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Positive Relationship Physical Activity Has on Cognitive Function in High School Students

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A Synthesis of the Research Literature

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Abstract

Research shows a link between physical activity and cognitive function. This connection sheds light on the idea that physical activity can improve cognitive function. Penning et al., (2017) mentions that adolescents have high levels of sedentary behavior which makes them vulnerable for health concerns. During the school day students spend most of their time sitting and staying at a resting heart rate. Vazou, Pesce, Lakes, and Smiley-Owen (2019) found consistent evidence that aerobic or motor skill physical activity, enhanced children's spatial abilities and working memory. Many hours were spent searching through data bases to find articles on this topic. The most common finding was that cognitive function improves, depending on the specific type of physical activity performed. Specific keyword searchers were performed to find the correct articles. Information was then sorted by keyword search and the types of physical activity performed. Data and articles were put into tables. In conclusion, there is viable information to prove physical activity can improve cognitive function.

Chapter 1 – Introduction

Performing routine physical activity (PA) can improve the bodies health, more specifically cardiovascular and muscular systems. Increased weight gain and health concerns stem from physical inactivity and led to a sedentary lifestyle (Kim & So, 2012). In school PA can be promoted and valued during physical education (PE) class. During this class specific objectives include three domains, cognitive, social and emotional. Schools are finding it difficult to increase student's PE and recess time. This is a result in increasing and focusing more attention on core subjects. This results in decreased activity time during the school day for students. The European Union report shows that Spain only provides 24-35 hours per year of PE. (Ardoy, Rodríguez, Jiménez-Pavón, Castillo, Ruiz & Ortega, 2013).

Results from current research provide evidence that there is a positive relationship between physical activity and cognitive function. This relationship also impacts academic achievement in children and adolescents (Ardoy et al., 2013). Cognitive functions are a broad term that involves how the brain functions, studies focus on executive functions (EF). The term EF refers to how the brain functions and controls behaviors. These behaviors are broken up into three categories, *updating, inhibition and shifting.* The category updating refers to converting information into the brains working memory. The category inhibition refers to avoiding negative responses. The last category shifting refers to being able to change between tasks and perform multiple duties at once. Children with high levels of EF's show readiness for school and academic achievement (Egger, Benzing, Conzelmann and Schmidt, 2019).

Kids need to get at least 60 minutes of activity per day, only about 33% are reaching that goal. This indicates that children must be active on their own every day (Foster, Moore, Singletary, and Skelton 2018). An afterschool program for overweight children which focused on

exercise improved their executive function, math skills and altered brain function (Ardoy et al., 2013). Physical activity promotes cognitive changes at the systemic, molecular and cellular levels. PA also influences an increase in memory, processing and attention (Crush and Loprinzi, 2017). One study tested a short bout of exercise lasting 30 minutes long, this exercise showed an improvement in 26 men's results on the stroop-cognition test. A 60-minute bout of vigorous PA showed improvements in prefrontal cortex functioning (Crush and Loprinzi, 2017). Another study proved that children's' selective memory increased after performing a 12-minute indoor run at 70-80% of their heart rate max (Ardoy et al., 2013).

A PE program developed around challenging students cognitively can be more successful then a regular curriculum. In order to get students to achieve higher order cognitive thinking they need to be challenged and not just focus on PA. This would include incorporating PA that focuses on, contextual interference, mental control and discovery (Egger at el., 2019). More specifically, games that are constantly changing and are unpredictable, challenging specific EF's and including open ended games (Egger at el., 2019).

Studies are focusing on what specific types of PA effect EF's in high school students. The goal is to see what the relation is between the three and if physical activity can improve the brains function and improve academic success. A recent study on acute exercise and EF's showed positive effects on accuracy and speed of response time. Students that perform quick exercise have a slight increase in the brains ability to function and process (Park and Etiner, 2019). Research shows a positive relationship between executive function and academic success (Benzing, 2019). Increasing student's activity during class has shown positive results and nothing negative to decrease student's academic success.

Statement of the Problem

This study is designed to outline the importance of physical activity. Stated earlier children aren't active enough during the school day. This paper highlights the benefits of being active and how it can help them be successful in school. It can also lead them to living a health and fit lifestyle.

Obesity is a growing concern for children and adults. The rates of obesity continue to climb each year and are related to less activity and increased portion size. Between 1980 to 1995 the number of overweight Americans jumped from a quarter to a third. This equaled to 58 million Americans being obese and by 1998, 97 million Americans were obese (Engel, 2018). This data is alarming for parents and school districts. It supports a need for change in what children learn and do during school. The most alarming statistic stated was during that time frame childhood obesity rose by 54% (Engel, 2018). Increasing the time students are active in school could help lower these percentages. If students don't have a proper diet, it's hard for them to not be obese if they are not active during the day.

Purpose of the Review of Literature

The purpose of this synthesis is to review the literature on the effects of physical activity on cognitive functioning and how more activity can improve high school student's achievement levels. The goal is to prove that physical activity is important and should be done every day. This synthesis should prove to administrators that physical activity should be performed more during the school day. Activity can help keep the brain healthy and keep humans away from aging diseases such as dementia. This synthesis will describe what types of physical activity are important, and the different cognitive effects on high school students.

Research Questions

1. Does the amount of time and type of activity affect their cognitive function? (how long they perform an activity in minutes) (fitness, aerobic, team games, sports)
2. Can more physical activity help students perform and function better in school? (tests and class work)
3. What type of cognitive function is improved by physical activity?

Operational Definitions

1. **Acute Exercise:** Exercise right away or in the first 10 minutes of a class period.
2. **Chronic Exercise:** Exercise which lasts for up to an hour and happens throughout the week.
3. **Executive Functions:** How the brain functions and controls behaviors.
4. **Physical Activity:** When the body is active, and the heart rate increases from resting.

Delimitations

1. All articles involve students in High School.
2. Research articles published between 2001-2019.
3. All the articles came from EBSCOhost.

Chapter 2 - Methods

The purpose of this chapter is to review the methods used to review the effects of physical activity on cognitive functioning and how more activity can improve high school student's achievement levels. The studies collected for this synthesis were located using the EBSCO database from The College at Brockport's Drake Library. Within the EBSCO database the following databases were searched: SPORTDiscus, Academic Search Complete, and Physical Education index. Within these databases a total number of 10 articles met the criteria for inclusion as part of the critical mass within this literature review. In order for an article to meet the criteria for selection in this synthesis it must have been published between 2000-present, this will provide the synthesis with the most up to date and current information available. Other criteria for selection included scholarly and peer reviewed articles that were full-text. Having scholarly and peer reviewed articles provides more validity within the articles and better overall quality. Other articles or sources selected as part of this literature review provided context about the topic, background information and supplemental information to complete the review. All articles and sources are appropriately cited in the reference section of this paper.

In order to gather valuable articles for this synthesis certain keywords and phrases were used when searching the data base. Keywords were determined by using words from the research purpose statement. The first data base utilized was Sport Discus. The first key word searched was physical activity that resulted in 29,018 articles. The second keyword searched was cognitive function that resulted in 351 articles. The third keyword searched was high school that resulted in 28 articles. The next data base used was academic search complete. The first keyword searched was physical activity that resulted in 105,627 articles. The second keyword searched was cognitive function that resulted in 2,163 articles. The third keyword searched was high

school that resulted in 149 articles. The last data base used was physical education index. The first keyword searched was physical activity that resulted in 98,791 articles. The second keyword searched was cognitive function that resulted in 8,587 articles. The third keyword searched was high school that resulted in 4,611 articles. articles appeared. From these data bases 5 articles were selected from Sport Discus, 2 articles from academic search complete and 3 from physical education index. The physical education index search resulted in more articles and options to pick from. Academic search complete provided a good number of articles that had relation to the research topic.

Articles that were selected for use in this synthesis were scholarly and peer reviewed articles that were full-text. Also when selecting articles for use in this synthesis it was important that each article selected had valuable information related to the effects of physical activity on cognitive functioning and how more activity can improve high school students achievement levels.

Specific criteria were used in order to be a part of the literature review. All the articles selected were based on how physical activity affected cognitive functioning and academic achievement. Participants in the studies reviewed were high school students.

For this synthesis a total number of 10 articles were used to compile data on the topic of physical activity and cognitive functioning. Articles came from a variety of journals including; Journal of Physical Activity and Health, Journal of Sport & Exercise Psychology and Journal of Sports Science and Medicine.

The critical mass for this synthesis is comprised of 78,008 number of participants. Within the 10 articles used for the literature review there was a total of 39,749 males and 38,259 females.

Data were analyzed using the following methodologies for the study under review. The literature included, five qualitative articles, three quantitative article, two mixed methods and two research review. Most data collection was completed by using charts and graphs. Information about participants was gathered and put into a table. Interview data was logged into a table and specific quotes were also used. Other data was collected by using a scale, heart rate monitor and survey methods.

Chapter 3 - Literature Review

The purpose of this chapter is to present a review of literature on the effects of physical activity on cognitive functioning and how more activity can improve high school student's achievement levels. In particular the following topics will be reviewed, acute effects PA has on cognitive performance, the effects of increased time and intensity of PE, the effects of increased cognitive brain engaging PA breaks, and cognitive chronic PA increases EF. There were a list of at least two articles for category related to the topic.

Acute Effects of PA on Cognitive Performance

Presenting a study on high intensity training on cognitive performance, Mezcua-Hidalgo, Ruiz-Ariza, Suarez-Manzano and Martinez-Lopez (2019) examined the cognitive effects high intensity training bouts of 16 minutes had on adolescents' cognitive function. The authors systemic review found a positive relationship between PA and cognitive function in young people. Research has showed a low level of EF between the ages (6-18) relates to low self esteem and emotions that effect each day. Having high levels of EF can predict better PA levels because it is related to high self-esteem and self-concept. The authors also mentioned students who performed two moderate workouts for 20 minutes had better selective attention scores then those who did 1 exercise bout or just sat in their seat (Mezcua-Hidalog at el., 2019). The participants in the study had a mean age of 14.06 and mean body mass index of 21.40. These students came from two secondary schools in Andalusia (Spain), and included 158 males/females. The students took part in a randomized controlled and blind trial. A pretest was taken which included a sociodemographic questionnaire.

The purpose was to test student's memory, selective attention, and concentration. The focus was 48 hours after the intervention took place which was, 16 minutes of coordinated and

monitored C-HIIT. This workout consisted of a 4-minute warm up followed by an intense 16-minute workout at 85% heart rate max. Students wore heart rate monitors and their data was projected on the screen to make sure they stayed in the proper zone. The control group included 81 students who performed only static stretching because it was related to low levels of CP. The experiments group included 77 students who performed the C-HITT program at 8:30am. The students were not together while performing their exercise. The student's memory was tested using a one-minute ad hoc test. During this time students where shown 15 random Spanish cards for 20 seconds, they had 40 seconds to write down how many they remembered. Each student received a number from 1-15 depending on how many they got correct. Brickenkamp's d2 Test was used to assess participants selective memory and concentration and lasted 4 minutes and 20 seconds. The goal was to quickly focus on pertinent information and ignore other things going on.

Each test was assessed at during seven time periods in the classroom, 8am before exercise, 9am post exercise, 2, 3, 4, 24 and 48 hours. The results showed that students who participated in the C-HITT selective attention by 17.39% during the next hour, and they increased their concentration by 20.31% and 15.26% during the next one and two hours (Mezcua-Hidalog at el., 2019).

Similarly, Harveson, Hannon, Brusseau, Podlog, Papadopoulos, Durrant, Hall, and Kyoung-doo Kan (2016) examined the effects of 30 minute aerobic and resistance training on high school students' cognitive function. The authors mention that PA has many benefits to improve health, reduce obesity, improve cardiovascular health and decrease depression. Also research has showed increased EF after youth has performed acute exercise (Harveson at el., 2016). Resistance training focuses on improving muscle strength, better body function and goes

along with aerobic exercise (AE). Likewise, resistance training (RE) can improve, body composition coordination, strength, cognitive arousal, quality of life and protection against disease (Harveson at el., 2016).

The purpose of this study was to examine youths' cognitive function after performing acute bouts of resistance training, aerobic training and no exercise (NE). The study was a randomized crossover design and participants had 7 days to get familiar with the exercise and cognitive tests. The participants in this study came from a public school in the southwest and included 48 boys and 46 girls. Participants completed one of the three interventions with 7 days in between, these interventions were aerobic exercise, resistance exercise and no exercise. Participants completed cognitive testing on the same day 5-40 minutes after their intervention. The AE lasted 30 minutes and involved jogging or walking which elevated the participants heart rate above resting rate. The RE lasted 30 minutes and included two sets of 15 reps. This workout involved 6 standard machines, squat, leg press, bench press, unilateral pull-down, seated row, and overhead press. Lastly, the NE group watch a sport related DVD for 30 minutes without sleeping or moving. Throughout each interventions students heart rate was monitored using Ekho WMP-88 Heart Rate Monitors. (Harveson at el., 2016).

In order to test cognitive functions participants completed a stroop test and trail making test. These tests included 3 tasks, during these tasks' participants had to identify colors (red, green, blue and yellow) which appeared on different flashcards. These colors appeared as random dots or non-colors words, in total there was 24 items. In part A of the trail making test participants had to draw a line between circles 1-25, in part B they had to draw a line between 1-13 and letter A-L (Harveson at el., 2016). To analyze their data authors used Repeated-measures analysis of variance to see differences between each intervention. This analysis was also used to

show differences between sex. Overall the results showed better cognitive results from AE and RE then the NE group. Time to complete the cognitive tests was shorter in the exercise groups then in the NE group. In this study the boys also outperformed the girls from each intervention group. This is an interesting finding because other research shows that women outperform men in these types of cognitive tests (Harveson at el., 2016).

In addition, Park & Etnier (2019) performed a study on the effects acute exercise has on executive function. The authors noted that research since the 1950's shows that acute and chronic exercises have benefits for cognitive function. Specifically, acute exercise has a slight positive effect on cognitive performance. The authors performed two systemic reviews based on their topic of interest. The first study showed an increase in students' cognitive function who were already at low levels during the pretest. These students performed an intense workout for 12 minutes long. The second study focused on a sprinting exercise which resulted in participants increased Stroop test results (Park & Etnier, 2019).

The purpose of this study was to test the effects moderate intense physical activity had on executive functions. The goal was to shed light on if exercise at the adolescent age could help brain development. The areas of the brain responsible for executive functions typically stop developing around early to late adolescent years (Park & Etnier, 2019). The participants for the study came from a high school in South Korea. These participants aged between 15-16 years old, consisted of 11 males and 11 females and had an average body mass index of 21. Participants participated in 2 sessions, one was exercising and the other was studying homework. These sessions consisted of 20 minutes, followed by cognitive tests later that day.

To gather data from participants, heart rate was tracked during the whole process. The students wore a heart rate monitor on their chest which synced up with a watch they wore on

their wrist. Their resting heart rate was obtained while sitting for 3-5 minutes, and then obtained every 5 minutes during their exercise. Students target heart rate was determined by subtracting their age by 220 and multiplying by 64%. This provided the number they should achieve while exercise. Authors used the Borg scale to asses students perceived exertion every 5 minutes during exercise. This scale included 6 being very light and 20 being maximal exertion, the goal for the study was 13-16. To test brain functioning authors used the symbolic digital modalities test. This test includes 9 numbers that are associated with a symbol and participants much match them together as fast as possible. The Stroop color word test challenged students brain flexibility and ability to pick out colors and organize them. Overall the results showed an increase in each cognitive test between the control group and the exercise group. The exercise group had better results then the control group who sat and studied (Park & Etnier, 2019).

Effects of increased time and intensity of PE

Presenting a study on increasing physical education time Ardoy et al., (2013) examined the effects it had on student's cognitive performance. During the school day students didn't have much time for physical education class or physical activity. Most schools tend to focus on core subjects such as math, language and science. There focus has been on standardized test scores resulting in less physical activity during school for students (Ardoy et al., 2013). Physical education has plenty of benefits for students since it focuses on, cognitive and social domains. Previous research has also hinted that physical education can benefits students' academic achievement (Ardoy et al., 2013).

The purpose of this study was to see how an intervention focused on increasing physical activity time effected students' academic achievement. The study used a group randomized control trial. The data collection came from a high school in South East Spain. The participants

included 43 boys and 24 girls who took part in a 4-month intervention. Three groups were used, control group, experimental group 1 and experimental group 2. Each groups intervention was as follows; control group (2 55 minute) sessions, experimental group 1 (4-55 minute) sessions and experimental group 2 (4-55 minute) session plus high intensity. This intensity meant exercise that resulted in heart rates above 120 beat per minute. Participants cognitive function was tested using the M version of the Spanish Overall and Factorial Intelligence exam. This exam was a specific questionnaire with each question ranging from 0-100 and higher scores equal better performance. Academic achievement was assessed by documenting students' grades in core subjects, these grades were taken from the first trimester and end of the academic year. The Spanish academic grade ranges from 1 being low and 10 being the highest (Ardoy et al., 2013).

The results from this study showed greater improvement in cognitive function and academics in participants from the exercise group 2 then the other two intervention groups. Their cognitive indicators improved by about 75%. Group 2 also had a greater improvement in their academic scores then the other two intervention groups. This indicates the high intensity workout had better effects, but intervention group 1 also had better results then the control group (Ardoy et al., 2013).

Additionally, Crush and Loprinzi (2017) looked at effects of exercise duration and recovery on cognitive functioning. The authors focused on how acute exercise and recovery periods affect cognitive functioning. This experiment was a randomized control. The authors selected 352 participants between the ages of 18-35 and broke them into 16 experimental groups. Each person would visit the lab twice a week for a test and then take one week off. They tested participants on their cognitive functioning based on how long they exercised for and how long they recovered. The researchers noted that further research of qualitative nature would need to

be done as well. It would be helpful to compare the differences between exercise intensity and recovery time. This would help see how the body handles each differently. It could also shed some light on at which point cognitive function is high (Crush & Loprinzi, 2017)

Effects of increased cognitive brain engaging PA breaks

Presenting a study on enhancing children's executive functions, Egger, Benzing, Conzelmann and Schmidt (2019) performed a new study on children taking breaks during learning time. The intervention in this study took place during classroom teaching time. Research has shown a positive relationship between physical activity and cognitive function (Egger et al., 2019). Executive functions can be described as a set of top down operations that allows the brain to function and set goals. Research has shown that their functions are increase from physical activity and can help academic achievement in children (Egger et al., 2019).

The purpose of this study was to look at how qualitative breaks during classroom time effects students cognitive and academic achievement. The study included 142 boys and girls age 7-9 from, Switzerland. These participants had no diagnosed medical issues or concerns. The intervention consisted of three different groups and lasted 20 weeks. Each intervention happened twice a school day for 10 minutes. The three groups were, the combo group, aerobic group and cognition group. The combo group included high levels of activity and cognitive engagement. These students played games involving remembering words and names. The aerobic group included high activity and low cognitive engagement. These students played a similar game as the cognitive group, but they didn't have to remember words and names. The cognition group included low activity and high cognitive engagement. This group sat down, and their game included no movement. Pre and posttests gathered data on students' social economic statues,

biography and fitness level. Students also wore step counters to track their activity levels (Egger et al., 2019).

In order to test student's cognitive ability, they performed two tests on the computer that took 12 minutes. The color recall task required students to remember the order of disks and replace them. The flanker test required students to change the order of bricks and move them around. The results showed an improvement in shifting performance from the combo group, and the aerobic group was lower. The combo and cognitive group had better mathematic results then the aerobic group (Egger et al., 2019).

Similarly, Penning et al., (2017) performed a study that focused on students sitting time in school. Throughout student's school day they are constantly sitting, and this time increases as they get old. One study showed that replacing students sitting time with activity reduced their fatty acid concentrations. Some research hints that reducing sedentary time can help improve cognitive function (Penning et al., 2017). The purpose of this study was to test the effects of lowering children's sitting time in school and compare it to their cognitive function and metabolic outcomes. The participants included 18 students that were all 13 years old. The study followed a randomized crossover design.

Participants were asked to eat their normal diet and fast for 8 hours at night before they arrived at the lab by 8am. The lab could accommodate two students at a time, their first visit was to get familiar with the area and the last two visits were to practice. The testing lasted from 9am – 3pm to simulate a school day. At the end of the day they completed the paper test of their cognitive ability. Participants got their choice of food for breakfast, lunch and snack. The interventions were broken up into two, the normal school day and the reduced sitting school day. The typical day included 240 minutes sitting and 28 minutes of exercise. The reduced school day

included 117 minutes sitting and 28 minutes active. The use of a treadmill helped simulate students walking between classes (Penning et al., 2017). The results from the study did not indicate any differences in student's cognitive ability. The study did show that students in decreased sitting time had low HDL levels and cholesterol.

Additionally, Kim and So (2012) performed a study that focused on the relationship students school performance had on the amount of physical education class. When students participate in regular PA it helps to improve overall wellbeing, cardiovascular system and skeletal muscle. On the other side being physically inactive can lead to obesity and health issues (Kim and So, 2012). The purpose of this study was to see if the amount of PE classes students participated in per week increased their academic achievement.

In 2009 the 5th Korean youth surveillance survey was taken. From this survey a sample of 76,937 students age 13-18 years old was utilized. Of these students the classroom teachers asked if they would participate in an online survey and gave them a number to log in. The total number of students that participated was 75,066. The survey asked general questions and then asked how many PE classes they attended per week. The participants could select, none, once, twice, and more then 3 times. The authors used two groups to organize their data, three or more PE classes and less then 3 PE classes. The results of the study showed that students who attended less then 3 PE classes per week increased their bad school performance by 19.1%.

Cognitive chronic PA increases EF

The article by Schmidt et al., (2015) selected 181 participants ranging from ages 10-12 years old. The purpose of the study was to test the effects two physical education interventions had on children's executive function. The participants took a physical activity questionnaire prior to the study.

The study lasted for 6 weeks, and interventions happened twice a week in physical education class. These interventions resulted in 12 lessons which lasted 45 minutes each. Three different intervention groups were used, team games, aerobic exercise and control condition. The team games group (69 students) lessons focused on high levels of cognitive engagement and physical activity. The aerobic exercise groups (59 students) lessons focused on low cognitive engagement and high physical activity. The control groups (55 students) lessons followed the curriculum the district had to follow for physical education. This curriculum included finding a good balance between, athletics, gymnastics, dance, and team games. Participants executive functions were calculated using two computer tests which lasted 10 minutes. The non-spatial n-back test focused on students updating skills. During this test students had to select the fruit that was related two the second to last one shown. The flanker test focused on student's inhibition. During this test students had to organize a block to fit into certain spaces (Schmidt et al., 2015).

Their results showed that team games are the best type of activity in relation to improving cognitive and executive function. This was because the participants were working together and communicating. Improvement in students shifting performance was only found in the team games group (Schmidt et al., 2015).

Similarly, Stillman et al., (2016) examined the relationship PA had on learning and cognitive function. Many people would agree that physical activity promotes physical health, new research is mentioning that is also improves cognitive function (Stillman et al., 2016). The study included 50 participants with an average age of 20, of these participants 27 were female. The participants participated in study three times per a week separated by one week over 4 weeks. On the first- and third-day participants participated in several cognitive tests. The second

day participants performed a max workout on the treadmill. On the fourth day, 41 participants participated in taking an MRI (Stillman et al., 2016).

Their physical activity was always monitored by wearing a sensor on their arm. Participants were instructed to wear the device except when in the presence of water. The authors used this data to focus on three main points, average steps per day, PA bouts longer then 10 minutes, and metabolic burn. Implicit learning was examined by a computer test using circles and colors. Participants had to follow the order of the colors and plot them in diagrams. The results from the study showed that PA was positively related to memory and executive control.

Chapter 4

The purpose of this chapter is to present the results of the review of literature on the impact physical activity has on cognitive function in high school students and how these results align with the purported research questions which guided this synthesis project. In addition, recommendations for future research as it relates to physical activity and cognitive function are presented.

The results of this review of literature revealed the following. Physical activity and cognitive function in high school students has a positive relationship. Students which participated in more activity during school performed better on cognitive tests. This led students to do better in school and obtain higher grades. Students who attended less than 3 PE classes per week increased their bad school performance by 19.1% (Kim and So, 2012). Students who participated in an intense training intervention improved, selective attention by 17.39% during the next hour, and they increased their concentration by 20.31% and 15.26% during the next one and two hours (Mezcua-Hidalog at el., 2019). Data from these studies hints that students need to be more active during their school day.

Harveson et al., (2016) examined the effects of 30 minute aerobic and resistance training on high school students' cognitive function. Their results showed better cognitive results from AE and RE then the NE group. The AE group performed aerobic exercise, the RE group performed resistance training and the NE group sat down and watched a movie. Time to complete the cognitive tests was shorter in the exercise groups then in the NE group. In this study the boys also outperformed the girls from each intervention group. Park & Etnier (2019) performed a study on the effects acute exercise has on executive function. Their study included two intervention groups, one group performed aerobic exercise and the other sat and completed

homework assignments. The results showed an increase in each cognitive test between the control group and the exercise group. The exercise group had better results than the control group who sat and studied.

Schmidt et al., (2015) selected 181 participants ranging from ages 10-12 years old. Their results showed that team games are the best type of activity in relation to improving cognitive and executive function. This was because the participants were working together and communicating. Improvement in students shifting performance was only found in the team games group.

Discussion

Interpretations

As part of this literature review, several research questions were posed. The first research question was, does the amount of time and type of activity affect their cognitive function? This question examined if there is a specific type of physical activity that is better for cognitive improvement, along with how long students need to be active. Mezcua-Hidalog at el., (2019), performed a study with 3 intervention groups. Each group performed a different type of exercise during their intervention. The group with the best results participated in an intense workout session which was 16 minutes long at 85% of their heart rate max. In line with that study, Harveson at el., (2016) examined the effects of aerobic exercise and resistance training has on cognitive function. Their results showed no great difference between each type, but they both had positive effects on cognitive function compared to the group that just performed static stretching.

The second research question was, can more physical activity help students perform and function better in school? This question examined the effects of more physical activity during a

student's school day. Kim and So, (2012), used a survey students took to gather data on how many days a week they had physical education class. The researchers compared those days with the student's academic reports. These results showed that students who participated in 3 or more physical activity classes per week had better grades. The group who improved their cognitive inhibitors participated in 4 55 minutes session per week which included high intensity training.

The third research question was, what type of cognitive function is improved by physical activity? This question examined the effects physical activity had on the brain and its executive functions. Crush and Loprinzi, (2017) focused on exercise duration and recovery times. Their results showed that memory can be improved from short recovery periods of about 5 minutes. In line with this study, Stillman et al., (2016) focused on participants implicit memory. Participants memory and executive control had the biggest improvement from physical activity.

Implications

The results from this synthesis are like the conclusions made from other studies performed by researchers. Previous research shows there is a positive effect on cognitive functions after physical activity. While performing research 9 articles were found which showed a positive impact of physical activity on cognitive function. Data from this synthesis specifically adds to these conclusions. One study performed by Stillman et al., (2016), showed a negative effect PA had on explicit learning and it was greater in females.

Recommendations for Future Research

In reviewing the data base on the impact physical activity has on cognitive function in high school students the following limitations were noted regarding the studies under review. These limitations included, only one researcher, not being specific on gender and looking at all types of physical activity. Future research on this topic should focus on a specific type of

physical activity. For example, this could include increasing a participant's heart rate during a high intensity exercise. This will allow more results and data which are all related. During this synthesis each study selected included different types of physical activity. Future research on this topic should also focus on studies which included the same methods of testing cognitive function. This will allow the results and data to be similar and easy to compare. Further studies that are similar and quantitative in nature would be helpful.

Based on these limitations and other insights related to the literature the following recommendations for future research should be considered:

1. Type of physical activity
2. Amount of physical activity
3. Difference between male and female
4. When during the day or school activity happens
5. Specific type of study and what participants are doing

Summary

The purpose of this literature review was to determine on the impact physical activity has on cognitive function in high school students. Delimiting variables were used to do an exhaustive data-based search which yielded 10 articles. These articles were then systematically used to determine the impact physical activity has on cognitive function in high school students. Research revealed that physical activity had a positive effect on participants cognitive function and showed improved results in cognitive tests compared to participants that weren't from an higher activity group. These participants that improved cognitive function took place in activities which, increase their resting heart rate, high intense workouts, team games, aerobic exercise and resistance training.

References Used

Ardoy, D. N., Fernández, R. J. M., Jiménez, P. D., Castillo, R., Ruiz, J. R., & Ortega, F. B. (2014). A Physical Education trial improves adolescents' cognitive performance and academic achievement. *Scandinavian Journal of Medicine & Science in Sports*, *24*(1), e52–e61.

Crush, E. A., & Loprinzi, P. D. (2017). Dose-response effects of exercise duration and recovery on cognitive functioning. *Perceptual & Motor Skills*, *124*(6), 1164–1193.

Egger, F., Benzing, V., Conzelmann, A., & Schmidt, M. (2019). Boost your brain, while having a break! The effects of long-term cognitively engaging physical activity breaks on children's executive functions and academic achievement. *PLoS ONE*, *14*(3), 1–20.

Harveson, A. T., Hannon, J. C., Brusseau, T. A., Podlog, L., Papadopoulos, C., Durrant, L. H., … Kang, K. (2016). Acute Effects of 30 Minutes Resistance and Aerobic Exercise on Cognition in a High School Sample. Research Quarterly for Exercise & Sport, 87(2), 214–220.

Mezcua-Hidalgo, A., Ruiz-Ariza, A., Suárez-Manzano, S., & Martínez-López, E. J. (2019). 48-Hour Effects of Monitored Cooperative High-Intensity Interval Training on Adolescent Cognitive Functioning. *Perceptual & Motor Skills*, *126*(2), 202–222.

Park, S., & Etnier, J. L. (2019). Beneficial Effects of Acute Exercise on Executive Function in Adolescents. Journal of Physical Activity & Health, 16(6), 423–429.

Penning, A., Okely, A. D., Trost, S. G., Salmon, J., Cliff, D. P., Batterham, M., … Parrish, A.-M. (2017). Acute effects of reducing sitting time in adolescents: a randomized cross-over study. *BMC Public Health*, *17*, 1–11

Sang-Yeob Kim, & Wi-Young So. (2012). The relationship between school performance and the number of physical education classes attended by Korean adolescent students. *Journal of Sports Science & Medicine*, *11*(2), 226–230.

Schmidt, M., Jäger, K., Egger, F., Roebers, C. M., & Conzelmann, A. (2015). Cognitively Engaging Chronic Physical Activity, But Not Aerobic Exercise, Affects Executive Functions in Primary School Children: A Group-Randomized Controlled Trial. *Journal of Sport & Exercise Psychology*, *37*(6), 575–591.

Stillman, C. M., Watt, J. C., Jr.Grove, G. A., Wollam, M. E., Uyar, F., Mataro, M., … Erickson, K. I. (2016). Physical Activity Is Associated with Reduced Implicit Learning but Enhanced Relational Memory and Executive Functioning in Young Adults. *PLoS ONE*, *11*(9), 1–21.

Author	Title	Source	Purpose	Methods & Procedures	Analysis	Findings	Discussion/ Recommendations Research Notes – Commonalities/Differences
SeYun Park and Jennifer L. Etnie	Beneficial Effects of Acute Exercise on Executive Function in Adolescent	Journal of Physical Activity and Health	To assess the effect of moderate-intensity acute exercise on subsequent EF performance in this population.	Students volunteered to participate. They had to take cognitive test such as Stroop Test, the Symbol Digit Modalities Test, and the Tower of London Test. Resting HR (RHR) was taken before activity, and every 5 minutes during exercise.	Repeated-measures analyses of variances (RM ANOVAs) was used to asses heart rate and how it effect participants scores on cognitive tests.	The exercise intervention led to better stroop color test results, and stroop word test. SDMT also resulted in better performance after exercise.	"Importantly, the results of this study suggest the importance of considering order effects when examining the effects of acute exercise on cognitive performance"
Egger F, Benzing V, Conzelmann A, Schmidt	Boost your brain, while having a break! The effects of long-term cognitively engaging physical activity breaks on children's	Plus One	To examine the effects of qualitatively different PA breaks on children's cognitive outcomes.	Three 20 week interventions were used. "(1) The combo group with high levels of both cognitive engagement and physical exertion, (2) the aerobic group with low cognitive	Computer software was used to analyze the results. These test took 12 minutes to perform. Spss. 24.0 was used.	The cognition group had lower physical exertion. The combo group showed the best results In mathematics.	"pure" physical PA breaks with little cognitive effort are not able to enhance specific cognitive components, including the core EFs as well as more global cognitive components, such as academic achievement."

	executive functions and academic achievement			engagement and high physical exertion, and (3) the cognition group with high cognitive engagement and low physical exertion"			
Mirko Schmidt, Katja Jäger, Fabienne Egger, Claudia M. Roebers, and Achim Conzelmann	Cognitively Engaging Chronic Physical Activity, But Not Aerobic Exercise, Affects Executive Functions in Primary School Children	Journal of Sport & Exercise Psycholog	To investigate the effects of two qualitatively different chronic PA interventions on executive functions in primary school children.	Three different 6 week programs were used. One focused on team game, one focused on aerobic exercise and one with low activity and low cognitive engagement.	Heart rate and physical activity time was used to compare each group. Groups were compared looking at their change in executive functions.	A performance in shifting ability was improved from team games.	"the combination of physical exertion and cognitive engagement in the team games condition seems to have the strongest effect on EFs"
Elizabeth A. Crush1 and Paul D. Loprinzi1	Dose-Response Effects of Exercise Duration and Recovery on Cognitive Functioning	Perceptual and Motor Skills	to extend our knowledge of the potential dose–response relationship between acute exercise duration and recovery	Randomized control with 16 experimental groups. One group performed PA and the other just took tests. The PA was 40% HRR on a treadmill. The tests focused on, reasoning,	Results were analyzed using SPSS. Evaluated individual performance on cognitive tests. Participants were separated by, exercise,	Duration has a different effect on cognitive functioning. Acute exercise increased memory function in people with lower cognition. The study also	"only researchers who evaluated individual differences when examining the relationship between acute exercise and cognitive function"

			periods on cognitive function	concentration, memory, attention, and planning.	rest time and activity time.	showed that a 5 minute recovery time was less favorable for planning based tests.	
StillmanCM,WattJC ,GroveGA,Jr., WollamME,UyarF, MataroM,etal	Physical activity is reduced with implicant learning but enhanced relational memory and executive functioning in young adults	Plus One	To examine how PA relation implicit cognitive function	The researchers used several different methods to measure physical activity and cognitive functioning. Participants wore a triplet sense band to track physical activity on the treed mil. In order to test cognitive functioning they use, spatial task, triplet learning task and color word stoop task	Data was put into tables and charts.	There was an increase in memory executive control after physical activity. They also noted that females had a slight negative effect in implicit learning.	"more PA was associated with fewer errors on the relational memory task, as well as with less interference on the Stroop task."
Sang-Yeob Kim 1 and Wi-Young S	The relationship between school performance and the number of physical education	Journal of Sports Science and Medicine	To investigate the association between school performance and attending <3 PE classes per week in	Schools took a web based survey. The data was used to compare results between school performance and physical activity.	The data was put into a table, with the corresponding question.	<3 PE classes per week, good school performance increased by 12.5%, average school performance increased by	Increased PA class resulted in better school performance.

	classes attended by Korean adolescent students		Korean adolescents.			14.7%, poor school performance increased by 14.6%, and very poor school performance increased by 19.1% as compared to very good school performance.	
Alberto Mezcua-Hidalgo1, Alberto Ruiz-Ariza1 , Sara Sua ´rez-Manzano1, and Emilio J. Martı	48-Hour Effects of Monitored Cooperative High-Intensity Interval Training on Adolescent Cognitive Functioning	Perceptual and Motor Skills	Analyzed the effect of 16 minutes of monitored cooperative high-intensity interval training	Quantitative randomized controlled and blind trial. Parents signed consent forms. The control group performed static stretching; control group performed 16 minutes of HIT. Cognitive performed was assessed; baseline (8 a.m.), post exercise (9 a.m.), and after 2, 3, 4, 24, and 48 hours	Pearson's correlation was used to compare each group.	C-HIIT increased their selective attention by 17.39% during the next hour, it increased their concentration by 20.31% and 15.26% during the next one and two hours. Heart rate was high in HIT group.	"PA increases blood lactate so that it contributes about 25% to cerebral energy requirements after the exercise, while blood lactate is only at 7% during rest (van Hall, 2010)." "PA also increases the level of brain neurotransmitters such as serotonin or norepinephrine, which positively affect CP (Lojovich, 2010)."

D. N. Ardoy1,2,3,4, J. M. Fernández-Rodríguez5, D. Jiménez-Pavón6,7, R. Castillo8, J. R. Ruiz1,3, F. B. Ortega1	A Physical Education trial improves adolescents' cognitive performance and academic achievement: the EDUFIT stud	Scand J Med Sci Sport	analyze the effects of an intervention focused on increasing the time and intensity of Physical Education (PE), on adolescents' cognitive performance and academic achievement	A 4-month intervention selecting 3 schools, control group (CG) 2- 55 min PE classes, experimental group 1 (EG1) 4-55 minutes PE classes or experimental group 2 (EG2) 4 - 55 minutes PE classes plus intensity. Posttest, cognitive performance, academic achievement and questionnaires.	Data was put into tables and charts to shows results.	Heart rate was higher in the EG2 group then other groups. Cognitive performance increased significantly in students from EG2 by 75%. EG2 also had an improved academic performance.	""dose" of PE in terms of both volume and intensity has a clear and significant effect on cognitive performance and academic achievement" Higher intensity exercise is important. "Rasberry et al. (2011) reported that regular physical activity seems to have a positive impact on academic performance through a variety of direct and indirect physiological, cognitive, emotional, and learning mechanisms. Current research on brain development indicates that cognitive development occurs in tandem with motor ability (Smith et al., 1999)"
Andrew T. Harveson,1 James C. Hannon,1 Timothy A. Brusseau,1 Leslie Podlog,1 Charilaos Papadopoulos,	Acute Effects of 30Minutes Resistance and Aerobic Exercise on Cognitionina High School Sample	RESEARCH QUARTERLY FOR EXERCISE AND SPORT	To determine differences in cognition between acute bouts of resistance exercise, aerobic exercise, and a				

2 Lynne H. Durrant,1 Morgan S. Hall,1 and Kyoung-doo Kan			nonexercise control in an untrained youth sample				
Acute effects of reducing sitting time in adolescents: a randomized cross-over study	Anisse Penning1,3, Anthony D. Okely1,3, Stewart G. Trost4, Jo Salmon5, Dylan P. Cliff1,3, Marijka Batterham2,3, Steven Howard1,3 and Anne-Maree Parris	Penning et al. BMC Public Health	to examine the acute effects of reducing total and prolonged bouts of sitting time compared to a traditional sitting time during an adolescents' school day on cognitive function and cardiometaboli c outcomes in a laboratory setting.	Written consent was given and a randomized crossover design was used. Participants participated in one of the 3 groups (interventions were (a) AE, (b)RE, and(c)NE control) separated by 7 days. EF's were assessed 5 to 40 minutes after exercise. AE = single bout exercise lasting 30 minutes. RE = resistance training. AE = time and intensity.	Repeated-measures analysis of variance (ANOVA) was used.	RE led to similar improvements in the cognitive tests and demonstrated significant results on all three versions of the STs	"The authors found that speed of processing increased significantly in the resistance group as compared with both an endurance-training group and a control group (Özkaya et al., 2005)"