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Aerobic Exercise and Cognition

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NORTHERN ILLINOIS UNIVERSITY

(Aerobic Exercise and Cognition)

A Capstone Submitted to the

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In Partial Fulfillment of the

Requirements of the Baccalaureate Degree

With Honors

Department Of

(Allied Health and Communicative Disorder)

By

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HONORS CAPSTONE ABSTRACT

This literature review contains research about aerobic exercise and cognition. Three areas were addressed: timing of the exercise, the intensity of the exercise, and age of the participants. From these areas I was able to develop a few research questions. Does the timing of exercise affect cognitive performance? Is it better to perform exercise before a cognitive test? During? After? Does the time between exercise and the cognitive performance have an effect? Does the intensity of the exercise matter? Does exercise improve declining memory in older adults? Many articles presented with conflicting information. Two questions were answered. Moderate-intensity exercise appears to be the most beneficial exercise in association with a cognitive test and exercise in older adults has the potential to reduce risks of memory loss. The studies suggested that more research needs to be performed for researchers to understand how exercise affects the brain.

Final Draft

Introduction

With age, many people experience not only physical changes, such as wrinkles and gray hair, but also cognitive changes, such as a decline in memory. While many of these changes are inevitable, there is research being done to explore possible relationships between cognition/cognitive performance and exercise, and the ability of exercise to possibly mitigate the effects of aging on cognition, and/or improve cognitive performance. Although there is evidence supporting the beneficial effects of exercise on cognition/cognitive performance, many questions remain. For example, it is unknown to what extent dosage effects, such as the length and the intensity of an exercise, or the proximity of an exercise session to a cognitive challenge (i.e., timing), are ideal for maximizing cognitive benefits. Therefore, the purpose of this literature review was to explore the effect of exercise on cognition, with specific attention to the timing of the exercise, the intensity of the exercise, along with the age of the participants.

Research Questions

Based on the current research, there are still many unanswered questions:

1. Does the timing of exercise affect cognitive performance? Is it better to perform exercise before a cognitive test? During? After?
2. Does the time between exercise and the cognitive performance have an effect? Does the cognitive test need to be performed immediately before or after the exercise? Can the individual take a 5-10 minute break between and have no negative effect on the cognitive test?
3. Does the intensity of the exercise matter?

4. Does exercise improve declining memory in older adults? Can the decline in memory be slowed?

Literature Review

Proximity of Exercise

A systemic review conducted by McMorris and Hale (2012) focused on moderate-intensity activities effect on cognitive performance. They looked specifically at the speed and the accuracy of processing information in the brain. They reviewed 53 articles and studies and looked at many other variables involved, including the timing of the exercise. They looked to see if the performance of the cognitive test was better performed during the exercise or post-exercise. From the review of studies, McMorris and Hale (2012) found no significant effect of cognitive performance during exercise or post-exercise. However, they did note a very small effect on the accuracy of processing when the test was performed after a moderate-intensity activity.

Contrarily, Chang et. al. (2012) briefly discussed a study from Lambourne and Tomporowski (2010), which they found in younger adults a detrimental effect on cognitive performance when exercise was performed during, yet a positive effect on cognitive performance when exercise was performed beforehand. According to the research done by Chang et. al. (2012), a single bout of exercise, or acute exercise, has a small positive effect on cognitive performance, and it does not matter if the exercise was done during the learning challenge, immediately before, or delayed sometime after the exercise.

Labban and Etnier (2013) tested individuals' long-term memory through a paragraph recall task. Participants were placed in one of three groups: exercise prior to paragraph recall, exercise after paragraph recall, or no-exercise. All groups were asked to recall 35 minutes after

the first exposure to the paragraph, which was read to them. They found a significant positive effect on exercise on recall; but this effect did not change whether exercise occurred before or after the exposure to the paragraph.

Barella, Etnier, and Chang (2010) examined both the immediate and the delayed effects of acute exercise on cognitive performance of healthy adults. The cognitive performance was assessed through the Stroop test, which is a color and word test where individuals are tasked with either identifying the color of the word or the color of what the word reads. There were two groups: an exercise group, which consisted of 20 minutes of walking, or the control group who quietly sat. They administered the Stroop test at a baseline time and then at 12 separate times after the treatment. The 12 times was not specified as minutes, hours, occasions, etc. Overall, they found that acute exercise resulted in better Stroop test performance immediately post-exercise. There were also other Stroop tests performed as well: the Stroop interference and inhibition tests. From these tests, they found no effects of exercise on cognitive performance. Their findings suggest that acute exercise has short-term benefits for speed of processing but does not affect other types of cognitive functioning.

Lastly, a study looked to evaluate moderate-to-vigorous physical activity and cognitive performance in elementary school students (Pirrie & Lodewyk, 2012). The authors looked at four cognitive processes: planning, attention, simultaneous processing, and successive processing. The participants were fourth grade students who completed a standardized test for each cognitive process. All students would do a standardized test following an exercise or no exercise condition. The physical activity was 20 minutes within a total of a 45-minute lesson. The results indicated that performance on the planning test improved significantly after physical activity. However, no improvement was observed for attention, simultaneous processing, or successive processing.

They suggested that since planning is associated with problem solving skills and behavior self-regulation, these skills may be improved in elementary school students immediately following physical activity (Pirrie & Lodewyk, 2012).

Intensity

According to McMorris and Hale (2012), Davey (1973) proposed that exercise induces a change in arousal levels. This theory was based on the overall concept from Yerkes and Dodson's (1908) arousal performance interaction theory that stated that there was an inverted-U effect on cognitive performance. In McMorris and Hale's (2012) systemic review, they used these theories as a basis for their hypothesis. They stated that moderate intensity exercise should have a significant effect on cognitive performance. McMorris and Hale (2012) also looked at Cooper's (1973) assertion to form their hypothesis. From his assertion, McMorris and Hale (2012) believed that an increase of neurotransmitter concentrations has a positive effect on the speed of processing, while causing neural noise in areas of the brain involved in the accuracy of processing. By combining the ideas of Davy (1973) and Cooper (1973), they hypothesized that moderate intensity exercise would demonstrate larger effect sizes compared to low and high intensity exercises on cognitive performance. They also suggested that different intensities of exercise would create different effect sizes. McMorris and Hale used Borer's (2003) definition for moderate intensity, which stated that it was between 40% and 79% maximum power output. McMorris and Hale (2012) conducted a systemic review where they found that moderate intensity exercise generates optimal cognitive performance. Through the 53 articles/studies they reviewed, they found that the speed and accuracy of processing information was affected by acute exercise. Moderate intensity exercise activates a part of the brain called the reticular

system. This part of the brain is responsible for increasing arousal which, based on their hypothesis, increases cognitive performance.

Chang et. al. (2012), also examined exercise intensity. The findings found no significant evidence supporting that exercise intensity has an impact on cognitive performance. This contradicts the findings of McMorris and Hale. One significant piece of evidence that was found by Chang et. al. (2012), that the more time after exercise occurred, the worse the performance, however, the exercise had to be light to moderate. Ultimately, Chang et. al. (2012) stated that exercise intensity does not have a significant impact on cognitive performance, however, cognitive performance continues to decrease as more time after the acute bout of exercise has passed.

Exercise is typically ranked by intensity level (i.e., low, moderate, intense). Wassenaar et al. (2012) followed high school students through High Intensity Interval Training (HIIT) through their schools' physical education (PE) classes and examined their fitness, cognitive performance, and mental health. Specifically, they were looking to see if HIIT physical activity or vigorous physical activity would improve attainment in math. These students were aged 12-13 years and were randomized into two groups. One group was the control condition, which is regular PE class, and the second group consisted of 10 minutes of vigorous physical activity in every PE class for the entire academic year. Other outcomes included assessments of cardiorespiratory fitness, cognitive performance (executive functions, relational memory and processing speeding) and mental health. Overall, HIIT/vigorous physical activity did not significantly improve cardiorespiratory fitness, cognitive performance, or mental health. Results were essentially unclear due to drop-outs and low intervention compliance (Wassenaar et. al., 2021). It appears

that more research is necessary to answer the question of whether moderate intensity exercise would be more effective compared to lower intensity workouts.

Age

Chang et. al. (2012) also looked at studies that included children and older adults. They concluded that both high school aged kids and older adults were able to experience a positive cognitive performance with exercise. The study from Wassenar et. al. (2021) suggests that physical activity may have a positive affect on the brain and stimulate the brain, cognition, and mental health of adolescents because it is a period of dynamic neurobiological development. This concludes the idea that younger adults may be able to absorb and retain information easier compared to older adults (Chang et. al., 2012). A study published on the U.S. National Library of Medicine, National Institutes of Health concluded that aerobic exercise helps to reduce the risk of cognitive impairment and dementia and may be able to slow dementing illnesses (Ahlskog et. al., 2011). Intlekofer and Cotman (2012) also addressed exercise counteracting the decline of memory function in aging and Alzheimer's disease individuals. From their research, evidence continues to grow in support for physical activity and exercise having the potential to reduce the pathological features associated with Alzheimer's disease.

According to Tarumi et. al. (2019), aerobic and stretching exercises prevented cognitive decline in older adults with memory issues, similarly healthy older adults. Specifically, they showed that it may slow the shrinkage in the area of the brain that is associated with memory, the hippocampus. Beyond that, they also looked to see if exercise would reduce brain atrophy and amyloid buildup, both neuroimaging biomarkers for Alzheimer's disease (Citroner, 2019). For their study, they had individuals 55 and older who had mild cognitive impairment, split into two groups. One group performed aerobic exercise for 30 minutes, 4 to 5 times a week. The second

group performed flexibility training. As previously stated, they found that aerobic exercise and stretching exercise prevented cognitive decline. A result that they were not expecting was that aerobic exercise reduced hippocampus atrophy in individuals who had a lot of amyloid buildup in the brain. One of the authors, Zhang, believed that aerobic exercise is unique compared to other forms of exercise because it increases vascular function, neuron growth and survival, which ultimately may reduce any harmful effects of amyloid buildup in the hippocampus (Citroner, 2019). They are still speculating reasons and rationale for these findings as they still don't fully understand how exercise lowers dementia risk.

A systemic review by Ohman, Savikko, Strandberg, and Pitkala (2014) focused on older adults who have been diagnosed with mild cognitive impairment or dementia. Essentially, they wanted to note the effects of physical exercise on cognition for these individuals. They briefly discussed how there has been two recent systematic reviews on this subject so far, in which they both suggested that physical activity may protect against cognitive impairment in initially cognitively healthy individuals. In all, they reviewed 22 studies which looked at the effects of exercise in global cognition, executive function, attention, memory, and communication. Nine studies evaluated memory and physical exercise. Overall, they received varied results. One large study showed that there was a positive association between physical exercise intervention and delayed recall in participants with mild cognitive impairment. All the other studies showed no significance. However, they noted that the exercise intensity of the studies was high. High-intensity exercise was not defined. Considering all areas of effect that was looked at, the studies showed some positive effects of aerobic exercise on cognition. They concluded that there needs to be more studies with larger sample sizes, random allocations should be sound and assessments blinded. They also said it would be important to separate individuals with mild, moderate, and

severe dementia in order to evaluate if all stages would be able benefit. They also discussed how Alzheimer's disease and vascular dementia should be examined separately as they most likely respond differently to intervention. Finally, they suggested that the exercise be aerobic, sufficiently intense as well as long-term.

Sibley, Ethnier, and Le Masurier (2006) evaluated the effects of an acute bout of exercise on cognitive aspects of Stroop performance in college students (Sibley, Ethnier, & Le Masurier, 2006). Participants were split between a 20 minute self-paced moderate intensity exercise on a treadmill and a 20 minute sedentary control period. They found that the single bout of acute exercise led to improved performance on the Stroop color word interference task. They also had a second test, the negative priming task, on which there was no change. From this, they believe that exercise may facilitate cognitive performance by improving the maintenance of goal-oriented processing of the brain.

Other

Chang et. al. (2014) observed healthy college-age adults through a 30 minute moderate-intensity exercise and performing a Stroop Test. One thing Chang et. al. (2014) did that many other studies did not was rate each college student's cardiovascular fitness as low, moderate, or high. The college students performed the Stroop Test prior to and after an acute bout of cycling exercise. This consisted of 5 minute warm up, 20 minute moderate intensity exercise (65% VO_{2max}), and then a 5 minute cool down. They found that all participants, at all fitness levels showed improvement. However, they found a curvilinear relationship between fitness level and cognitive performance. This suggests that moderately fit individuals performed better on the cognitive performance. Furthermore, this implies that maintaining fitness at a moderate level is associated with better executive function (Chang et al., 2014).

Conclusion

There is an abundance of information regarding memory and exercise, however, the research has many conflicting results and conclusions. For example, in my review there were some articles that stated that it does not matter whether exercise is performed with learning whereas, some argue that exercise during learning is the most beneficial way to learn and some argue that exercise right before a cognitive learning period is the most beneficial. Also, some argue that the intensity of the activity does not matter, whereas some argue that moderate-intensity exercise is the most beneficial and if the exercise is too vigorous, cognitive performance will be limited.

Proximity of Exercise

Research regarding whether exercise before, during, or after a cognitive performance is inconclusive. More research needs to be performed as the results of all the studies are different. However, the one conclusion that can be made is that some exercise is better than no exercise.

Intensity

Research regarding the intensity of the exercise is also inconclusive. For example, reviews by McMorris and Hale (2012) and Chang et. al. (2012) contradicted one another. One study suggested that moderate-intensity exercise is the most beneficial exercise in association with cognitive performance and another study suggested that the intensity does not matter, but the time between the exercise and the cognitive performance has a greater effect. Therefore, more research regarding the intensity of the exercise is needed in order to give a more conclusive idea.

Age

Research regarding the effects of exercise on kids, healthy older adults, and adults diagnosed with memory problems such as dementia, Alzheimer's Disease, and mild cognitive impairment appear to be significant. However, many of the studies still suggest that more research needs to be done on separate populations to understand how exactly exercise works to slow or improve the memory of each separate population of individuals.

Other

Other factors that were discussed was the fitness level of the participants and the different areas of cognition, such as executive function, attention, memory, and communication. All of these variables should also be considered when testing participants to determine if certain aspects are beneficial or if only certain parts of cognition are affected. For example, in the study done by Chang et. al. (2014), they found that the student's fitness level may have an effect on the association of exercise and cognition. From these studies, there are many different areas and variables that need to be addressed and considered within future studies in order to come to conclusions about the effects of exercise on cognitive performance.

Discussions

Future Implications/Studies

A study I would like to carry out involves college students and older adults participating in a word recall test after they perform an exercise. Essentially, this would consist of a 5 week study of 2 weeks with no exercise and 3 weeks with moderate-intensity exercise. Brain HQ, a website that provides brain training software, has a program, also called a word recall test, that tests an individual's memory by having 15 words flash across the screen in 15 seconds, which is the cognitive test I would use. With this would be a survey where they would personally rate the intensity of the activity, type the words they remember, and give their thoughts and feedback

about the study and how they performed. The above review of studies gave more ideas of follow up studies along with things to include in the survey, such as their fitness level.

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