Long-Term Vipassana Meditation Enhances Executive Function in Adult Meditators

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ABSTRACT

Objective: Vipassana meditation (VM) is a traditional Buddhist meditation practice that focuses on monitoring of clear awareness of oneself exactly what is happening as it happens, without judging. Executive functions (EF) are the high-level cognitive processes that facilitate goal-directed behaviors. It is well known that VM has significant effects on various affective states of the mind, such as relaxation, reduce stress and anxiety; however, less is known about the effect of VM on the executive function. This study aims to examine the effects of VM practice on the performance of the executive function in the adult meditators.

Methods: Forty adult participants, age range between 25-50 year-olds, were recruited to this study. They were divided into three groups; the control group (N=20, mean age = 40.5 ± 5.8 years), Short-term VM group (N=6, mean age = 38.0±9.1 years), and Long-term VM group (N=14, mean age = 37.7±7.3 years). All participants were examined by 1) State-trait anxiety inventory (STAI); 2) Philadelphia mindfulness scale (PHLMS); 3) Digit span task of WAIS-IV, 4) Tower of Hanoi (ToH), and 5) Wisconsin Card Sorting Test (WCST-CV4). The mean scores of all task performance were statistically analyzed and compared between groups. Alpha values of .05 were considered significant throughout.

Results: Both short-term and long-term VM has common benefits to decreased anxiety and increased mindfulness score as compared with the non-meditator group. Although short-term VM shows some benefits to the performance of several EF tasks, the discrepancy was not significant when compared with the control group. In contrast, long-term VM had a significant benefit to the performance of working memory, planning, and shift/cognitive flexibility, when compared with the non-meditator group. Our results indicated that long-term VM practice not only reduces anxiety and improves mindfulness, but the benefit also extends to improve the performance of the executive function in adult practitioners.

Conclusion: In conclusion, our results suggest that continued practice of VM is highly effective for enhancing EF in healthy individuals. Long-term VM practice not only reduce stress and improve mindfulness but also enhance the performance of EF tasks of the practitioners.

Keywords: Vipassana meditation; executive function; Philadelphia Mindfulness Scale; Wisconsin Card Sorting Test; Digit Span; Tower of Hanoi (Siriraj Med J 2020; 72: 352-360)

INTRODUCTION

Meditation is the method of body and mind training for promoting relaxation, improving focus attention, and concentration.[1,2] Previous studies demonstrate various benefits of meditation practice on body and mind, such as; reduced anxiety and stress,[3-5] improve emotional stability,[6] improve concentration and enhance personal well-being,[7] and produce long-term increases

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http://dx.doi.org/10.33192/Smj.2020.47

in efficiency of the attentional network.[8] Moreover, the clinical effectiveness of meditation has been reported for the treatment of various physical and mental illnesses.[9-11]

Buddhist meditation can be classified into two main methods according to the mental skills that exercise during meditation practice as follows; 1) Focused Attention (FA) in which the practitioner requires to attend or focus onto the selected object, such as breathing or candlelight, and to avoid mind wandering for a period of practice,[12,13] and 2) Open Monitoring (OM)in which the practitioner requires to maintain awareness of their mental, interoceptive, and exteroceptive experiences, and without any object to focusing on.[14-16] These two types of meditation have been reported to affect brain function differently. For example, FA improves sustained attention associated with increased activity in the dorsolateral PFC (DLPFC).[17] In contrast, OM improves sustaining internalized attention associated with increased activity in the posterior insular cortex.[18] The previous study reported that one of the OM-like meditation called Mindfulness-based stress reduction (MBSR), not only has a significant benefit on emotional well-being but also improved cognitive inhibition in the school-aged students as examined by various cognitive tasks.[19] Importantly, a study in the healthy individuals shows that MBSR increased brain activity in the insular cortex (the brain area involved with self-awareness and interoceptive awareness) but no significant effect on the DLPFC activity.[20] In contrast, FA that focuses on the concentration training alone might have less benefit on cognitive abilities since the previous study reported that FA meditators perform various cognitive tasks as equal to the non-meditator group.[19]

Another type of Buddhist meditation that combines both FA and OM together is the so-called Vipassana meditation or VM. VM is the meditation practice that focuses on the monitoring of clear awareness of oneself exactly what is happening as it happens.[15,16] Usually, the VM starts by focusing attention (FA) on to the selected object (such as the breath) and then broadens the focus to the sensory or mental stimuli (OM). Therefore, VM practice uses both FA and OM in order to stay in the monitoring state to any experiences that may arise without selecting, judging, or avoiding the affective responses to that stimuli. In this way, the VM practice could enhance concentration, bare attention, and cultivate a non-reactive form of sensory awareness.

Executive function (EF) is an umbrella term representing higher cognitive processes that are essential for goal-directed behaviors.[21-24] There are 3 main components of EF which compose of; 1) working memory-the ability to updating and monitoring information; 2) Inhibitory control-the ability to inhibit the pre-potent responses and inhibit at the level of attention or inhibit distraction; and 3) Shift/cognitive flexibility-ability to shifting of mental set and flexible thinking.[23] EF gradually develops from early childhood to adulthood, correlate with the maturation of the neural networks that linking the prefrontal cortex with other brain regions.[25] In healthy adults, EF serves as a predictor of everyday functioning since intact is required for daily functions including; setting goals, planning, and prioritizing the complex tasks, initiating, sustaining attention despite distraction. People with proper EF skills show better in managing their life and work performance in the challenge situations, as compared to the one with poor EF.[21]

Although many studies consistently reported the common benefit of meditation on body and mind,[3,5,26,27] however, differential effects of short-term and long-term VM on the performance of EF tasks have yet to be fully elucidated. Interestingly, a recent study showed that amygdala activity response differently in the short-term or long term meditators in response to the negative emotional stimuli.[28] The present study employed various neuropsychological tests to investigate the effects of short-term and long-term VM on executive function in adult practitioners. We hypothesized that long-term VM practice associated with higher mindfulness scale and lower anxiety level that could enhance the performance of EF as compared to the non-meditator group.

MATERIALS AND METHODS

Participants

Participants are healthy adults, aged between 25-50 years, n=40. Vipassana meditators were recruited from the meditation centers in Bangkok metropolitan areas, whereas the control subjects were recruited from the communities in the same area. A demographic questionnaire was completed before any measurements, which included information about age, sex, general health information, and years of education. Participants were asked for information about their meditation background such as; duration, frequency, and average hours of lifetime VM practice, then, they were divided into three groups; 1) Control group, is the participants who had no prior experience of any meditation practice (n =20; mean age = 40.5±5.8 years), 2) Short-term VM group, is the beginner who had average VM practice around 3.5 years (n=6; mean age 38.0±9.1 years), and 3) Long-term VM group is the meditator who had average VM practice for 10 years (n=14; mean age=37.7±7.3 years). There were no significant differences in the mean ages and average years of education of the participants from all

groups (Table 1). The meditation background of the participant in the short-term and long-term VM group was shown in Table 2. Informed consents were obtained from all participants before any measurements, and the experimental protocol was strictly followed the ethical standards outlined of the Declaration of Helsinki in 1975 and has been approved by the Institutional Review Board (COA.No. 2014/146.2011). All participants had no history of neurological illness.

Measures

The State-Trait Anxiety Inventory (STAI-Adult)

The State-Anxiety scale (S-Anxiety) consists of twenty statements that evaluate how participants feel right now or at this moment.[29] The S-anxiety scale represents the feelings of apprehension, tension, nervousness, and worry of the participant at that time. Whereas the Trait-Anxiety scale (T-Anxiety) consists of twenty statements that assess how participants generally feel. The T-anxiety scale has been used for identifying persons with high levels of anxiety. The total questions are 40 items; each item was weighted score from 1 to 4. The raw scores were converted into the standard scores and the percentile rank. The higher means score indicated more anxiety in that section.

Philadelphia Mindfulness Scale (PHLMS-Thai)

Philadelphia Mindfulness Scale (Thai version) from the Department of Mental Health, Ministry of Public Health, Thailand, was used to assess the mindfulness level of the participants.[30,31] The PHLMS has high reliability, and high validity with Pearson's correlation for the awareness and acceptance scale is 0.88 and 0.89, respectively; and the Cronbach's alpha coefficient of the awareness and acceptance scale are 0.87 and 0.88, respectively.[30] It contains 20 items for measurement of awareness and acceptance level of the participants. The awareness and acceptance subscales were obtained from the sum of scores in all odd or even-numbered items, respectively. The score ranged from 10-50 points in each subscale or 20-100 points in the total score. The higher PHLMS score indicates more mindful than lower PHLMS scores.

TABLE 1. Demographic characteristics of the participants. Data represents means±SD.

Participants background	Non-meditation	Short-term VM	Long-term VM
Age (years)	40.5 ± 5.8	38.0±9.1	37.7±7.3
Gender (M:F)	18:2	4:2	11:3
N	20	6	14
Years of Education	15.6 ± 2.5	15.6±1.9	16.8±1.0

TABLE 2. Meditation background of the participants of the Vipassana meditation (VM) group. Data represents means±SD.

Meditation background	Short-term VM			Long-term VM		
	Average	Max	Min	Average	Max	Min
Years of practice	3.6±1.1	5.0	2.0	10.0±6.6	18.0	5.0
Duration of practice (hours/day)	0.5±0.1	0.5	0.3	1.2±0.6	3.0	0.5
Frequency of practice (days/week)	4.3±2.1	7.0	2.0	6.1±1.5	7.0	4.0
Total hours of practice	366±198	650	89	3,462±2,654	8,736	728

Working Memory Scale (WAIS-IV)

The working memory part of the Wechsler Adult Intelligence Scale (WAIS-IV) was used to evaluating the working memory (WM) capacity of the participants.[32] Two categories of WM tasks were used; the digit span forward and the digit span backward. In the forward session, the researcher read a series of number sequences to the subject, and then subjects had to repeat them immediately in the same order. After finish the forward session, the examiner began the digit span backward session by reading a series of number sequences, and subjects had to repeat the number sequences in the reversed order. There are eight blocks of digit span forward, and seven blocks of digit span backward. Each block contains two sets of questions. In both tasks, the length of the most extended number lists that the subject could recall was recorded. The scaled score by the age- and gender-matched was used to compare between the two groups.

Tower of Hanoi (ToH)

The Tower of Hanoi was used for evaluating a higher level of EF, especially the planning process (http://www.coolmath-games.com/0-tower-of-hanoi). It composes of 3 pieces of the rod with several discs. The discs are different in their size and can be moved among the rods. Subjects are required to move the disc from the start point until they reach the goal position. There were three to five discs that represent levels of task difficulties. The numbers of moves and the total time to complete the task were recorded. Lower numbers of moves and shorter response times indicate the better performance of the ToH task.

Wisconsin Card Sorting Test (WCST-CV4)

The Wisconsin Card Sorting Test®: Computer Version 4 (WCST:CV4) (PAR, Inc.) was used for measurement of various EF domains, including; mental shifting, planning, and working memory.[33] For the task, the stimulus cards were presented on the monitor, and the participants were asked to match the stimulus cards with one of the four category cards by trial and error. Subjects were given by the feedback on the screen ("right" or "wrong") immediately after each sorted. The following data were used for analysis: (1) trials administered, (2) total correct, (3) total errors, (4) perseverative responses, (5) perseverative errors, (6) non-perseverative errors, (7) % conceptual level responses, (8) number of Categories Completed, (9) trials to complete the 1st Category, and (10) failure to maintain set.

Data and statistical analysis

Data were analyzed using the SPSS software version 18.0, and the values were reported as mean ± SD. Group differences in the demographic variables were examined with non-parametric chi-square or independent samples t-tests. The normality of standardized residuals for the dependent variables was tested using the Kolmogorov-Smirnov (K-S) test. The data form all groups were found to be normally distributed with all variables demonstrating skewness and kurtosis within standard limits. To investigate the difference among the short-term-, long-term meditators and the control group, the statistical analysis for the mean scores of the state-trait anxiety inventory (STAI), tower of Hanoi (ToH), and the Philadelphia mindfulness scale (PHLMS); scale scores of the WAIS working memory index, and the standard scores of the Wisconsin card sorting test (WCST), were performed using the one-way analysis of variance (ANOVA) and following up a significant result with Tukey's multiple comparisons test. Pearson's correlation examined the correlation between the acceptance scale of PHLMS and the time to complete the 3-discs ToH task. The statistical significance was set at a p-value of less than 0.05.

RESULTS

State-Trait Anxiety Inventory (STAI)

The mean scores of S-Anxiety and T-Anxiety were compared between the three groups. Short-term VM had a significant lower in the mean score of the S-Anxiety as compared to the control group ($p<.05$) (Table 3). Long-term VM had a significant lower in the mean score of both the S- and T-Anxiety as compared to the control group ($p<.05$). Regarding the experience of VM practice, our results indicated that both short-term and long-term VM generally lead to a decrease in stress and anxiety as compared to the non-meditator control group.

Philadelphia Mindfulness Scale (PHLMS)

The mean score of the PHLMS awareness and acceptance subscale were compared between the three groups. Both short-term and long-term VM had a significantly higher mean score of the total mindfulness score of the PHLMS ($p<.01$ and $p<.001$, respectively). For the mean scores of each subscale, short-term VM had a significantly higher in the mean score of the awareness subscale ($p<.001$) as compared to the control group. While long-term VM had a significantly higher in the mean score of both awareness ($p<.001$) and acceptance subscale ($p<.01$), as compared to the control group (Table 3). Results indicate that both short-term and

long-term VM practices had a similar benefit on the mindfulness scale as compared to the non-meditator control group.

Digit Span

Raw scores of the total digit span (digit forward plus digit backward) were converted into the standard score. The standard scores were then compared between the three groups. The result demonstrated that only the long-term VM group had a significantly higher mean standard score of the total digit span as compared to the control group ($p<.001$) (Table 4). Although the short-term VM group show a small increase in the mean, standard score of the total digit span, however, the discrepancy was not significant when compared with the non-meditator control group. Results indicated that long-term VM had a significantly better performance on working memory tasks as compared to the non-meditator group.

Tower of Hanoi

For the ToH 3-Discs level, only long-term VM group significantly use less number of moves as compared to the control group ($p<.05$). For the times to complete the task, both short-term and long-term VM groups significantly perform faster when compared with the control group ($p<.05$ and $p<.01$, respectively) (Table 5). Results indicated that long-term and short-term VM had a significantly better performance on the plan/organize domain of EF than the non-meditator control group.

Wisconsin Card Sorting Test – Computer Version 4 (WCST-CV4)

Although there is no significant difference between the three groups in the Total correct of WCST test, long-term VM had a significantly higher standard score, which means better performance in overall WCST performance, as compared to the control (Table 6). For examples, long-term VM had a significant lower in total error ($p<.001$), perseverative responses ($p<.05$), perseverative errors ($p<.01$), and non-perseverative errors ($p<.001$), and a significant higher in % conceptual level response ($p<.001$), as compared to the control. Long-term VM also had a significant lower in the number of trials administered ($p<.001$), number of trials to completed the 1st Category ($p<.05$), and a significantly higher in number of categories completed ($p<.05$), as compared to the control. For the short-term VM, although they show a trend of better in the overall performance of WCST, however, most of the discrepancy was not significant when compared with the non-meditator or the long-term VM group. Short-term VM had a significantly lower only in the non-perseverative errors ($p<.05$), and a significantly higher in % conceptual level response ($p<.05$), as compared with the control. Our results indicated that long-term VM practice had a better performance on WCST that focuses on the set-shifting domain of EF, especially cognitive flexibility, as compared to the non-meditator group.

Correlation between PHLMS acceptance scale and the time to complete ToH task

Pearson's correlation analysis found the negative correlation between the acceptance scale of the PHLMS and the time to complete the ToH task (3-Discs) within the subjects of the VM group (both short-term and long-term) with $r = -0.52$, $p<0.05$ (Fig 1). The results indicated that the meditator who has a higher PHLMS acceptance score tends to use less time to complete the 3-Discs of ToH task (better performance) than the meditator who has a lower PHLMS acceptance score.

TABLE 3. Table compares the mean standard scores of the STAI and the PHLMS scale scores between the control, short-term, and long-term VM groups. Data represents means±SD.

Tasks	Control	Short-term VM	Long-term VM
State-trait anxiety inventory (STAI)			
State-anxiety	50.1 ± 6.3	43.0±6.5*	44.8±4.5*
Trait-anxiety	54.9 ± 7.6	50.8±8.5	47.2±7.9*
Philadelphia mindfulness scale (PHLMS)			
Awareness	33.8 ± 3.0	40.1±4.1**	42.2±4.4***
Acceptance	29.0 ± 6.2	34.0±5.1	37.2±7.9**
Total scores	62.9 ± 6.1	75.1±7.5**	77.4±9.7***

*$p<.05$, **$p<.01$ and ***$p<.001$, as compared to the control group.

TABLE 4. Table compares the mean standard scores of the digit span total between the control, short-term, and long-term VM groups. Data represents means±SD.

Working memory task	Control	Short-term VM	Long-term VM
Digit span total	9.5±1.9	12.2±1.7	15±3.7***

***p<.001, as compared to the control group.

TABLE 5. Table compares the performance of Tower of Hanoi (ToH) between the control, short-term, and long-term Vipassana group. Data represents means±SD.

Tower of Hanoi (3 discs)	Control group	Short-term VM	Long-term VM
Number of moves	10.0±4.4	7.0±0.0	7.0±0.0*
Moving time (sec)	41.8±29.9	16.6±6.9*	15.0±4.0**

*p<.05 and **p<.01, as compared to the control group.

TABLE 6. The performance of WCST-CV4 compared between the control group, short-term and long-term VM group. Data represents means±SD.

WCST-CV4	Control group	Short-term VM	Long-term VM
WCST-CV4 Standard scores			
Total Errors	82.5±16.5	96.2±11.1	99.6±4.9***
Perseverative Responses	86.3±23.8	95.0±10.9	97.1±4.9*
Perseverative Errors	85.8±23.3	94.0±11.2	97.1±4.7**
Non-perseverative Errors	85.2±23.0	97.2±11.2*	99.8±5.7***
% Conceptual Level Responses	82.5±16.1	97.3±12.8*	100.0±6.0***
WCST-CV4 Raw scores			
Trials Administered	108.1±21.7	92.3±22.7	77.4±7.5***
Trials to Complete 1st Category	30.4±30.3	13.3±5.2	11.6±2.1*
Total Correct	70.1±12.9	73.8±12.3	76.2±4.8
Categories Completed	4.5±2.2	6.0±0.0	6.0±0.0*
Failure to Maintain Set	0.8±1.6	1.0±1.5	0.3±0.4

*p<.05, **p<.01 and ***p<.001, as compared to the control group.

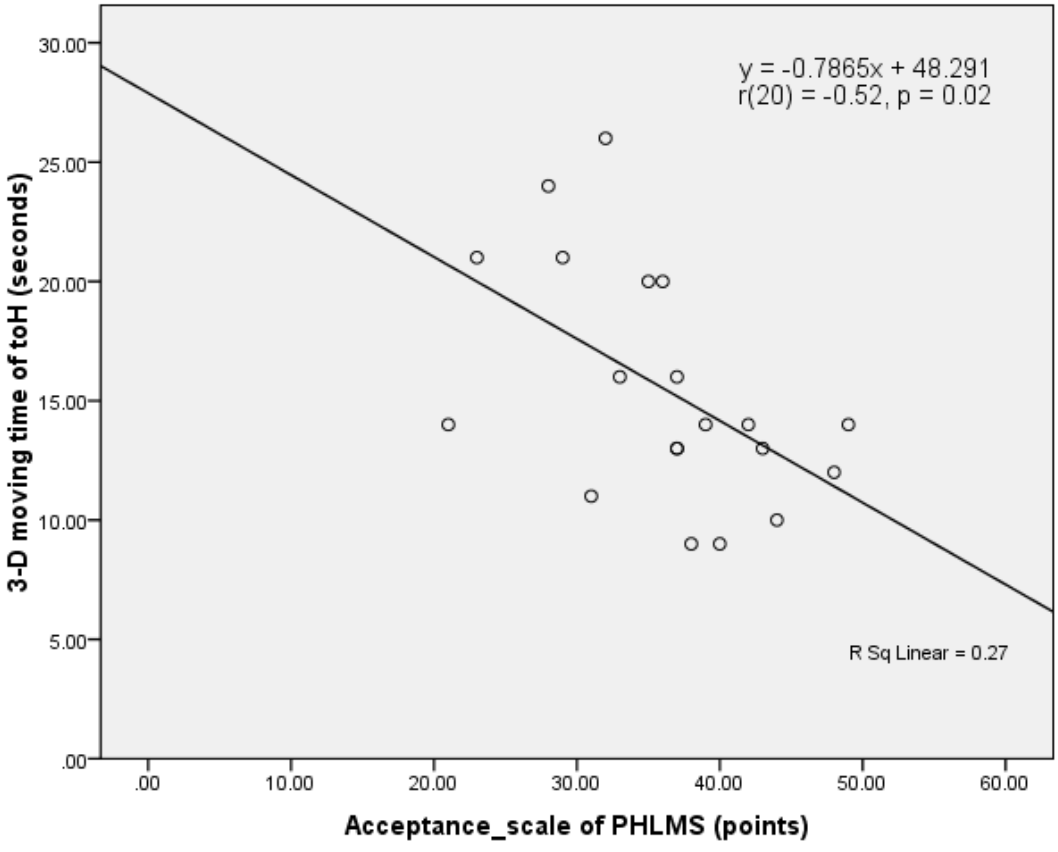

Fig 1. Scatter plot between acceptance scale of Philadelphia mindfulness scale (PHLMS) and 3-D time of tower of Hanoi (toH).

DISCUSSION

This study examined the long-term effects of Vipassana meditation on executive function in adult practitioners. The main findings are; 1) Both short-term and long-term VM groups had a significantly higher PHLMS mindfulness score and a significantly lower state- anxiety score as compared to the non-meditator group. 2) Although short-term VM shows a trend of improving performance on various EF tasks; however, the discrepancy was not significant when compared with the non-meditator group. 3) Only long-term VM shows significantly better performance on various EF tasks that require working memory, shift/ cognitive flexibility and planning, as compared to the non-meditator group. Furthermore, 4) The PHLMS acceptance scale significantly correlates with the performance on the EF task (ToH-3 discs).

Traditional Vipassana meditation combines both FA and OM together. VM usually begins with focus attention (FA) and followed by an open monitoring (OM) session. After practicing of VM for many years, the meditator could gradually cultivate both the narrow or focus attention (during FA) and the broader attention skill (during OM).[16] The previous study found that VM practice could enhance attention and reduce the distracting thoughts and behaviors, indicated that systematic attention training through VM practice has a benefit on the brain plasticity underlying a better cognitive inhibition or focus attention.[27,34] In opposite ways, the neural circuit for cognitive inhibition is required when the meditators monitoring own emotions or inhibit inappropriate behaviors. Importantly, cognitive inhibition is a fundamental requirement for executive function and self-regulation.[19,35]

In this study, we found that both short- and long-term VM group had significantly better performance on planning, as examined by the Tower of Hanoi (ToH) task, than the non-meditator group. Besides, the performance on ToH correlates with the PHLMS acceptance scale. The previous study revealed that during the ToH task, there is an increased activity in the dorsolateral PFC (DLPFC)[36] which is the brain area associated with planning and prediction of the sequence of actions, as well as sustaining focus and monitoring of attention.[37,38] Therefore, the VM practice could enhance the planning domain of EF via increased activity in the DLPFC, especially during the FA session.

Although short-term VM shows a trend of better in the overall performance of WCST, however, most of the discrepancy was not significant when compared with the non-meditator or the long-term VM group. In contrast, long term VM practice significantly improves performance in various executive function tasks. It is possible that during each VM practice, it requires the inhibitory control aspect of EF, either during FA or OM sessions. The inhibitory control composed of; 1) Response inhibition -which means the behavioral inhibition or self-control and 2) Interference control- or the inhibition of the wandering thought at the level of attention (similarly to inhibit distraction).[21] The inhibitory control (includes both response inhibition and interference control) could enhance attentional control, which in turn supports the working memory performance as well. Therefore, the interaction among these factors could explain how long term VM practice could enhance the executive function of the practitioners.

Results from the present study indicated that long term VM practice could improve the overall performance of various EF tasks, which required working memory, plan/organize, and cognitive flexibility. Moreover, the strong correlation between the mindfulness acceptance scale and the performance of EF tasks indicate the benefit of VM on the mindfulness acceptance that might support a better performance of EF tasks as well.

In conclusion, our results suggest that continued practice of VM is highly effective for enhancing EF in healthy individuals. Long-term VM practice not only reduce stress and improve mindfulness but also enhance the performance of EF tasks of the practitioners. Our results suggest that the benefit of VM practice on the performance of EF might need several hours of lifetime practice, therefore, the application of meditation to improve EF in patients with physical and mental problems, should consider both the types of meditation and the duration of practice. Long-term VM practice extends the benefit beyond stress reduction to improve higher cognitive executive function.

ACKNOWLEDGMENTS

The authors thank the Thailand Research Fund for financial support for this project. Also, we would like to thank Mr. Supakij Patthanapitoon to help us collect the data. Finally, we would like to give a sincere thanks to all participants who agree to participate in this study.

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