Is Physical Activity Causally Associated With Symptoms of Attention-Deficit/Hyperactivity Disorder?

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Objective: Emerging evidence suggests that physical activity (PA) enhances cognition and may be a protective factor for attention-deficit/hyperactivity disorder (ADHD). Yet the impact of PA on ADHD symptoms has been investigated only in a few undersized, nonrandomized, and retrospective studies. We examined the effect of PA during late adolescence on ADHD symptoms in early adulthood while controlling for unmeasured genetic and shared environmental confounding.

Method: The effect of PA at age 16 to 17 years (baseline) on ADHD symptoms at age 19 to 20 years (follow-up) was examined using a within–monozygotic (MZ) twins fixed-effects model in 232 MZ twin pairs born in Sweden between May 1985 and December 1986. Parents rated their children's *DSM* ADHD symptoms at baseline and follow-up. Participants' weekly energy expenditure (in metabolic equivalent task minutes per week) was based on self-reports at baseline of PA frequency, intensity, and duration.

Results: Greater weekly energy expenditure in adolescence was significantly associated with reduced ADHD symptom levels in early adulthood, even when controlling for unmeasured confounding (all genetic and environmental factors shared within MZ twin pairs) as well as ADHD symptoms and body mass index (BMI) at baseline, $\beta = -0.21$, $p = .013$ (95% CI = −0.38 to −0.05). Similar results were observed for the 2 ADHD subcomponents: hyperactivity/impulsivity, $\beta = -0.21$, $p = .022$ (95% CI = −0.39 to −0.03), and inattention, $\beta = -0.19$, $p = .049$ (95% CI = −0.36 to −0.0005).

Conclusion: In line with a causal hypothesis, PA was inversely associated with ADHD symptoms, even after adjusting for unmeasured confounding. These findings suggest that PA in adolescence might decrease ADHD symptoms in early adulthood. However, given the size of the effect, the clinical value of this intervention needs to be explored further.

Key Words: physical activity, ADHD, exercise, twin modeling, TCHAD

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Attention-deficit/hyperactivity disorder (ADHD) is a complex neurodevelopmental disorder characterized by developmentally inappropriate and impairing levels of hyperactivity, impulsivity, and/or inattention.[1] Both the symptoms and functional impairments associated with ADHD persist from childhood into adolescence and adulthood in around 65% of individuals with the disorder.[2] Across the lifespan, ADHD is associated with a significant risk of lower academic and occupational achievement,[3] interpersonal problems, mental illness, and delinquency.[4] Multimodal treatment plans including psychostimulant medication, nonpsychostimulant medication, and psychological interventions, tailored to the specific needs of the patient, are recommended for the treatment of ADHD.[5] Because of their persistence, there is a continued need for treatment and management of ADHD symptoms and impairments from childhood through adolescence and into adulthood.

A robust evidence base stemming from randomized controlled trials attests to the efficacy of psychostimulant and nonpsychostimulant medication in reducing the symptoms of ADHD.[6] Yet treatment with medication has its limitations. Some individuals may not respond to medication, and complete normalization of symptoms is rare.[7] Medication may be less effective for treating associated impairments of ADHD, such as poor social skills[8] and executive function (EF) deficits,[9] and its long-term effectiveness for control of ADHD symptoms and impairments is yet to be established.[10] Adverse side effects on sleep, appetite, and growth are also possible.[11] Furthermore, some patients, parents, and clinicians have reservations about medication use,[12] and the majority of individuals who are prescribed medication stop taking it within the first year.[13] These potential problems are acknowledged by the National Institute for Health and Care Excellence (NICE) clinical guidelines, which recommend that nonmedical interventions should be considered as possible first-line treatment where ADHD is associated with moderate levels of impairment.[5]

A variety of nonpharmacological interventions, such as psychological (cognitive training, neurofeedback, and behavioral training) and dietary (restricted elimination diets, artificial food color exclusions, and free fatty acid supplementation) interventions, are also available. A recent meta-analysis found blinded evidence that behavioral interventions used to treat children and adolescents with ADHD had beneficial effects on important aspects of child

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and parent functioning, namely decreasing comorbid childhood conduct problems and increasing positive parenting.[14]

Yet the evidence for the efficacy of nonpharmacological treatment interventions on reducing ADHD symptoms is far from clear and is limited by the unblind status of researchers and raters of behavior, as another recent meta-analysis by the same group concluded.[15] Blinded evidence for small but significant reductions in ADHD symptoms was found only for free fatty acid supplementation and artificial food color exclusion.[15]

Identifying new nonpharmacological treatments on the basis of our growing understanding of the pathophysiology as well as risk and protective factors of ADHD would therefore be a significant advance in the management of ADHD. Animal research and studies in typically developing children, adolescents, and adults suggest physical activity (PA) and exercise as a putative treatment target, potentially diminishing an individual's level of ADHD symptoms and associated impairments.[16] Here, PA is defined as any bodily movement produced by skeletal muscles that requires energy expenditure, whereas exercise is a subcategory of PA that is planned, structured, repetitive, and purposeful. Yet more and better-quality evidence is needed to establish the impact of PA on ADHD symptoms and its efficacy in alleviating the symptoms and impairments associated with the disorder.

Findings from a study investigating the correlation between cognitions and exercise quantity are consistent with the notion that PA may be beneficial for individuals with high levels of ADHD symptoms and associated impairments. Exercise quantity was measured each day over a period of 1 week using an accelerometer in 18 boys diagnosed with ADHD. The study found that exercise quantity was significantly correlated with working memory, inhibition, and information processing.[17] Yet the correlational and nonrandomized design prohibits causal interpretations and limits conclusions about efficacy.

A study assessing the effects of a 10-week moderate-to–high-intensity exercise program on fitness, cognitive functioning, and ADHD-related behavior in 10 children with ADHD, compared to a no-intervention control group consisting of 11 children with ADHD, reported significant improvements in muscular capacities, motor skills, level of information processing, and parent- and teacher-rated social, thought, and attention problems following the intervention.[18] No information is available as to whether this study was randomized and blinded.

Three studies investigating the effect of PA in individuals with ADHD have used a randomized prospective design. One of these studies examined the effects of acute exercise on EF.[19] Thirty minutes of moderate-intensity running facilitated selective attention, processing speed, and set-shifting in 20 children with ADHD who were randomly assigned to the PA group, relative to 20 children with ADHD assigned to the control condition of watching a PA-related video.[19] The second study explored the association between chronic PA and attention in 84 children with ADHD. Compared to individuals who did not receive an intervention, individuals randomly assigned to a moderate-intensity 10-week exercise program of 3 sessions per week improved on teacher ratings of attention, motor skills, and academic and classroom behavior.[20] In the third randomized study, teacher-rated cooperativeness and EF, as indicated by the digit symbol test, were significantly improved by 12 biweekly exercise sessions, relative to behavioral educational sessions, in 28 boys with ADHD.[21] Although no significant changes were found with regard to hyperactivity scores, inattention scores improved in the exercise group. These randomized prospective studies thus suggest that PA has positive effects on EF and behavioral symptoms associated with ADHD. Yet none of these studies established whether any short-term effects of PA were followed by longer-term benefits. Furthermore, none of these studies elaborate on the blinding status of the researchers and informants.

The findings from the studies reviewed above provide some support for the hypothesis that exercise has the potential to act as a protective factor for ADHD symptoms and associated impairments. Yet, concluding causality from nonrandomized, retrospective, and cross-sectional data is problematic. The studies looking at case-control differences are limited by inadequate control conditions, and the results may therefore be confounded by unmeasured genetic and environmental factors that may lead to spurious associations. The nonblinded status of the researchers and raters of behavior may further inflate the positive effects of exercise on the various outcome variables due to the nonspecific effects evoked by a child' s participation in a treatment program.[16] Furthermore, little is known about the developmental influence of PA on ADHD symptoms. The purpose of this study was to examine the effect of PA during late adolescence on ADHD symptoms in early adulthood. Both the symptoms and functional impairments associated with ADHD often persist from childhood into adolescence and adulthood.[2] Although attention problems remain relatively stable, symptoms of hyperactivity and impulsivity tend to decline with age.[22] PA may thus be particularly beneficial for the age group examined here, as PA seems to affect inattention more than hyperactivity/impulsivity symptoms.[18,20,21] In light of these findings, the impact of PA on ADHD symptoms is examined together and separately for the 2 subcomponents of ADHD, inattention and hyperactivity/impulsivity. Investigating the effect in 232 monozygotic (MZ) twin pairs enables us to control for unmeasured genetic and shared environmental confounding factors that may influence the relationship between PA and ADHD symptoms, allowing us to draw tentative causal inferences about this relationship.

METHOD

Sample

Data came from the Swedish Twin Study of CHild and Adolescent Development (TCHAD). TCHAD is an ongoing prospective longitudinal twin study concerning health and behavior in twins from childhood to early adulthood.[23] The study is a subsample of the Swedish Twin Registry and contains about 1,450 twin pairs born in Sweden between May 1985 and December 1986. The twins and their parents have been contacted on 4 different occasions using postal questionnaires. The current study used data from waves 3 and 4.