EXECUTIVE FUNCTIONING INTERVENTIONS FOR INDIVIDUALS WITH ADHD: A SYSTEMATIC REVIEW

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EXECUTIVE FUNCTIONING INTERVENTIONS FOR INDIVIDUALS WITH ADHD: A SYSTEMATIC REVIEW

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ABSTRACT

Ongoing research regarding interventions for executive functions (EFs), the top-down cognitive processes that guide planning and decision-making behaviors, aims to determine whether intervention programs result in significant improvements in EFs for both neurotypical and neurodivergent populations (Diamond & Ling, 2016). EFs are critical because they predict performance in other daily living domains, including physical health, quality of life, and job performance (Cristofori et al., 2019; Diamond, 2013). Research has found that individuals with a variety of mental health disorders as well as neurodegenerative disease often perform poorly on EF tasks. Particular attention has been devoted to the study of EF deficits in attention-deficit/hyperactivity disorder (ADHD), as many, but not all, individuals with this disorder display EF deficits (Weyandt, 2009). Cognitive training (i.e., EF interventions) has been suggested as a mechanism to help to improve EFs and other symptoms among individuals diagnosed with ADHD. Previous reviews suggest that some EF interventions are efficacious for individuals diagnosed with ADHD but have focused on a specific intervention modality or age group (Lambez et al., 2020; Liang et al., 2021; Poissant et al., 2019). The purpose of the current systematic review was to examine whether non-pharmacological interventions result in significant improvement in EFs for individuals with ADHD, and whether intervention efficacy differs with regard to: a) intervention modality, and b) age of participants. Results demonstrated that non-pharmacological interventions are efficacious for improving EFs in individuals with ADHD. Interventions were found to be efficacious across modalities and age groups, with small to large effect sizes.

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PREFACE

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PUBLICATION STATUS

The present review is being prepared for submission to *Neuropsychology*.

INTRODUCTION

Executive Functioning

Theoretical models for executive functions (EFs) typically consider these abilities to be a collection of higher cognitive processes (Cristofori et al., 2019; Diamond, 2013). While several models of EF are found in the literature, one of the most commonly used is Miyake and colleagues' model (2000) of three core EFs. The first core EF domain is set shifting, which consists of the ability to easily switch between different paradigms or tasks. Next, inhibition consists of the ability to suppress automatic or inappropriate responses in favor of a more desirable response. Lastly, updating (i.e., working memory) consists of the ability to mentally hold and manipulate information in the mind even when the stimulus for that information is no longer present (Diamond, 2013; Miyake et al., 2000). Miyake et al. (2000) propose that complex EFs are expansions of these core domains. The Miyake model is often used in EF studies, as EF tasks or surveys may be utilized as global measures of EF or matched to individual domains (i.e., set shifting, inhibition, and updating/working memory) by researchers (Diamond, 2013).

Because EFs are involved in everyday behavior and decision-making, EF impairments may result in poorer functioning in several areas of life (Cristofori et al., 2019; Diamond, 2013). In children and adolescents, impaired EFs have been linked to poorer academic performance, while adults with declining or impaired EFs often display poorer job performance or burnout (Bailey, 2007; Borella et al., 2010; Deligkaris et al., 2014; Duncan et al., 2007). Impaired EFs are also related to deficits or problems in health-related and affective domains. Crescioni et al. (2011) found that adult individuals with worse self-control (i.e., the ability to control or change responses to meet a given standard, similar to Miyake and colleagues' domain of inhibition) ate more calories and lost less weight than their counterparts with better self-control. In a study of adolescents, Junger and van Kampen (2010) similarly found that individuals who scored higher on a cognitive ability task also reported having healthier diets and engaging in exercise more frequently than their peers. Self-control and self-regulation may also play a role in decreasing aggressive behaviors. Results from Denson et al. (2011) showed that bolstering individuals' self-regulatory resources after provocation and rumination improved their performance on a measure of inhibitory control. Better EFs, including self-regulatory mechanisms or inhibitory control, may be related to better social functioning and fewer social problems (Cristofori et al., 2019; Diamond, 2013).

As noted previously, EF impairments, while present among the broader population, are often present among individuals with ADHD (Kofler et al., 2019; Weyandt, 2009). Several studies have examined the relationship between EFs and other areas of life within the population, with results upholding the same general trend seen in non-clinical populations; EF impairments are related to deficits or worse performance in academic, health-related, or affective life domains. For example, a study of college students conducted by Weyandt et al. (2013) found that students diagnosed with ADHD reported lower grades and worse overall EFs than their peers without ADHD. Additionally, a study of health-related quality of life (HRQOL) in adults with ADHD being treated with stimulant medication found that improvements in EF between the start of the study and the endpoint correlated with reported improvement in HRQOL across study duration (Brown & Landgraf, 2010). Lastly, married adults with ADHD reported poorer marital adjustment and greater family dysfunction than their peers without ADHD (Eakin et al., 2004). It is important to note, however, that EF deficits are not characteristic of all individuals with ADHD, are not sufficient for a diagnosis of ADHD, and are often present in other psychological and neurodegenerative disorders (Diamond, 2013; Snyder, 2013; Stein et al., 2019; Weyandt, 2009). However, given that EF deficits are often found in individuals with ADHD (Diamond, 2013; Weyandt, 2009), it is particularly important to develop efficacious options for improving EF in this population.

Attention-Deficit/Hyperactivity Disorder

According to the Diagnostic and Statistical Manual of Mental Disorders Fifth Edition (DSM-5), ADHD is characterized by symptoms of inattention, hyperactivity, and/or impulsivity that result in impaired functioning across multiple settings (American Psychiatric Association, 2013). Additionally, ADHD symptoms must have been present before 12 years of age to meet diagnostic criteria, although diagnosis can occur later in life and symptoms may persist into adulthood for many individuals diagnosed in childhood (up to 50% of individuals) (Adler et al., 2017; American Psychiatric Association, 2013; Kessler et al., 2005). ADHD diagnoses can be further categorized into presentations (i.e., subtypes): predominantly inattentive, if an individual meets criteria for symptoms of inattention but not hyperactivity/impulsivity; predominantly hyperactive/impulsive, if an individual meets criteria for symptoms of hyperactivity/impulsivity but not inattention; and combined presentation, if an individual meets criteria for symptoms of both inattention and hyperactivity/impulsivity (American Psychiatric Association, 2013).

Because ADHD is a neurodevelopmental disorder with diagnostic criteria tied to onset during childhood, a higher prevalence of ADHD diagnoses is seen in children than in adults. A review by Sayal et al. (2018) found that community prevalence of ADHD in children ranged from 2-7% and averaged approximately 5% globally. Within the United States, approximately 6.1 million children (9.4%) aged 2-17 years had received an ADHD diagnosis in their lifetime, with an estimated 5.4 million children (8.4%) experiencing current ADHD at the time of data collection based on parent-report data from the 2016 National Survey of Children's Health (NSCH) (Danielson et al., 2018). The overall trend across available NSCH data from 2003-2016 is one of growth and increasing numbers of children diagnosed with ADHD (Danielson et al., 2018; Visser et al., 2014).

While ADHD is less prevalent in the adult population than among children, it remains a common disorder throughout the lifespan. The DSM-5 estimates the prevalence of ADHD in most cultures at 5% of children and 2.5% of adults. Data from the National Comorbidity Survey Replication (NCS-R), representative of the U.S. population, resulted in an estimated prevalence of 4.4% of current ADHD in a subsample of 18-44-year-old respondents (Kessler et al., 2006). These data are consistent with the estimate that up to half of individuals diagnosed with ADHD in childhood continue to experience symptoms as adults (Kessler, Wai, et al., 2005; Weyandt & DuPaul, 2013). A recent systematic review of the literature investigated the global prevalence of persistent and symptomatic adult ADHD (Song et al., 2021). The authors operationally defined persistent adult ADHD as ADHD that required both a childhood onset and adult symptoms; they found a global prevalence of 2.58%, in line with previous estimates. Prevalence was higher when only adult symptoms (without childhood onset) were considered; 6.76% global prevalence was reported for individuals with symptomatic adult ADHD (Song et al., 2021).

In summary, ADHD is a highly prevalent mental health disorder that affects millions of individuals globally. Although it is typically regarded as a disorder of childhood, ADHD affects individuals across the lifespan, from childhood through adulthood.

The Relationship between ADHD and EFs

Although EF impairments are not necessary or sufficient for the diagnosis of ADHD, individuals diagnosed with ADHD are likely to report EF difficulties or perform worse in laboratory tasks of executive functioning compared to typically developing peers (Weyandt, 2009). However, the extent of EF impairment experienced by individuals with ADHD may vary across EF domains and across the lifespan (Adler et al., 2017; Barkley et al., 2008; Kofler et al., 2019; Weyandt, 2009). For example, a review by Weyandt (2009) found that children and adolescents with ADHD do not experience impairments in all EF domains, but rather differing levels of impairment across domains. However, Weyandt noted there was disagreement in the literature as to which EF domains were impaired and the degree of inter- and intravariability in individuals with ADHD. The review by Weyandt (2009) also upheld that the presence of EF impairments is not necessary for a diagnosis of ADHD to be made, as some individuals with ADHD did not experience impairments or perform significantly different on EF measures than their peers without ADHD (Weyandt, 1991). Kofler et al. (2019) also found heterogenous EFs in children with ADHD. Using laboratory tasks that corresponded to Miyake and colleagues' core EF domains of set shifting, working memory, and inhibition, Kofler et al. (2019) found that 89% of children with ADHD in their sample met the threshold for impairment in at least one domain (Miyake et al., 2000). Working memory was the most commonly impaired domain in this study (62% of children met criteria for impairment), followed by set shifting (38%) and inhibition (27%).

Like their younger counterparts, variability in EF abilities can also be seen in adults with ADHD. Barkley et al. (2008) reported that adults with ADHD were most likely to perform significantly worse than their control group peers in measures of inattention, inhibition, non-verbal and verbal working memory, and design fluency. Adults with ADHD did not perform significant differently in measures of set shifting. As suggested by Adler et al. (2017), EF deficits in adults with ADHD may appear in differing and more diverse patterns than those seen in children with ADHD. While some adults with ADHD do not present EF deficits (Barkley et al., 2008), Adler et al. (2017) suggest that executive dysfunction is an important component to the structure of adult ADHD, as central to the structure as DSM-5 symptoms of ADHD.

Previous Reviews and Purpose of the Current Review

Because of the importance of EFs to many aspects of daily life, research into EF interventions is ongoing, and some researchers have begun to investigate types of training approaches that may be effective or the populations that are likely to benefit from these interventions. For example, a prior review of EF interventions suggests that individuals with the poorest EFs have the most to gain from EF training (Diamond & Ling, 2016). This general trend occurred across the different types of interventions evaluated, including physical activity, computer-based interventions, and mindfulness interventions. Based on this finding, it seems plausible that individuals diagnosed with ADHD are likely to benefit from EF training. This relationship has been upheld in recent reviews of interventions for individuals diagnosed with ADHD. For example, Poissant et al. (2019) reviewed studies that utilized mindfulness-based training as a principal or partial intervention in adults with ADHD and found that the training was effective at reducing ADHD symptoms and some facets of EFs/cognitive functioning. In addition, Lambez et al. (2020) reviewed studies that utilized non-pharmacological intervention modalities (alone or in conjunction with medication) in children, adolescents, and adults with ADHD, and found that all the intervention modalities evaluated provided some benefit to cognitive symptoms, with physical exercise being the most effective modality and inhibition and flexibility being the cognitive domains that saw the most improvement. However, Lambez et al. (2020) did not examine differences between age groups. Lastly, Liang et al. (2021) reviewed exercise interventions for children and adolescents with ADHD. Liang and colleagues found that exercise interventions had a positive effect on overall EF ability for children and adolescents with ADHD. Overall, these reviews demonstrated cognitive improvements in both children and adults with ADHD, and that different intervention modalities may be related to significant improvement in cognitive functioning. Reviews of interventions for individuals with ADHD that currently are or have been treated with stimulant medications also indicate that interventions may be useful for those who do not tolerate or only partially respond to medication (Poissant et al., 2019). Given these findings, interventions to improve EFs may serve as an important treatment option that should be further investigated.

In summary, the current literature supports that EF deficits are often characteristic of ADHD and that interventions targeting EFs can possibly result in EF improvement. However, a dearth of information exists concerning the efficacy of EF interventions across age and modality. Hence, the present systematic review aims to build on the extant literature by examining whether interventions result in significant improvement in EFs for individuals with ADHD, and whether intervention efficacy differs with regard to: a) intervention modality (e.g., intervention type or method of delivery), and b) age of participants.

METHODS

A systematic review of the literature was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al., 2021). Three databases (CINAHL, PubMed, and PsycINFO) were reviewed using the following search term: *(attention deficit hyperactivity disorder OR ADHD) AND (executive funct* OR cognitive funct* OR cognition OR set shifting OR cognitive flexibility OR working memory OR updating OR inhibition OR planning OR self-regulation OR verbal fluency) AND (intervention OR training OR program OR exercise OR physical activity OR mindful* OR computer-based)*.

Study abstracts were examined to determine if they met eligibility criteria. Abstracts that violated criteria were excluded from further review; abstracts that did not appear to violate eligibility criteria proceeded to full-text review. Articles that met all eligibility criteria during full-text review were included in the current systematic review. Eligibility criteria included:

A. The study was published in a scientific journal or dissertation database.

B. The study was published between January 2012 – December 2022.

C. The study was originally published in English.

D. Participant sample size was greater than one; case studies were excluded.

E. The study used an original or secondary dataset; reviews and meta-analyses were excluded.

F. The study utilized self-report, parent- or teacher-report, or laboratory task EF measure(s).

G. Some or all participants meet diagnostic criteria for ADHD; if the study contains additional non-ADHD groups (e.g., healthy controls), only data concerning the ADHD group will be included.

H. Executive function(s)/functioning/dysfunction was a primary or secondary outcome of the study.

I. The study utilized a non-pharmacological or hybridized (combining pharmacological and non-pharmacological elements) intervention.

J. The study intervention was provided to the same population that outcome measures were drawn from (e.g., studies of parenting interventions in which child outcomes were measured were excluded).

In addition to database searches, relevant studies were also sourced from previously published reviews in accordance with the eligibility criteria. All articles were scored according to a 27-item checklist to determine study quality and availability of information; the checklist includes items regarding methods of data reporting, validity, bias, independence of sample, and statistical power (Downs & Black, 1998). The checklist demonstrates high internal consistency and test-retest reliability, and good inter-rater reliability. Using the Downs & Black checklist, items were scored individually; in the case of discrepancies in item scoring, reviewers met to resolve the issue and mutually decide on a score. An overall quality index score (QIS) was determined by calculating the average of the criteria scores, with higher scores indicative of higher overall quality.

Database reviews were conducted by the primary investigator. Full-text and quality reviews were conducted independently by the primary investigator and an additional student researcher; all reviewers were trained according to the study protocol prior to article review. In the case of discrepancies in article inclusion or exclusion, reviewers met to resolve the issue and mutually decide on an article's inclusion in the current review.

After full-text review, available participant demographics and descriptive statistics, including means, standard deviations, and sample sizes were extracted from relevant studies. Reported *p*-values were used to confirm that study results were statistically significant. To assess study results and availability of information, the percentages of studies that included power and effect size were reported, along with the range of power and effect sizes achieved across studies, and the mean power and effect size of relevant studies. Reported effect size and effect direction were used to examine intervention efficacy trends across studies according to the aims of the current review:

A. General trends across studies regarding demographic information (e.g., availability of information or homogeneity of participant samples) were reported, as the demographic diversity of studies, or lack thereof, may influence the generalizability of the results (Clark et al., 2019; DuPaul et al., 2021; Shea et al., 2022). Additional findings were also reported, such as significant efficacy differences regarding reported demographic variables (e.g., sex, race and/or ethnicity, socioeconomic status (SES), medication status, or comorbid disorders).

B. To address whether there were efficacy differences regarding intervention modality, studies were sorted into categories by intervention type, and effect size and effect direction were examined within and between categories. Effect sizes were examined according to numerical value and associated qualitative magnitude (small, medium/moderate, or large). Common EF intervention formats include physical activity/exercise, mindfulness training, and/or computerized training programs (Diamond & Ling, 2016). EF interventions range from one modality to multiple modalities (e.g., hybridized interventions). For the purposes of this review, interventions were sorted into four categories: a) exercise programs; b) mindfulness training; c) computer-based training; and d) hybridized/miscellaneous training.

C. To address whether efficacy differences emerged regarding age of participants, effect size and effect direction were examined between groups. Effect sizes were examined according to numerical value and associated qualitative magnitude (small, medium/moderate, or large). Studies were divided into two categories: a) a child/adolescent age group (participants aged 2-19 years old; children and adolescents are included in one category as there may be overlap between these age groups); and b) an adult age group (participants aged 17 years or older in order to include the age groups of college students and emerging adults) (American Psychological Association, n.d.-a , n.d.-b, n.d.-c; Anastopoulos & King, 2015; Arnett, 2014).

Study authors were contacted for additional information if effect size was not reported in the published article. When reported, the qualitative magnitude of effect sizes provided by study authors was used. When study authors did not report qualitative magnitude, effect size magnitude was interpreted based on established guidelines. For Cohen's *d*, effect sizes were interpreted as small (0.2), medium (0.5), and large (0.8) (Harlow, 2014; Lakens, 2013). For eta squared (η^2) and partial eta squared (η_p^2), effect sizes were interpreted as small (0.01), medium (0.06), and large (0.14) (Cohen, 1988).

RESULTS

Reported demographic information and intervention outcomes were reviewed to determine whether interventions resulted in significant improvement in EFs for individuals with ADHD. Descriptive analyses were performed to determine whether intervention efficacy differs with regard to a) intervention modality (e.g., intervention type or method of delivery), and b) age of participants. Results of this review are presented below.

Search Results

A total of 10,501 records were returned using the search terms in CINAHL, PubMed, and PsycINFO. After systematic reviews, meta-analyses, articles not published in English, and articles published outside of the review timeframe (2012-present) were excluded, 2,245 records remained. After undergoing abstract review, 222 records remained for full-text review. Following full-text review, 73 articles and five dissertations remained that met all review criteria as determined by the procedure previously described (pp. 17-20). A flowchart of the review process is shown in Figure 1 of Appendix A. An additional three articles were sourced from previously published reviews.

Duplicate articles were excluded during abstract and full-text review. Items were considered duplicates if a) the same article or dissertation was returned multiple times (either within the same database or across databases), b) a dissertation and a corresponding published journal article were returned (either within the same database or across databases) or c) an article or dissertation used the same dataset as a previously published article but did not provide additional or unique information about participants' EF ability post-intervention.

In studies consisting of participants with and without diagnosed ADHD, only results pertaining to the ADHD group were reported in the present review. If the study did not separate participants with diagnosed ADHD from participants with subthreshold ADHD or without ADHD, the study was excluded.

Quality Scores

Quality Index Scores ranged from 0.37 to 0.89 (Mean = 0.65, Median = 0.67). Scores in the reporting domain ranged from 0.55 to 1 (Mean = 0.80, Median = 0.82). In the external validity domain, scores ranged from 0 to 0.67 (Mean = 0.23, Median = 0.33). Bias scores ranged from 0.43 to 1 (Mean = 0.72, Median = 0.71), while scores in the confounding domain ranged from 0 to 1 (Mean = 0.46, Median = 0.5). All scores are reported on a scale from 0 to 1. Twenty-four of the 81 studies included information about statistical power.

Demographic Information Availability and Trends

Demographic Information

Studies in the current review represent research from 18 countries. The amount of participant demographic information reported differed by variable and study (see Table 1 in Appendix B). All studies reported age of participants and either gender or sex of participants. While gender and sex have different definitions, they are sometimes treated as interchangeable terms by researchers (Gentile, 1993; Madsen et al., 2017; Torgrimson & Minson, 2005). All studies included in this review treated gender or sex as a binary variable, reporting on the number or percentage of male and female participants. Other demographic variables were less frequently reported.

Twenty-eight studies (34.6%) provided some information regarding participants' race or ethnicity, either a partial report (listing the most commonly endorsed identity) or a full report. Thirty-four studies (42.0%) provided some information regarding participants' socioeconomic status (SES). The American Psychological Association (APA) considers SES to be determined by "a combination of social and economic factors such as income, amount and kind of education, type and prestige of occupation, place of residence, and—in some societies or parts of society—ethnic origin or religious background" (American Psychological Association, n.d.-e). For the purposes of this review, studies were considered to have provided information on participants' SES if they provided an SES rating or information regarding participants' employment, income, or education. In child and adolescent studies, provision of parental employment, income, or education was considered. See Table 1 for a list of participant information reported by study.

No studies investigated intervention efficacy related to race, ethnicity, or SES. No studies investigated intervention efficacy related to sex as a primary outcome, but one study (LaCount et al., 2022) conducted a *post hoc* analysis to investigate possible sex differences in EF measure performance. The results showed that effects were approximately similar across men and women on the measure of inhibition, larger for men and smaller for women on the measure of sustained attention, and smaller for men and larger for women on the measures of processing speed and response variability. Significance of the *post hoc* analyses was not reported.

ADHD Subtype and Medication Status

Studies differed in the amount of information provided on participant medication status and ADHD subtype. Fifty-two studies (64.2%) provided information on participants' ADHD subtype, either a partial report (listing the most commonly diagnosed subtype) or a full report. Of the studies that reported subtype information, six studies (Bigorra et al., 2016; Dentz et al., 2020; Dovis et al., 2015; Lan et al., 2020; Miranda et al., 2013; Passarotti et al., 2020) included only the combined subtype of ADHD, and one study (Cardoso-Moreno et al., 2015) included only the predominantly hyperactive/impulsive subtype of ADHD. The remaining studies included two or more subtypes of ADHD in their participant samples. No studies investigated intervention efficacy related to ADHD subtype as a primary outcome, but one study (Bikic et al., 2018) conducted a *post hoc* analysis examining the relationship between intervention results and ADHD subtype. Results revealed that participants with the predominantly inattentive subtype made the greatest gains on a number of outcomes compared to the controls, although significance and effect size were not reported.

Seventy-seven studies (95.1%) provided some information on participants' medication status. Of the studies that reported medication information, 21 studies (27.3%) excluded medication or used a sample of participants that were not receiving pharmacological treatment for ADHD. Most studies (64.9%) allowed pharmacological treatment for participants regardless of group assignment, and some (but not all) participants were treated with ADHD medication. Four studies (Carboni, 2012; Dentz et al., 2020; Gerber et al., 2012; Pan et al., 2022) included a sample in which all participants were treated with ADHD medication or pharmacological treatment was required. Two studies (Azami et al., 2016; Farias et al., 2017) established group assignment based on medication status, including pharmacologically treated and untreated groups. Azami et al. (2016) found that the experimental group receiving a computer-assisted cognitive rehabilitation program performed significantly better than the medication group on some EF measures post-intervention (with large effect sizes, d = 1.112 – 1.743), but that they did not perform significantly differently at follow-up. Farias et al. (2017) provided all participants with computerized cognitive training and tested their EF abilities pre- and post-intervention. Both the medicated and unmedicated groups improved significantly on several EF measures, with similar patterns of improvement, except for the Rey-Osterrieth Complex Figure test.

Comorbidity

Forty-seven studies (58.0%) did not report information concerning comorbid disorders or diagnoses in their participant samples. These studies varied in their exclusion criteria, so that some participants may have had comorbid disorders that went unreported, while other studies did not allow individuals to participate if they had any diagnosed disorder other than ADHD. Thirty-four studies (42.0%) provided partial or full information on the comorbid disorders or diagnoses present in their participant samples. Of those, seven studies (Becker et al., 2022; Chimiklis, 2019; Dentz et al., 2020; Farias et al., 2017; Heishman, 2015; Horowitz-Kraus, 2015; Horowitz-Kraus et al., 2019) required the presence of ADHD and a comorbid disorder in their inclusion criteria for one or more groups. All but one study (Dentz et al., 2020) found that interventions significantly improved EFs in individuals with ADHD even in the presence of a comorbid disorder. For example, Becker et al. (2022) found that a behavioral sleep intervention did significantly improve reported EFs in adolescents with ADHD and co-occurring sleep problems. Chimiklis (2019) investigated the use of a computerized training program (ACTIVATE) in children with ADHD and with or without co-occurring reading difficulties. Results revealed that both groups significantly improved some EF domains after training, with few differences between groups. Horowitz-Kraus (2015) and Horowitz-Kraus et al. (2019) also investigated the effects of computerized training on children with ADHD and comorbid reading difficulties. Horowitz-Kraus (2015) included children with ADHD with or without comorbid reading difficulties in their study; results revealed that both groups improved with training, but there was some divergence in the measures on which they improved. Horowitz-Kraus et al. (2019) included children with reading difficulties with or without ADHD in their study. Results showed that individuals with ADHD and reading difficulties improved on some EF measures relative to the non-ADHD groups.

Farias et al. (2017) and Heishman (2015) also investigated the use of computerized programs in children with ADHD and a comorbid condition. Farias et al. (2017) examined the use of a computerized cognitive training program (Captain's Log) in children with ADHD and a comorbid learning disorder. Results revealed that the intervention significantly improved performance in several EF domains. Heishman (2015) investigated the efficacy of Cogmed Working Memory Training (CWMT) in a sample of children with ADHD and math difficulties. Results demonstrated that the participants significantly improved in several EF domains.

In contrast, Dentz et al. (2020) investigated the use of a computerized training program (CWMT) in youth with ADHD and a comorbid learning disability (LD), Tourette syndrome (TS), or oppositional defiant disorder (ODD). Results did not produce a significant improvement in EFs with training, but the authors noted that the use of medication in this study may have normalized participants' performance and limited the detection of intervention effects.

Trends Across Intervention Categories

Exercise Programs

Thirteen studies (16.0%) were assigned to the exercise program category. The majority of studies in this category (92.3%) found a significant improvement in some aspect of EF as a result of an exercise intervention. Effects were mostly large in size; of the studies that found a significant improvement in EF, one study found an effect size below threshold, one study's effect size range included small effect sizes, three studies' effect size range included medium effect sizes, and 10 studies' effect size range included large effect sizes (see Table 2 in Appendix B). Within this category, 76.9% of studies report effect size and 30.8% of studies provided some information regarding statistical power. Studies were split almost evenly on the duration of the exercise intervention applied. Seven studies (53.8%) utilized an acute intervention, in which individuals participated in a single bout of exercise ranging from 5-40 minutes in total (including warm-up and cool-down periods). The remaining six studies

(46.2%) employed a long-term intervention, with individuals participating in repeated exercise sessions for 8-12 weeks. The majority of studies in this category (76.9%) investigated exercise interventions for children and adolescents with ADHD; only three studies (23.1%) investigated exercise interventions using adult participants. Almost all studies (92.3%) used performance-based measures to evaluate EF abilities. Types of exercise varied, with interventions including walking or standing, aerobic exercise, high intensity interval training (HIIT), and sports training; see Table 2 in Appendix B for a brief overview of studies in this category.

Mindfulness Training

Eleven studies (13.6%) were assigned to the mindfulness training category. The majority of studies in this category (90.9%) found a significant improvement in some aspect of EF as a result of a mindfulness intervention. Effects were mostly large in size; of the studies that found a significant improvement in EF, two studies found small effect sizes, three studies' effect size range included medium/moderate effect sizes, four studies' effect size range included large effect sizes, and one study's effect size range included very large effect sizes (see Table 3 in Appendix B). Within this category, 81.8% of studies report effect size and 27.3% of studies provided some information regarding statistical power. MYmind was the most commonly applied mindfulness training program, with 27.3% of articles investigating its efficacy. Other studies examined training in tranquil abiding (TTA), mindfulness-oriented meditation (MOM), mindfulness-based cognitive therapy (MBCT) or another form of mindfulness practice. Most interventions combined group mindfulness training with individual practice at home; only one study (Carboni, 2012) investigated individual mindfulness training in a school-based setting. The mindfulness training category had the highest percentage of adult studies, with 45.5% of articles investigating mindfulness training programs in adults. See Table 3 in Appendix B for a brief overview of studies in this category.

Computer-Based Training

Fifteen studies (18.5%) were assigned to the computerized intervention category. The majority of studies in this category (73.3%) found a significant improvement in some aspect of EF as a result of a computerized intervention. Effects were mostly medium and large in size; of the studies that found a significant improvement in EF, two studies' effect size range included small/modest effect sizes, four studies' effect size range included medium/moderate effect sizes, and five studies' effect size range included large effect sizes (see Table 4 in Appendix B). Within this category, 73.3% of studies report effect size and 40.0% of studies provided some information regarding statistical power. Cogmed Working Memory Training (CWMT) was the most frequently studied intervention, utilized in six studies (40.0%). Other interventions in this category included Computer-Assisted Cognitive Rehabilitation (CACR), ACTIVATE, Braingame Brian (BGB), Cognifit, AttenFocus, Captain's Log, and a computer-based Reading Acceleration Program (RAP). Most studies (93.3%) investigated the efficacy of computerized interventions for children and adolescents with ADHD; only one study (Stern et al., 2016) investigated the efficacy of computer-based interventions using a sample of adults with ADHD. The majority of studies (86.7%) included a control or comparison group or condition, with six studies (40.0%) utilizing a non-adaptive or partially-active control. Three studies (Chimiklis, 2019; Horowitz-Kraus, 2015; Horowitz-Kraus et al., 2019) investigated computerized training programs for children with comorbid ADHD and reading difficulties. In contrast, one study (Farias et al., 2017) investigated computerized training programs for children with comorbid ADHD and learning disorders. An additional study (Passarotti et al., 2020) investigated computerized training programs in two pediatric samples: children with ADHD, and children with pediatric bipolar disorder (PBD). See Table 4 for a brief overview of studies in this category.

Hybridized/Miscellaneous Interventions

The hybridized or miscellaneous category was the largest intervention modality category in the current review, with 42 articles (51.9%) included. Within this category, 81.0% of studies report effect size and 26.2% of studies provided some information regarding statistical power. The majority of studies in this category (92.9%) found a significant improvement in some aspect of EF as a result of a hybridized or miscellaneous intervention. Effects were mostly medium in size; of the studies that found a significant improvement in EF, eight studies' effect size range included minimum practically significant/small effect sizes, 21 studies' effect size range included medium/moderate effect sizes, and 15 studies' effect size range included large effect sizes (see Table 5 in Appendix B). Within this hybrid category, most articles (81.0%) investigated intervention efficacy in children and adolescents with ADHD. Six articles (14.3%) investigated the efficacy of Cognitive-Functional occupational therapy (Cog-Fun), making it the most commonly applied intervention. Other types of occupational, cognitive, or behavioral therapeutic interventions were also common. Five studies (11.9%) investigated biofeedback, neurofeedback, or neurostimulation interventions. Four studies (9.5%) investigated hybridized interventions combining exercise and technological (virtual reality or digital game) elements. See Table 5 in Appendix B for a brief overview of studies in this category.

Trends Across Age Categories

Child/Adolescent

The majority of studies included in the present review (79.0%) investigated the use of interventions for children or adolescents with ADHD. Within this category, 75.0% of studies report effect size and 32.8% of studies provided some information regarding statistical power. Thirty-four studies (53.1%) used a hybridized or miscellaneous intervention, 14 studies (21.9%) used computerized training, 10 studies (15.6%) used exercise training programs, and six studies (9.4%) used mindfulness training. Nearly all studies (90.6%) found that the applied intervention had a significant improvement in some aspect of EF. Effects were mostly medium and large in size; of the studies that found a significant improvement in EF, one study found an effect size below threshold, nine studies' effect size range included small/modest/minimum practically significant effect sizes, 26 studies' effect size range included medium/moderate effect sizes, and 27 studies' effect size range included large effect sizes. Fifty-five studies (85.9%) reported mean age of all participants or participant groups and of those, most studies (78.2%) used participant samples in which the mean age of participants fell between 6-12 years of age (the periods of time identified as middle childhood and preadolescence) (American Psychological Association, n.d.-c , n.d.-d; Collins, 1984). Six studies (10.9%) used early childhood participant samples in which the mean age was less than six years of age (American Psychological Association, n.d.-c); another six studies (10.9%) used adolescent participant samples in which the mean age was greater than twelve years of age. See Table 6 in Appendix B for a brief overview of studies in this category.

Adult

Only seventeen studies (21.0%) in the present review investigated the use of interventions for adults with ADHD. Within this category, 88.2% of studies report effect size and 17.7% of studies provided some information regarding statistical power. Eight studies (47.1%) used a hybridized or miscellaneous intervention, five studies (29.4%) used mindfulness training, three studies (17.6%) used an exercise training program, and one study (5.9%) used computerized training. The majority of the studies (82.3%) found that the applied intervention had a significant improvement in some aspect of EF. Effects were mostly large in size; of the studies that found a significant improvement in EF, four studies' effect size range included small effect sizes, six studies' effect size range included medium/moderate effect sizes, eight studies' effect size range included large effect sizes, and one study's effect size range included very large effect sizes. Ten studies (58.8%) used samples of emerging and young adult participants, with mean ages falling between approximately 20-35 years of age (American Psychological Association, n.d.-b); five studies (29.4%) focused on college students in particular. The remaining seven studies in this category (41.2%) used participant samples with mean ages characteristic of middle adulthood, approximately 36-64 years of age (American Psychological Association, n.d.-b). Solanto et al. (2018) investigated the oldest age group in the review, using a subsample of adults with a mean age of 56.15 years. While Solanto et al. (2018) characterized this group as older adults, they had not yet reached the stage of later adulthood, which typically begins around 65 years of age (American Psychological Association, n.d.-b). No studies in this review examine interventions for individuals in later adulthood with ADHD. See Table 7 in Appendix B for a brief overview of studies in this category.

DISCUSSION

The purpose of the current review was to examine whether interventions result in significant improvement in EFs for individuals with ADHD, and whether intervention efficacy differs with regard to: a) intervention modality, and b) age of participants. Additionally, trends in demographic information availability were examined. In general, results supported that non-pharmacological interventions are efficacious for improving EFs in individuals with ADHD across intervention modalities and age groups. While reported ES varied across studies, 88.9% found significant improvement in either overall EF or one or more domains. Some 11.1% studies found no significant improvement related to the intervention. No studies reported significant worsening of EF or serious adverse events related to the intervention. These findings may suggest that, while additional research into EF interventions is still necessary, non-pharmacological interventions may be a low-risk method of improving EFs in individuals with ADHD.

Demographic Information

The studies differed substantially in how they reported the demographics of their participant sample. For example, age and sex were always reported. Other variables, such as race/ethnicity and SES, were reported in less than half the studies. Previous research has shown that disparities in ADHD diagnosis and treatment exist with regard to demographic variables (Morgan et al., 2013; Mowlem et al., 2019; Rucklidge, 2010; Russell et al., 2016). Specifically, Morgan et al. (2013) conducted a study in the United States using a nationally representative cohort of school children and found that minority children were significantly less likely to receive an ADHD diagnosis or prescription medication than their white counterparts. This relationship held even when potential confounding variables (such as SES) were controlled for

(Morgan et al., 2013). Additionally, a systematic review conducted by Russell et al. (2016) examining the relationship between ADHD and different dimensions of SES (including both indices and individual measures such as parental income, occupation, education, and marital status) found that, overall, ADHD was associated with low SES. Lastly, in a study investigating SES and ADHD treatment using data from a national cohort of U.S. children, Simoni & Drentea (2016) found that higher parental income was significantly correlated with ADHD medication use. Simoni & Drentea (2016) also found that children taking medication were more likely to be white, younger, and male as compared to children not taking ADHD medication. Sex differences in ADHD diagnosis and treatment have also been observed in additional studies (Mowlem et al., 2019; Rucklidge, 2010). Future studies of individuals with ADHD would benefit from reporting demographic information more thoroughly, as it affects the generalizability of the findings.

Additionally, future research should address the role that demographic variables may play in the relationship between ADHD and EF abilities. For example, previous research has found a mediating effect of EF in SES and ADHD problems of Chinese preschool children, wherein SES affected ADHD directly and indirectly through EF, particularly the domains of working memory and inhibition (Fan et al., 2022). None of the studies in the current review used the demographic variables of sex, race/ethnicity, or SES as a grouping criterion to investigate potential differential effects of the chosen intervention(s).

ADHD Subtypes and Medication Status

Most studies reported information on participants' diagnosed subtype, and almost all studies reported information on participants' medication status. Previous studies investigating EF differences between ADHD subtypes have yielded mixed, but mostly non-significant, results (Bahçıvan Saydam et al., 2015; Geurts et al., 2005;

Martel et al., 2007). These studies have compared EF performance between individuals with predominantly inattentive and combined subtype; one study suggests that children with ADHD-I performed significantly better than children with ADHD-C in specific EF domains (verbal working memory and verbal category shifting) (Bahçıvan Saydam et al., 2015). However, Bahçıvan Saydam et al. (2015) did not find significant differences between ADHD subtypes in other domain measures, consistent with previous studies that demonstrated no significant differences in EF performance between ADHD subtypes (Bahçıvan Saydam et al., 2015; Geurts et al., 2005; Martel et al., 2007). Although previous research has found that individuals with different EF subtypes do not display significantly different patterns of EF impairment, research has not addressed whether they respond to non-pharmacological EF interventions in the same way. No studies in the current review investigated differences in intervention response related to ADHD subtype, although one study (Bikic et al., 2018) conducted a *post hoc* analysis that suggested that participants with ADHD-I made the greatest improvement relative to controls (however, significance and ES were not reported for this analysis).

Stimulant medication has been shown to significantly improve core symptoms in individuals with ADHD, and is one of the most common methods used to treat ADHD (Center for Disease Control and Prevention, 2022; Schweitzer et al., 2012). However, stimulant medication may not be effective for all individuals, or may have undesirable side effects such as decreased appetite or insomnia (Schweitzer et al., 2012; The National Institute of Mental Health, 2021; Weyandt, 2019). Additionally, research has demonstrated variable results regarding the effect of stimulant medication on cognition, including EFs (Coghill et al., 2007; Rhodes et al., 2006). For these reasons, non-pharmacological treatments that may be used as a supplement or alternative to medication to improve EFs and core ADHD symptoms are of interest. Results from the present systematic review support the potential efficacy of non-pharmacological interventions. However, only a small number of studies that investigated non-pharmacological interventions in the absence of or compared to stimulant medication. Results from these studies suggest that non-pharmacological interventions may be effective even without being paired with pharmacological treatment, but future research should continue to investigate the combined and individual effects of pharmacological and non-pharmacological interventions.

Intervention Modalities

Results of the current review suggest that multiple modalities, including exercise, mindfulness, computer-based training, and various therapeutic interventions may significantly improve EFs in individuals with ADHD across the lifespan. However, there are differences in study design that should be considered when interpreting these results. First, previous research has demonstrated that performance-based and reporting neuropsychological measures may not provide the same information about EF abilities; it has been suggested that reporting measures may provide information about individuals' typical EF performance, while performance-based measures may provide information about optimal EF performance (Toplak et al., 2013). In the present review, exercise studies were measured almost exclusively with performance-based measures, while the majority of mindfulness studies (63.6%) used only reporting measures. Additionally, studies in the current review used a broad range of controls, including having no control group, a passive control group, or an active control group. Although speculative, this finding may indicate that studies do not control for non-specific or therapeutic effects to the same degree. However, a recent meta-analysis (Au et al., 2020) has found that there were no profound performance differences between active and passive control groups in cognitive intervention studies using objective performance-based measures.

Age Groups

Results of the current review suggest that exercise, mindfulness training, computerized training, and some hybridized or miscellaneous interventions are effective at improving EFs in individuals with ADHD across the lifespan. However, different age groups were not studied or exposed to intervention modalities in the same proportions. The majority of the studies in the current review used samples of children or adolescents, and within this age group category, most studies used participants with a mean age in the developmental period of middle childhood (6 – 12 years of age). While ADHD can be diagnosed in early childhood, most diagnoses occur in school-age children; in the United States, the median age of onset in children with ADHD was six years of age, with age of diagnosis ranging from four to seven years depending on severity (American Psychiatric Association, 2013; Visser et al., 2014). Therefore, it is not surprising that this age group (early childhood) received less representation in the current review. It was surprising, however, that relatively few studies investigated interventions in adolescent samples with a mean age greater than 12 years old. U.S. survey data from 2016 – 2019 showed that 3.3 million (13%) adolescents aged 12 – 17 years old had been diagnosed with ADHD compared to 2.4 million children (10%) aged 6 – 11 years old (Bitsko et al., 2022). Additionally, teenagers with ADHD may experience academic, organizational, and interpersonal difficulties, impaired executive functions, and are more likely to participate in risky behaviors such as substance use or unsafe sexual activity (Martel et al., 2007; The National Institute of Mental Health, 2021). Because of the prevalence of ADHD and related impairment in teenagers, future studies should further investigate the efficacy and utility of EF interventions, particularly the intervention modalities of exercise and mindfulness training, which were not applied to this age group in *any* of the studies included in the current review.

While ADHD is less prevalent in adults than in children and adolescents, prevalence rates may be increasing more rapidly in adults than children. A study investigating the prevalence rates of ADHD in adults and children aged 5 – 11 years using medical records from a large U.S. regional health care delivery system found that from 2007 – 2016, prevalence increased by 26.4% in children, while in adults prevalence increased by 123.3% (Chung et al., 2019). Additionally, impairments associated with ADHD continue into adulthood; a 16-year follow-up study of male participants found that, compared to controls without ADHD, participants with ADHD were significantly more likely to experience a comorbid psychiatric disorder in their lifetime, report greater impaired current global functioning and family conflict, and experience significant impairment on neuropsychological measures (Biederman et al., 2012). While the results of the current review suggest that interventions are effective at improving EFs in adults with ADHD, most adult studies used either a behavioral or cognitive therapy or mindfulness training intervention. Only three studies investigated exercise interventions, and all of them used an acute training paradigm. Only one study investigated the use of computerized training. Future studies should expand upon the types of interventions designed to improve EFs and core ADHD symptoms offered to adults with ADHD.

Limitations

There are limitations in the present systematic review that should be considered when interpreting the results. First, the use of reviewer-assigned qualitative effect sizes based on fixed thresholds may not reflect the true effect sizes achieved, as appropriate thresholds may vary with field and study design (Harlow, 2014; Lakens, 2013). For this reason, qualitative effect sizes assigned by study authors were preferentially reported, and qualitative effect sizes were only assigned by reviewer when the study did not provide this information.

Additionally, review criteria relied on studies to identify EF as a primary or secondary outcome. EF is an umbrella term used to describe a related set of cognitive functions and lacks a standardized definition (Weyandt, 2009). Therefore, it's likely that additional articles using the same measures or tapping into the same functions as included studies (or related cognitive outcomes within the included studies) were excluded due to the terminology used in their article (e.g., cognitive function or neuropsychological function instead of EF). However, despite this limitation, the current systematic review included 81 studies across four intervention modalities and two age categories, producing meaningful findings that inform clinical practice and future research.

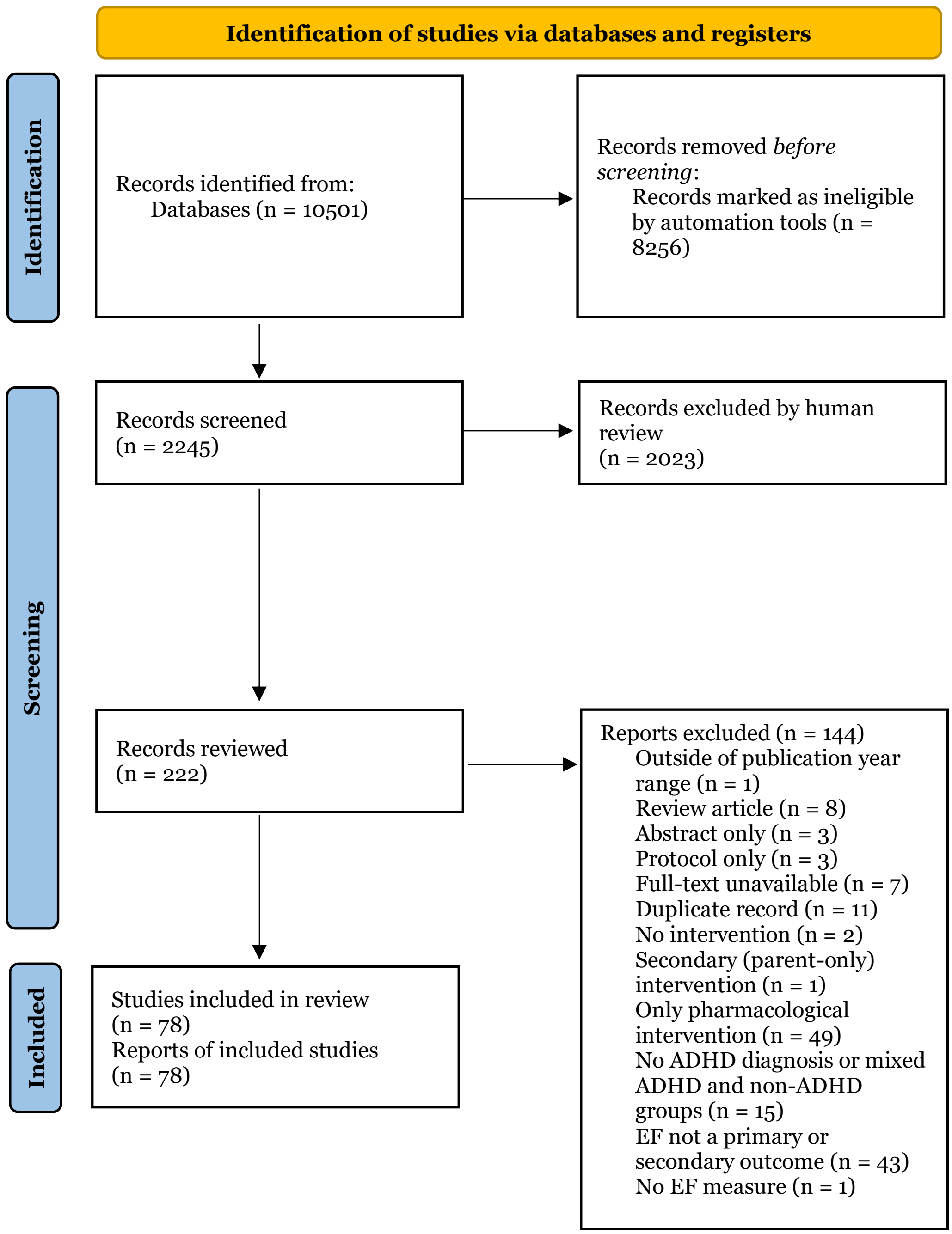
CONCLUSION

The purpose of the present systematic review was to examine whether interventions result in significant improvement in EFs for individuals with ADHD, and whether intervention efficacy differs with regard to: a) intervention modality, and b) age of participants. Results demonstrated that non-pharmacological interventions are efficacious for improving EFs in individuals with ADHD. Interventions were found to be efficacious across modalities and age groups, with small to large effect sizes. However, future research should increase the number of intervention modalities applied to teenagers and adults with ADHD, and further investigate how demographic variables are related to intervention outcomes.

APPENDIX A. FIGURES

Figure 1.

PRISMA Flowchart (Page et al., 2021)



APPENDIX B. TABLES

Table 1.

Summary of Demographic Information Provided

Reference	*n* Participants with ADHD	Participant Information Reported					
		Sex or Gender	Race or Ethnicity	SES, Employment, Income, or Education	ADHD Subtype or Presentation	Medication Status	Comorbidity
Anastopoulos & King (2015)	43	Yes	Yes	Yes	No	Yes	Yes
Anastopoulos et al. (2020)	88	Yes	Yes	Yes	Yes	Yes	Yes
Anastopoulos et al. (2021)	250	Yes	Yes	Yes	Yes	Yes	Yes
Azami et al. (2016)	34	Yes	No	No	No	Yes	No
Barudin-Carreiro (2020)	22	Yes	Yes	Yes	Yes	Yes	Yes
Becker et al. (2022)	14	Yes	Yes	Yes	Yes	Yes	Yes
Benzing et al. (2018)	46	Yes	No	Yes	No	Yes	No
Benzing & Schmidt (2019)	51	Yes	No	Yes	No	Yes	No
Bigorra et al. (2016)	66	Yes	Yes	Yes	Yes	Yes	Yes
Bikic et al. (2018)	70	Yes	Yes	No	Yes	Yes	No
Bir (2019)	13	Yes	Yes	No	No	Yes	Yes
Bögels et al. (2021)	167	Yes	Yes	Yes	Yes	Yes	No
Boyer et al. (2015)	159	Yes	No	Yes	Yes	Yes	Yes

Carboni (2012)	4	Yes	Yes	No	No	Yes	No
Cardoso-Moreno et al. (2015)	25	Yes	No	No	Yes	Yes	No
Chang et al. (2012)	40	Yes	No	No	Yes	Yes	No
Chang et al. (2022)	48	Yes	No	No	No	Yes	No
Chimiklis (2019)	20	Yes	Yes	Yes	Yes	No	Yes
Dentz et al. (2020)	60	Yes	Yes	Yes	Yes	Yes	Yes
Dovis et al. (2015)	89	Yes	No	No	Yes	Yes	Yes
Durgut et al. (2020)	30	Yes	No	No	Yes	Yes	No
Estrada-Plana et al. (2019)	27	Yes	No	Yes	Yes	Yes	No
Farias et al. (2017)	27	Yes	No	No	No	Yes	No
Gapin et al. (2015)	10	Yes	Yes	No	Yes	Yes	Yes
Gawrilow et al. (2016)	47	Yes	Yes	No	No	Yes	No
Gerber et al. (2012)	40	Yes	No	No	Yes	Yes	No
Gilboa & Helmer (2020)	25	Yes	No	No	No	Yes	No
Guillaume et al. (2021)	6	Yes	No	Yes	Yes	Yes	Yes
Hahn-Markowitz et al. (2017)	107	Yes	No	Yes	No	Yes	No
Hahn-Markowitz et al. (2020)	107	Yes	No	Yes	Yes	Yes	No
Hannesdottir et al. (2017)	41	Yes	No	No	Yes	Yes	No
Heishman (2015)	23	Yes	Yes	No	No	Yes	No
Hepark et al. (2019)	103	Yes	No	No	Yes	Yes	No
Horowitz-Kraus (2015)	28	Yes	No	No	No	Yes	Yes

Horowitz-Kraus et al. (2019)	18	Yes	No	No	No	No	Yes
Huguet et al. (2017)	5	Yes	Yes	No	Yes	Yes	No
In de Braek et al. (2012)	27	Yes	No	Yes	No	Yes	No
Janssen et al. (2018)	120	Yes	No	Yes	Yes	Yes	Yes
Janssen et al. (2020)	31	Yes	No	Yes	Yes	Yes	Yes
Kim et al. (2020)	3	Yes	No	No	No	Yes	No
Korpa et al. (2020)	52	Yes	No	Yes	Yes	Yes	No
LaCount et al. (2022)	18	Yes	Yes	Yes	Yes	Yes	No
Lan et al. (2020)	81	Yes	No	No	Yes	Yes	No
Levanon-Erez et al. (2019)	22	Yes	No	No	No	Yes	No
Liang et al. (2022)	80	Yes	No	No	Yes	Yes	No
Liao et al. (2022)	50	Yes	No	Yes	No	Yes	No
Maeir et al. (2014)	19	Yes	No	Yes	No	Yes	No
McGough et al. (2015)	24	Yes	Yes	No	Yes	Yes	Yes
Mehren et al. (2019)	23	Yes	No	No	No	Yes	No
Memarmoghad-dam et al. (2016)	40	Yes	No	No	Yes	Yes	No
Menezes et al. (2015)	18	Yes	No	No	No	Yes	No
Miranda et al. (2013)	42	Yes	Yes	Yes	Yes	Yes	No
Mitchell et al. (2017)	20	Yes	Yes	Yes	Yes	Yes	Yes
Nejati et al. (2020)	15, 10	Yes	No	No	No	Yes	No

Nejati (2021a)	30	Yes	No	No	Yes	Yes	No
Nejati (2021b)	29	Yes	No	No	No	No	No
Pan et al. (2016)	32	Yes	No	No	No	Yes	No
Pan et al. (2019)	30	Yes	No	No	Yes	Yes	No
Pan et al. (2022)	98	Yes	No	Yes	Yes	Yes	Yes
Passarotti et al. (2020)	13	Yes	Yes	No	Yes	Yes	Yes
Piepmeier et al. (2015)	32	Yes	No	No	Yes	Yes	No
Qian et al. (2017)	68	Yes	No	No	Yes	Yes	Yes
Qian et al. (2021)	70	Yes	No	No	Yes	Yes	Yes
Rosenberg et al. (2015)	17	Yes	No	No	No	No	No
Salomone et al. (2015)	51	Yes	Yes	Yes	No	Yes	Yes
Santonastaso et al. (2020)	25	Yes	No	No	Yes	Yes	No
Shema-Shiratzky et al. (2019)	14	Yes	No	No	No	Yes	No
Shuai et al. (2021)	96	Yes	No	No	Yes	Yes	Yes
Solanto et al. (2018)	88	Yes	No	Yes	Yes	Yes	Yes
Solanto & Scheres (2021)	18	Yes	No	Yes	Yes	Yes	Yes
Steeger et al. (2016)	91	Yes	Yes	Yes	Yes	Yes	Yes
Steiner et al. (2014)	104	Yes	Yes	Yes	No	Yes	No
Stern et al. (2016)	60	Yes	No	Yes	Yes	Yes	No
Tamm et al. (2013)	105	Yes	Yes	No	Yes	Yes	Yes
Tamm et al. (2014)	24	Yes	Yes	No	Yes	Yes	No
Tamm & Nakonezny (2015)	25	Yes	Yes	No	Yes	Yes	Yes

Valero et al. (2022)	30	Yes	No	Yes	Yes	Yes	Yes
van der Oord et al. (2014)	40	Yes	No	No	Yes	Yes	Yes
van Dongen-Boomsma et al. (2014)	51	Yes	Yes	No	Yes	Yes	Yes
Zhang et al. (2016)	11	Yes	No	Yes	No	Yes	Yes
Ziereis & Jansen (2015)	43	Yes	No	No	Yes	Yes	No

Note: Information provided is categorized "Yes" if partial or full information is reported for the category. In adult studies, socioeconomic status (SES) is categorized "Yes" if information regarding participant SES, employment, income, or education is provided. In child/adolescent studies, SES is categorized "Yes" if information regarding parental SES, employment, income, or education is provided.

Table 2.

Summary of Exercise Studies

Reference	Age Group	Intervention	Intervention Duration	Control or Comparison	Significant Effect of Intervention on EF	Measures	Significant Effect Size(s)
Barudin-Carreiro (2020)	Child/ Adolescent	Walking or standing	Acute (20 min)	Yes (Sitting control group)	No	SCWT, WCST	
Chang et al. (2012)	Child/ Adolescent	Aerobic exercise	Acute (30 min)	Yes (Non-active control group)	Yes	Stroop Test*, WCST*	$\eta_p^2 = 0.12 – 0.27$ (medium to large effect sizes)
Durgut et al. (2020)	Child/ Adolescent	Treadmill training (TT) + Whole body vibration training (WBVT)	Chronic (8 weeks)	Yes (TT only group)	Yes	BRIEF*	Not reported
Gapin et al. (2015)	Adult	Aerobic exercise	Acute (40 min)	Yes (Non-ADHD group)	Yes	Stroop Test*, TMT, WAIS-IV subtest (Digit Span)	*d* = 0.36 – 0.82 (small to large effect sizes)
Gawrilow et al. (2016)	Child/ Adolescent	Trampoline jumping	Acute (5 min)	Yes (Sedentary task group)	Yes	Combined classification and Go/No-Go task*	*d* = 0.04 (below threshold)

LaCount et al. (2022)	Adult	High intensity interval training (HIIT)	Acute (19 min)	Yes (Non-ADHD group)	Yes	AX-CPT*	$\eta_p^2 = 0.15$ **(large effect sizes)**
Liang et al. (2022)	Child/ Adolescent	Aerobic and neurocognitive exercise	Chronic (12 weeks)	Yes (Wait-list control)	Yes	Arrow Flanker Task*, Tower of London* Trail Making Test*	$\eta^2 = 0.095$ – 0.24 (medium to large effect sizes)
Mehren et al. (2019)	Adult	Aerobic exercise (Cycling)	Acute (30 min)	Yes (Non-ADHD group, movie condition)	Yes	Flanker Task*	$\eta^2 = 0.18$ – 0.20 (large effect sizes)
Memar-moghaddam et al. (2016)	Child/ Adolescent	Selected exercise program	Chronic (8 weeks)	Yes (Non-active control group)	Yes	Stroop Test*, Go-No-Go Test*	$\eta^2 = 0.703$ – 0.86 (large effect sizes)
Pan et al. (2016)	Child/ Adolescent	Table tennis training	Chronic (12 weeks)	Yes (Waitlist control group with crossover design)	Yes	Stroop*	$\eta^2 = 0.48$ (large effect size)
Pan et al. (2019)	Child/ Adolescent	Table tennis training	Chronic (12 weeks)	Yes (Non-ADHD group, non-training condition)	Yes	Stroop Color-Word*, WCST*	$\eta_p^2 = 0.10$ – 0.15 (medium to large effect size)
Piepmeier et al. (2015)	Child/ Adolescent	Aerobic exercise	Acute (30 min)	Yes (Non-ADHD group, non-exercise condition)	Yes	Stroop Test*, TOL, TMT	$\eta_p^2 = 0.14$ (large effect size)
Ziereis & Jansen (2015)	Child/ Adolescent	Ball handling, balance, dexterity	Chronic (12 weeks)	Yes (Waitlist control group)	Yes	HAWIK-IV tasks (digit span*,	$\eta^2 = 0.17$ – 0.38 (large effect sizes)

training (EG1) or sports training (EG2)	letter-number-sequencing*), Corsi block tapping test *Note: index-score Working Memory* (composed of index scores from HAWIK-IV tasks) was used in analysis*

Note: Significant effect size(s) listed are those associated with significant effect of intervention on EF. Bolded qualitative effect sizes were provided by study authors. Non-bolded qualitative effect sizes were assigned by reviewer according to Cohen's standards for *d,* η_p^2, and η^2.

* Measure associated with significant effect of intervention on EF

Table 3.

Summary of Mindfulness Studies.

Reference	Age Group	Intervention	Control or Comparison	Significant Effect of Intervention on EF	Outcome Measures	Significant Effect Size(s)
Bögels et al. (2021)	Child/ Adolescent	MYmind	No	Yes	BRIEF*	*d* = -0.44 – -0.77 **(medium to approaching large effect sizes)** *Note: negative ES here denotes improvement*
Carboni (2012)	Child/ Adolescent	Individual mindfulness training	No	Yes	BRIEF*	Not reported
Guillaume et al. (2021)	Adult	Training in tranquil abiding (TTA)	No	Yes	BRIEF-A*	*d* = 0.71 – 1.66 **(medium to very large)**
Hepark et al. (2019)	Adult	Adapted mindfulness-based cognitive therapy (MBCT)	Yes (Waitlist control group)	Yes	BRIEF-A*	*d* = 0.43 – 0.93 **(moderate to large)**
Huguet et al. (2017)	Child/ Adolescent	Mindfulness training program	No	Yes	CPT-3, Stroop Test*, WISC subtests	Not reported

					(Arithmetic, Coding-Digit Symbol*, Digit Span)	
Janssen et al. (2018)	Adult	MBCT	Yes (TAU only group)	Yes	BRIEF-A*	*d* = 0.49 (small effect size)
Janssen et al. (2020)	Adult	MBCT	No	Yes	BRIEF-A*	*d* = 0.28 – 0.48 (small effect sizes)
Mitchell et al. (2017)	Adult	Mindfulness meditation training	Yes (Waitlist control group)	Yes	ANT, BRIEF-A*, CPT, DEFS*, Trail-making test	*d* = 1.45 – 2.67 **(large effect sizes)**
Santonastaso et al. (2020)	Child/ Adolescent	Mindfulness-oriented meditation (MOM)	Yes (Emotion education program (EEP) group)	Yes	CPT-II*, Stroop Color Word Test*, Stop task*, N-Back task*	$\eta_p^2 = 0.21$ **(large effect size)**
Valero et al. (2022)	Child/ Adolescent	MYmind	Yes (Waitlist control group)	Yes	WISC-IV subtest (Letter-Number Sequencing), NEPSY-II subtest (Inhibition), Conners 3 subtest (executive functions*)	$\eta_p^2 = 0.314$ **(large effect size)**

Zhang et al. (2017)	Child/ Adolescent	MYmind	No	No	BRIEF

Note: Significant effect size(s) listed are those associated with significant effect of intervention on EF. Bolded qualitative effect sizes were provided by study authors. Non-bolded qualitative effect sizes were assigned by reviewer according to Cohen's standards for *d,* η_p^2, and η^2.

* Measure associated with significant effect of intervention on EF

Table 4.

Summary of Computer-Based Studies

Reference	Age Group	Intervention	Control or Comparison	Significant Effect of Intervention on EF	Outcome Measures	Significant Effect Size(s)
Azami et al. (2016)	Child/ Adolescent	Computer-Assisted Cognitive Rehabilitation (CACR)	Yes (Medication group, Placebo CACR group)	Yes	CPT*, TOL*, WISC-R sub-tests (Forward/Backward digit span*), Raven's Progressive matrices*, Span Board*	*d* = 1.12 – 1.436 (large effect sizes)
Bigorra et al. (2016)	Child/ Adolescent	Cogmed Working Memory Training (CWMT)	Yes (Non-adaptive CWMT control group)	Yes	BRIEF*, WISC-IV sub-tests (Digit span backward, Letter-Number Sequencing), WMS-III sub-test (Spatial span backward),	*d'* = -0.86 – 0.81 **(small to large effect sizes)** *Note: all ES in expected direction*

					CPT II*, TOL DX, WCST-64, TMT-B *Note: WMS-III and WISC-IV subtests were combined into a working memory composite score**	
Bikic et al. (2018)	Child/ Adolescent	ACTIVATE + TAU	Yes (TAU only group)	Yes	BRIEF, CANTAB subtests (SWM, SOC*, IED, and SST)	0.30 of a standard deviation **(modest effect size)**
Bir (2019)	Child/ Adolescent	CWMT	No	No	BRIEF, SST	
Chimiklis (2019)	Child/ Adolescent	ACTIVATE	Yes (Non-impaired reading group)	Yes	BRIEF*, WISC-IV subtests (Coding, Symbol Search, Digit Span, Letter-Number Sequencing), D-KEFS subtest (TMT*), TEC*	$\eta_p^2 = 0.28 – 0.52$ (large effect sizes)
Dentz et al. (2020)	Child/ Adolescent	CWMT	Yes (Non-adaptive CWMT	No	BRIEF	

			control group)			
Dovis et al. (2015)	Child/ Adolescent	Braingame Brian (BGB)	Yes (Partially-active treatment group and Placebo treatment group)	Yes	BRIEF, Stop task, Troop, CBTT*, Digit span, TMT, Raven coloured progressive matrices	$\eta_p^2 = 0.12$ (medium effect size)
Farias et al. (2017)	Child/ Adolescent	Captain's Log Computerized Cognitive Training (CCT)	Yes (Medicated group)	Yes	WCST*, ROCF*, d2 test*, WISC-III subtest (Digit Span)	Not reported
Heishman (2015)	Child/ Adolescent	CWMT	No	Yes	BRIEF*	$\eta_p^2 = 0.15 – 0.18$ (large effect sizes)
Horowitz-Kraus (2015)	Child/ Adolescent	Cognifit	Yes (ADHD + Reading Disability (RD) group)	Yes	WAIS-III subtests (Digit span*, Coding, Symbol search*), Letters*, Rapid alternating stimulus, WCST*	Not reported
Horowitz-Kraus et al. (2019)	Child/ Adolescent	Reading Acceleration Program (RAP)	Yes (RD only group)	Yes	CTOPP subtest (naming),	$\eta^2 = 0.086$ (medium effect size)

					D-KEFS subtest (Stroop test*), TEA-Ch subtest (Sky-search*)	
Passarotti et al. (2020)	Child/ Adolescent	CWMT	Yes (Pediatric bipolar disorder (PBD) group)	Yes	BRIEF, TMT-B*, WISC-III subtest (Digit span forward*), WNV subtest (Spatial span forward*), SST	*d* = 0.58 – 0.65 **(medium effect sizes)**
Stern et al. (2016)	Adult	AttenFocus	Yes (Less-demanding AttenFocus control group)	No	BRIEF-A, IntegNeuro subtests (Working memory, Sustained attention, Intrusions, Inhibition, Response variability, Fluency)	
van der Oord et al. (2014)	Child/ Adolescent	BGB	Yes (Waitlist control group)	Yes	BRIEF*	η^2 = 0.16 – 0.39 **(large effect sizes)**

van Dongen-Boomsma et al. (2014)	Child/ Adolescent	CWMT	Yes (Placebo non-adaptive CWMT control group)	No	BRIEF, WISC-III sub-test (Digit span), Knox Cubes LDT, Shortened Raven Coloured Progressive Matrices, Day-Night Stroop task, Sustained attention dots task (02K), Shape School

Note: Significant effect size(s) listed are those associated with significant effect of intervention on EF. Bolded qualitative effect sizes were provided by study authors. Non-bolded qualitative effect sizes were assigned by reviewer according to Cohen's standards for *d*, η_p^2, and η^2.

* Measure associated with significant effect of intervention on EF

Table 5.

Summary of Hybridized and Miscellaneous Studies

Reference	Age Group	Intervention	Control or Comparison	Significant Effect of Intervention on EF	Outcome Measures	Significant Effect Size(s)
Anastopoulos & King (2015)	Adult	ACCESS	No	Yes	BRIEF-A*	*d* = 0.74 – 0.88 **(large effect sizes)**
Anastopoulos et al. (2020)	Adult	ACCESS	No	Yes	BRIEF-A*	*d* = -0.66 – -0.53 **(medium effect sizes)**
Anastopoulos et al. (2021)	Adult	ACCESS	Yes (Waitlist control group)	Yes	BRIEF-A*	*d* = 0.43 – 0.56 **(medium effect sizes)**
Becker et al. (2022)	Child/ Adolescent	Behavioral sleep interven-tion (TranS-C)	No	Yes	BDEFS-CA*	*g* = 0.69 – 0.81 **(mod-erate-to-large effect sizes)**
Benzing et al. (2018)	Child/ Adolescent	Acute exer-gaming	Yes (Sedentary control group)	Yes	Modified Flanker Task* Modified Color Span Backwards Task	η_p^2 = 0.094 – 0.117 **(moderate effect sizes)**

Benzing & Schmidt (2019)	Child/ Adolescent	Exergaming	Yes (Waitlist control group)	Yes	Modified Flanker Task*, Modified Simon Task*, Modified Color Span Backwards Task	*d* = 0.58 – 0.65 (medium effect sizes)
Boyer et al. (2015)	Child/ Adolescent	CBT	Yes (SFT group)	Yes	BRIEF*, Tower Test, DKEFS subtest (TMT), Key Search Test, Zoo Map Test	η_p^2 = 0.023 – 0.031 (small effect sizes)
Cardoso-Moreno et al. (2015)	Child/ Adolescent	Socio-emotional intervention program	No	Yes	Tower of Hanoi*, Zoo Map Test*	Not reported
Chang et al. (2022)	Child/ Adolescent	Table tennis training, Exergaming	Yes (Non-training group)	Yes	Stroop Test*, WCST*	η^2 = 0.141 – 0.168 (large effect sizes)
Estrada-Plana et al. (2019)	Child/ Adolescent	Board game-based cognitive training	Yes (Waitlist control group)	Yes	Corsi block span task, WISC-IV subtest (Direct Digits*), Keep Track Task,	η_p^2 = 0.27 **(large effect size)**

					Go/NoGo task, TMT	
Gerber et al. (2012)	Child/ Adolescent	ADHD Summer Camp Training (ASCT)	Yes (SPC group)	Yes	TMT*	Not reported
Gilboa & Helmer (2020)	Child/ Adolescent	Equine-assisted occupational therapy (STABLE-OT)	No	Yes	BRIEF*	*d* = 0.32 – 0.49 **(small to medium effect sizes)**
Hahn-Markowitz et al. (2017)	Child/ Adolescent	Cognitive-Functional (Cog-Fun) occupational therapy	Yes (Waitlist control group)	Yes	BRIEF*	η_p^2 = 0.046 – 0.193 **(minimum practically significant to moderate effect sizes)**
Hahn-Markowitz et al. (2020)	Child/ Adolescent	Cog-Fun	Yes (Waitlist control group)	Yes	BRIEF*	η_p^2 = 0.08 – 0.11 **(moderate effect sizes)**
Hannesdottir et al. (2017)	Child/ Adolescent	OutSMARTers Program	Yes (Waitlist control group and parent training group)	No	WISC-IV subtests (Coding, Letter-number sequencing, Arithmetic), Lumosity assessment tasks (Stop signal	

					response, Letter memory)	
In de Braek et al. (2012)	Adult	Goal management training (GMT)	Yes (Psychoeducation only group)	No	CFQ, BADS subtest (Zoo Map)	
Kim et al. (2020)	Child/ Adolescent	Cog-Fun	No	Yes	BRIEF*, Children's Color Trails Test*, Stroop test*	Not reported
Korpa et al. (2020)	Child/ Adolescent	EF Train	Yes (Non-training group)	Yes	Digit Span*, Tower Task*, TSVA*, TSAA*, Raven's Colored Progressive Matrices	η_p^2 = 0.06 – 0.43 (medium to large effect sizes)
Lan et al. (2020)	Child/ Adolescent	Group executive function training (GEFT), Social skills training (SST)	Yes (Waitlist control group)	Yes	Conners' CPT-II*, Operational Span Test*, WCST	η^2 = 0.13 – 0.219 **(moderate to large effect sizes)**
Levanon-Erez et al. (2019)	Child/ Adolescent	Cog-Fun	No	Yes	BRIEF*	*d* = 0.76 – 1.13 **(large effect sizes)**
Liao et al. (2022)	Child/ Adolescent	Will Well Neurofeedback (WWNF) +	Yes (Waitlist control group)	Yes	Tower of London, WCST,	η^2 = 0.079 – 0.087 (medium effect sizes)

		cognitive training			CNAT subtests (Focus, Search*, Inhibition*, Distract), Daily EF Questionnaire *Note: omission errors from Inhibition and Distract subtests form dysexecutive function index**	
Maeir et al. (2014)	Child/ Adolescent	Cog-Fun	Yes (Waitlist control group)	Yes	BRIEF*	*g* = 0.56 – 0.69 **(small to medium effect sizes)**
McGough et al. (2015)	Child/ Adolescent	Trigeminal nerve stimulation (TNS)	No	Yes	BRIEF*	Not reported
Menezes et al. (2015)	Child/ Adolescent	Intervention Program for Self-regulation and Executive Functions (PIAFEx)	Yes (Control group)	Yes	CHEXI, Computerized Stroop Test*, CAT, TMT, WCST,	Not reported

						AWM*, VWM, FAS and Animals Verbal Fluency Test	
Miranda et al. (2013)	Child/ Adolescent	Psychosocial intervention	Yes (no-treatment control group)	Yes		CPT*, Stroop test*, WMS*, WISC-R subtest (Inverse Digits*), TSRT*, Tower of London*, WCST	η^2 = 0.125 – 0.396 (medium to large effect sizes)
Nejati et al. (2020)	Child/ Adolescent	tDCS	Yes (Sham condition)	Yes		Stroop task* *(experiment 1 only)*, Go/No-Go task*, N-Back test*, WCST*	η_p^2 = 0.33 – 0.62; η_p^2 = 0.33 – 0.64 (large effect sizes)
Nejati (2021a)	Child/ Adolescent	Program for attention rehabilitation and strengthening (PARS)	Yes (Control group)	Yes		PART*, Color-word Stroop test*, TMT, Go/No-Go task*, 1-back task*	η_p^2 = 0.097 – 0.424 (medium to large effect sizes)
Nejati (2021b)	Child/ Adolescent	Balance-based Attention Rehabilitation of Attention	Yes (Aerobic exercise group)	Yes		WCST*, SST*, 1-back test*	η_p^2 = 0.108 – 0.431

		Networks (BARAN)				(medium to large effect sizes)
Pan et al. (2022)	Adult	CBT + medication	Yes (Medication only group)	No	BRIEF, TMT, Stroop Color Test	
Qian et al. (2017)	Child/ Adolescent	Ecological executive skills training program (EEST)	Yes (Waitlist control group, non-ADHD group)	Yes	BRIEF*, Stroop test, ROCF, TMT	Not reported
Qian et al. (2021)	Child/ Adolescent	EEST	Yes (Waitlist control group)	Yes	BRIEF, CANTAB subtests (CGT*, IED, SOC*, SST, SWM)	$\eta^2 = 0.07 – 0.1$ (medium effect sizes)
Rosenberg et al. (2015)	Child/ Adolescent	Cog-Fun	No	Yes	BRIEF-P*	Not reported
Salomone et al. (2015)	Adult	Self-Alert Training (SAT)	Yes (Placebo group)	Yes	Hotel task*	$\eta^2 = 0.07$ (medium effect size)
Shema-Shiratzky et al. (2019)	Child/ Adolescent	Combined virtual reality + treadmill training	No	Yes	CTT*, NeuroTrax battery index score* (Stroop test, Go-NoGo, Verbal memory task, Non-verbal memory	*d* = 0.63 – 1.46 **(medium to large effect sizes)**

					task, Catch game)	
Shuai et al. (2021)	Child/ Adolescent	Executive Function Training for Preschool (EFT-P)	Yes (Waitlist control)	Yes	BRIEF-P, NEPSY-II subtests (Memory for Designs, Narrative Memory, Statue, Affect Recognition, Theory of Mind, Word Generation, Comprehension of Instructions, Block Construction, Visuomotor Precision*)	$\eta_p^2 = 0.05$ (small effect size)
Solanto et al. (2018)	Adult	CBT	Yes (Support group)	Yes	BRIEF-A, Brown ADD Scales*, ON-TOP*	*d'* = 0.33 – 0.40 (small effect sizes)
Solanto & Scheres (2021)	Adult	Cognitive-Behavioral Intervention	No	Yes	BDEFS*, LASSI*	$\eta_p^2 = 0.635$ – 0.722 (large effect sizes)
Steeger et al. (2016)	Child/ Adolescent	CWMT + Behavioral Parent Training (BPT)	Yes (Treatment CWMT + Control BPT group,	Yes	BRIEF*	$\eta_p^2 = 0.06$ – 0.08 (medium effect sizes)

			Control CWMT + Treatment BPT group, Control CWMT + Control BPT group)			
Steiner et al. (2014)	Child/ Adolescent	Neurofeedback or Cognitive training (CT)	Yes (Control group)	Yes	BRIEF*	*d* = -0.33 – -0.23 (small effect sizes)
Tamm et al. (2013)	Child/ Adolescent	Pay Attention!	Yes (Waitlist control group)	Yes	BRIEF*, WISC-IV subtests (Digit span, Letter-number sequencing, Matrix reasoning), WJ-III subtest (Understanding directions), D-KEFS subtests (Tower test*, Color-word interference)	*d* = 0.53 – 1.16 **(medium to large effect sizes)**
Tamm et al. (2014)	Child/ Adolescent	Metacognitive Executive Function Training	No	Yes	BRIEF*, NEPSY subtest (Visual Attention*), CELF-IV subtest	*d* = 0.39 – 0.64 **(small to moderate effect sizes)**

					(Concepts and Following Directions*), Shape School, Wechsler subtests (Digit Span*, Matrix Reasoning)	
Tamm & Nakonezny (2015)	Child/ Adolescent	Metacognitive Executive Function Training	Yes (Waitlist control group)	Yes	BRIEF*, NEPSY subtest (Visual Attention), CELF-IV subtest (Concepts and Following Directions), WISC subtest (Matrix Reasoning)	*g* = 0.97 – 1.01 **(large effect sizes)**

Note: Significant effect size(s) listed are those associated with significant effect of intervention on EF. Bolded qualitative effect sizes were provided by study authors. Non-bolded qualitative effect sizes were assigned by reviewer according to Cohen's standards for *d,* η_p^2, and η^2.

* Measure associated with significant effect of intervention on EF

Table 6.

Summary of Child/Adolescent Studies

Reference	Intervention Category	Intervention	M(SD) Age	Significant Effect of Intervention on EF
Azami et al. (2016)	Computer-Based Training	CACR	*Not reported* *Range: 7 – 12 years*	Yes
Barudin-Carreiro (2020)	Exercise Program(s)	Walking or standing	9.51 (1.42) years	No
Becker et al. (2022)	Hybridized/ Miscellaneous	TranS-C	14.93 (1.39) years	Yes
Benzing et al. (2018)	Hybridized/ Miscellaneous	Acute Exergaming	10.48 (1.38) years	Yes
Benzing & Schmidt (2019)	Hybridized/ Miscellaneous	Exergaming	Experimental group: 10.46 (1.30) years Control group: 10.39 (1.44) years	Yes
Bigorra et al. (2016)	Computer-Based Training	CWMT	Experimental group: 8.79 (1.75) years Control group: 9.04 (1.68) years	Yes
Bikic et al. (2018)	Computer-Based Training	ACTIVATE + TAU	9.95 (1.7) years	Yes
Bir (2019)	Computer-Based Training	CWMT	*Not reported* *Range: 9 – 17 years*	No
Bögels et al. (2021)	Mindfulness Training	MYmind	11.4 (2.27) years	Yes
Boyer et al. (2015)	Hybridized/ Miscellaneous	CBT	PML group: 14.4 (1.2) years SFT group: 14.4 (1.3) years	Yes
Carboni (2012)	Mindfulness Training	Individual mindfulness training	*Not reported*	Yes

			Range: 8 years 3 months – 8 years 9 months	
Cardoso-Moreno et al. (2015)	Hybridized/ Miscellaneous	Socioemotional intervention program	*Not reported* *Range: 8 – 12 years*	Yes
Chang et al. (2012)	Exercise Program(s)	Acute aerobic exercise	10.43 years	Yes
Chang et al. (2022)	Hybridized/ Miscellaneous	Table tennis training, Exergaming	Table tennis group: 8.31 (1.30) years Exergame group: 8.38 (1.20) years Control group: 8.38 (1.31) years	Yes
Chimiklis (2019)	Computer-Based Training	ACTIVATE	8.4 (1.1) years	Yes
Dentz et al. (2020)	Computer-Based Training	CWMT	CWMT group: 10.76 (1.98) years Control group: 9.42 (2.06) years	No
Dovis et al. (2015)	Computer-Based Training	BGB	Full-active group: 10.6 (1.4) years Partial-active group: 10.3 (1.3) years Placebo group: 10.5 (1.3) years	Yes
Durgut et al. (2020)	Exercise Program(s)	TT + WBVT	TT + WBVT group: 7.93 (1.22) years TT group: 8.33 (1.17) years	Yes
Estrada-Plana et al. (2019)	Hybridized/ Miscellaneous	Board game-based cognitive training	*Not reported* *Range: 8 – 12 years*	Yes
Farias et al. (2017)	Computer-Based Training	Captain's Log	Medicated group: 9.4 (1.5) years	Yes

			Unmedicated group: 11.1 (1.5) years	
Gawrilow et al. (2016)	Exercise Program(s)	Acute trampoline jumping	10.47 (1.49) years	Yes
Gerber et al. (2012)	Hybridized/ Miscellaneous	ASCT	ASCT group: 12.3 (2.3) years SPC group: 10.3 (3.5) years	Yes
Gilboa & Helmer (2020)	Hybridized/ Miscellaneous	STABLE-OT	9.44 (1.75) years	Yes
Hahn-Markowitz et al. (2017)	Hybridized/ Miscellaneous	Cog-Fun	Experimental group: 8.4 (0.9) years Control group: 8.6 (0.8) years	Yes
Hahn-Markowitz et al. (2020)	Hybridized/ Miscellaneous	Cog-Fun	Experimental group: 8.4 (0.9) years Control group: 8.6 (0.8) years	Yes
Hannesdottir et al. (2017)	Hybridized/ Miscellaneous	OutSMARTers Program	9.2 (0.62) years	No
Heishman (2015)	Computer-Based Training	CWMT	*Not reported* *Range: 11 – 18 years*	Yes
Horowitz-Kraus (2015)	Computer-Based Training	CogniFit	ADHD only group: 12.92 (0.65) years ADHD + RD group: 13.19 (0.75) years	Yes
Horowitz-Kraus et al. (2019)	Computer-Based Training	RAP	ADHD + RD group: 9.69 (1.18) years	Yes
Huguet et al. (2017)	Mindfulness Training	Mindfulness training	9.2 (1.30) years	Yes
Kim et al. (2020)	Hybridized/ Miscellaneous	Cog-Fun	*Not reported* *Range: 9 years 4 months – 10 years 3 months*	Yes

Korpa et al. (2020)	Hybridized/ Miscellaneous	EF Train	Experimental group: 5.72 (1.06) years Control group: 5.65 (1.07)	Yes
Lan et al. (2020)	Hybridized/ Miscellaneous	GEFT, SST	10.54 (1.16) years	Yes
Levanon-Erez et al. (2019)	Hybridized/ Miscellaneous	Cog-Fun	14.22 (1.45) years	Yes
Liang et al. (2022)	Exercise Program(s)	Aerobic and neurocognitive exercise	Experimental group: 8.37 (1.42) years Control group: 8.29 (1.27) years	Yes
Liao et al. (2022)	Hybridized/ Miscellaneous	WWNF + cognitive training	Experimental group: 9.82 (1.32) years Control group: 10.07 (2.12) years	Yes
Maeir et al. (2014)	Hybridized/ Miscellaneous	Cog-Fun	5.97 (0.66) years	Yes
McGough et al. (2015)	Hybridized/ Miscellaneous	TNS	10.3 (2.1) years	Yes
Memarmoghaddam et al. (2016)	Exercise Program(s)	Selected exercise program	Experimental group: 8.31 (1.29) years Control group: 8.29 (1.31) years	Yes
Menezes et al. (2015)	Hybridized/ Miscellaneous	PIAFEx	*Not reported* *Range: 7 – 13 years*	Yes
Miranda et al. (2013)	Hybridized/ Miscellaneous	Psychosocial intervention	*Not reported* *Range: 7 – 10 years*	Yes
Nejati et al. (2020)	Hybridized/ Miscellaneous	tDCS	Experiment 1 group: 10 (2.3) years Experiment 2 group: 9 (1.8) years	Yes
Nejati (2021a)	Hybridized/	PARS	10.74 (1.81) years	Yes

	Miscellaneous			
Nejati (2021b)	Hybridized/ Miscellaneous	BARAN	Experimental group: 9.73 (1.94) years Control group: 9.21 (1.25) years	Yes
Pan et al. (2016)	Exercise Program(s)	Table tennis training	Experimental group: 8.93 (1.49) years Control group: 8.87 (1.56) years	Yes
Pan et al. (2019)	Exercise Program(s)	Table tennis training	ADHD training group: 9.08 (1.43) years ADHD non-training group: 8.90 (1.66) years	Yes
Passarotti et al. (2020)	Computer-Based Training	CWMT	ADHD group: 12.18 (1.87) years	Yes
Piepmeier et al. (2015)	Exercise Program(s)	Acute aerobic exercise	10.7 (2.27) years	Yes
Qian et al. (2017)	Hybridized/ Miscellaneous	EEST	Experimental group: 8.3 (1.3) years Control group: 7.8 (1.2) years	Yes
Qian et al. (2021)	Hybridized/ Miscellaneous	EEST	Experimental group: 9.13 (0.83) years Control group: 9.36 (1.22) years	Yes
Rosenberg et al. (2015)	Hybridized/ Miscellaneous	Cog-Fun	5.6 (0.4) years	Yes
Santonastaso et al. (2020)	Mindfulness Training	MOM	8.9 (1.2) years	Yes
Shema-Shiratzky et al. (2019)	Hybridized/ Miscellaneous	VR + treadmill training	9.3 (1.2) years	Yes

Shuai et al. (2021)	Hybridized/ Miscellaneous	EFT-P	Experimental group: 61.78 (6.67) months Control group: 59.09 (6.62) months	Yes
Steeger et al. (2016)	Hybridized/ Miscellaneous	CWMT + BPT	12.5 (1.2) years	Yes
Steiner et al. (2014)	Hybridized/ Miscellaneous	NF or CT	NF group: 8.4 (1.1) years CT group: 8.9 (1.0) years Control group: 8.4 (1.1) years	Yes
Tamm et al. (2013)	Hybridized/ Miscellaneous	Pay Attention!	9.3 (1.4) years	Yes
Tamm et al. (2014)	Hybridized/ Miscellaneous	MEFT	5.2 (1.2) years	Yes
Tamm & Nakonezny (2015)	Hybridized/ Miscellaneous	MEFT	5.0 (1.3) years	Yes
Valero et al. (2022)	Mindfulness Training	MYmind	10.6 (1.69) years	Yes
van der Oord et al. (2014)	Computer-Based Training	BGB	9.79 (1.04) years	Yes
van Dongen-Boomsma et al. (2014)	Computer-Based Training	CWMT	Experimental group: 6.5 (0.6) years Control group: 6.6 (0.7) years	No
Zhang et al. (2016)	Mindfulness Training	MYmind	9.5 (1.4) years	No
Ziereis & Jansen (2015)	Exercise Program(s)	Ball handling, balance, dexterity training, or sports training	9.45 (1.43) years	Yes

Note: Mean and standard deviation for age of all participants is reported if available; when overall mean and standard deviation were not provided, group means and standard deviations are reported. Age range is reported if no means are provided.

Table 7.

Summary of Adult Studies

Reference	Intervention Category	Intervention	M (SD) Age	Significant Effect of Intervention on EF
Anastapoulos & King (2015)	Hybridized/ Miscellaneous	ACCESS	20.3 years	Yes
Anastopoulos et al. (2020)	Hybridized/ Miscellaneous	ACCESS	20.2 years	Yes
Anastopoulos et al. (2021)	Hybridized/ Miscellaneous	ACCESS	19.7 years	Yes
Gapin et al. (2015)	Exercise Program(s)	Acute aerobic exercise	21.75 (1.99) years	Yes
Guillaume et al. (2021)	Mindfulness Training	TTA	31.33 (4.53) years	Yes
Hepark et al. (2019)	Mindfulness Training	MBCT	Experimental group: 36.5 (10) years Control group: 35.2 (9) years	Yes
In de Braek et al. (2012)	Hybridized/ Miscellaneous	GMT + psychoeducation	Experimental group: 35.5 years Control group: 37.9 years	No
Janssen et al. (2018)	Mindfulness Training	MBCT	Experimental group: 39.7 (11.1) years Control group: 39.0 (10.1) years	Yes
Janssen et al. (2020)	Mindfulness Training	MBCT	38 (12.4) years	Yes

LaCount et al. (2022)	Exercise Program(s)	Acute HIIT	20.8(1.7) years	Yes
Mehren et al. (2019)	Exercise Program(s)	Acute aerobic exercise	ADHD group: 29.9 (9.5) years	Yes
Mitchell et al. (2017)	Mindfulness Training	Mindfulness meditation training	Experimental group: 40.55 (6.83) years Control group: 36.22 (6.92) years	Yes
Pan et al. (2022)	Hybridized/ Miscellaneous	Group CBT	Experimental group: 26.84 (5.65) years Control group: 24.78 (5.59) years	No
Salomone et al. (2015)	Hybridized/ Miscellaneous	SAT	Experimental group: 32.7 (12.4) years Control group: 31.6 (11.3) years	Yes
Solanto et al. (2018)	Hybridized/ Miscellaneous	CBT	Younger group: 35.30 (7.60) years Older group: 56.15 (4.31) years	Yes
Solanto & Scheres (2021)	Hybridized/ Miscellaneous	Cognitive-behavioral intervention	ADHD group: 23.61 (2.75) years	Yes
Stern et al. (2016)	Computer-Based Training	AttenFocus	37.31 (10.11) years	No

Note: Mean and standard deviation for age of all participants is reported if available; when overall mean and standard deviation were not provided, group means and standard deviations are reported.

Table 8.

Abbreviations Used in Tables and Corresponding Measure Names

Abbreviation	Measure Name
ANT	Attention Network Task
AWM	Auditory Working Memory Test
AX-CPT	AX – Continuous Performance Test
BADS	Behavioral Assessment of Dysexecutive Syndrome
BDEFS *(DEFS)*	Barkley Deficits in Executive Functioning Scale
BDEFS-CA	Barkley Deficits in Executive Functioning Scale – Children and Adolescents
BRIEF	Behavior Rating Inventory of Executive Functions
BRIEF-A	Behavior Rating Inventory of Executive Function – Adult version
BRIEF-P	Behavior Rating Inventory of Executive Function – Preschool version
CANTAB	Cambridge Neuropsychological Test Automated Battery
CAT	Cancellation Attention Test
CBTT	Corsi Block Tapping Task
CELF-IV	Clinical Evaluation of Language Fundamentals – Fourth Edition
CFQ	Cognitive Failures Questionnaire
CGT	Cambridge Gambling Task
CHEXI	Childhood Executive Functioning Inventory
CNAT	Comprehensive Nonverbal Attention Test
CPT	Continuous Performance Test
CPT-II	Conners' Continuous Performance Test – II
CPT-3	Conners' Continuous Performance Test – 3

CTOPP	Comprehensive Test of Phonological Processing
CTT	Color Trails Test
D-KEFS *(DKEFS)*	Delis-Kaplan Executive Function System
HAWIK-IV	Hamburg Wechsler Intelligenztest für Kinder – IV
IED	Intra-Extra Dimensional Set Shift
LASSI	Learning and Study Skills Inventory
NEPSY	
NEPSY-II	NEPSY – Second Edition
ON-TOP	On Time Management Organization and Planning questionnaire
PART	Persian Attention Registration Task
ROCF	Rey-Osterrieth Complex Figure test
SCWT	Stroop Color and Word Test
SOC	Stockings of Cambridge
SST	Stop Signal Task
SWM	Spatial Working Memory
TEA-Ch	Test of Everyday Attention for Children
TEC	Tasks of Executive Control
TMT	Trail-Making Test
TMT-B	Trail-Making Test Part B
TOL	Tower of London
TOL DX	Tower of London DX
TSAA	Test of Selective Auditory Attention
TSRT	Temporal Spatial Recall Task
TSVA	Test of Selective Visual Attention
VWM	Verbal Working Memory Test
WAIS-III	Wechsler Adult Intelligence Scale – Third Edition
WAIS-IV	Wechsler Adult Intelligence Scale – Fourth Edition
WCST	Wisconsin Card Sorting Test

WCST-64	Wisconsin Card Sorting Test – 64
WISC	Wechsler Intelligence Scale for Children
WISC-III	Wechsler Intelligence Scale for Children – Third Edition
WISC-IV	Wechsler Intelligence Scale for Children – Fourth Edition
WISC-R	Wechsler Intelligence Scale for Children – Revised
WJ-III	Woodcock Johnson Tests of Achievement
WMS	Working Memory Sentences
WMS-III	Wechsler Memory Scale – Third Edition
WNV	Wechsler Nonverbal Scale of Ability

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