Selected factors related to behavior control by executive function in Thai preschool children with epilepsy

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Abstract

Purpose – This descriptive correlational study describes behavior control by executive function (EF) and explores the relationship among age at seizure onset, duration of epilepsy, seizure frequency, number of antiepileptic drugs (AEDs), family income, the caregiver's education, home environment and behavior control by EF in preschool children with epilepsy.

Design/methodology/approach – The purposive sample was 69 caregivers of preschool children with epilepsy. Data were collected in two medical centers in Bangkok from June 2019 to February 2020. The research instruments constituted: (1) a sociodemographic and medical information form for children with epilepsy and the caregiver; (2) early childhood-home observation for the measurement of the environment (EC-HOME) inventory and (3) the behavior rating inventory of executive function-preschool version® (BRIEF-P). The data were analyzed using Pearson's product-moment correlation and Spearman's Rho correlation.

Findings – Most of the participants had quite high scores on home environment (mean = 44.35) and mildly elevated levels of EF deficit (mean = 61.04). The duration of epilepsy and the number of AEDs were positively correlated with behavior control by EF. Family income was negatively associated with behavior control by EF. However, age at seizure onset, seizure frequency, the caregiver's education and home environment had no association with behavior control by EF.

Originality/value – Preschool children with epilepsy have poor behavioral control by EF. Consequently, healthcare providers should promote interventions in children to control seizures and to decrease the factors that impact the development of EF.

Keywords Behavior control by executive function, Executive function, Preschool children with epilepsy

Paper type Research paper

Introduction

Epilepsy is a common chronic neurological disorder in children and impacts children's lives physically, socially, emotionally and behaviorally [1]. One of the significant problems

resulting in an abnormal neural network that could cause seizures is executive dysfunction. Executive function (EF) is an umbrella term that "encompasses the set of higher-order processes that govern goal-directed action and adaptive responses to novel, complex, or ambiguous situations" [2]. The processes of EF are to control ideas, organize tasks, problem-solving, respond to emotions, conduct behavior and social interactions. The children that have effective EF are seen to have a lifelong achievement, good health, good school success and good quality of life [3]. EF deficit however can cause children to have difficulties in initiating and organizing daily living activities. These children also tend to have poor self-care, which affects their low health-related quality of life [1].

Children with epilepsy have poorer EF than healthy children [4]. According to the nature of epilepsy, the disease affects brain development by exposing abnormal neural activity and showing epileptogenic lesions. On the other hand, the immature brain is more inclined to develop seizures, which trigger epileptic seizures more than the adult brain [5]. The prefrontal cortex plays a significant role in EF development because of its rich interconnections with other cerebral regions and its central role in efficient EF. The components of EF are slightly different depending upon dimensions and theories. This study investigated the EF components from the model of Diamond and Gioia *et al.* [3, 6]. This model suggested five core dimensions of EF: working memory (WM), inhibitory control, cognitive flexibility or shift, emotional control (EC) and plan/organize (PO). First, "inhibitory control" or "inhibition" is the skill of screening our thoughts so that we can resist temptations, distractions and pause and think before acting. Second, cognitive flexibility or shifting, is changing perspectives or flexibly adjusting to new demands such as switching tasks. Third, EC is the ability to manage emotions in order to complete tasks or to control one's behavior. Fourth, WM is the capability to hold and manipulate information in our brains over short periods. Fifth, PO is the capacity to create a roadmap to achieve a goal involving making decisions and creating priorities [3, 6].

According to a literature review, many scholars found several factors related to EF in children with epilepsy, such as age at seizure onset, the duration of epilepsy and seizure frequency. However, most research has examined the relationships among the variables and EF in school-age children and adolescents, along with some findings that are still considered controversial [7]. For example, the home environment may relate to the EF level in children because the children that have a good home environment tend to have a suitable environment for the child's development. Furthermore, much of the research has provided information on the EF level on healthy children [8, 9], while the EF level on children with epilepsy in Thailand was not raised as an issue of concern. The window period of opportunity for dramatic growth in EF is two to six years or preschool age [8]. If preschool children with epilepsy can receive suitable care and eliminate the precipitating factors for seizure, they will develop efficient EF and have a good quality of life from childhood to adulthood. The aims of this study however were to explore behavior control by EF and to examine the correlations among age at seizure onset, duration of epilepsy, seizure frequency, number of AEDs, family income, the caregiver's education, the home environment and behavior control by EF in preschool children with epilepsy.

Methods
Participants
The 69 participants in this study were caregivers of preschool children with epilepsy. The data were collected from tertiary hospitals in Bangkok: Ramathibodi Hospital and Phramongkutklao Hospital. The sample size was determined using the G*power program and using an acceptable statistical significance level at $\alpha = 0.05$ with a power set at 80%. The effect size was calculated from a prior study on EFs in children with epilepsy and was 0.29 [7]. The sample size calculation for this study was 69 subjects, 49 participants at Ramathibodi

Hospital and 20 participants at Phramongkutklao Hospital based on the statistics of the number of patients at both hospitals from 2015 to 2017. The participants eligible according to the inclusion criteria and purposive sampling were recruited for this study. The inclusion criteria for the caregivers were (1) being under 60 years of age; (2) being the primary caregivers of children with epilepsy; (3) taking care of a child with epilepsy for at least six months and (4) being able to speak and read the Thai language. The inclusion criteria of children with epilepsy were being aged 3 to 6 years and diagnosed with epilepsy by a pediatric neurologist at least three months before the day of the study. The children were excluded if they were diagnosed with (1) frontal lobe epilepsy or intractable epilepsy; (2) other chronic illnesses such as intellectual disability, Down's syndrome, hearing loss, color blindness; (3) other progressive illnesses that affected the brain structure such as traumatic brain injury and (4) had an emergency condition while collecting the data such as a seizure attack, hypoxia or shock.

Research instruments

(1) Sociodemographic and a medical information form for children with epilepsy and the caregiver

This form recorded the health information in children with epilepsy, such as the child's age, gender, age at seizure onset, duration of epilepsy, types of seizure, number of current AEDs, number of prior AEDs taken and seizure frequency. The sociodemographic and medical information form for the caregiver was composed of the caregiver's age, marital status, gender, relationship with the patient, duration of taking care of the child, family income, education and occupation, and sources of information about epilepsy.

(2) Early childhood-home observation for the measurement of the environment (EC-HOME) inventory

The EC-HOME was used to measure the quality and quantity of the home environment to support a child. Fifty-five EC-HOME items were categorized into eight subscales and scored with a binary choice (yes/no). The EC-HOME was translated into the Thai version using the back-translation process, and the content validity of this instrument was .845, which was examined by five experts. The instrument reliability was .75, which was tested with 10 caregivers and analyzed using Kuder–Richardson 20 (KR-20).

(3) Behavior rating inventory of executive function-preschool version® (BRIEF-P)

Sixty-three items of the BRIEF-P were developed to assess everyday EF in children aged two to five years and 11 months. The BRIEF-P comprises five subscales, which are inhibition, shift, EC, WM and PO. The subscales were then summarized into three broad indexes: inhibitory self-control (ISC), flexibility (FI) and emergent metacognition (EMI). For each clinical scale, raw scores can be converted to T-scores. The GEC is the sum score from inhibition, shift, EC, WM and PO. The 3-point rating is constituted by Never (1), Sometimes (2) or Often (3), which were responded to by the child's behavior related to EF deficit. A T-score greater than 60 explains that the child tends to have a clinically elevated level of EF deficit. The internal correlation of the BRIEF-P-Thai was high with Cronbach's alphas ($r = 0.92$) tested in this study.

Ethical considerations
The committee on human rights at Ramathibodi Hospital (COA.NO. MURA 2019/463) and Phramongkutklao Hospital (IRBRTA 888/2562) approved this study.

Data collection
The data were collected from June 2019 to February 2020. The children and caregivers eligible according to the inclusion criteria were waiting to see the physician in the outpatient clinic or inpatient department. The researcher and research assistant approached the participant, introduced the name, explained the study's objective, the essential data related to the research and asked about their willingness to join the research. When the participants accepted and signed the consent form, the researcher gave them a questionnaire copy. The participants spent approximately 15–20 min filling out the questionnaire.

Data analysis
Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 21. The normality test of the data was examined by skewness and kurtosis. As a result, age at seizure onset, duration of epilepsy, number of AEDs, the caregiver's education, the home environment and behavior control by EF had a normal distribution. Seizure frequency and family income had a non-normal distribution. The sociodemographic and medical characteristics of the preschool children with epilepsy and caregivers were analyzed using descriptive statistics, such as mean, standard deviation and frequency. The relationships among behavior control by EF, seizure frequency, family income and the caregiver's education were analyzed with Spearman's Rho correlation. The relationships among age at seizure onset, duration of epilepsy, number of AEDs, home environment and behavior control by EF were analyzed using Pearson's product-moment correlation.

Results
Table 1 shows the sociodemographic and medical information of children with epilepsy. The majority of the children with epilepsy were male (58%) and were 55.93 months old on average. Most of the children had an age of seizure onset of less than one year, at 52.2%, and had had epilepsy for more than 24 months to 36 months (30.4%). The largest group of children had a generalized tonic-clonic seizure (91.3) and they were seizure-free over the past year (69.6%). Moreover, most of the children were taking one antiepileptic drug at present (75.4%).

The majority of the caregivers were female (84.1%) and mothers (73.9%). They ranged in age from 30 to 40 years (mean = 37.72, SD = 7.01), and most of them were middle adults. Most (49.3%) of the participants graduated with a bachelor's degree and had a family income ranging widely from 2,000 to 300,000 baht (mean = 51,000, SD = 47102.51). Most of the caregivers had taken care of their children with epilepsy for more than three years (63%). See additional details of the caregivers' characteristics in Table 2.

Table 3 presents the home environment score of the preschool children with epilepsy. The average score of the caregivers' overall home environment was 44.35 (SD = 6.17; range 25–54). The top-three mean scores of the subscales for the home environment were for academic stimulation (mean = 4.68, SD = 0.79), language stimulation (mean = 6.39, SD = 0.91) and physical environment (mean = 6.33, SD = 1.02).

Table 4 demonstrates the behavior control by EF of preschool children with epilepsy. The mean score for the GEC was 61.04 (SD = 15.02; range 32–104). The top-three mean scores for the subscales for behavior control by EF in preschool children with epilepsy were for M, inhibit and PO.

Tables 5 and 6 show the relationships among the variables and behavior control by EF in preschool children with epilepsy. The duration of epilepsy and the number of AEDs had a low positive correlation with behavior control by EF ($r = 0.245$, and 0.262, respectively, $p < 0.05$). Family income had a low negative correlation with behavior control by EF ($r_s = -0.282$, $p < 0.05$). When examining the association between the selected factors and the subscale of

Variables	N	Frequency (%)
Sex		
Female	29	42
Male	40	58
Age (months)		
36–48	18	26.1
>48–60	22	31.9
>60–72	29	42
(Mean = 55.93, SD = 11.36, min = 36, max = 72)		
Age at seizure onset (months)		
≤12	36	52.2
>12–24	15	21.7
>24–36	9	13
>36–48	4	5.8
>48–60	3	4.3
>60–72	2	2.9
(Mean = 19.46, SD = 16.19, min = 0, max = 62)		
Duration of epilepsy (months)		
≤12	10	14.5
>12–24	10	14.5
>24–36	21	30.4
>36–48	16	23.2
>48–60	6	8.7
>60–72	6	8.7
(Mean = 34.13, SD = 16.55, min = 5, max = 67)		
Seizure frequency in last year (times per year)		
0	48	69.6
1–10	19	27.5
11–50	2	2.9
Number of current antiepileptic drugs		
None	8	11.6
1	48	69.6
2	10	14.5
3	3	4.3

Table 1.
Children's
characteristics and
medical
information ($n = 69$)

EF, the results revealed that inhibition had a significantly low positive correlation with the duration of epilepsy and the number of AEDs ($p < 0.05$). The shifting was significantly associated with the duration of epilepsy ($p < 0.05$). Furthermore, WM had a low correlation with the duration of epilepsy, the number of AEDs and the home environment ($p < 0.05$). Family income had a low negative correlation with inhibition ($p < 0.01$) and a low negative relationship with WM ($p < 0.05$). However, age at seizure onset, seizure frequency and the caregiver's education was seen to have no significant correlation with EF.

Discussion

Most children with epilepsy have difficulty managing their daily activities and school success, caused by their disease and several related factors. This study found that preschool children with epilepsy tended to have an EF deficit. The subscales that had a high deficit score in children were WM and the EMI. This research finding is consistent with an EF survey of Thai preschool children between two to six years of age, which found that healthy children demonstrated delayed development in behavior related to executive dysfunction [8, 9].

Variables	N	Frequency (%)
Sex		
Female	58	84.1
Male	11	15.9
Age (years)		
>20–30 years	11	15.9
>30–40 years	36	52.2
>40–50 years	19	27.5
>50–60 years	3	4.3
(Mean = 37.72, SD = 7.01, min = 20, max = 56)		
Relationship with epileptic children		
Father	11	15.9
Mother	51	73.9
Relative	7	10.1
Educational level		
Elementary school	5	7.2
High school	13	18.8
College diploma	6	8.7
Bachelor's degree	34	49.3
Higher than a bachelor's degree	11	15.9
Other	2	2.9
Family income (baht/month)		
≤10,000	7	10.1
10,001–50,000	45	65.2
>50,000	17	24.6
(Mean = 51,000, SD = 47102.51, min = 2,000, max = 300,000, median = 45,000, mode = 50,000)		
Duration of taking care of their children (years)		
<1	6	8.7
1–3	21	30.4
3–6	42	60.9

Table 2.
Caregivers'
sociodemographic
characteristics ($n = 69$)

Home environment	Mean	SD	Range Possible range	Actual range
Total score	44.35	6.17	0 – 55	25 – 54
Subscale				
Learning materials	7.62	2.08	0 – 11	2 – 11
Language stimulation	6.39	0.91	0 – 7	2 – 7
Physical environment	6.33	1.02	0 – 7	2 – 7
Responsivity	5.55	1.56	0 – 7	2 – 7
Academic stimulation	4.68	0.79	0 – 5	0 – 5
Modeling	3.60	1.25	0 – 5	0 – 5
Variety	7.23	1.79	0 – 9	0 – 9
Acceptance	2.92	1.21	0 – 4	0 – 4

Table 3.
Mean, standard
deviation and range for
the home environment
of preschool children
with epilepsy and its
subscales ($n = 69$)

However, children with epilepsy are more likely to have a behavior problem regarding EF than healthy children [4]. This point may affect their neuron circuit and EF brain function because of epileptogenic lesions. The poorer EF in Thai preschool children with epilepsy in this study was

harmonized with EF impairment in children with epilepsy in many countries worldwide. For this reason, the caregiver and healthcare provider need to find the cause and support the resources for improving EF in children with epilepsy productively.

The preschool children with epilepsy had quite a good home environment. When comparing the home environment score with that of other countries, the present research's environment scores were lower than those found in a Korean study for almost all EC-HOME subscales [10]. Moreover, the home environment scores analyzed in a Brazilian study were lower than those in this study in almost all EC-HOME aspects [11]. This point shows that the difference in context, culture and parenting in each country affects the home environment scores and child development. There is little evidence to present the differences in the home environment between western and eastern countries. However, a few studies explored the parental resources in eastern countries, such as Japan and Korea. The result showed that the regional difference in rural and urban areas was reflected in the parents' resources and opportunities for accessing learning resources, as well as modifying the home environment to increase the child's development efficiently.

The present study demonstrated the correlations between the selected factors and behavioral control by EF. Some of the findings, however, did not match the prior literature. Concerning age at seizure onset, it was not associated with behavior control by EF in preschool children with epilepsy. This study's findings were consistent with previous papers on children with epilepsy who ranged from 7 to 16 years [7]. On the other hand, a study in the Netherlands found that EF problems decreased when the children became older [12]. This point could explain that early age at seizure onset contributes to greater executive dysfunction. Typically, the child's brain can improve some brain function better at later ages, such as cognitive function. EF develops continuously from children until young adult [8]. Hence, age at seizure onset was not associated with behavior control by EF in the present study.

Further, the duration of epilepsy was positively related to behavior control by EF in preschool children with epilepsy. This finding showed that preschool children with epilepsy with a long duration of epilepsy were more likely to have worse EF. This result harmonizes with previous studies that indicated that children with longer durations of epilepsy have worse cognitive development [7]. Longer epilepsy duration naturally affects brain damage from the epileptic activity and high seizure frequency [13]. In the case of this study, the children with epilepsy had average GEC scores with mild executive dysfunction. Thus, the children with a long duration of epilepsy tend to have greater EF deficit.

In the present study, there was no correlation between seizure frequency and behavior control by EF. This result is congruent with previous research [7]. On the other hand, a previous study found that higher frequencies of seizures were related to cognitive function and three dimensions of EF: inhibition, shifting and EC [14]. That is to say, children with a greater number of seizure frequencies may have a worse cognitive function. However, most of

	Mean	SD	Clinical range ($T \geq 65$)
BRIEF-P (T scores)			
Inhibit	59.97	11.74	37 – 90
Shift	53.26	10.30	38 – 86
Emotional control (EC)	54.26	13.97	30 – 96
Working memory (WM)	65.15	16.56	36 – 104
Plan/organize (PO)	57.86	13.76	32 – 94
Global executive composite (GEC; inhibit + shift + EC + WM + PO)	61.04	15.02	32 – 104

Table 4.
Mean, standard deviation and range for behavior control by EF in preschool children with epilepsy ($n = 69$)

	1	2	3	4	5	6	7	8	9	10
Age at onset	1									
Duration of epilepsy	-0.732**	1								
Number of AEDs	-0.037	0.049	1							
Home environment	0.044	0.050	-0.324**	1						
Global executive composite (GEC)	-0.057	0.245*	0.262*	-0.210	1					
Inhibit	-0.134	0.258*	0.269*	-0.147	0.926**	1				
Shift	-0.080	0.282*	0.164	-0.166	0.776**	0.620**	1			
Emotional control (EC)	0.102	0.078	0.233	-0.139	0.810**	0.684**	0.651**	1		
Working memory (WM)	-0.106	0.237*	0.264*	-0.240*	0.927**	0.856**	0.637**	0.619**	1	
Plan/organize (PO)	-0.021	0.215	0.186	-0.205	0.918*	0.830**	0.663	0.694**	0.847**	1

Note(s): *$p < 0.05$, **$p < 0.01$, r = Pearson's product moment correlation

Table 5.
The relationships
among age at seizure
onset, duration of
epilepsy, number of
AEDs, home
environment and
subscales of behavior
control by EF in
preschool children with
epilepsy ($n = 69$)

the children in the present study were seizure-free during the previous year, and some children had a high score on EF deficit. This finding demonstrates that children with no seizures might have an opportunity to detect the deficit of EF as well.

Furthermore, the number of AEDs was related to behavior control by EF and had a low positive correlation with inhibition and WM. This finding yielded support to previous studies – that an increasing number of AEDs caused the acceleration of the risk of EF deficit [7]. Some studies did not support this finding; that is, there was no association between the number of AEDs and behavior control by EF [15]. Not only does the number of AEDs have to be of concern but the types of AEDs should also be considered. Some AEDs were not affected by cognitive function or EF; others directly impacted EF. For example, phenytoin induces attention deficit, declines visuomotor function and slows mental speed [16].

Additionally, family income in the present study was associated with behavior control by EF. Considering the subscales of EF, the family income had a low negative correlation with inhibition and WM. This finding supports the results of previous studies – that family income was related to and predicts the worse performance of EF [17]. Children of families that have a high income or socioeconomic status have a chance to access healthcare services. On the other hand, some prior studies found that socioeconomic status did not correlate with cognitive function or EF [18]. As a result of equal standard education and social welfare in Thailand, every child has a chance to study in school based on the child's right to education. The family is part of the children's lives in terms of supporting and encouraging a good environment for learning new things. The family income is also an important factor regarding access to healthcare services and learning resources for the child's development. Thus, family income was seen to be related to behavior control by EF.

The caregiver's education in the present study was not associated with behavior control by EF in preschool children with epilepsy. The previous literature was against this finding; that is, parental education was significantly related to EF and the brain's surface area [19]. Nonetheless, the results were harmonized with Thai healthy preschool children in that the parents' education level was not related to EF level [9]. The children were able to access the standard curriculum from the government, and the children were able to receive information and reach learning resources similarly. Moreover, most of the participants in this study had a level of education that did not differ in much in its pattern and in terms of the parents' knowledge about raising children.

In this study, the home environment was not related to behavior control by EF in preschool children with epilepsy. However, it was found that the home environment was

	1	2	3	4	5	6	7	8	9
Seizure frequency	1								
Family income	−0.225	1							
Caregiver's education	0.087	0.447[**]	1						
Global executive composite (GEC)	0.185	−0.282[*]	0.046	1					
Inhibit	0.228	−0.312[**]	0.066	0.896[**]	1				
Shift	0.108	−0.092	−0.049	0.675[**]	0.507[**]	1			
Emotional control (EC)	0.142	−0.106	−0.015	0.710[**]	0.613[**]	0.531[**]	1		
Working memory (WM)	0.231	−0.298[*]	0.071	0.922[**]	0.814[**]	0.555[**]	0.527[**]	1	
Plan/organize (PO)	0.022	−0.155	0.102	0.867[**]	0.728[**]	0.586[**]	0.599[**]	0.808[**]	1
Note(s): *$p < 0.05$, **$p < 0.01$, Rho = Spearman's Rho correlation									

Table 6.
The relationships among seizure frequency, family income, the caregiver's education and the subscales of behavior control by EF in preschool children with epilepsy ($n = 69$)

associated with WM. This finding was congruent with a study of Dilworth-Bart [20], where EF was not significantly related to preschoolers' home environment. Further, other studies found that the home environment mediates the relationship between EF and other factors such as socioeconomic status and school performance [17]. This illustrates that the home environment relies on other factors for the correlation with EF. Nevertheless, the home environment was associated with working memory in children. A good home environment will provide children with a safe habitat, sufficient equipment for learning and a warm bond with family members, all of which will assist the child with the improvement of his/her performance in terms of memory.

Conclusion

Most of the children with epilepsy had mild levels of EF deficit. Duration of epilepsy, the number of AEDs and family income had a relationship with behavior control by EF. The healthcare provider should encourage the child to effectively control his or her seizures, and decrease the factors related to executive dysfunction. Healthcare providers have to provide information about methods, techniques or learning resources to the children with epilepsy or the caregiver, such as monitoring applications and daily notebooks for self-record measures of seizure activity. Further, they have to emphasize the importance and advantages of controlling seizures, which will reduce the taking of AEDs and the duration of the epilepsy. Moreover, the nurse should develop interventions to promote EF in children with epilepsy to improve productively. The interventions should relate to EF's five dimensions in order to practice managing tasks and organizing ideas better. Example interventions are board games as well as training activities to contribute to children's use of their memory in their responses, planning to play a game as a teamwork, and practicing waiting for playing in the next round and building emotional management. In addition, further study can explore other factors associated with EF at different ages in a larger sample size than this research and investigate EF using a longitudinal study in order to clarify EF development in children with epilepsy explicitly.

Limitations

This study was conducted in the tertiary care hospitals with epilepsy clinics, which might limit the generalization of the information concerning the caregivers of preschool children with epilepsy at different hospital levels.

Conflicts of Interest: None

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