The Effect of Aerobic Exercise on Children with Autism Spectrum Disorder: A Systematic Literature Review

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THE EFFECT OF AEROBIC EXERCISE ON CHILDREN WITH AUTISM SPECTRUM DISORDER: A SYSTEMATIC LITERATURE REVIEW

by

DELANEY K. COLE

A thesis submitted in partial fulfillment of the requirements for Honors in the Major Program in Sports and Exercise Science in the College of Health Professions and Sciences and in the Burnett’s Honors College at the University of Central Florida Orlando, Florida

Spring Term, 2021

Thesis Chair: Dr. Anna Valdes
ABSTRACT

The purpose of this study was to examine the effects that aerobic exercise activities can have on various stereotypical behaviors found in children on the autism spectrum. Autism spectrum disorder (ASD) is a lifelong, developmental disability that can impact how an individual communicates, behaves, as well as moves. Physical activity has long been implemented in the treatment plans of children with diagnoses along the autism spectrum; however, specific data relating to the impact of aerobic activity is quite scattered. Aerobic activities require the body to be able to take oxygen from the air around it and circulate it through the blood as a form of energy production and can include exercises of low to high intensity. This strain on the cardiovascular system then stimulates behaviors for a child with ASD. By using systematic literature review methodology this study discusses the benefits that aerobic activities, in particular, can have on the many stereotypical behaviors found in children on the autism spectrum including, irregular sleep patterns, shortened attention spans, repetitive movements, as well as overall wellness and the health improvements that arise as a result of this physical activity. Results from this review indicate that there is a positive correlation between increased aerobic activities and a decline in stereotypical behavior in children on the autism spectrum, however, the long-term effects of this practice are not discussed in this literature review.
DEDICATION

I wish to dedicate this work to my family, particularly to my mother and my grandfather, papa. I would like to thank them for their unwavering support throughout my educational journey and reminding me that I am capable of achieving anything I put my mind to.
AKNOWLEDGEMENTS

I would like to first thank my thesis chair Dr. Anna Valdes for her continued help through the duration of this research. While this experience has been understandably different due to remote learning, she was always just an email away and was very encouraging. Recognition is also deserved for my committee member, Dr. Thomas Fisher. Thank you, Dr. Tom, for devoting so much of your time to educating students and truly enlightening them with your life experiences.
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GLOSSARY

**ASD:** Autism spectrum disorder

**Comorbidities:** Presence of an additional diagnoses or condition. Often is the result of the preexisting condition.

**Stereotypical behaviors:** Repetitive, self-stimulating movements or actions which serves no communication purpose.

**Aerobic exercise:** Cardiovascular based exercise that focuses on increasing the heart rate and circulating oxygen.
CHAPTER ONE: INTRODUCTION

Statement of Question

This purpose of this study was to examine the effects that aerobic exercise activities can have on various stereotypical behaviors found in children on the autism spectrum. Passion for this study came from the current stigma surrounding medicating children with ASD diagnoses instead of implementing other treatment methods to help control their behaviors. Conclusions as a part of this review may significantly influence the way in which treatment plans are designed. These changes could impact the way that public school systems organize their special education departments and the allotted time given for both structured and unstructured physical activities.

The overall purpose of this review is to look at the broad range of improvements that children on the autism spectrum may see from engaging in different types of aerobic activities. This compilation of findings could be used as an aid for a variety of purposes including in medical, educational, and fitness settings as well as by parents when trying to find alternative methods to keep their children active and engaged.

The studies used in this analysis were primary and secondary studies primarily on children aged newborn-eighteen, with the exception of limited studies that used a sample population of <25. Content from this review was included largely between the years of 2015 and 2020, with a single study being analyzed from 2008; This outlier study did not significantly alter conclusions determined in this paper.
Description of special population

Autism Spectrum Disorder (ASD) can be defined as a non-progressive, lifelong, developmental disability that can impact how an individual communicates, behaves, as well as moves. It is the third most common developmental disability preceded by intellectual disability (i.e., fetal alcohol syndrome) and cerebral palsy. In the year 2020, the prevalence of autism had increased nearly 10% with 1 in every 54 children being diagnosed with a form of autism, and it being four to five times more common in boys. Autism is not the result of one single cause and is believed to be the effect of genetic and/or environmental factors. In the instance of identical twins, it has been found that after one child has been diagnosed with autism spectrum disorder, the second child has 60%-90% chance of also falling within the spectrum, there are also greater statistical trends showing one or both identical twins being on the spectrum rather than fraternal twins.

Figure 1: Diagnoses requirements for ASD: DSM-5
Benefits of exercise on the brain and body

The functions of exercise on both the brain and the body are astounding. Physiologically an increase in heart rate results in additional oxygen being pumped to the brain as well as the promotion of hormones which facilitates healthy maturation of neurons and non-neurons (glia). In addition to new growth of brain cells, exercise has also been shown to improve brain plasticity and invigorate new connections between both hemispheres of the cerebrum.

Aerobic exercise in particular has recently shown to have an effect on increasing the overall size of the brain as well as improving cognitive functions. Persistent aerobic exercise training has been linked to increase in growth of the hippocampus, the cranial structure responsible for emotion regulation, memory, motivation, and overall learning capabilities (Dutta 2019). With many children on the autism spectrum facing difficulties with short term memory, but keen capabilities to remember long term facts and phrases, improvements in their hippocampus function through aerobic exercise could very well have drastic improvements of their quality of day-to-day life (Deweerdt 2016).

Description of exercise intervention

Aerobic, meaning requiring or utilizing free oxygen, is a form of exercise that requires the body to be able to take oxygen from the air around it and circulate it through the blood as a form of energy production. Aerobic activities can include any exercise of low to high intensity that is putting strain on the cardiovascular system, particularly with the goal of increasing the heart rate. This review analyzes both traditional aerobic activities such as running, walking, and various high intensity interval training (HITT) style circuits, as well as more easily reproducible and natural activities that children show interest in including basketball, swimming, and trampoline
training. The guidelines for aerobic exercise for the general population is 30 minutes a day for at least 5 days a week, but preferably seven.
CHAPTER TWO: REVIEW OF LITERATURE

Autism: Current rates, Effects, and Severity

With the number of autism diagnoses increasing by nearly 178% since the year 2000, the need for alternative intervention practices is at an all-time high. When an individual is diagnosed with autism, they are given a rating on a 0-3 scale with 0 being typically developing/no symptoms of autism, 1- mild, 2- moderate, and 3- severe. This review includes studies that have all levels of severity in their study population. In many cases, researchers find that mildly severe children are better suited for aerobic activity intervention and show more significant results when compared to patients with a more severe, level 3 diagnosis (Yu 2020).

Figure 2: Comparative results between ASD severity following aerobic program (Yu 2020)

<table>
<thead>
<tr>
<th>Item</th>
<th>Time (T)</th>
<th>Group (G)</th>
<th>Repeated ANOVA (P-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mild ASD (n=17)</td>
<td>Severe ASD (n=18)</td>
</tr>
<tr>
<td>Cardiopulmonary endurance (sec)</td>
<td>Pre</td>
<td>6.09±0.33</td>
<td>6.13±0.31</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>6.59±0.35</td>
<td>5.95±0.40</td>
</tr>
<tr>
<td>Flexibility (cm)</td>
<td>Pre</td>
<td>−6.21±3.89</td>
<td>−6.33±3.34</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>−0.54±2.99</td>
<td>−7.68±2.80</td>
</tr>
<tr>
<td>Strength (kg)</td>
<td>Pre</td>
<td>17.19±4.59</td>
<td>15.78±5.10</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>19.44±4.23</td>
<td>17.66±3.79</td>
</tr>
<tr>
<td>Endurance (rep.)</td>
<td>Pre</td>
<td>14.29±2.52</td>
<td>13.28±2.11</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>15.76±2.54</td>
<td>11.44±1.79</td>
</tr>
</tbody>
</table>
Types of intervention – Evidence based practices

While the premise that all exercise is good exercise remains true regarding not only children on the autism spectrum but a majority of all populations, the findings related to specific improvements made when engaging in aerobic physical activity is an especially important factor to take note of when in the role of a treatment program designer. It is known that children on the autism spectrum spend significantly less time engaging in moderate-to-vigorous activities than typical developing children, with this knowledge it is important to consider a wide variety of activities when creating a regimen for this special population. Currently, the types of aerobic exercises that appear to be making the largest impact in the field of autism are surfing, swimming, walking, martial arts, trampoline training, and generalized circuit training. Not only does surfing require the heart to remain working and forces the body to continue pumping oxygen to the muscles, but it can also serve as a stimulating exercise which is an additional benefit to those on the autism spectrum.

Figure 3: Results of differences between surf and pool groups. (Clapham 2020)

<table>
<thead>
<tr>
<th>Measures</th>
<th>Variable</th>
<th>N</th>
<th>U</th>
<th>SE</th>
<th>Z</th>
<th>r</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-</td>
<td>Curl-up</td>
<td>89</td>
<td>796.5</td>
<td>101.52</td>
<td>1.049</td>
<td>0.111</td>
<td>0.294</td>
</tr>
<tr>
<td></td>
<td>Push-up</td>
<td>90</td>
<td>849.5</td>
<td>102.72</td>
<td>1.455</td>
<td>0.153</td>
<td>0.146</td>
</tr>
<tr>
<td></td>
<td>20m Pacer run times</td>
<td>87</td>
<td>792.0</td>
<td>98.96</td>
<td>1.233</td>
<td>0.132</td>
<td>0.218</td>
</tr>
<tr>
<td></td>
<td>Sit &amp; Reach - Right</td>
<td>87</td>
<td>669.5</td>
<td>95.35</td>
<td>0.509</td>
<td>0.055</td>
<td>0.611</td>
</tr>
<tr>
<td></td>
<td>Sit &amp; Reach – Left</td>
<td>87</td>
<td>624.5</td>
<td>96.37</td>
<td>0.037</td>
<td>0.004</td>
<td>0.971</td>
</tr>
<tr>
<td>Post-</td>
<td>Curl-up</td>
<td>87</td>
<td>789.5</td>
<td>98.89</td>
<td>0.996</td>
<td>0.107</td>
<td>0.319</td>
</tr>
<tr>
<td></td>
<td>Push-up</td>
<td>87</td>
<td>794.0</td>
<td>100.36</td>
<td>1.136</td>
<td>0.122</td>
<td>0.256</td>
</tr>
<tr>
<td></td>
<td>20m Pacer run times</td>
<td>86</td>
<td>749.0</td>
<td>97.67</td>
<td>0.911</td>
<td>0.098</td>
<td>0.362</td>
</tr>
<tr>
<td></td>
<td>Sit &amp; Reach - Right</td>
<td>83</td>
<td>633.5</td>
<td>90.41</td>
<td>0.536</td>
<td>0.059</td>
<td>0.592</td>
</tr>
<tr>
<td></td>
<td>Sit &amp; Reach – Left</td>
<td>83</td>
<td>566.0</td>
<td>90.44</td>
<td>−0.210</td>
<td>0.023</td>
<td>0.834</td>
</tr>
</tbody>
</table>
Comorbidities within the special population

In additional to the stereotypical behaviors that are associated with the diagnosis of autism, there are a few conditions and trends that are also common for this population. There is a high prevalence of children on the autism spectrum who are also dealing with being overweight and obese; In fact, individuals diagnosed autism are nearly two times more likely to be obese when compared to their typically developing peers. A major contributor of this discrepancy between the two population’s weights can be traced back to dietary issues related to sensory processing difficulties that many children on the spectrum face (Dhaliwal 2019). This lapse must then be made up for in the areas of fitness and physical activity which past research has shown children with ASD already struggle with, participating in nearly 50% less daily activity than their peers (Thomas 2019).

Other commonly occurring diagnoses in this population include diabetes, sleep disorders, and ADHD. While these diagnoses may also have a long history of pharmaceutical based treatment, there have been many positive changes that occur after engaging in regular aerobic activities particularly high intensity exercises. A solution that may seem like a simple fix all to weight related difficulties in the typically developing population, daily walks, one study in particular cited the dangers that come with the very real possibility of elopement of participants on the autism spectrum mid walk and the risks that come with that.
Figure 4: Autism-Specific Impairments (Srinivasan 2014)

Figure 5: Daily average time spent in physical activity by group. (Tyler 2014)

<table>
<thead>
<tr>
<th></th>
<th>Children with autism (N = 17)</th>
<th>Children without autism (N = 12)</th>
<th>F value</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M ± SD</td>
<td>Min–max</td>
<td>M ± SD</td>
<td>Min–max</td>
</tr>
<tr>
<td>Sedentary</td>
<td>452.1 ± 100.5***</td>
<td>218–572</td>
<td>369.14 ± 105.7</td>
<td>143–518</td>
</tr>
<tr>
<td>Light</td>
<td>104.6 ± 36.1***</td>
<td>54–195</td>
<td>122.7 ± 22.2</td>
<td>66–159</td>
</tr>
<tr>
<td>Moderate</td>
<td>154.9 ± 50.1***</td>
<td>85–263</td>
<td>210.8 ± 51.1</td>
<td>139–304</td>
</tr>
<tr>
<td>Total MVPA</td>
<td>165.9 ± 58.7**</td>
<td>86–286</td>
<td>218.3 ± 65.6</td>
<td>143–358</td>
</tr>
</tbody>
</table>
Short term and long-term effects

With most recent research showing that an individual may actually lose some of their stereotypical behaviors as they age, beginning in early adolescence, this is not true in all cases and it is still unknown why this change occurs.

Given the overall nature of ASD it is common for parents, caregivers, and educators to plan more short-term goals for their children rather than find an intervention that they feel will work for their entire lifetime. As with typically developing children, it is just as important to get these individuals engaged and interested in aerobic activities from a young age; in doing so, it not only helps to combat the risks of obesity and diabetes, but it also enforces the routine and schedules that so many children on the spectrum crave and yearn for and hopefully will carry the habits later on into life.

Influences of motor and social skills

Limiting or hampering motor skills is another common symptom associated with autism. Motor impairment when preceded by an ASD diagnosis may mean that individuals have an increased difficulty when trying to preform activities of daily living (ADL) and as a result, have a lower-than-normal cardiorespiratory fitness level. A 2018 study including 40 male participants (20 being controls and 20 having an ASD diagnosis) identified the extreme effects that motor impairment can have in terms of achieving physical activity goals. In the ASD group, flexibility, explosive power, and muscular strength were all significantly lower. The ASD group had a lower VO2 peak than the controls, and showed lower effort duration, maximal speed and treadmill slope compared to the controls (Bricout 2018).
Further research has shown that an increase in aerobic physical activity has led to improvements of motor skills; However, a study using trampoline training witnessed the most significant outcomes and noted drastic changes in the participants motor proficiency (Lourenco 2015). Working with children to increase their participation in aerobic fitness has also been linked to improving their spatial awareness and has even been shown to encourage further improvements up to nine months after completing a structured program (Niederer 2011).

Education based practices

Improving common stereotypical behaviors among children with autism through aerobic physical activity can not only lead to an improvement of social skills, but also increase their attention span and regulate their emotions which can lead to major break throughs both in and outside of the classroom. With children on the autism spectrum having an increased risk for obesity combined with decreased engagement in physical activity, the results from standardized fitness tests held during the K-12 years and what school districts are doing to shrink the gap is a question now being brought to light.

One way that some special education teachers are utilizing aerobic physical activity in their classrooms is by incorporating short 10-minute jogging/running breaks throughout the school day (Mays 2013). This technique comes at no cost to teachers or school districts which is a major benefit and is believed to have shown such strong outcomes due to the sensory input that these students are experiencing by exercising so strongly for such a short period of time. Following the analysis of over 23 articles which included physical activities ranging from dance to trampoline training in 2018, it has also been determined that exercise can be considered an evidence base
practice for school aged children in accordance with the *Every Student Succeeds Act* of 2015. (Bittner 2018)

The importance of sensory stimulation for this population in particular is derived from integrating new stimuli in order to create new neural pathways. This form of stimulation has been known to improve focus, as well as have positive correlations to a stronger academic performance. While those on the spectrum may experience two very different type of sensitivities (hyper and hypo), an activity such as jogging may be better fit for kids needing strong stimulation. This type of intervention is able to provide children with an almost immediate “relief” and is able to quiet their minds quickly. While this tactic does not result in permanent changes, there has been no research stating that this technique becomes less effective the more it is done and therefore could be a great tool for children to use into their later years as well. Jogging has also been linked to improving children’s ability to regulate their emotions and behaviors.

**Sleep specific responses**

With various sleep disorders effecting nearly 83% of children with autism (Thomas 2019), improving sleep patterns is typically one of the initial tasks that parents work on with their children. It has been found that typically developing children who are more physically active have more consistent sleep patterns, which has led many to believe that many ASD diagnosed children’s stationary habits contribute to their nocturnal frustration. In a 2015 study with aims of examining the impact of aerobic exercise on sleep and motor skills in children with autism spectrum disorders the researcher’s population sample contained both mild and moderate insomnia suffers. It was reported that following a day where aerobic exercise training occurred,
sleep efficiency increased, sleep onset latency shortened, and wake time after sleep onset decreased for 63%. Logs filled out by the parents also showed that there was an improvement in mood at time of wake up on days following AET. With the pattern of results received, the researchers deemed it permittable to say that regular AET and MST positively impact sleep, MSs, and mood among children with ASD. Not only may aerobic exercise aid individuals with an ASD diagnose, but it may also be equally as beneficial to their siblings. A recently released study funded by the National Institutes of Health reports that sleep problems are also common among children who have a sibling on the autism spectrum (MacDuffie, 2020)

**Engagement in team sports and activities**

By introducing children with ASD to a team sport rather than putting them through routine aerobic fitness sessions, they will not only experience positive health improvements, but it can also aid them in areas such as their social skills as well as get them involved in a new hobby/interest. With children on the autism spectrum being less likely to engage in sustained and vigorous activities and take part in team sport environments (Srinivasan 2014) this can be a fantastic way to incorporate both positive fitness experiences and social skills while taking part in either a specialized league or by encouraging teams designed for typically developing children to be more inclusive. With increased involvement of course comes the need for accepting teams and clubs. Nationwide organizations such as the YMCA have recently begun special needs inclusion programs for beneficial activities such as soccer, swim, and basketball.
Specialized fitness testing for autism

In addition to the common comorbidities that accompany an ASD diagnosis, there are a distinct set of physical differences in the autism population as opposed to the typically developing population. Ensuring that the fitness tests used on this population are just as accurate and valid as they are with the general population is of the utter importance, both for the individual’s sake as well as for research. After completing seven standard fitness assessments that are commonly used in medical and educational settings, it was determined that shorter tests with single instructions like the standing long jump were moderately to excellently reliable. Longer tests that required more detailed instructions such as the Modified 6-minute walk test (Bremer 2019), were more susceptible to errors and were not recommended as the preferred mode of testing for those on the autism spectrum. While it was found that children on the Autism spectrum ran the shuttle run at only a slightly slower pace than their peers, it still signifies the poor cardiovascular endurance and strength of this special population and the lack of effort many schools have put towards inclusive physical activity programs. Errors in interpreting the fitness test’s results of a child with ASD, especially in comparison to the results of a typically developing child, could very well sway the findings of a research study and therefore should be considered when testing a child before and after completing an experimental aerobic fitness program.
Figure 6: Fitness testing validity within the special population (Bremer 2019)

<table>
<thead>
<tr>
<th></th>
<th>Bruce Protocol Mean (SD)</th>
<th>MWMWT Mean (SD)</th>
<th>Wingate Mean (SD)</th>
<th>MPST Mean (SD)</th>
<th>Long Jump Mean (SD)</th>
<th>Grip Strength Mean (SD)</th>
<th>Sit and Reach Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Assessor-rated</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ease of Administration</td>
<td>76.29 (21.71)</td>
<td>82.64 (17.59)</td>
<td>85.00 (10.02)</td>
<td>82.89 (17.75)</td>
<td>83.96 (21.36)</td>
<td>88.82 (13.73)</td>
<td>70.96 (29.67)</td>
</tr>
<tr>
<td>Participant Understanding</td>
<td>79.36 (17.04)</td>
<td>83.18 (18.69)</td>
<td>83.75 (11.85)</td>
<td>83.71 (16.97)</td>
<td>85.61 (22.10)</td>
<td>86.64 (17.24)</td>
<td>74.25 (25.18)</td>
</tr>
<tr>
<td>Participant Performance</td>
<td>83.61 (14.44)</td>
<td>71.18 (22.80)</td>
<td>77.64 (17.12)</td>
<td>74.97 (24.68)</td>
<td>82.11 (22.30)</td>
<td>83.00 (17.15)</td>
<td>71.71 (25.65)</td>
</tr>
<tr>
<td>Total Score</td>
<td>79.75 (16.89)</td>
<td>79.00 (18.92)</td>
<td>82.13 (11.23)</td>
<td>80.23 (18.50)</td>
<td>83.89 (21.65)</td>
<td>86.15 (15.63)</td>
<td>72.31 (26.49)</td>
</tr>
<tr>
<td><strong>Child-rated (n = 7)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ease of Task</td>
<td>45.86 (37.36)</td>
<td>54.07 (35.51)</td>
<td>51.07 (36.71)</td>
<td>55.07 (34.83)</td>
<td>69.14 (33.01)</td>
<td>81.29 (23.97)</td>
<td>58.00 (30.31)</td>
</tr>
<tr>
<td>Task Enjoyment</td>
<td>76.43 (30.11)</td>
<td>68.57 (22.26)</td>
<td>82.50 (15.23)</td>
<td>68.57 (22.26)</td>
<td>88.21 (15.87)</td>
<td>65.93 (39.84)</td>
<td>59.64 (24.28)</td>
</tr>
<tr>
<td>Perceived Effort</td>
<td>86.14 (22.9)</td>
<td>86.86 (21.71)</td>
<td>88.64 (12.43)</td>
<td>88.60 (16.43)</td>
<td>90.29 (12.22)</td>
<td>92.57 (8.98)</td>
<td>81.97 (19.38)</td>
</tr>
<tr>
<td>Total Score</td>
<td>69.48 (26.92)</td>
<td>69.79 (20.48)</td>
<td>74.07 (16.94)</td>
<td>70.55 (13.60)</td>
<td>82.35 (14.99)</td>
<td>79.93 (17.70)</td>
<td>66.24 (17.07)</td>
</tr>
</tbody>
</table>
CHAPTER THREE: METHODOLOGY

This thesis reviewed experimental results on aerobic exercise and the effects it has on children diagnosed on the autism spectrum. The types of studies that were analyzed in this review include case studies, cross sectional, experimental, and longitudinal. Additional materials that were reviewed include age and developmental milestones, parent completed logs and questionnaires, and public-school guidelines. The desired participant age in the reviewed studies was between pre-school and late high school.

Data Sources

To investigate the effect that aerobic exercise has on children who have been diagnosed with Autism Spectrum Disorder, a literature review was conducted. Key words such as aerobic, autism, ASD, physical activity, and developmental disorder were used on UCF library database, PubMed, and Google Scholar to search articles relevant to this topic.

Study Selection

Once these key words established articles from the selected search engines, the sources were analyzed and reviewed for their accuracy and relevancy before being formally chosen for this review. Additional filters that were used to collect the most relevant articles included the date of publication as well as the average age of the participant pool.
CHAPTER FOUR: RESULTS

After reviewing ten studies related to the effects of aerobic exercise on children who have been diagnosed with autism spectrum disorder, results from six of the studies showed direct positive correlation among increased aerobic activities and a decline in stereotypical behavior in children on the autism spectrum, while one study showed insignificant data. The other three studies were used to determine appropriate fitness testing for the special population and to gain a better understanding of how the cardiorespiratory system in a ASD diagnosed child functions.

The studies used in this analysis were primary and secondary studies primarily on children aged newborn-eighteen, with the exception of limited studies that uses a sample population of <25. Content from this review was included largely between the years of 2015 and 2020, with a single study being conducted in 2008; This outlier study did not have an effect on the conclusions determined in this paper.

Indirectly Analyzed Studies

<table>
<thead>
<tr>
<th>Study Title</th>
<th>Citation</th>
<th>Study Method</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reliable and Feasible Fitness Testing for</td>
<td>Bremer, E. &amp; Cairney, J. (2019)</td>
<td>Reliability</td>
<td>Researchers in this study declared that the validity of the short, single instruction tests (i.e standing long jump) to be moderate- to excellently reliable; While longer duration tests (i.e M6MWT) to be more prone to errors and there for less accurate.</td>
</tr>
<tr>
<td>Children on the Autism Spectrum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduced Cardiorespiratory Capacity in</td>
<td>Bricout, V. A., Pace, M., Dumortier, L.,</td>
<td>Experimental</td>
<td>In this study, 40 male children participated, 20 were controls.</td>
</tr>
<tr>
<td>Children</td>
<td>Baillieul, F., Favre-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Study</td>
<td>Author(s)</td>
<td>Findings</td>
<td></td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Young Children with ASD Participate in the Same level of Physical Activity as Children Without ASD: Implications for Early Intervention to Maintain Good Health</td>
<td>Thomas, S., Hinkley, T., Barnett, L. M., May, T., &amp; Rinehart, N. (2019).</td>
<td>Typically developing children engage in about 125 minutes of moderate to vigorous physical activity a day while children ASD only participate in around 86 minutes a day. Regardless of diagnosis it is also proven that younger children and males are generally more active. Sleep problems are estimated to affect up to 83% of children with ASD; typically developing children, who are more physically active have more consistent sleep patterns.</td>
<td></td>
</tr>
<tr>
<td>with Autism Spectrum Disorders</td>
<td>Juvin, A., &amp; Guinot, M. (2018)</td>
<td>while 20 were diagnosed with ASD. In the ASD group, flexibility, explosive power, and muscular strength were all significantly lower. The ASD group had a lower VO2 peak than the controls, and showed lower effort duration, maximal speed and treadmill slope compared to control.</td>
<td></td>
</tr>
</tbody>
</table>
## Directly Analyzed Studies

<table>
<thead>
<tr>
<th>Study Title</th>
<th>Citation</th>
<th>Study Method</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effectiveness of surf therapy for children with disabilities</td>
<td>Clapham, E. D., Lamont, L. S., Shim, M., Lateef, S., &amp; Armitano, C. N. (2020).</td>
<td>Experimental</td>
<td>Based on data taken from standardized fitness tests before and after the program, it showed that while there were no drastic improvements in the overall fitness of the surfing group, they were the ones with a major decrease in body composition measurements as well as significant improvements in their bone mineral density. Researchers noted that this information was helpful for coordinating activities with the goal of weight loss in mind as the prevalence of obesity in the autism population is fairly high.</td>
</tr>
<tr>
<td>Group aquatic aerobic exercise for children with disabilities</td>
<td>Fragala-Pinkham, M., Haley, S. M., &amp; O’Neil, M. E. (2008)</td>
<td>Experimental</td>
<td>Circuits with this program were made with target heart rate zones in mind. The endurance portion included exercises such as swimming laps and relay races while</td>
</tr>
</tbody>
</table>
the strength section consisted of exercises using barbells, aquatic noodles, and water resistance. Standard fitness testing consisted of exercises using barbells, aquatic noodles, and water resistance were used to monitor progress and improvements. Results showed great improvements with Most children improving their ability to exercise for longer periods in their target HR zone. The findings in this study are also consistent with other land-based aerobic exercise programs for children with cerebral palsy.

| Using antecedent aerobic exercise to decrease stereotypic behavior in children with autism | Mays, Melanie Nicole McGaha. (2013) | Experimental | The focus of this research was to see how 10 minutes straight of moderate-vigorous jogging would have an effect on elementary aged students who typically display the stereotypical signs of being on the autism spectrum. Two students were used |
in this study, an 11-year-old girl, and a 10-year-old boy. Both students’ results show a functional relation between jogging and a reduction in stereotypy. Overall – Improved stemming + stereotypical tendencies.

<p>| Relationship of aerobic fitness and motor skills with memory and attention in preschoolers | Niederer, I., Kriemler, S., Gut, J., Hartmann, T., Schindler, C., Barral, J., &amp; Puder, J. J. (2011). | Cross sectional analysis | Better performance in agility-based tests such as the shuttle run showed correlation to higher functioning attention spans and working memory. |
| Assessment of Walking Routes as a Possible Approach for Promoting Physical Activity in Children with Autism Spectrum Disorder | Oreskovic, N. M., Neumeyer, A. M., Duggan, M. P., &amp; Kuhlthau, K. A. (2020) | Experimental | Researchers located 12 individuals with autism diagnoses who are also in the overweight and obese ranges, these twelve children were encouraged to walk 30 minutes or more at a time for 3 months. the results did not meet requirements to be deemed statistically significant. A routine like this may work best to supplement daily physical activity goals in individuals who participate in higher levels of exercise on other days of the week. |</p>
<table>
<thead>
<tr>
<th>Study Title</th>
<th>Author(s)</th>
<th>Group Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact of a Physical Exercise Intervention on Emotion Regulation and Behavioral Functioning in Children with Autism Spectrum Disorder</td>
<td>Tse A. (2020).</td>
<td>Experimental</td>
<td>The experimental group received a 12-week jogging program while the control group continued on with their daily routines. Based on the daily emotional regulation checklist and behavior log that parents filled out before and after their child attended the jogging session, the experimental group shows significant improvement in their capability to regulate their emotions, they also experienced a decline in behavioral concerns.</td>
</tr>
<tr>
<td>Effects of Mini-Basketball Training Program on Executive Functions and Core Symptoms among Preschool Children with Autism Spectrum Disorders</td>
<td>Wang, J. G., Cai, K. L., Liu, Z. M., Herold, F., Zou, L., Zhu, L. N., Xiong, X., &amp; Chen, A. G. (2020).</td>
<td>Experimental</td>
<td>This was a 12 weeklong study engaging 33 preschoolers all with a ASD diagnosis in guided basketball training while continuing their routine conventional rehabilitation program (i.e Occupational, physical, and/or speech therapy). The main findings of this study concluded that the</td>
</tr>
</tbody>
</table>
Aquatic Based

Comparisons done on the effects of a regulated surfing program as opposed to unstructured pool time showed that while there were no drastic improvements in the overall fitness of the surfing group, they were the ones with a major decrease in body composition measurements as well as significant improvements in their bone mineral density (Clapham 2020). Group aquatic exercise on the other hand has been shown to help improve the overall cardiorespiratory endurance and stamina of children on the autism spectrum, and also helps them stay in their target heart rate for a longer period of time (Fragala-Pinkham 2008).

Basketball

A four-month long study held in China involving 33 preschoolers all on the autism spectrum was successful in improving major executive functions and social communication as well as decrease repetitive behaviors through the use of a guided basketball training program (Wang 2020). The main findings of this study concluded that the training program improved executive functions, social communication, as well as repetitive behaviors. These results also support the idea that a sports-based program along similar lines of this study can serve as an effective, inexpensive, easily accessible intervention that can be applied in various settings across different cultures and countries.
**Jogging/Walking**

After a 12-week jogging program, a group of 15 children on the autism spectrum between the ages of 8 and 12 showed significant improvements in their capability to regulate their emotions, they also experienced a decline in behavioral concerns (Tse 2020). In addition to safety concerns including fleeing and straying, it was also found that results were not nearly as significant in the case of walking as in instances when children are engaging in enjoyable and naturally occurring games and activities (Oreskovic 2020). This should still be considered as a way to supplement daily physical activity goals in individuals who participate in higher levels of exercise on other days of the week.
CHAPTER FIVE: CONCLUSIONS/DISCUSSION

Aerobic exercise has a time and place when it comes to implementation in an ASD treatment plan. While many forms of exercise have shown success when it comes to improving stereotypical behaviors and overall health, there is no one size fits all especially when it comes to varying severity and interests. Fitness testing should never be skipped prior to beginning a new aerobic exercise program as it not only gauges the participants starting point, but to also ensures there are no underlying conditions that could be worsened. When organizing a treatment plan that incorporates new types of equipment and exercises remember the ideals of ASD and attempt to keep to as regular as a schedule possible to maximize comfort and interaction.

Prevalence

Autism spectrum disorder is a developmental disability that can affect a person’s communication and movement skills. It is the third most common developmental disability preceded by intellectual disability (i.e., fetal alcohol syndrome) and cerebral palsy. In the year 2020, the prevalence of autism had increased nearly 10% with 1 in every 54 children being diagnosed with a form of autism, and it being four to five times more common in boys. Aerobic exercise is any type of cardiovascular training and focuses mainly on increasing breathing and heart rate. Children on the autism spectrum have been known to have several stereotypical behaviors like involuntary repetitive movements, lower muscle tone than peers, as well as disruptive and irregular sleep patterns. Aerobic based activities help reduce these stereotypical behaviors and, in a sense, improves the child’s quality of life by strengthening their attention span, cardiovascular capabilities, and sleep patterns.
Limitations

Limitations that were faced not only in this literature review, but in this field of research as a whole is the lacking number of studies that include females in their groups of selected participants, both control and independent. In terms of implementing aerobic interventions in public school systems, while low-cost options like jogging and jump roping do exist, more engaging options such as trampoline and basketball training require significantly more funding and overall effort on all parts; not to mention any training that would be required for teachers, assistants, etc. These expenses and challenges could very well serve a gate keeper to many activities that could be incredibly transformational in many children’s lives. As with all children, having to rely on feedback from parents to gauge the success of a certain intervention can also result in some reluctancy to claim overall satisfactory results. This scenario becomes much more relevant when conducting studies with individuals with a greater severity of ASD. While this may not be as relevant when scientific data is being compared such as VO2 max and weight; However, in studies that focus on judgement-based results such as mood a generalized key must be approved by the researchers, provided and explained to the parents, and finally reexamined and checked by the researchers.

Future Research

Possibilities for future research could include identifying gender specific improvements that aerobic activities can provide, as well as the long-term effects that participating in aerobic activities have on the ASD population leading into adult hood. As we know, these individuals are prone to an abundance of comorbidities, but how can aerobic exercise prevent these diagnoses from happening? Studies incorporating ethnically and demographically diverse groups, as well as
effects on different cultures and systems of beliefs also appear to have much room for growth in the coming years.

Creating a valid and reliable fitness testing protocol similar to the Fitnessgram that could be used for not only children on the autism spectrum but also for other children diagnosed with developmental disabilities. Having an appropriate and specific set of benchmarks for these children would be incredible in terms of examining trends over time and cross analyzing those findings depending on whether a child’s severity has increased or decreased across their life span.

Lastly, incorporating sensory activities into aerobic based workouts could also be an insightful piece of future research. For example, constructing a plan that requires children to perform a circuit of exercises while on a sandy beach, a texture that is commonly difficult for many ASD kids to interact with, could possibly serve as a way to take a child’s attention away from the bothersome texture and thus improve both their aerobic performance and threshold for sensory stimuli. The same goes for creating other aerobic exercise that include textures similar to dry rice, shaving cream, glue, etc.
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Practical Application

Incorporating exercise into the routine of a child on the autism spectrum should occur gradually. The end goal should be getting children engaged in vigorous activities for >20 minutes each day.

Small ways to begin introducing the concept of regular exercise can include walking the dog or beginning to walk to or from school and scheduling designated family outdoor play time after dinner.

An example of an exercise prescription that follows the guidelines and recommendations of this study is as follows.

Vigorous Activity Incorporation

<table>
<thead>
<tr>
<th></th>
<th>Frequency</th>
<th>Time</th>
<th>Progression/ Goals + Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 1</td>
<td>3d/wk</td>
<td>20 min/day</td>
<td>Get children used to increasing and maintaining their heart rates for a longer period of time. A MWF physical education block in the school setting would be adequate at meeting this phase’s goal.</td>
</tr>
<tr>
<td>Phase 2</td>
<td>5d/wk</td>
<td>20 min/day</td>
<td>Begin having children engage in strenuous physical activity more frequently. Less structured circuits and more reliance on involvement in team sports and group activities.</td>
</tr>
<tr>
<td>Phase 3</td>
<td>7d/wk</td>
<td>20 min/day</td>
<td>Activities and exercise at this point should be easily navigated by children and natural in occurrence. Running and brisk walks could also be used independently.</td>
</tr>
</tbody>
</table>

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