Research article

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Executive functions and their correlates among pre-schoolers in Ho Chi Minh City, Vietnam: Results from a SUNRISE Pilot Study

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Abstract

Purpose: Executive function in the early years is associated with academic achievement and health determinants in the adulthood. This study aimed to describe the levels and physical-related correlates of executive functions among pre-school-aged children in Ho Chi Minh City, Vietnam.

Methods: A cross-sectional study with convenience sampling was conducted on 135 healthy pre-schoolers in HCMC. Executive functions (working memory, inhibition, and shifting) were assessed using Early Year Toolbox. Physical activity was measured for three consecutive days using Actigraph accelerometers. Gross and fine motor skills were examined with the Ages and Stages Questionnaire 3. Parent questionnaires were administered to obtain demographics, screen time, sleep time, and sitting time. Binary comparisons with Wilcoxon rank-sum testing were applied to examine the differences in executive functions vis-à-vis potential associates.

Results: The response rate was 35.4%. Children scored a median of 2.0 points in working memory (IQR 1.00 - 2.33), 0.5 points in inhibition (IQR 0.2 - 0.6), and 8.0 points in shifting (IQR 6.0 - 10.0). 4-year-olds outperformed 3-year-olds in all three components of executive function. Adiposity was negatively associated with working memory, while adequate gross and fine motor skills were associated with better working memory and inhibition. Compliance with sleep and screen time guidelines was associated with higher inhibition scores, whereas getting enough sleep time was associated with higher shifting scores.

Conclusion: Performance in executive function tasks was adequate among preschoolers in Ho Chi Minh City. Some positive associations between executive function, motor skills, nutritional status and physical activity levels were detected.

Keywords: Executive function; development; physical activity; early years; pre-schooler.

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1. INTRODUCTION

Executive functions (EFs) are cognitive abilities needed to guide and adapt behaviours toward a goal in various situations [1]. In the early years, EFs play a crucial role due to their association with academic achievements, while inadequate EF levels are linked to adverse health outcomes later in adulthood, such as poor health, financial and social problems [2], [3]. The foundational components of EF include working memory, inhibition, and shifting. Working memory allows the child to remember goals and task-directed information; inhibition helps resist distraction and impulses; shifting provides flexibility in shifting attention if the information is no longer goal-relevant [4].

Associations between EFs and physical activities and motor skills in children under five

years have emerged in the past ten years. Recent systematic reviews have shown a favourable association of physical activities but mixed associations of sleep and sedentary behaviour (SB) on EFs [5] - [7]. However, most studies were conducted in high-income countries. A systematic review by Zeng et al. found that no studies were implemented outside high-income countries [7]. Another systematic review by Carson et al. found that only one study was in the Philippines, an upper-middle-income country, while the rest were in high-income countries [5].

Given the lack of data in this area, especially in lower-middle-income countries, we conducted this study to describe the epidemiological profile of EFs among children in Ho Chi Minh City, Vietnam. Specifically, this study aimed to describe levels of working memory, inhibition and attention shifting in pre-schoolers, and examine their association with demographics, nutritional status, and movement behaviour.

2. METHODS

Study design and participants

This cross-sectional study was part of the pilot phase of the International Study of Movement Behaviour in the Early Years (SUNRISE study, https://sunrise-study.com) in Vietnam [8]. We included children aged three to four who were reportedly without any apparent acute or chronic illness.

Participants were selected via convenience sampling. Within the scope of a preliminary study, we determined a minimum sample size of 100 children (50 from urban and 50 from rural areas), so we selected two rural preschools (Binh Chanh and Nha Be District) and two urban preschools (District 1 and Tan Binh). Parents and caregivers were invited to a formal meeting in which we gave detailed information about the study. Those who were interested would hand in the signed consent forms. Recruitment and data collection took place between June and December 2019.

Data collection

Data collectors included the authors and public health students. Prior to data collection, collectors spent one day at a training workshop and another day in a field-testing session.

Data collection took place in a one-week time frame. On the first day of the week (usually Monday), prior to classes, data collectors took anthropometric measurements, assessed motor skills and EFs, fit accelerometers, and handed out questionnaires to parents. To ensure reliability, each participant would be supported by only one data collector throughout the entire process. At the end of the week, data collectors revisited the preschools to retrieve the devices and parent questionnaires. Parents were reminded up to twice a day about filling in the questionnaire and how to monitor accelerometer wearing.

Measurement of height and weight followed WHO standardised procedures [9]. Gross and fine motor skills were assessed using the Ages and Stages Questionnaire 3rd edition for children aged 48 months [10]. Physical activity (PA) and SB were assessed using Actigraph GT3X+ accelerometers. The protocol followed the evidence-guided recommendation described elsewhere [11]. PA levels were defined using the cut-offs from Pate et al. [12], [13] as 0–199 counts per 15s epoch for SB, 200–419 for light PA, 420–841 for moderate PA, and ≥ 842 for vigorous PA.

A self-administered parent questionnaire was used to assess sedentary screen time, sleep time, and demographic characteristics (i.e. age, sex, school location, and caregiver's education). The questionnaire was translated to Vietnamese with minor adaptations. Screen time, sleep duration and sleep schedule (i.e., go-to-bed and wake-up times) were reported in hours and minutes.

Based on accelerometer-based PA data and parent-reported sleep time and screen time, children were categorised according to WHO guidelines [14], which recommend that children 3-4 years of age spend at least 180 minutes of total PA (of which 60 minutes is of moderate- to vigorous intensity), no more than 1 hour of sedentary screen time, no more than 1 hour of restrained sitting, and 10–13 hours of quality

sleep in 24 hours. Children were categorised as either meeting or not meeting individual guidelines.

EFs

EFs were assessed using a set of iPad-based tests named Early Year Toolbox (EYToolbox, http://www.eytoolbox.com.au). In our study, the components of interest were working memory, inhibition and attention shifting, which corresponded to the EYToolbox games Mr Ant, Go-No-Go, and Rabbits & Boats [4]. Each test would take about 5 minutes to complete.

Executive tests comprised a practice phase and a test phase. During the practice phase, data collectors gave instructions and hints if the children was confused. In the test phase, only positive encouragement and instructions from the game audio (translated to Vietnamese) were given. To minimise distraction, children would face the wall when playing games on iPads. EF tasks were interleaved with short breaks or other physical tasks to avoid mental fatigue.

In Mr Ant (working memory), dots appear on the body of a cartoon character (Mr Ant), and disappear shortly after. Participants are asked to recall the dots' position by tapping on the screen. The number of dots corresponds to the level, and the child will pass a level if he/she gets two out of three trials right (i.e., correctly tap all dots in two trials). The total score is the number of levels he/she has passed, plus 1/3 point for correct trials at the last level (the level he/she fails).

In Go-No-Go (inhibition), a child is instructed to "catch the fish" (Go) and "avoid the sharks" (No-Go). The score is Go accuracy multiplied by No-Go accuracy, and ranges from 0 to 1. Responses faster than 300 milliseconds are discarded to eliminate attempts in which participants have responded indiscriminately [4].

In Rabbits and Boats (shifting), children are asked to sort a combination of cards (rabbits and boats, red and blue) according to specific rules that vary among three stages of the game. The pre-switch stage, which is based on the card's colour, has a total of six trials which are not scored. In the second stage, which also has six trials, the rule switches to the shape of the card. Finally, the rule for the six trials in the third stage changes according to whether there is a frame surrounding the card. The total score of a participant is the number of correct trials in stage 2 and 3, which ranges from 0 to 12 [4].

Data management and statistical analysis

Questionnaires, anthropometrics, and motor skills were collected on a paper form, then entered and managed using iPad-based REDcap. Accelerometer data were downloaded and managed with ActiLife 6.1.2.1 software (Lite version). EYToolbox data were collected and managed on iPads. Categorical data were presented as frequency and percentage. Continuous data were presented as mean and standard deviation if normally distributed and as median and interquartile range otherwise. EF data, which was not normally distributed, were presented in various formats for future use as references. EF differences in groups were compared using Wilcoxon rank-sum tests. PA, sleep, screen time, and sitting were categorised as meeting or not meeting WHO guideline. Nutritional status was classified as normal, possible risk of overweight, overweight, or obese by BMI for age Z-scores as per WHO guidelines [15]. Pairwise deletion was employed to handle missing data. Normality was determined by the Shapiro-Wilk test. The level of statistical significance was set at 0.05. Data analysis was done using R (version 4.0.5).

Ethical clearance

The study was conducted upon ethical approval from the University of Wollongong, Australia and Pham Ngoc Thach University of Medicine, Vietnam. Parents were required to provide written informed consent for their child to participate in the study. Children provided verbal assent.

3. RESULTS

Figure 1 reports the response rates of the study. Among 381 consent forms distributed, we received 149 (39.1%) signed consent forms. 135 children (90.6%) completed all assessment steps. Participation rates among received

consents were higher in rural schools (93.8%, 75/80) than in urban schools (87.0%, 60/69).

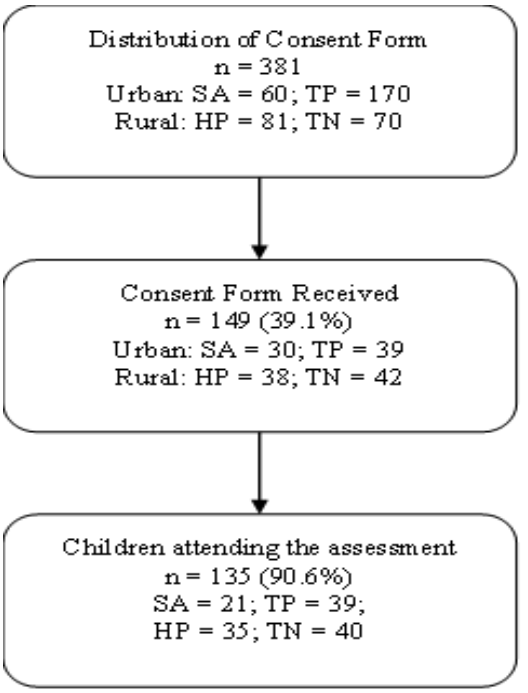

Figure 1. Response rates. SA, TP, HP, TN: Abbreviated names of preschools.

Table 1 presents the characteristics of the children involved in the analysis. The mean age was 4.08 years. Over half of the children were male, while 44.4% of them were from urban preschools. Regarding PA profile, an average child had a 17.7% chance of being overweight or obese, spent around 3 hours daily in PA, 10 hours in sleep, 1.5 hours in sedentary screen time, and one hour in restrained sitting. Fifteen percent of children scored zero points (i.e., not paying attention, or not cooperating) for working memory and 21.3% for inhibition, respectively. For shifting, all children received a score.

Table 1: Descriptive characteristics of participants

Characteristic	Summary estimates[1]
Total	135 (100%)
Age, years	4.08 (0.5)
Sex being boys	74 (54.8%)
School location being urban area	60 (44.4%)
Caregiver's having higher education (n = 125)	95 (76.0%)
BMI categories	
Normal range	82 (61%)
Possible risk of overweight	29 (21%)
Overweight	11 (8.1%)
Obese	13 (9.6%)
Gross Motor Skills being on track	85 (63%)
Fine Motor Skills being on track	84 (62%)
MVPA, minutes (n = 112)	86.7 (26.9)
TPA, minutes (n = 112)	185.8 (42.6)
Sleep time, minutes (n = 124)	623.8 (69.4)
Sedentary screen time, minutes (n = 121)	90 (60, 120)
Sitting time, minutes (n = 116)	52.5 (20.0, 93.8)
Working memory, points (n = 127)	
Mean (SD)	1.7 (1.1)
Median (IQR)	2.0 (1.00, 2.33)
Range	0.0, 4.0
Zero-scorers, %	15
Inhibition, points (n = 127)	
Mean (SD)	0.4 (0.3)
Median (IQR)	0.5 (0.2, 0.6)
Range	0.0, 0.9
Zero-scorers, %	21.3

Characteristic	Summary estimates[1]
Shifting, points (n = 127)	
Mean (SD)	8.0 (2.2)
Median (IQR)	8.0 (6.0, 10.0)
Range	3.0, 12.0
Zero-scorers, %	0.0

Mean (SD), Median (25th,75th), or n (%) unless particularly indicated

Data regarding demographics, nutritional status, motor development and movement behaviour have already been described elsewhere [8]. EF difference among children in the respective groups are shown in Table 2. Children aged 4 did significantly better than those aged 3 in any EF components. On the other hand, no significant difference in EF was observed in terms of sex, school location, or caregiver's education. For working memory, obese children scored significantly lower than the others, while those on track for fine and gross motor scored significantly higher than those who were delayed/at-risk. Regarding inhibition, children whose sleep time and screen time met WHO global guidelines performed significantly better than those who did not. Children with on-track motor skills received higher inhibition scores in comparison with their counterparts.

Table 2: Bivariate comparison by demographics, nutritional status, motor development and movement behaviour

Characteristic		Working memory	Inhibition	Shifting
Age group	Three, N = 51[1]	1.33 (0.33, 2.00)	0.33 (0.22, 0.50)	6 (6.0, 9.0)
	Four, N = 84[1]	2.33 (1.33, 2.33)	0.55 (0.24, 0.72)	9 (6.0, 10.0)
	p-value[2]	**< 0.001**	**0.002**	**0.022**
Sex	Boys, N = 74[1]	2 (1.00, 2.33)	0.46 (0.20, 0.63)	6 (6.00, 9.0)
	Girls, N = 61[1]	2 (1.00, 2.33)	0.5 (0.27, 0.66)	9 (6.0, 10.0)
	p-value[2]	0.566	0.493	0.144
School location	Urban, N = 60[1]	2 (0.67, 2.33)	0.43 (0.22, 0.58)	9 (6.0, 10.0)
	Rural, N = 75[1]	2 (1.00, 2.33)	0.53 (0.22, 0.69)	8 (6.0, 9.0)
	p-value[2]	0.468	0.167	0.512
Caregiver's education	High school or below, N = 30	2.3 (1.3,2.7)	0.50 (0.00,0.70)	7.0 (6.0, 10.0)
	Higher education, N = 95	2.00 (0.9,2.3)	0.50 (0.20,0.70)	9.0 (6.0, 10.0)
	p-value[2]	0.169	0.822	0.680
Nutritional status	Non-obese, N = 122[1]	2.00 (1.00, 2.33)	0.46 (0.21, 0.64)	8.50 (6.0, 10.0)
	Obese, N = 13[1]	1.33 (0.00, 2.00)	0.56 (0.52, 0.77)	6.00 (6.0, 7.5)
	p-value[2]	**0.028**	0.122	0.059

Characteristic		Working memory	Inhibition	Shifting
Gross Motor Skills	Delayed/At risk, N = 50[1]	1.33 (0.33, 2.33)	0.36 (0.22, 0.53)	7.50 (6.0, 10.0)
	On track, N = 85[1]	2.33 (1.17, 2.33)	0.55 (0.22, 0.73)	8.00 (6.0, 9.5)
	p-value[2]	**0.017**	**0.007**	0.733
Fine Motor Skills	Delayed/At risk, N = 51[1]	1.33 (0.25, 2.00)	0.31 (0.19, 0.54)	6.50 (6.0, 9.0)
	On track, N = 84[1]	2.33 (1.50, 2.67)	0.53 (0.32, 0.71)	9.00 (6.0, 10.0)
	p-value[2]	**< 0.001**	**0.007**	0.316
Meeting physical activity guideline	Not meeting, N = 55[1]	2.33 (1.33, 2.33)	0.53 (0.24, 0.67)	8.0 (6.0, 9.0)
	Meeting, N = 57[1]	2.00 (0.33, 2.33)	0.43 (0.20, 0.69)	6.0 (6.0,9.0)
	p-value[2]	0.106	0.483	0.617
Meeting sleep guideline	Not meeting, N = 24[1]	2.00 (1.00, 2.33)	0.25 (0.00, 0.53)	8.5 (6.0, 10.0)
	Meeting, N = 100[1]	2.00 (1.00, 2.33)	0.53 (0.30, 0.69)	8.5 (6.0,10.0)
	p-value[2]	0.872	**0.011**	0.968
Meeting screen time guideline	Not meeting, N = 68[1]	2.00 (0.33, 2.33)	0.44 (0.00, 0.62)	6.0 (6.0,9.0)
	Meeting, N = 53[1]	2.33 (1.33, 2.33)	0.54 (0.33, 0.69)	9.0 (6.0,10.0)
	p-value[2]	0.136	**0.044**	**0.045**
Meeting sitting guideline	Not meeting, N = 39[1]	2.00 (1.33, 2.33)	0.53 (0.27, 0.77)	9.0 (6.0,10.0)
	Meeting, N = 77[1]	2.00 (0.75, 2.33)	0.47 (0.16, 0.61)	6.5 (6.0,10.0)
	p-value[2]	0.376	0.120	0.282

[1]Median (IQR); n (%)
[2]Wilcoxon rank sum test

4. DISCUSSION

This is the first known study in Vietnam to examine pre-schoolers' EFs and their association with other related health indicators. It described levels of working memory, inhibition and attention shifting in pre-schoolers in relation to demographics, nutritional status, motor skills, and movement behaviour. Overall, EF performance in our study aligned well with prior studies in other countries, and various associations were found between certain types of EF and motor skills as well as levels of PA.

Participants in our study generally performed well in EFs compared with normal ranges in Australian children aged 3 to 4 and similar studies (Figure 2). Working memory scores were within normal ranges of Australian children of the same age group (0.85–1.74 points) and are in line with other countries [4], [16]–[18], with the exceptions of South Africa and Japan, whose scores were

higher than the norms (3.4 and 2.0 points) [19], [20]. Our shifting points (8.00) were well above Australian norms, as it is the case with other Asian countries such as Japan (7.50) and Bangladesh (7.15). Swedish and South African findings were similarly high, but to a lesser extent. This is against the hypothesis that EFs would be less developed in lower-income settings from a previous study [21]. Interestingly, two South African studies reported noticeably different results (5.73 in 2019 vs 2.20 in 2020).

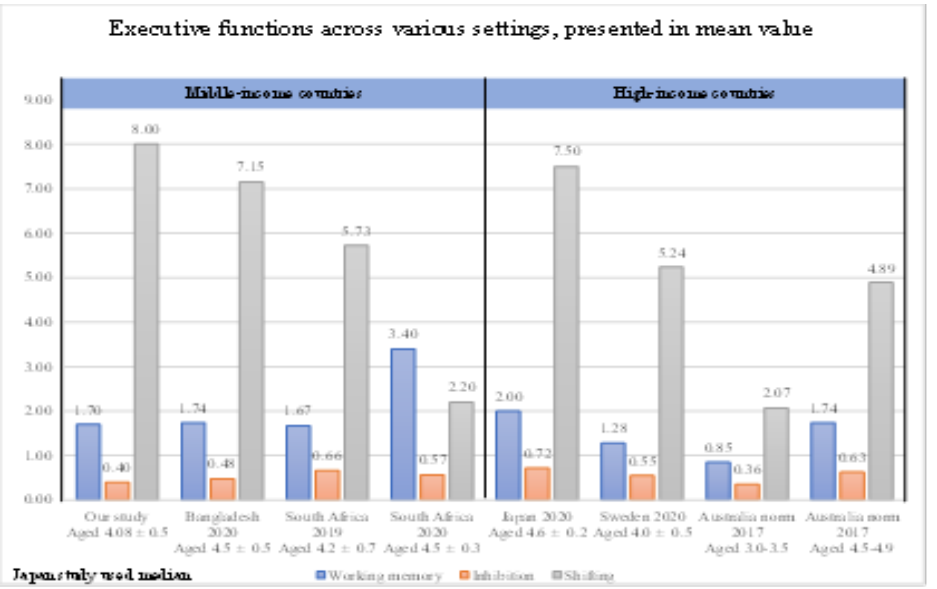

Figure 2. Schematic comparison between studies on executive functions using Early Year Toolbox

Regarding inhibition, our score of 0.40 was placed at the lower end of Australian norms (0.36 - 0.63) and was lower than most of the previous studies: Japan (0.74), South Africa (0.57), Sweden (0.55) and Bangladesh (0.48). This discrepancy could be explained by the younger age of our participants (4.08 years) in contrast to 4.5 - 4.6 of the previous literature [16], [17], [19], [20]. Improvement of simple inhibition, as characterised by the fish-and-shark game, is observed in the early years where children make a developmental leap, while working memory and shifting improve at a more steady rate until adolescence or adulthood [22]. In other words, at the age of 4 - 5, inhibition might be more sensitive to age than the other two EF categories.

However, comparison between mean values across studies should be cautiously interpreted because EF scores might be distributed differently. Our EF data was skewed (i.e., not normally distributed) and a relatively high proportion of children in our study scored zero in working memory and inhibition, which was not reported in other studies [16], [17], [19], [20].

In our study, the only demographic that was significantly associated with all three EF categories was age, which matched the data of Australian and South African pre-schoolers [4], [18]. However, in this study, the lack of association between execution and other demographics (sex, school location, and caregiver's education) was not in alignment with some other authors. A study in Sweden found that girls performed better than boys in Card Sorting (shifting) and Mr Ant (working memory) [17]. In South African settings, urban pre-schoolers scored higher than rural ones in working memory and shifting, whereas the reverse was true in Bangladesh [16], [20].

A positive relationship between good nutritional status (i.e., non-adiposity) and higher working memory performance was observed. The association between adiposity and shifting performance was also marginal at p-value of 0.059, which could be due to the small sample size. This relationship can also be seen in the study of Draper et al, in which

BMI for age z-score was negatively associated with EF composite score [20]. Obesity-related impairments in EFs, as described in detail by Ronan et al., have been well supported by evidence, and cortical function is being under investigation as the causative factor behind such an association [23].

Likewise, in the study of Draper et al., EFs were positively associated with fine motor skills but negatively associated with gross motor skills [20]. Our data, however, suggest a favourable association between both motor skills and working memory as well as inhibition.

The relationship between movement behaviours and EFs in the early years has gained recent attention [24]–[26]. In most studies, better EF was associated with better observation of WHO movement guidelines [26]. It was found in a couple of systematic reviews that the association between longer screen time with EF is unfavourable or null. Meanwhile, associations between sleep time and EF were mixed [24], [25]. As for our study, children who met WHO's sleep and screen time requirements had higher scores in inhibition but not in the other two aspects of EF.

Strengths and limitations

Strengths of the study include the use of standardised tools for the assessment of EF and PA in Vietnamese pre-schoolers. The recent development of the EYToolbox for assessing EF has simplified data collection4. The suite paved the way for collecting EF data in resource-limited settings and facilitated comparison between various studies [16]–[20]. Along with the protocol that is in worldwide use, these allow for high-quality preliminary data in Vietnam.

However, due to a small sample size and convenience sampling method, it is difficult to generalise the results of our study. There is also risk of recall bias for sleep time, screen time and sitting time because of the self-administered parent questionnaire. Moreover, our study did not address factors such as dietary intake, characteristics at birth, and parent-related features. Our study was not intended to establish a causal relationship as the direction of causality cannot be ascertained due to its cross-sectional design, and in the presence of a possible multitude of confounding factors. Therefore, our findings call for longitudinal data in future studies.

Nevertheless, our study could provide preliminary data and experience for expanding this project into a large-scale main study in Vietnam.

5. CONCLUSION

We found a good level of EFs and their associates such as age, nutritional status, motor skills, sleep time, and screen time. As a pilot study, it also provides preliminary data for future research and practical experience for implementing large-scale studies.

LIST OF ABBREVIATIONS

- BMI: Body mass index
- EF: Executive function
- HCMC: Ho Chi Minh City
- IQR: Interquartile range
- PA: Physical activity
- SB: Sedentary behaviour
- SD: Standard deviation

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