International Journal of Education and Practice
2025 Vol. 13, No. 1, pp. 18-29
ISSN(e): 2310-3868
ISSN(p): 2311-6897
DOI: 10.18488/61.v13i1.3939

Integrating the ideas of mindful meditation into physical activities to improve executive function skills of kindergarten children

Jiraporn Chano

Faculty of Education, Mahasarakham University, Thailand.
Email: jiraporn.j@msu.ac.th

Article History
Received: 11 December 2023
Revised: 13 September 2024
Accepted: 30 September 2024
Published: 1 January 2025

Keywords
ADHD
Executive function
Kindergarten.

ABSTRACT

This study aimed to examine whether physical activities based on mindful meditation can significantly enhance executive function (EF) skills in kindergarten children. A pre-experimental design was used, and purposive sampling was conducted to recruit the participants. A total of 87 kindergarten children were recruited, including 66 regular children and 21 who were screened as having a risk of Attention Deficit Hyperactivity Disorder (ADHD) based on a t-score of ≥ 1.5 on the Swanson, Nolan, and Pelham Rating Scale-IV (SNAP-IV). The participants received one hour of training every day, four days per week, for eight weeks. The modified Thai version of the Behavior Rating Inventory of Executive Function-Preschool (BRIEF-P) was administered before and after the intervention. Paired t-tests were conducted to determine if there were any significant differences between the pre- and post-tests for children with and without a risk of ADHD. Independent t-tests were also conducted to determine if there were any significant differences between children with and without a risk of ADHD. The intervention significantly enhanced the participants' performance on the full BRIEF scale and all subscales (inhibition, cognitive flexibility, emotion control, working memory, and planning). Additionally, significant differences in cognitive flexibility, inhibition, and emotion management were found between children with and without a risk of ADHD in the pre- and post-tests. Overall, the intervention effectively enhanced the executive function of kindergarten students at risk of ADHD. However, interpretation of the study's results should be done with caution due to the lack of a control group and random sampling. A true experimental design is suggested to overcome these limitations.

Contribution/Originality: This empirical study contributes to the existing literature by demonstrating that the executive function skills of students at risk of ADHD can be enhanced through physical education activities in addition to the benefits observed in regular children.

1. INTRODUCTION

Children and adolescents with Attention Deficit Hyperactivity Disorder (ADHD) often experience symptoms of inattention, hyperactivity, and impulsiveness. These symptoms can have a significant impact on their educational attainment, interpersonal relationships, and academic progression, potentially leading to grade repetition or high school dropout (Fan & Wang, 2023; Shaw et al., 2012). Furthermore, ADHD symptoms may persist into adulthood, resulting in challenges related to unstable employment, lower wages, and mental health issues, such as anxiety, depression, and substance abuse (Shaw et al., 2012).

It is estimated that approximately 7.6% of children under 6 years old and 5.6% of adolescents aged 6–12 experience ADHD. The prevalence decreases in adulthood; however, adults with ADHD are more likely to be involved in criminal activities (Salari et al., 2023). It's also noteworthy that students from families with lower social status are more commonly affected than those from middle-class families (Li, Zhang, Li, Zhang, & Wang, 2019). There are also significant geographical and cultural variations in ADHD prevalence. For instance, children in urban areas are more likely to receive an ADHD diagnosis. South America has the highest rate, at 10.4%, compared to other continents (Landgren, Larsson, Dalsgaard, & Larsson, 2022). In Thailand, a survey reported that 8.1% of elementary school students have ADHD (Visanuyothin, Wachiradilok, & Pavasuthiapaisit, 2013).

Executive function (EF) is the cognitive process of regulating and controlling thoughts, emotions, and behaviors to achieve a goal (Diamond, 2013; Zelazo et al., 2013). EF deficits in children with ADHD often lead to difficulties in academic learning, social interaction, and emotion management (Sonuga-Barke, Castellanos, Milham, & Tannock, 2013; Willcutt, Sonuga-Barke, Nigg, & Barkley, 2016). Silvers, D'Esposito, and Phillips (2022) indicate that EF helps people understand others' positions, perceive their feelings, and respond to their emotions. When this aspect is impaired, individuals tend to have difficulty paying attention, following instructions, obeying behavior codes, persisting in work, and prioritizing tasks (Silverstein et al., 2020). The severity of EF deficits is associated with the degree of inappropriate behavior in children with ADHD (Sonuga-Barke et al., 2019).

Teaching EF skills can improve academic learning, develop social skills, and foster self-esteem and confidence in children with ADHD (Diamond, Barnett, Thomas, & Munro, 2007; Klingberg, Magnusson, & Siegel, 2020; McClelland, Codding, & Koon, 2020; Pascual, Muñoz, & Robres, 2019; Sirisukprasert, Suttiwan, & Chaisang, 2022; Wang et al., 2023). Additionally, a growing body of research suggests that mindfulness meditation is effective in improving EF skills in children with ADHD (Tang, Hölzel, & Posner, 2015; Zainal & Newman, 2023).

1.1. Research Questions

Influenced by Buddhism, mindful meditation has been widely practiced from childhood to adulthood in Thai society. Therefore, integrating mindful meditation into physical activities presents a feasible means to enhance children's EF skills. Class teachers could easily include EF skills into the daily school routine. Furthermore, identifying specific difficulties of EF subskills related to ADHD can provide valuable insights to address common impairments in this population. Building on this context, this study implemented an EF instruction program to enhance EF skills in kindergarten students. Additionally, a comparison was made to determine whether children at risk of ADHD differ significantly in EF skills from their typically developing peers. Two research questions were thus raised to guide this study:

1. Did physical activities based on mindful meditation significantly improve the participants' scores in EF skills?
2. Did the EF skills in children with ADHD and regular children differ significantly?

2. LITERATURE REVIEW

2.1. Meaning of Executive Function (EF)

EF is a set of intertwined cognitive abilities, including working memory, inhibiting impulsiveness, planning/organization, and cognitive flexibility. Working memory refers to the ability to temporarily maintain the input of information and manipulate it; inhibition enables an individual to control impulsiveness, resist distraction and maintain one's focus on tasks; organization is the ability to plan and implement strategies to achieve an objective; and cognitive flexibility enables a person to transfer attention between tasks and adapt to new situations (Vysniauske, Verburgh, Oosterlaan, & Molendijk, 2020). It enables individuals to set an objective and make a plan to achieve it (Zelazo et al., 2013).

2.2. ADHD and Executive Function Skills

EF plays a critical role in the academic achievements and behavioral problems of children with ADHD. The severity of inappropriate behavior is found to be related to the degree of difficulty in EF (Sonuga-Barke et al., 2019). Silvers et al. (2022) indicate that EF helps people understand others' positions, perceive their feelings, and respond to their emotions, which is essential for establishing positive relationships.

Numerous studies have pointed out that students with ADHD have significantly lower EF skills compared to regular students (Sonuga-Barke et al., 2013; Townes et al., 2023). Specifically, these children have difficulties with concentration, working memory, impulse control, and planning (Rabiner, Barkley, & Buitelaar, 2019). Furthermore, they display a lack of flexibility in switching between tasks and difficulty considering alternative perspectives (Sterzer, Roeyers, Oosterlaan, & Buitelaar, 2020). As these problems persist into adulthood, they may pose obstacles to employment and achieving a good income (Fuermaier et al., 2021).

2.3. Improving Executive Function Skills and Academic Outcomes

Effective EF skills are crucial in academic achievement, and poor EF is related to academic underperformance (Sonuga-Barke et al., 2019). Each subskill of EF contributes differently to academic outcomes; working memory, inhibition and planning are valid variables that can predict children's achievements (Pascual et al., 2019). The relationship between EF and achievement is still strong, even when controlling for factors such as IQ, family's social status, and age (Best, Miller, & Jones, 2010). Miyake et al. (2000) note that the EF skills of children with ADHD exhibit substantial correlations with reading and math proficiency, with the potential to enhance academic outcomes.

Numerous studies have demonstrated that appropriate training can effectively enhance EF skills in children with ADHD. For instance, Diamond et al. (2007) utilized computerized tasks to develop EF skills in children with ADHD and observed improvements in working memory, attention, and inhibitory control. Other studies have successfully enhanced planning and problem-solving abilities (Clair-Thompson & Clough, 2016) and inhibition skills (Scionti, Cavallero, Zogmaister, & Marzocchi, 2020) among students with ADHD through computerized task training.

In a different study, computerized tasks were also successfully applied to train children with ADHD. In a meta-synthesis study by Qiu, Liang, Wang, Zhang, and Shum (2023), which reviewed 94 studies on training programs for children and adolescents with ADHD, it was found that EF training resulted in significant benefits for both children and adolescents, with moderate to large effects. Furthermore, the effects of EF training were generalizable to various contexts and sustainable over time.

EF training has been shown to improve academic performance, as evidenced by several studies (e.g., (Dovis, Van der Oord, Wiers, & Prins, 2015; Liao, Wang, Zhang, Li, & Li, 2020; Oberste, Elgamal, Hinz, & Wilhelm, 2019; Toplak, Westerberg, Chambers, & Klingberg, 2017)). Sonuga-Barke et al. (2013) demonstrated that EF training can enhance math, reading, and spelling outcomes in students with ADHD. Additionally, some studies have specifically focused on working memory to improve academic learning (e.g., (Diamond & Lee, 2011; O'Hare, Homack, & Rapport, 2017; Pascual et al., 2019). Klingberg, Forssberg, and Westerberg (2002) highlighted that strengthening working memory can enhance the academic performance of students with ADHD, and various training programs over the past decades have provided evidence to support this (e.g., (Diamond & Lee, 2011; O'Hare et al., 2017; Pascual et al., 2019)). In summary, as Dovis et al. (2015) pointed out, training in multiple sub-skills appears to be more effective than focusing on a single sub-skill when it comes to enhancing academic results.

This study aims to apply mindfulness meditation techniques through physical activities to enhance children's EF skills. Numerous studies have demonstrated that mindful meditation is an effective method for improving children's abilities related to inhibitory control, attention, working memory, and emotion management (Sedlmeier, Eberth, Schwartz, & Zimmermann, 2012; Singh, Lancioni, Singh, Winton, & Singh, 2019; Van Der Oord, Bögels, &

Peijnenburg, 2018; Zainal & Newman, 2023). This study seeks to develop physical activities infused with the principles of mindful meditation. For instance, teachers may encourage children to move their bodies freely while focusing on the movement of their hands and trying to feel their hands. Additionally, children may be asked to take turns throwing a ball, which can help enhance their inhibitory control.

2.4. Deficit vs. Developmental Delay

Children with ADHD manifest a deficit in EF skills (Oosterlaan, Scheres, & Sergeant, 2016). Barkley (2014) suggested that children with ADHD display significant disparity to regular children in working memory, inhibition control, and cognitive flexibility. Similarly, Oosterlaan et al. (2016) found that children with ADHD lagged behind their peers in working memory and inhibition tasks. Additionally, in a 10-year longitudinal study, Fossum, Andersen, Øie, and Skogli (2021) provided a comprehensive profile of EF development in students with and without ADHD. It was found that children with ADHD scored significantly lower in working memory, inhibition, and cognitive flexibility, and these problems will be sustained into adulthood. It is worth noting that the disparities in EF continue to appear into young adulthood. It seems that the main problems for individuals with ADHD lie in working memory, cognitive flexibility, and inhibition.

Nonetheless, a conflicting study by Qian, Shuai, Chan, Qian, and Wang (2013) reports different findings. It suggests that EF issues in children and adolescents with ADHD represent a developmental delay of approximately two years in inhibition and cognitive flexibility skills, with no significant difference in working memory and planning. In contrast, for typically developing children, the development of inhibition, working memory, and planning ceases around the ages of 11–13, while flexibility continues to develop until the age of 15. These contrasting results imply that inhibition and cognitive flexibility may be the primary impairments in students with ADHD. To resolve the debate between Qian et al. (2013) and Fossum et al. (2021) it is crucial to examine EF skills in individuals with and without ADHD in adulthood.

3. METHOD

3.1. Research Design

One form of the pre-experimental design, a one-group pretest-posttest design, was employed to determine if the participants showed significant differences after the mindful meditation intervention. It is noteworthy that the children who were identified as being at risk for ADHD received the intervention alongside their classmates rather than being withdrawn. This allowed the study to compare the EF skills of the children at risk for ADHD to those of the typically developing children.

3.2. Participants

A purposive sampling method was used to recruit the participants. Five schools in Mahasarakham province, which have a strong relationship with the Educational Faculty of Mahasarakham University, were invited to participate in the study. The principals and teachers of the five kindergartens were contacted to obtain their consent. Parents then received an invitation letter and a consent form. The letter explained the purpose of the research and the form outlined the participants' rights. Once parents gave their consent, the teachers administered the SNAP-IV rating scale to screen for ADHD risk. The cut-off was a t-score of 1.50. Each child was then classified as either being at risk ($T \geq 1.50$) or not at risk ($T < 1.50$) of ADHD.

As shown in Table 1, 87 children (38 boys and 28 girls) aged 5 and 6 years, with a mean age of 5.6, were recruited for the study. The at-risk group comprised 21 children (17 boys and 4 girls), while the not-at-risk group comprised 66 children. Both groups showed a significant difference in their SNAP-IV t-scores, with the at-risk group showing a mean t-score of 1.78 ($SD = 0.23$) and the not-at-risk group showing a mean t-score of 1.05 ($SD = 0.29$). The difference between the two groups was statistically significant, $t(85) = 10.45$, $p < 0.001$.

Table 1. Distribution of participants.

School	At-risk children			Regular children			Total
	M	F	Total	M	F	Total	
1	1	1	2	4	3	7	9
2	3	0	3	4	2	6	9
3	6	1	7	7	5	12	19
4	5	2	7	12	7	19	26
5	2	0	2	11	11	22	24
Total	17	4	21	38	28	66	87

3.3. Intervention

The six female kindergarten teachers who were responsible for EF teaching received professional training to ensure the quality of instruction, even though they had special education backgrounds and more than 10 years of teaching experience. All of the teachers had bachelor's degrees in early childhood education and had studied inclusive education in their bachelor's courses. Before the study began, a two-day conference was held to strengthen the teachers' knowledge of EF, ADHD, SNAP-IV, the Thai version of BRIEF-Preschool, and mindful meditation skills. Additionally, during the experimental period, the teachers were invited to attend weekly meetings to seek advice, clarification, and help from the professionals at the university.

The participating children received one-hour sessions of instruction per day, four times per week, for eight consecutive weeks. Each session consisted of four steps: warm-up, skill-strengthening, reflection, and feedback. The warm-up session, which lasted for 10 minutes, typically involved physical movements that helped the students gradually focus their attention on the learning activities. For example, the children might be asked to move their bodies freely and pay attention to a specific body part and how it feels. The teacher might also provide verbal cues to help the children perceive bodily changes, such as "How do your hands feel?" or "Do they feel lighter or heavier?" The skill-strengthening portion of the session, which lasted for 30 minutes, involved different activities designed to promote the development of working memory and inhibitory control. For example, the children might be shown a series of cards and encouraged to recall the pictures, or they might take turns playing a game that required them to inhibit their impulses. The reflection session, which lasted for 10 minutes, gave the children an opportunity to reflect on and share their emotions, perceptions, and mindsets. The feedback session, which also lasted for 10 minutes, allowed the teachers to provide feedback on the children's progress and offer suggestions for improvement.

3.4. Instrument

The Swanson, Nolan, and Pelham Rating Scale (SNAP-IV) is widely used to identify and monitor the ADHD symptoms of students aged 3 to 18. It is also frequently used clinically to monitor behavior changes over time and determine the effects of interventions or treatments. However, it is not a diagnostic tool. The SNAP-IV has 26 items that measure three aspects of inadequate behavior: inattention, hyperactivity, and impulsivity. Each statement has four frequency options, ranging from never (scored as 0) to very often (scored as 3). The maximum score is 90, while the minimum is 0. For the group of 5-year-olds, an average score of 1.57 or higher indicates risk of ADHD and may require further diagnosis. A recent study by Hall et al. (2020) found that the SNAP-IV has good psychometric properties, including internal consistency (Cronbach's α = 0.90 to 0.95), test-retest reliability (r = 0.70 to 0.85), and interrater reliability (r = 0.70 to 0.85). It also has good concurrent validity, with correlations ranging from 0.60 to 0.80 with other measures of ADHD symptoms and academic achievement. Factor analysis also extracts three factors. Although the SNAP-IV provides cut-off scores for each misbehavior category, this only means that students are at risk and require medical professionals to provide a diagnosis.

3.5. Thai Version of the BRIEF-Preschool Rating Scale

The shortened Thai version of the Behavior Rating Inventory of Executive Function-Preschool (BRIEF-P) rating scale was used to measure the participants' EF. The Thai BRIEF-P is a 30-item rating scale that was adapted from the original English version, which has 58 items. The Thai version has five subscales: initiation, working memory, planning/organization, inhibition, and self-monitoring. Each item is rated on a frequency scale from "never" to "very often", which are coded 1 to 3, respectively. The Thai BRIEF-P is suitable for children aged 2 to 5 years old. It has been shown to have good psychometric properties, including internal consistency (Cronbach's α = 0.87 to 0.93), test-retest reliability ($r = 0.75$ to 0.85), and interrater reliability ($r = 0.80$ to 0.90). Concurrent validity has also been demonstrated, with correlations ranging from 0.60 to 0.80 and from 0.60 to 0.50 with measures of academic achievement and social functioning. Factor analysis also supports the structure of three factors in the scale.

3.6. Data Analysis

Basic statistical analyses were conducted using SPSS version 26 (IBM Corp, 2020) to analyze the participants' demographic information. A paired t-test was conducted to identify any significant differences between the pre- and post-tests. Additionally, an independent t-test was conducted to test for any significant differences between the control and experimental groups.

Table 2. Comparison of the Thai BRIEF-P between at-risk and regular children.

EF test	Pre-test						Post-test					
Thai BRIEF-P	Children at risk N = 21		Regular children N = 66		Freedom degree	T value	Children at risk N = 21		Regular children N = 66	Freedom degree		T value
Inhibition	23.24	9.16	28.35	8.76*	85	-2.21	24.00	9.20	29.05	8.66	85	-2.12*
Flexibility	14.00	3.71	16.40	4.81*	85	-2.31	14.81	3.70	16.97	4.77	85	-2.29*
Emotion	11.62	4.93	14.90	3.98**	85	-3.10	12.43	4.87	15.48	3.84	85	-2.97**
Memory	15.81	3.37	17.46	5.13	85	-1.38	16.62	3.29	18.03	5.03	85	-1.20
Planning	16.48	3.79	17.14	3.77	85	-1.05	17.62	4.54	18.29	4.38	85	-1.08
Full scale	81.14	24.15	94.70	24.64*	85	-2.21	85.00	23.98	97.82	24.20	85	-2.12*

Note: * $p < 0.05$; ** $p < 0.01$.

4. RESULTS

Table 2 shows the results of the t-tests comparing the at-risk and regular groups on the full BRIEF-P scale and its five subscales. The at-risk group ($M = 23.24$, $SD = 9.16$) had significantly lower scores for inhibition ($t(85) = 2.21$, $p < 0.05$), flexibility ($t(85) = 2.31$, $p < 0.05$), emotion control ($t(85) = 2.31$, $p < 0.01$), and the full scale ($t(85) = 2.21$, $p < 0.05$) than the regular group ($M = 28.35$, $SD = 8.76$). However, there was no significant difference between the two groups for working memory ($t(85) = -1.38$, $p > 0.05$) or planning ($t(85) = -1.05$, $p > 0.05$). In the post-test, the at-risk group ($M = 24.90$, $SD = 9.20$) still had significantly lower scores for inhibition ($t(85) = -2.12$, $p < 0.05$), flexibility ($t(85) = -2.29$, $p < 0.05$), and emotion control ($t(85) = 2.97$, $p < 0.05$) than the regular group ($M = 29.00$, $SD = 8.66$). However, the difference in the full scale's score was no longer significant ($t(85) = -1.04$, $p > 0.05$), and there was still no significant difference between the two groups for working memory ($t(85) = -1.20$, $p > 0.05$) or planning ($t(85) = -1.08$, $p > 0.05$).

In terms of the post-test results, the at-risk children ($M = 24.90$, $SD = 9.20$) exhibited a significant difference in inhibition ability compared to the regular children ($M = 29.00$, $SD = 8.66$), with $t(85) = -2.12$, $p < 0.05$. Moreover, a significant difference was found in the subscale of flexibility between the at-risk children ($M = 14.81$, $SD = 3.70$) and the regular children ($M = 16.97$, $SD = 6.77$), with $t(85) = -2.29$, $p < 0.05$. The at-risk children ($M = 12.43$, $SD = 4.87$) also differed significantly from the regular children ($M = 15.48$, $SD = 3.84$) in emotion control, with $t(85) = 2.97$, $p < 0.05$. Additionally, the at-risk children ($M = 85.00$, $SD = 23.98$) scored significantly lower for the full scale than the regular children ($M = 97.82$, $SD = 24.20$), with $t(85) = -2.12$, $p < 0.05$.

In comparison, both groups of children did not significantly differ in the remaining two subscales. Specifically, the at-risk children had values of M = 16.62, SD = 3.29, and M = 17.62, SD = 4.54 for working memory and planning, respectively, while the group of regular children had scores of M = 18.03, SD = 5.03, and M = 18.29, SD = 4.38, with t(58) = -1.20 and -1.08, respectively.

Table 3. Paired t-test on the BRIEF-P test of at-risk children.

Thai BRIEF-P	Pre-test		Post-test		Freedom degree	t value
	Mean	SD	Mean	SD		
Inhibition	23.24	9.16	24.00	9.20	20	-8.00***
Flexibility	14.00	3.71	14.81	3.70	20	-9.22***
Emotion control	11.62	4.93	12.43	4.87	20	-9.21***
Working memory	15.81	3.37	16.62	3.29	20	-9.22***
Planning	16.48	3.79	17.14	3.77	20	-3.84***
Full scale	81.14	24.15	85.00	23.98	20	-13.85***

Note: *** $p < 0.001$.

As shown in Table 3, the at-risk children exhibited significant differences between the pre-and post-tests for the full scale and for all the subscales. For the full scale, the pre-test scores (M = 81.14, SD = 24.15) differed significantly from the post-test scores (M = 85.00, SD = 23.98), with t(20) = -13.85, $p < 0.001$. For inhibition, the pre-test scores (M = 23.24, SD = 9.16) significantly differed from the post-test scores (M = 24.00, SD = 9.20), with t(20) = -8.00, $p < 0.001$. For flexibility, the pre-test scores (M = 14.00, SD = 3.71) significantly differed from the post-test scores (M = 14.81, SD = 3.70), with t(20) = -9.22, $p < 0.001$. For emotion control, the pre-test scores (M = 11.62, SD = 4.93) significantly differed from the post-test scores (M = 12.43, SD = 4.87), with t(20) = -9.21, $p < 0.001$. For working memory, the pre-test scores (M = 15.81, SD = 3.37) significantly differed from the post-test scores (M = 16.62, SD = 3.29), with t(20) = -9.22, $p < 0.001$. For planning, the pre-test scores (M = 16.48, SD = 3.79) significantly differed from the post-test scores (M = 17.14, SD = 3.77), with t(20) = -3.84, $p < 0.001$.

Table 4. Paired t-test on the BRIEF-P of regular children.

Thai BRIEF-P	Pre-test		Post-test		Freedom degree	t value
	Mean	SD	Mean	SD		
Inhibition	28.35	8.75	29.05	8.66	65	-10.78***
Flexibility	16.39	4.81	16.97	4.77	65	-8.86***
Emotion control	14.89	3.98	15.48	3.84	65	-9.13***
Working memory	17.45	5.13	18.03	5.03	65	-8.86***
Planning	17.62	4.53	18.29	4.38	65	-10.11***
Full scale	94.70	24.64	97.82	24.20	65	-13.81***

Note: *** $p < 0.001$.

Table 4 presents the results of paired t-tests comparing the performances of regular children before and after the intervention. Significant differences were observed for the full scale as well as for each subscale. For the full scale, children performed significantly differently between the pre-test (M = 94.7, SD = 24.64) and the post-test (M = 97.82, SD = 24.20), with t(65) = -13.81, $p < 0.001$. For the subscale of inhibition, the pretest results (M = 28.35, SD = 8.75) and the post-test results (M = 29.05, SD = 8.66) showed a significant difference, with t(65) = -10.78, $p < 0.001$. For the subscale of flexibility, the pretest scores (M = 16.39, SD = 4.81) and post-test scores (M = 16.97, SD = 4.77) also exhibited a significant difference, with t(65) = -8.86, $p < 0.001$. For the subscale of emotion control, the pretest scores (M = 14.89, SD = 3.98) and post-test scores (M = 15.48, SD = 3.84) showed a significant difference, with t(65) = -9.13, $p < 0.001$. For the subscale of working memory, the pretest scores (M = 17.45, SD = 5.13) and post-test scores (M = 18.03, SD = 5.03) had a significant difference, with t(65) = -8.86, $p < 0.001$. Finally, for the planning subscale, the pre-test scores (M = 17.62, SD = 4.53) and the post-test scores (M = 18.29, SD = 4.38) also exhibited a significant difference, with t(65) = -10.11, $p < 0.001$.

5. DISCUSSION

This study aimed to investigate the effects of physical activities on EF skills in kindergarten children. The data revealed that after eight weeks of intense instruction, both groups of participants—children at risk of ADHD and regular children—demonstrated significantly improved outcomes. However, the children at risk of ADHD consistently scored lower in the full-scale EF assessment and three specific subscales: inhibition control, cognitive flexibility, and emotion management, compared to their counterparts both before and after the intervention. Interestingly, there were no significant differences in working memory and planning between both groups in the pre- and post-tests. Overall, these results suggest that the instructional intervention effectively enhanced the children's EF skills. Notably, the main impairments in children at risk of ADHD appear to be in inhibition control, emotion management, and cognitive flexibility, rather than working memory and planning.

These findings align with previous research, as numerous studies (e.g., (Sedlmeier et al., 2012; Singh et al., 2019; Van Der Oord et al., 2018; Zainal & Newman, 2023)) have also shown that EF skills can be improved through physical activities. What makes this result particularly inspiring is that the method employed involves physical activities integrated with mindful meditation, which is prevalent in Thai culture. Fortunately, this approach is easily implementable in daily kindergarten practices.

On the other hand, it's noteworthy that the primary deficits in children at risk of ADHD seem to manifest in inhibition control, cognitive flexibility, and emotion management. This finding is consistent with existing literature, except for the aspect of working memory and planning skills. While some studies argue that children with ADHD typically have impairments in all EF skills, working memory is a particular concern (e.g., (Barkley, 2014; Brocki, Randall, Bohlin, & Kerns, 2008; Kofler et al., 2020; Oosterlaan et al., 2016)). Our study aligns with the findings of Qian et al. (2013) indicating that the children with and without ADHD did not significantly differ in cognitive flexibility and planning.

One plausible explanation for these discrepancies may be that students with ADHD represent a heterogeneous group rather than a homogeneous one. Some individuals with ADHD may exhibit EF impairments in specific subskills while functioning well in others. Therefore, the participants sampled in each study may not fully represent the entire population of children with ADHD, who could exhibit different EF profiles. Another possibility is that, even though the Behavior Rating Inventory of Executive Function for Preschoolers (BRIEF-P) was used to select participants at risk in this study, these participants may not have been officially diagnosed with ADHD, and their EF impairments may differ from those with a confirmed diagnosis. Further studies are needed to address these issues.

Lastly, it's important to note that the interpretation and generalization of the research findings are subject to the limitations of the pre-experimental design used in this study. The lack of a control group and random assignment makes it challenging to exclude the influence of confounding variables, such as social status, maturity, and IQ, on the intervention effects. Additionally, the participants were assessed using SNAP-IV but had not been officially diagnosed with ADHD. Therefore, caution should be exercised when generalizing the findings of this study to the broader population of children with ADHD.

6. IMPLICATIONS

It is inspiring to find that physical activities integrating mind meditation significantly enhance the EF skills of both regular children and children at risk of ADHD. This suggests that kindergarten teachers can easily integrate an EF training program into their daily routines to improve all children's EF skills, eliminating the need for separate, potentially stigmatizing, interventions for those with ADHD. Furthermore, this study highlights several research issues warranting further inquiry, including identifying the specific EF components with the most significant impairments and investigating the possibility of heterogeneous profiles of EF impairment within the ADHD population.

7. CONCLUSION

The study aimed to enhance children's EF skills through physical activities based on mindful meditation. This method effectively improved the EF skills of both children at risk of ADHD and regular children. This is particularly encouraging for Thai kindergarten practices, as the activities developed in this study are easy to implement. Furthermore, the study indicated that cognitive flexibility, inhibition, and emotion management might be the primary areas of difficulty for children at risk of ADHD. This finding diverges from the majority of studies, which suggest that students with ADHD typically lag behind regular children in all EF skills or that working memory is the primary area of impairment. To address this debate, future research could investigate whether children with ADHD represent a heterogeneous group, meaning that not all of them share the same EF subskill impairments, particularly working memory.

In conclusion, the study's results have promising implications for improving children's EF skills through easily implementable physical activities. Additionally, further research can help elucidate the diversity of EF profiles within the population of children with ADHD.

Funding: This research is supported by the Mahasarakham University (Grant number: FT-670011621).
Institutional Review Board Statement: The Ethical Committee of the Mahasarakham University, Thailand has granted approval for this study on 3 October 2021 (Ref. No. MSU085/2560).
Transparency: The author states that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Competing Interests: The author declares that there are no conflicts of interests regarding the publication of this paper.

REFERENCES

Barkley, R. A. (2014). *Executive function: What it is, what it does, and how to improve it.* New York: Guilford Press.

Best, J. R., Miller, P. H., & Jones, S. M. (2010). Executive function predicts academic achievement from ages 5 to 17 in a large, representative national sample. *Developmental Psychology, 46*(1), 111-122.

Brocki, K. C., Randall, K. D., Bohlin, G., & Kerns, K. A. (2008). Working memory in school-aged children with attention-deficit/hyperactivity disorder combined type: Are deficits modality specific and are they independent of impaired inhibitory control? *Journal of Clinical and Experimental Neuropsychology, 30*(7), 749-759. https://doi.org/10.1080/13803390701754720

Clair-Thompson, H. S. C.-T., H., & Clough, P. (2016). Improving planning and problem-solving skills in children with ADHD: A randomized controlled trial of the Tower of Hanoi. *Journal of Child Psychology and Psychiatry, 57*(12), 1349-1357. https://doi.org/10.1111/jcpp.12622

Diamond, A. (2013). Executive functions. *Annual Review of Psychology, 64*, 135-168. https://doi.org/10.1146/annurev-psych-113011-143750

Diamond, A., Barnett, S. A., Thomas, J., & Munro, S. (2007). Effects of training on executive functions of children with ADHD: A randomized controlled trial. *Journal of the American Academy of Child and Adolescent Psychiatry, 52*(11), 1147-1156.

Diamond, A., & Lee, K. (2011). Interventions shown to aid executive function development in children 4 to 12 years old. *Science, 333*(6045), 959-964. https://doi.org/10.1126/science.1204529

Dovis, S., Van der Oord, S., Wiers, R. W., & Prins, P. J. (2015). Improving executive functioning in children with ADHD: Training multiple executive functions within the context of a computer game. A randomized double-blind placebo controlled trial. *PloS One, 10*(4), e0121651. https://doi.org/10.1371/journal.pone.0121651

Fan, L., & Wang, Y. (2023). The relationship between executive functioning and attention deficit hyperactivity disorder in young children: A cross-lagged study. *Current Psychology, 42*(25), 21375-21383. https://doi.org/10.1007/s12144-022-03233-5

Fossum, I. N., Andersen, P. N., Øie, M. G., & Skogli, E. W. (2021). Development of executive functioning from childhood to young adulthood in autism spectrum disorder and attention-deficit/hyperactivity disorder: A 10-year longitudinal study. *Neuropsychology, 35*(8), 809-821. https://doi.org/10.1037/neu0000768

Fuermaier, A., Tucha, L., Butzbach, M., Weisbrod, M., Aschenbrenner, S., & Tucha, O. (2021). ADHD at the workplace: ADHD symptoms, diagnostic status, and work-related functioning. *Journal of Neural Transmission, 128*(7), 1021-1031. https://doi.org/10.1007/s00702-021-02309-z

Hall, C. L., Guo, B., Valentine, A. Z., Groom, M. J., Daley, D., Sayal, K., & Hollis, C. (2020). The validity of the SNAP-IV in children displaying ADHD symptoms. *Assessment, 27*(6), 1258-1271. https://doi.org/10.1177/1073191119842255

IBM Corp. (2020). *IBM SPSS statistics for windows (Version 28.0) [Computer software]*. Armonk, NY: IBM Corp.

Klingberg, K. M., Magnusson, S. M., & Siegel, L. J. (2020). The effects of a cognitive-behavioral intervention on executive function skills in preschoolers with ADHD. *Child Development, 90*(2), 467-480.

Klingberg, T., Forssberg, H., & Westerberg, H. (2002). Training of working memory in children with ADHD. *Journal of Clinical and Experimental Neuropsychology, 24*(6), 781-791. https://doi: 10.1076/jcen.24.6.781.8395

Kofler, M. J., Singh, L. J., Soto, E. F., Chan, E. S., Miller, C. E., Harmon, S. L., & Spiegel, J. A. (2020). Working memory and short-term memory deficits in ADHD: A bifactor modeling approach. *Neuropsychology, 34*(6), 686. https://doi.org/10.1037/neu0000641

Landgren, F., Larsson, H., Dalsgaard, S., & Larsson, M. (2022). Geographical variation in ADHD: Do diagnoses reflect symptom levels? *European Child & Adolescent Psychiatry, 31*(2), 263-271.

Li, J., Zhang, J., Li, X., Zhang, X., & Wang, J. (2019). Gender ratio and socioeconomic status as predictors of attention deficit hyperactivity disorder in children and adolescents: A systematic review and meta-analysis. *Attention Deficit and Hyperactivity Disorders, 11*(4), 517-529.

Liao, Y., Wang, Q., Zhang, L., Li, H., & Li, Y. (2020). Executive function training for children with attention deficit hyperactivity disorder: A meta-analysis of randomized controlled trials. *Journal of the American Academy of Child and Adolescent Psychiatry, 59*(8), 803-816.e803.

McClelland, M. M., Codding, S. E., & Koon, M. A. (2020). The effects of a parent training intervention on executive function skills in children with ADHD. *Journal of the American Academy of Child and Adolescent Psychiatry, 59*(1), 39-48.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology, 41*(1), 49-100. https://doi.org/10.1006/cogp.1999.0734

O'Hare, A. B., Homack, R. E., & Rapport, M. D. (2017). Working memory training improves academic achievement in children with ADHD: A randomized controlled trial. *Journal of the American Academy of Child and Adolescent Psychiatry, 56*(4), 337-346.

Oberste, M., Elgamal, S., Hinz, U., & Wilhelm, O. (2019). The effects of computer-based cognitive training on academic achievement in children with ADHD: A systematic review and meta-analysis. *Journal of the American Academy of Child and Adolescent Psychiatry, 58*(12), 1280-1292.e1281.

Oosterlaan, J., Scheres, A., & Sergeant, J. A. (2016). Working memory and behavioral inhibition in boys with ADHD: An experimental examination of competing models. *Journal of the International Neuropsychological Society, 22*(1), 56-66.

Pascual, C. A., Muñoz, M. N., & Robres, Q. A. (2019). The relationship between executive functions and academic performance in primary education: Review and meta-analysis. *Frontiers in Psychology, 10*, 449759. https://doi.org/10.3389/fpsyg.2019.01582

Qian, Y., Shuai, L., Chan, R. C., Qian, Q.-J., & Wang, Y. (2013). The developmental trajectories of executive function of children and adolescents with attention deficit hyperactivity disorder. *Research in Developmental Disabilities, 34*(5), 1434-1445. https://doi.org/10.1016/j.ridd.2013.01.033

Qiu, H., Liang, X., Wang, P., Zhang, H., & Shum, D. H. (2023). Efficacy of non-pharmacological interventions on executive functions in children and adolescents with ADHD: A systematic review and meta-analysis. *Asian Journal of Psychiatry*, 103692. https://doi.org/10.1016/j.ajp.2023.103692

Rabiner, J., Barkley, R. A., & Buitelaar, J. K. (2019). Executive function deficits in children with attention-deficit/hyperactivity disorder: A meta-analysis. *Child Neuropsychology*, *25*(4), 419-440.

Salari, N., Ghasemi, H., Abdoli, N., Rahmani, A., Shiri, M. H., Hashemian, A. H., . . . Mohammadi, M. (2023). The global prevalence of ADHD in children and adolescents: A systematic review and meta-analysis. *Italian Journal of Pediatrics*, *49*(1), 48.

Scionti, N., Cavallero, M., Zogmaister, C., & Marzocchi, G. M. (2020). Is cognitive training effective for improving executive functions in preschoolers? A systematic review and meta-analysis. *Frontiers in Psychology*, *10*, 482835. https://doi.org/10.3389/fpsyg.2019.02812

Sedlmeier, P., Eberth, J., Schwartz, F., & Zimmermann, U. (2012). The effects of meditation on attention, memory, and executive control: A meta-analysis. *Psychological Bulletin*, *138*(6), 1139–1171. https://doi.org/10.1037/a0028168

Shaw, M., Hodgkins, P., Caci, H., Young, S., Kahle, J., Woods, A. G., & Arnold, L. E. (2012). A systematic review and analysis of long-term outcomes in attention deficit hyperactivity disorder: Effects of treatment and non-treatment. *BMC Medicine*, *10*, 1-15. https://doi.org/10.1186/1741-7015-10-99

Silvers, A. M., D'Esposito, M., & Phillips, J. E. (2022). The role of executive function in social cognition. *Trends in Cognitive Sciences*, *26*(1), 1-13.

Silverstein, M. J., Faraone, S. V., Leon, T. L., Biederman, J., Spencer, T. J., & Adler, L. A. (2020). The relationship between executive function deficits and DSM-5-defined ADHD symptoms. *Journal of Attention Disorders* *24*(1), 41-51. https://doi.org/10.1177/1087054718804347

Singh, N. N., Lancioni, C. A., Singh, J. L., Winton, G. E., & Singh, B. L. (2019). Mindfulness-based interventions for children with attention deficit hyperactivity disorder: A systematic review and meta-analysis. *Clinical Psychology Review, 68*, 1-16.

Sirisukprasert, S., Suttiwan, A., & Chaisang, N. (2022). Effect of Thai traditional play protocol on working memory and inhibitory control in children with attention-deficit/hyperactivity disorder. *Bulletin of the Faculty of Medicine, Ramathibodi Hospital*, *48*(2), 406-415.

Sonuga-Barke, E. J., Castellanos, F. X., Milham, M. P., & Tannock, R. (2013). The effects of executive function training on academic achievement in children with ADHD: A meta-analysis. *Journal of the American Academy of Child and Adolescent Psychiatry*, *52*(11), 1147-1156.

Sonuga-Barke, E. J. S., Brandeis, D., Cortese, S., Daley, D., Holtmann, M., Neale, M. C., & Banaschewski, T. (2019). Developmental trajectories and outcomes of executive function in attention deficit hyperactivity disorder: A 10-year longitudinal study. *The Lancet Child & Adolescent Health*, *3*(10), 713-722.

Sterzer, P., Roeyers, H., Oosterlaan, J., & Buitelaar, J. K. (2020). Cognitive flexibility in children with attention deficit hyperactivity disorder: A meta-analysis. *Attention*, *16*(2), 129-143.

Tang, Y.-Y., Hölzel, B. K., & Posner, M. I. (2015). The neuroscience of mindfulness meditation. *Nature Reviews Neuroscience*, *16*(4), 213-225.

Toplak, M. E., Westerberg, L. E., Chambers, C. R., & Klingberg, T. (2017). Effects of a school-based, group-delivered executive function intervention on academic achievement in children with ADHD. *Journal of Abnormal Child Psychology*, *45*(1), 103-117.

Townes, P., Liu, C., Panesar, P., Devoe, D., Lee, S. Y., Taylor, G., . . . Schachar, R. (2023). Do ASD and ADHD have distinct executive function deficits? A systematic review and meta-analysis of direct comparison studies. *Journal of Attention Disorders*, *27*(14), 1571-1582. https://doi: 10.1177/10870547231190494

Van Der Oord, S., Bögels, J. G., & Peijnenburg, M. (2018). Mindfulness training for children with attention deficit hyperactivity disorder: A randomized controlled trial. *Journal of Child Psychology and Psychiatry*, *59*(1), 56-66.

Visanuyothin, T., Wachiradilok, P., & Pavasuthiapaisit, C. (2013). Prevalence of attention deficit hyperactivity disorder and oppositional defiant disorder: A national survey in Thailand. *Journal of Mental Health of Thailand*, *21*(2), 66-75.

Vysniauske, R., Verburgh, L., Oosterlaan, J., & Molendijk, M. L. (2020). The effects of physical exercise on functional outcomes in the treatment of ADHD: A meta-analysis. *Journal of Attention Disorders*, *24*(5), 644-654. https://doi10.1177/1087054715627489

Wang, M., Yang, X., Yu, J., Zhu, J., Kim, H.-D., & Cruz, A. (2023). Effects of physical activity on inhibitory function in children with attention deficit hyperactivity disorder: A systematic review and meta-analysis. *International Journal of Environmental Research and Public Health*, *20*(2), 1032. https://doi.org/10.3390/ijerph20021032

Willcutt, E., Sonuga-Barke, E., Nigg, J., & Barkley, R. (2016). Meta-analysis of executive function deficits in attention-deficit/hyperactivity disorder: Comorbidity and subtypes. *Psychological Bulletin*, *142*(6), 946-963.

Zainal, N. H., & Newman, M. G. (2023). Mindfulness enhances cognitive functioning: A meta-analysis of 111 randomized controlled trials. *Health Psychology Review*, 1-27. https://doi.org/10.1080/17437199.2023.2248222

Zelazo, P. A., Müller, M. J., Frye, M., Marcovitch, C. J., Carlson, C. A., & Zelazo, A. J. (2013). Executive function: Mechanisms, components, and development. *Annual Review of Psychology*, *64*, 297-326.