar regions than DG White Matter - DG showed larger volume increases in right and left frontal and right parietal white matter. The SG showed higher volume increases in right temporal and right occipital COGNITIVE - visuospatial memory improved after both as well as delayed recall Other cognitive functions did not change in either groups	If the program were longer in duration, it may be assumed that results in cognitive function would show more of a significant change. Results are generalized to healthy and motivated elderly people because this is the group that was selected - results for all elderly would need a more broad population studied. VBM assessments are criticized as unreliable.

the elderly. *PLoS ONE*		heart rate taken after warm up twice, during exercise and after cool down to keep workload even between all participants - Physical Working Capacity 130 Test used on bike and endurance related fitness Dance instructor and qualified trainer supervised each DG and SG training sessions respectively SG repeated same exercises over and over - endurance, strength, and flexibility	longitudinal registration. Gray and white matter were compared using DARTEL Diffeomorphic Anatomical Registration Through Exponentiated Lie Algebra t-tests for independent samples compared volume changes in gray and white matter between the two groups Cognitive and Physical data was assess using SPSS 22 - intervention effects tested using repeated measurements ANOVA	significantly Effects of training on cognitive function were low with no significant difference between groups. DG and SG both have a strong potential to induce more positive effects on brain volumes in elderly people including working memory and attention, which are closely associated to age-related cognitive degeneration.	