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PHYSICAL ACTIVITY

ADHD and Physical Activity

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Abstract

A small portion of American children, adolescents, and adults are affected by attention deficit/hyperactivity disorder (ADHD), a chronic mental condition that includes a variety of symptoms. The brain activity of individuals with ADHD is abnormal in its characteristics of neurotransmitter activity during tasks that require attention. Symptoms are often treated with medication that stimulates attention levels. For individuals diagnosed with ADHD, these pharmaceutical interventions are often paired with structured social and behavioral support as well as dietary modifications for further remediation of symptoms. In addition, physical activity (PA) interventions present additional nonpharmaceutical opportunities that reduce ADHD symptoms. This article presents an extensive literature review assessing the notion that neuroactivation and attentional performance of children and adolescents with ADHD can be optimized with interventions of PA. Overall, research has suggested that PA interventions that are free of cost and do not rely on health care professionals can be easily adapted into a daily schedule for individuals with ADHD and effectively prepare individuals for bouts of attentional effort.

Attention deficit/hyperactivity disorder (ADHD) is a chronic condition that affects children, adolescents, and adults and includes a variety of symptoms. ADHD symptoms often include some combination of inactivity, hyperactivity, and impulsivity, as well as problems with self-esteem, relationships, and performance in school (Mayo Clinic, n.d.). The symptoms are often detected in childhood

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and sometimes carry into adulthood; however, the strategies for treating childhood-diagnosed ADHD may help alleviate the symptoms into adulthood (Healthline, 2019).

According to a parent report conducted by the Centers for Disease Control and Prevention (2019), in 2016 approximately 9.4% (6.1 million) of American children and adolescents 2 to 17 years of age had been diagnosed with ADHD at some point. Over half of those diagnosed from the report (3.3 million) were in the age range of 12 to 17 years. According to the National Institute of Mental Health (2016), symptoms are often treated with medications that increase thinking and attention-stimulating catecholamines (e.g., dopamine and epinephrine). Other treatments that replace or accompany pharmacological prescriptions include behavioral and social skills training, cognitive training, and dietary modification, but with varying amounts of success and agreement among researchers (Caye et al., 2019).

Using information from the 2014 National Survey of the Diagnosis and Treatment of ADHD, Danielson et al. (2018) reported the treatments of 2,495 U.S. children and adolescents (4 to 17 years) with ADHD. Danielson et al. reported that most children and adolescents in the sample had received medication (90.8%) and school support (school and classroom accommodations; 85.8%) as treatment for their ADHD. These treatments for the children and adolescents were often paired with psychosocial training such as social skills training (38.7%), parent training (30.9%), or peer intervention (30.2%), with less than 20% of children and adolescents receiving dietary supplements, cognitive training, or neurofeedback (Danielson et al., 2018). Danielson et al. concluded that they had particular concern for the lack of parent training given the strength of evidence suggesting it is an effective treatment. Given the results of this study, it is clear that an attempt is being made to treat ADHD symptoms of children and adolescents in the United States through a combination of pharmaceutical and nonpharmaceutical strategies.

Given the prevalence of childhood ADHD, the effectiveness of various treatments must be explored. Pharmacological interventions are common, but often they are not stand-alone treatments for children and adolescents with ADHD (Danielson et al., 2018). Apart from the mentioned treatment pairings, physical activity (PA)

interventions may present additional nonpharmaceutical opportunities that can reduce ADHD symptoms (Healthline, 2019).

Physical Activity Interventions and ADHD

Authors of meta-analyses have suggested that aerobic exercise interventions point to reduced short- and long-term symptoms of ADHD such as impulsivity, inattention, and hyperactivity exhibited by children (Cerrillo et al., 2015; Den Heijer et al., 2017). The studies reviewed in these analyses were not without limitations. Several research studies neglected to include analysis of covariates that may mediate the variability of symptoms observed in children and adolescents with ADHD (e.g., parent's education level, BMI, time of breastfeeding, and time commuting to school; Suarez-Manzano et al., 2018). Also, the authors of these meta-analyses could not make an association between nonaerobic or yoga activities and improved ADHD symptoms in children and adolescents (Cerrillo et al., 2015; Den Heijer et al., 2017), but these activities have been linked to cognitive gains for population-based controls (Nanthakumar, 2018). In terms of nonaerobic activities that are more intense and shorter in duration, researchers of PA intervention studies have suggested that different durations, intensities, and types of exercises may not alter the strength of the positive cognitive effect (Tan et al., 2016) but that longer bouts of exercise seem to show a more significant effect (Vysniauske et al., 2016).

Research is somewhat limited regarding the potential benefits for children and adolescents with ADHD performing anaerobic activity interventions. Of nonaerobic high-intensity activities, high-intensity interval training is anaerobic in nature, and children and adolescents with ADHD who participate may improve their cognition during manual tasks (Mebler et al., 2018). Therefore, the agreement among research teams about the positive effects of aerobic exercise on ADHD symptoms is promising. In another systematic literature review, Christiansen et al. (2019) stated that exercise has repeatedly been shown to improve ADHD-related behaviors throughout research studies. They emphasized the agreement of study results suggesting that individuals with ADHD who regularly partake in PA during adolescence may have less severe symptoms in early adulthood. Therefore, children and adolescents diagnosed with ADHD may have an opportunity to alleviate their own symptoms by

establishing a consistent and long-term outlet for PA as they age. This concept holds true for population-based controls, with authors of meta-analyses reporting improvements in individuals with ADHD in executive function and attention as a result of participation in long-term exercise intervention studies (de Greeff et al., 2017; Xue et al., 2019). Together, the context of these meta-analyses yields validation that PA may be a low-cost replacement or additive for standard treatments that improve cognitive performance and behavior in children and adolescents with ADHD, especially when the PA exposure is prolonged.

A variety of activities are likely available for most children and adolescents with ADHD to participate in and have been the subject of various research investigations regarding their potential benefit to cognition. Many modalities of activities have been selected to compare individuals with ADHD's results from cognitive tests to assess the effect of aerobic PA interventions. In Piepmeier et al.'s (2015) study, children and adolescents (K–12) with ADHD either performed 30 min of aerobic exercise or watched a nature documentary prior to taking various cognitive tests. Individuals with ADHD performed better on the tests relating to cognitive processing speed following the short bout of aerobic exercise as opposed to following nonexercise conditions. In another study, adults with ADHD (M_{age} = 24.8 years) walking on a treadmill demonstrated better scores on tests, showing faster reaction times with less errors on a continuous performance task than when sedentary (Rassovsky & Alfassi, 2018). Also, the population-based controls in Rassovsky and Alfassi's (2018) study showed the opposite effect; adults' performance was lower during treadmill walking compared to resting. Another study suggested that PA may improve mental health and cognition in children and adolescents with ADHD as a result of their swim training intervention (Silva et al., 2019). In Silva et al.'s (2019) study, 20 children and adolescents diagnosed with ADHD (trained: n = 10, M_{age} = 12.2 ± 2 years; untrained: n = 10, M_{age} = 12 ± 1 years) were included in the analysis. The improvements were expressed as increased scores on psychological and neurological tests taken by the trained group (Silva et al., 2019). However, these swim training interventions were somewhat simple in nature, and executive function might further improve when children and adolescents with

ADHD participate in activities that require more cognition and coordination, such as sports (Diamond & Ling, 2016). Thus, several different interventions that utilize a variety of equipment can serve to benefit children and adolescents with ADHD in their cognitive performance and mental health.

Given the varying protocols and durations of studied PA interventions, it is highly important that future research teams attempt to better justify the outcomes of interventions in reference to their methods (Vysniauske et al., 2016). In addition to the PA method, outcome measures of cognitive performance have varied in research studies. The improvements in cognition can be quantified in many ways. While many of the aforementioned research investigations involved a cognitive test, brain activity is also of interest to researchers when studying ADHD and PA.

Physical Activity and ADHD Brain Activity

To validate the effect of PA, one must understand the cognitive mechanisms that may help individuals with ADHD to better manage their symptoms. At a molecular level, individuals with ADHD have irregular cortical pathways that make it difficult to regulate executive function, impulses, and behavior, especially during complex tasks (Sharma & Couture, 2014). Huang et al. (2018) introduced the notion that the brain activity of individuals with and without ADHD differs in terms of theta/beta and theta/alpha ratios given resting electroencephalographic (EEG) measurements. Elevated theta activity and reduced beta activity are common in children with ADHD, and this is likely due to cortical underarousal (Lubar, 1991). Huang et al. claimed theta/beta and theta/alpha ratios are higher for children with ADHD and their results supported this claim; they found a significantly higher ratio of theta/beta activity in their sample of children with ADHD (n = 24 boys, age 7 to 12 years) compared with age-matched controls (n = 28 boys; Huang et al., 2018). Also, Huang et al. repeated the EEG measurements after interventions of video-watching (30 min) and treadmill exercise (5-min warm-up, 20 min at target heart rate, 5-min cooldown). Analysis of EEG readings for both groups indicated significant decreases in theta/beta ratios after exercise for the ADHD group, but not for the control (Huang et al., 2018). The results of this study suggest that EEG is normalized after a single bout of aerobic exercise. The normalizations observed in

Huang et al.'s study add to the body of evidence that suggests that physically active children and adolescents have increased cortical brain activity and that exercise participation serves to influence cortical function (Hillman et al., 2008; Lardon & Polich, 1996).

Ludyga et al. (2017) supported and tested the common belief within research that increased P300 amplitude (component of a neural event-related potential) is associated with inhibition of unnecessary neuronal activity that may slow executive control and attention. Specifically, they tested whether higher rates of P300 amplitude in the readings correlated to better cognition via improved inhibitory control for children and adolescents with ADHD (Ludyga et al., 2017). In fact, it is well known that overall physical fitness and aerobic exercise is related to optimization of this neural activity in healthy adolescent and adult populations (Hillman et al., 2005; Hillman et al., 2006). Ludyga et al. tested this hypothesis by recording EEG of children and adolescents (n_{ADHD} = 18, $n_{Control}$ = 18; age 11 to 16 years) performing an inhibitory control task (modified Flanker task). They found that 20 min of aerobic (cycle ergometer) or coordinative (balancing tasks) PA increased amplitudes of P300 during the Flanker task. No P300 increases occurred after a 20-min inactive condition (TV-watching). These results occurred in both groups, indicating that PA interventions can also benefit neural inhibition of children and adolescents without ADHD. Aerobic conditions produced more P300 improvements than coordinative PA for both groups. However, no significant improvements in the Flanker task occurred as a result of the PA conditions. The results of Ludyga et al.'s study are interesting given the results of a similar experiment by Chuang et al. (2015), who found that EEG measurements (contingent-negative variation) of children with ADHD (n = 19, no controls, age 8 to 12 years) were more optimal after 30 min on a treadmill compared to video-watching. However, Chuang et al.'s team observed significantly better performance of the participants in cognitive tests (Go/No Go Task) of reaction time. The results of these studies indicate that acute exercise may promote normalization of neural arousal and alertness for both children and adolescents with ADHD. Although results differed between the two experiments in regard to cognitive test performance, PA may serve to improve reaction time in cognitive tests.

The findings in these ADHD studies concerning children and adolescents, EEG activity, and PA support exercise prescription for cognitive performance. However, actual performance of cognitive tasks was assessed in only two of the experiments and the results were not consistent in observations of significant improvements following PA conditions. The authors of these EEG studies (Chuang et al., 2015; Huang et al., 2018; Ludyga et al., 2017) discussed the possible implications of optimal neuroactivation levels exhibited by children and adolescents with ADHD. An overarousal of superfluous neurotransmitter systems in the brain is thought to be a critical component leading to inattention of individuals with ADHD (Huang et al., 2018). The conditions of PA within all mentioned EEG studies resulted in children and adolescents with ADHD displaying more optimal values of neural activity for cognitive performance. The research outcomes of these studies provide a promising notion that PA can better normalize neural conditions for children and adolescents with ADHD. Given these findings, the temporary improvements of arousal and attention should be promoted to ADHD students through singular sessions of acute exercise in the moments before academic performance.

While researchers have used the performance of cognitive tasks and brain activity readings of children and adolescents with ADHD to determine the effect of PA participation, other outcome measures still exist. For example, a student may perform better and have more optimal brain conditions, but their behavior may not improve as a result of PA participation. Therefore, an observational measure provided by a parent, teacher, or researcher can provide a useful appraisal of ADHD symptom improvement.

Parental and Teacher Reports of Physical Activity and ADHD Symptoms

Multiple PA-related studies have analyzed behavior improvements through the perspective of the parents and teachers of children and adolescents with ADHD. Researchers who administered ADHD symptoms questionnaires along with PA interventions recorded positive associations of PA through parent and self-reports of ADHD symptoms in children and adolescents (age 8 to 13 years) after high-intensity interval training interventions (Mebler et al., 2018). Teacher reports of ADHD symptoms in children (age 10 to 11

years) after a 12-week intervention that included physically and cognitively challenging exercises also noted improvements (Taylor et al., 2019). The aforementioned study results suggest that parents and teachers have found ADHD symptoms to improve when both children and adolescents participate in exercise. In concert with these findings, parent and teacher ratings of behavior for children (7 to 11 years) without ADHD show that overweight and obese children have significantly more behavior problems (Slykerman et al., 2020).

In one of the few studies that include a large sample randomized trial to address ADHD symptoms at home and in the classroom, teachers and parents rated young children (M_{age} = 6.83 years) with ADHD (n = 94) and typical development (n = 108) on their behaviors before and after PA interventions (Hoza et al., 2015). Hoza et al. (2015) reported a significant reduction in inattention as reported by parents in the home setting of both groups of students, but no significant reduction was shown in the teacher reports of classroom behavior for either ADHD or typical development. Hoza et al. introduced an interesting concept given the results of previous and current PA interventions. They suggested that although PA interventions are limited in their explanation and causality of improved symptoms, they have not yet produced a negative effect in relation to the ADHD symptoms of young children. However, they could not further validate this statement, because their study lacked a no-treatment control group. Once again, a relationship exists between reduced ADHD symptoms and PA, but not without limitations.

Parents play an important role in identifying PA interventions that may help alleviate their child's ADHD symptoms. Parents who enroll their ADHD-diagnosed children in sport programs might find that certain activities have a different effect on symptoms. Recall that many of the studies described in this article found that aerobic activities have a significant effect. However, a portion of children and adolescents likely are participating in sport disciplines that not only require moments of anaerobic movement but also require more cooperative skills within a team than interventions such as walking, swimming, high-intensity interval training, and cycling. This is well described by Gapin and Etnier (2014), who state that organized team sport activities may not produce desired changes in behavior because of inherent challenges of the game that may inhibit benefit.

For example, children and adolescents with ADHD may struggle more to follow rules and control reactive aggression in fast-paced team sports (e.g., soccer) than their traditional developmental peers. This notion makes it imperative that parents engage in their children's sport and physical education class to ensure that their child's behavior is not negatively affecting ADHD symptom normalization (Prichard & Deutsch, 2013, 2015). Also, researchers should attempt to further delineate sport disciplines and nonsport exercise to more accurately determine the benefits of each. Overall, there appears to be a positive association between PA and ADHD symptoms according to parental reports (Gapin & Etnier, 2014).

Conclusion

In conclusion, millions of children and adolescents between 2 and 17 years of age are currently diagnosed with ADHD, with the majority being in their adolescence (12 to 17 years). While pharmaceutical and behavioral training remedies are prevalent for the treatment of ADHD symptoms in children and adolescents, the inclusion of daily exercise may further potentiate symptom relief. The brain activity of individuals with ADHD is abnormal in its characteristics of neurotransmitter activity during tasks that require attention. Works of several research teams support the notion that this neuroactivation can be optimized with PA interventions. Also, performance on cognitive tasks has been shown to improve in individuals with ADHD following PA interventions such as aerobic exercise and swimming. However, these improvements are not as prominent when the task is performed while they are exercising. Also, dose dependence may be a factor. Individuals with ADHD who are typically quite active may show less symptom improvement following PA interventions than sedentary individuals. Parents who have children with ADHD who undergo PA intervention programs may report an improvement in symptoms, but teacher reports may be less promising, showing the variability of PA intervention effect. Limitations that require certain consideration have been identified within research studies. Research studies have not been without limitation and should attempt to further eliminate covariates that may mediate the relationship between PA and ADHD symptom improvement. However, PA intervention has yet to show any negative effect on ADHD symptoms within an EEG, cognitive test, or parent- and teacher-report study. The type and

timing of PA required for a positive effect on ADHD symptoms may be unique to the individual. Nevertheless, individuals with ADHD can benefit from the addition of daily PA to their already established treatment regimen. This presents a tremendous opportunity for adults, children, and adolescents with ADHD: PA interventions can be easily adapted into a daily schedule in preparation for bouts of attentional effort. Also, PA interventions can be utilized completely free of cost and without reliance on health care professionals.

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