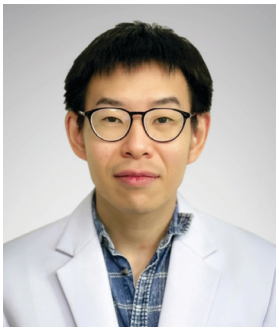
Review Article

Executive Functions in Children with ADHD

Prakasit Wannapaschaiyong[1] ; Soranant Kiewkong[2] ; Sitthiphon Bunman[3]



Prakasit Wannapaschaiyong

[1] Division of Child Development, Department of Pediatrics, Faculty of Medicine, Siriraj Hospital, Mahidol University, Bangkok, Thailand.
[2] Kasemrad International Hospital, Bangkok, Thailand.
[3] Department of Community and Family Medicine, Faculty of Medicine, Thammasat University, Thailand.

*Address Correspondence to author:
Prakasit Wannapaschaiyong, MD
Division of Child Development,
Department of Pediatrics,
Faculty of Medicine, Siriraj Hospital, Mahidol University,
Bangkok 10700, Thailand
email: pra_ka_sit@hotmail.com

Received: July 24, 2022
Revision received: August 5, 2022
Accepted after revision: August 17, 2022
BKK Med J 2022;18(2): 136-140.
DOI: 10.31524/bkkmedj.2022.23.002
www.bangkokmedjournal.com

Abstract

Executive Functions (EFs) play an important role in everyday life, lifelong achievement, and quality of life. Patients with developmental problems are more likely to have executive dysfunctions, especially those with attention deficit hyperactivity disorder (ADHD), who often have impaired working memory, inhibitory control, and organization. Currently, many studies have shown that poor EFs are not directly related to behavioral problems and social impairments due to ADHD symptoms. However, ADHD patients with executive dysfunctions tend to have difficulties in the learning process. Therefore, evaluating EFs along with ADHD symptoms is essential. The most widely used tools for EF assessment include the Behavior Rating Inventory of Executive Function (BRIEF) and the Executive Function assessment in Mahidol University version (MU-EF). Promoting EFs should be done in conjunction with treating ADHD symptoms in ADHD patients with executive dysfunctions. This article aims to review the knowledge of EFs, EF assessment, and evidence-based interventions promoting EFs in ADHD patients, such as pharmacological treatment (Methylphenidate), cognitive training, exercise, white noise, and organization skill intervention.

Keywords: executive functions, ADHD

Executive functions (EFs) are a set of skills which manage and control thinking, emotions, and behaviors in new or complicated situations to achieve set goals.[1] The development of EFs starts in early childhood and continues until 20 to 25 years of age, and the most rapid EF development is from 3 to 5 years old.[2]

EFs are extremely crucial in daily life, for good health and quality of life, learning ability, and life achievement, along with proper emotional, behavioral, and social functions in children.[3-5] Impairments in EFs lead to negative impacts in many ways, including physical health problems (obesity, hypertension, diabetes mellitus, and dyslipidemia)[6-9], mental health problems (substance dependence, attention deficit hyperactivity disorder, depression, and obsessive-compulsive disorder)[10-14], working and learning problems (learning disability, decreased productivity, and inability to maintain a job position)[15,16], marriage problems (difficulty in maintaining good married life)[17] as well as threats toward public security (crimes, violence, negligent behaviors, and emotional outbursts).[18,19]

As previously mentioned, executive dysfunctions which are frequently seen in pediatric psychiatric patients[9,20-25] include specific learning disorders, intellectual disability, autistic spectrum disorder, anxiety disorder, depressive disorder, and ADHD.

ADHD is one of the most common mental disorders affecting children. Symptoms of ADHD include difficulty paying attention, hyperactivity, and impulsive behavior. ADHD is known to impact individuals in many areas of life including academic and professional achievements, interpersonal relationships, self-esteem, and social functions.[26] In the past, impaired EFs were considered to be the cause of ADHD symptoms and its negative consequences; however, at present, there is evidence that contradicts this. Therefore, the purpose of this review is to describe

the links between EFs and symptoms of ADHD, as well as the need to evaluate and treat executive dysfunction in conjunction with ADHD symptoms.

Impaired EFs in ADHD patients

In 1998, it was believed that symptoms of ADHD resulted from EF impairment in specific areas,[27] including working memory, self-regulation, internalization of speech, and reconstitution, and it was discovered that children with ADHD had approximately 3 to 5 years' delay in EF development compared to children without ADHD.[28]

Later in 2001, a study by Brown et al.[29] found that symptoms of ADHD were caused by impaired EFs in multiple aspects such as organization, focusing, regulating alertness, modulation of emotion, working memory, and self-regulation, while Kofler's study[30] showed that symptoms of ADHD resulted mainly from impairments of working memory.

However, the traditional belief stating that symptoms of ADHD resulted from executive dysfunctions started to change. In 2014, Coghill et al.[31] conducted a study comparing EFs between boys with ADHD and boys with normal development. Although it was suggested that boys with ADHD had poorer EFs in all aspects, especially working memory, one-fourth of boys with ADHD showed no impairments in EFs. In addition, a study by Silverstein et al.[32] in 2020 found that some children with executive dysfunctions had no symptoms of ADHD, including inattentive symptoms and hyperactive/impulsive symptoms. This is in accordance with a study by Krieger et al.[33] that factors affecting symptoms of ADHD are not only impaired EFs but also personality traits. Conscientiousness directly affects both inattentive and hyperactive/impulsive symptoms, while neuroticism, lack of agreeableness, and poor extraversion directly affect hyperactive/impulsive symptoms. A study also followed children with ADHD into adulthood, indicating that the children had slower EF development compared with normal individuals though symptoms of ADHD had improved.[34]

From the stated evidence, it is supported that patients with ADHD do not necessarily have executive dysfunctions, and children with executive dysfunctions may not show symptoms of ADHD (as shown in Figure 1). However, executive dysfunctions are associated with impairments in reading, writing, and calculation, resulting in poorer academic performance while symptoms of ADHD are correlated with impaired social interactions, problems in conducting activities with friends, and behavioral problems in classrooms.[35] Consequently, the author suggests that symptoms of ADHD and EFs be assessed separately as well as providing appropriate treatment based on the assessments to alleviate ADHD symptoms and promote EFs.

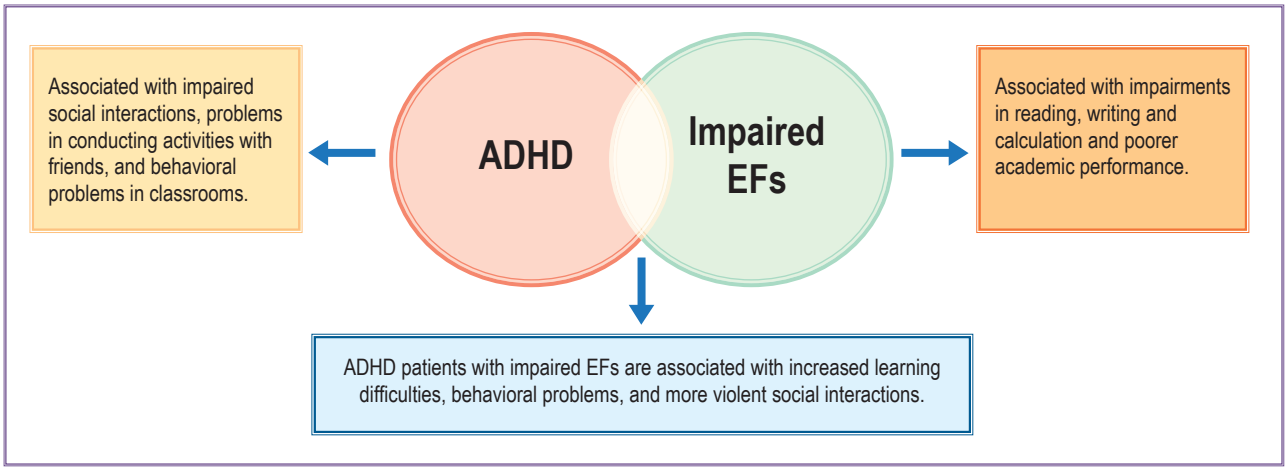


Figure 1: Illustrating the association between ADHD and impaired EFs

Executive function assessment

As EFs consist of multiple basic skills, including working memory, inhibitory control, cognitive flexibility, reasoning, problem-solving and planning. The frequently used behavioral observation tools are questionnaires are not only easy to apply but they also assess all of EFs' skills and standard scores can be compared with normal children. The selected tools are BRIEF[36] and MU-EF[37], which the latter was developed by Chutabhakdikul et al.[37] and also provides a standard score of EFs in Thai children.

Executive function promotion in children with ADHD

Strategies to improve EFs in ADHD patients which are currently approved by research are:

1. ***Methylphenidate*** is a medication used for ADHD which is approved to help develop EFs in ADHD patients with an effect size equal to 0.38. If the effect size is clarified in each aspect of EFs, it is found that methylphenidate affects response inhibition (0.40) and sustained attention (0.42).[38] Additionally, a study comparing methylphenidate and atomoxetine, another group of medications for ADHD, reveals that only methylphenidate affects the development of EFs and reduces ADHD symptoms.[39]

2. ***Cognitive training*** is a therapy of training specific skills, including working memory, self-regulation, and concentration. This strategy is based on the principle of neuroplasticity which describes that if a skill is trained repetitively, not only is the part of the brain responsible for the skill strengthened, but the skill will also be more developed. One study discovered that cognitive training by computer programs helps develop working memory but does not improve ADHD symptoms.[40] Meanwhile, coach-based training, such as ThinkRx, and virtual classroom cognitive remediation can also develop almost all of the skills of EFs similar to methylphenidate but cannot relieve symptoms of ADHD.[41,42]
3. ***Physical Exercise*** consists of engaging cognitive exercise, such as football or basketball, and aerobic exercise, such as running or swimming. According to the analysis, both types of exercise affect EF development in all aspects if the exercise is in moderate-intensity or a heart rate is maintained approximately 65-75% of the maximum heart rate for at least 20 minutes.[43] This correlates with a study of physical change in the brain that exercise induces cell production in the hippocampus, increases blood supply, and also stimulates the prefrontal cortex, which is the control center of EFs; however, there is no scientific evidence supporting that physical exercise is associated with reducing ADHD symptoms.[44,45]
4. ***White noise*** is a low, humming sound from many combined frequencies, such as the sound of rain, wind, river, or forest ambiance. Soderlund et al.[46] found that if the white noise is turned on during psychological assessment in ADHD patients, scores of EFs increase significantly. This could be explained by the fact that appropriate disturbance sound increases dopamine secretion, stimulating the brain to be more active and focused.[46,47]
5. ***Organizational skill intervention*** is a training method for planning and prioritization in children's daily life which is one of the most crucial skills in EFs[48], and includes many programs such as the homework success program[49] and the challenging horizons program.[50] A study by Joshua et al. found that children with ADHD undergoing organizational skill intervention have better academic outcomes, and parents reported that they have less difficulties in dealing with their homework.

Furthermore, there are currently a variety of strategies for EF promotion, such as mindfulness-based intervention[51], neurofeedback[52], and noninvasive brain stimulation[53] but they still lack apparent supporting evidence.

In addition to evaluating and treating executive dysfunction, physicians should assess other difficulties of children with ADHD, such as poor relationships with friends and family, poor self-esteem, and academic problems, in order to provide appropriate treatment. The take-home message is that clinicians should be aware of a holistic assessment and treatment of problems associated with ADHD in order to improve patients' quality of life. Future research needs to find other effective interventions that can not only improve ADHD symptoms, but also promote EFs and reduce other negative impacts of ADHD.

Conclusion

Executive dysfunction is often seen in children with ADHD but is not the direct cause of ADHD symptoms. ADHD patients with impaired EFs were associated with poorer academic performance than those without EF impairment. Therefore, it is crucial to separate the assessment of EFs from ADHD symptoms to determine the direction of treatments.

To improve EFs, there are many strategies with supporting evidence, such as pharmacological treatment, cognitive training, physical exercise, white noise, and organization skill intervention, which should be conducted alongside ADHD treatment.

References

1. Miyake A, Friedman NP. The Nature and Organization of Individual Differences in Executive Functions: Four General Conclusions. *Curr Dir Psychol Sci.* 2012;21(1):8-14.
2. Garon N, Bryson SE, Smith IM. Executive function in preschoolers: a review using an integrative framework. *Psychol Bull*. 2008;134(1):31-60.
3. Hughes C, Ensor R. Executive function and theory of mind: Predictive relations from ages 2 to 4. *Dev Psychol*. 2007;43(6):1447-59.
4. Hughes C, Ensor R. Does executive function matter for preschoolers' problem behaviors? *J Abnorm Child Psychol*. 2008;36(1):1-14.
5. Blair C, Razza RP. Relating effortful control, executive function, and false belief understanding to emerging math and literacy ability in kindergarten. *Child Dev*. 2007;78(2):647-63.
6. Miller HV, Barnes JC, Beaver KM. Self-control and health outcomes in a nationally representative sample. *Am J Health Behav*. 2011;35(1):15-27.
7. Riggs NR, Spruijt-Metz D, Sakuma KL, Chou CP, Pentz MA. Executive cognitive function and food intake in children. *J Nutr Educ Behav*. 2010;42(6):398-403.
8. Will Crescioni A, Ehrlinger J, Alquist JL, Conlon KE, Baumeister RF, Schatschneider C, et al. High trait self-control predicts positive health behaviors and success in weight loss. *J Health Psychol*. 2011;16(5):750-9.
9. Moffitt TE, Arseneault L, Belsky D, et al. A gradient of childhood self-control predicts health, wealth, and public safety. *Proc Natl Acad Sci* U S A. 2011;108(7):2693-8.
10. Baler RD, Volkow ND. Drug addiction: the neurobiology of disrupted self-control. *Trends Mol Med*. 2006;12(12):559-66.
11. Lui M, Tannock R. Working memory and inattentive behaviour in a community sample of children. *Behav Brain Funct*. 2007;3:12.
12. Fairchild G, van Goozen SH, Stollery SJ, et al. Decision making and executive function in male adolescents with early-onset or adolescence-onset conduct disorder and control subjects. *Biol Psychiatry.* 2009;66(2):162-8.

ISSN 2287-0237 (online)/ 2228-9674 (print)

13. Taylor Tavares JV, Clark L, Cannon DM, et al. Distinct profiles of neurocognitive function in unmedicated unipolar depression and bipolar II depression. *Biol Psychiatry*. 2007;62(8):917-24.
14. Penades R, Catalan R, Rubia K, et al. Impaired response inhibition in obsessive compulsive disorder. *Eur Psychiatry.* 2007;22(6):404-10.
15. Borella E, Carretti B, Pelegrina S. The specific role of inhibition in reading comprehension in good and poor comprehenders. *J Learn Disabil*. 2010;43(6):541-52.
16. Bailey CE. Cognitive accuracy and intelligent executive function in the brain and in business. *Ann N Y Acad Sci*. 2007;1118:122-41.
17. Eakin L, Minde K, Hechtman L, et al. The marital and family functioning of adults with ADHD and their spouses. *J Atten Disord*. 2004;8(1):1-10.
18. Denson TF, Pedersen WC, Friese M, et al. Understanding impulsive aggression: Angry rumination and reduced self-control capacity are mechanisms underlying the provocation-aggression relationship. *Pers Soc Psychol Bull.* 2011;37(6):850-62.
19. Broidy LM, Nagin DS, Tremblay RE, et al. Developmental trajectories of childhood disruptive behaviors and adolescent delinquency: a six-site, cross-national study. *Dev Psychol.* 2003;39(2):222-45.
20. Best JR, Miller PH, Jones LL. Executive Functions after Age 5: Changes and Correlates. *Dev Rev.* 2009;29(3):180-200.
21. Tang YY, Holzel BK, Posner MI. The neuroscience of mindfulness meditation. *Nat Rev Neurosci.* 2015;16(4):213-25.
22. Bergmeier H, Skouteris H, Horwood S, et al. Associations between child temperament, maternal feeding practices and child body mass index during the preschool years: a systematic review of the literature. *Obes Rev.* 2014;15(1):9-18.
23. Perry V, Ellis K, Moss J, et al. Executive function, repetitive behaviour and restricted interests in neurodevelopmental disorders. *Res Dev Disabil.* 2022;122:104166.
24. McClain MB, Golson ME, Murphy LE. Executive functioning skills in early childhood children with autism, intellectual disability, and co-occurring autism and intellectual disability. *Res Dev Disabil*. 2022;122:104169.
25. Farah R, Ionta S, Horowitz-Kraus T. Neuro-Behavioral Correlates of Executive Dysfunctions in Dyslexia Over Development From Childhood to Adulthood. *Front Psychol.* 2021;12:708863.
26. American Psychiatric Association: Diagnostic and Statistical Manual of Mental Disorder, Fifth Edition: DSM-5. Washington, DC: American Psychiatric Association; 2013.
27. Barkley RA. Attention-deficit hyperactivity disorder. *Sci Am.* 1998;279(3):66-71.
28. Barkley RA. Distinguishing sluggish cognitive tempo from ADHD in children and adolescents: executive functioning, impairment, and comorbidity. *J Clin Child Adolesc Psychol.* 2013;42(2):161-73.
29. Brown TE. ADD/ADHD and Impaired Executive Function in Clinical Practice. *Curr Psychiatry Rep*. 2008;10(5):407-11.
30. Rapport MD, Alderson RM, Kofler MJ, et al. Working memory deficits in boys with attention-deficit/hyperactivity disorder (ADHD): the contribution of central executive and subsystem processes. *J Abnorm Child Psychol.* 2008;36(6):825-37.
31. Coghill DR, Seth S, Matthews K. A comprehensive assessment of memory, delay aversion, timing, inhibition, decision making and variability in attention deficit hyperactivity disorder: advancing beyond the three-pathway models. *Psychol Med.* 2014;44(9):1989-2001.
32. Silverstein MJ, Faraone SV, Leon TL, et al. The Relationship Between Executive Function Deficits and DSM-5-Defined ADHD Symptoms. *J Atten Disord.* 2020;24(1):41-51.
33. Krieger V, Amador-Campos JA, Guardia-Olmos J. Executive functions, Personality traits and ADHD symptoms in adolescents: A mediation analysis. *PLoS One.* 2020;15(5):e0232470.
34. Gordon CT, Hinshaw SP. Executive Functions in Girls With and Without Childhood ADHD Followed Through Emerging Adulthood: Developmental Trajectories. *J Clin Child Adolesc Psychol.* 2020;49(4):509-23.
35. Tamm L, Loren REA, Peugh J, et al. The Association of Executive Functioning With Academic, Behavior, and Social Performance Ratings in Children With ADHD. *J Learn Disabil.* 2021;54(2):124-38.
36. LeJeune B, Beebe D, Noll J, et al. Psychometric support for an abbreviated version of the Behavior Rating Inventory of Executive Function (BRIEF) Parent Form. *Child Neuropsychol.* 2010;16(2):182-201.
37. Lertladaluck K, Chutabhakdikul N, Chevalier N, et al. Effects of social and nonsocial reward on executive function in preschoolers. *Brain Behav.* 2020;10(9):e01763.
38. Tamminga HG, Reneman L, Huizenga HM, et al. Effects of methylphenidate on executive functioning in attention-deficit/hyperactivity disorder across the lifespan: a meta-regression analysis. *Psychol Med.* 2016;46(9):1791-807.
39. Kowalczyk OS, Cubillo AI, Smith A, et al. Methylphenidate and atomoxetine normalise fronto-parietal underactivation during sustained attention in ADHD adolescents. *Eur Neuropsychopharmacol.* 2019;29(10):1102-16.
40. Cortese S, Ferrin M, Brandeis D, et al. Cognitive training for attention-deficit/hyperactivity disorder: meta-analysis of clinical and neuropsychological outcomes from randomized controlled trials. *J Am Acad Child Adolesc Psychiatry.* 2015;54(3):164-74.
41. Moore AL, Carpenter DM, Miller TM, et al. Clinician-delivered cognitive training for children with attention problems: effects on cognition and behavior from the ThinkRx randomized controlled trial. *Neuropsychiatr Dis Treat*. 2018;14:1671-83.
42. Bioulac S, Micoulaud-Franchi JA, et al. Virtual Remediation Versus Methylphenidate to Improve Distractibility in Children With ADHD: A Controlled Randomized Clinical Trial Study. *J Atten Disord.* 2020;24(2):326-35.
43. Liang X, Li R, Wong SHS, et al. The impact of exercise interventions concerning executive functions of children and adolescents with attention-deficit/hyperactive disorder: a systematic review and meta-analysis. *Int J Behav Nutr Phys Act.* 2021;18(1):68.
44. Christiansen L, Beck MM, Bilenberg N, et al. Effects of Exercise on Cognitive Performance in Children and Adolescents with ADHD: Potential Mechanisms and Evidence-based Recommendations. *J Clin Med.* 2019;8(6).
45. Best JR. Effects of Physical Activity on Children's Executive Function: Contributions of Experimental Research on Aerobic Exercise. *Dev Rev.* 2010;30(4):331-551.

46. Soderlund GB, Sikstrom S, Loftesnes JM, et al. The effects of background white noise on memory performance in inattentive school children. *Behav Brain Funct*. 2010;6:55.
47. Baijot S, Slama H, Soderlund G, et al. Neuropsychological and neurophysiological benefits from white noise in children with and without ADHD. *Behav Brain Funct.* 2016;12(1):11.
48. Langberg JM, Epstein JN, Graham AJ. Organizational-skills interventions in the treatment of ADHD. *Expert Rev Neurother.* 2008;8(10):1549-61.
49. Garrison DR. Ending the homework wars : featuring the results-producing homework success program. Rev. ed. Cameron Park, CA: Leading Edge Press; 2005. 264 p. p.
50. Evans SW, Schultz BK, Demars CE, et al. Effectiveness of the Challenging Horizons After-School Program for young adolescents with ADHD. *Behav Ther*. 2011;42(3):462-74.
51. Oliva F, Malandrone F, di Girolamo G, et al. The efficacy of mindfulness-based interventions in attention-deficit/hyperactivity disorder beyond core symptoms: A systematic review, meta-analysis, and meta-regression. *J Affect Disord. 2021;292:475-86.*
52. Louthrenoo O, Boonchooduang N, Likhitweerawong N, et al. The Effects of Neurofeedback on Executive Functioning in Children With ADHD: A Meta-Analysis. *J Atten Disord.* 2021:10870547211045738.
53. Westwood SJ, Radua J, Rubia K. Noninvasive brain stimulation in children and adults with attention-deficit/hyperactivity disorder: a systematic review and meta-analysis. *J Psychiatry Neurosci.* 2021;46(1):E14-E33.