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FACTORS ASSOCIATED WITH EXECUTIVE FUNCTION AMONG ADOLESCENTS AGED 12 TO 16 YEARS IN PETALING PERDANA, SELANGOR, MALAYSIA

JOYCE TEE YING HUI

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By

JOYCE TEE YING HUI

Thesis submitted to the School of Graduate Studies, Universiti Putra Malaysia, in fulfilment of the requirement for the Degree of Master of Science

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Chair : Gan Wan Ying, PhD
Faculty : Medicine and Health Sciences

Adolescence represents one of the most dynamic and influential periods in human life stages, with profound changes of physiological, cognitive, and psychosocial developments. Individual differences of successful transition across adolescence are critically determined by their self-regulatory abilities, known as executive function (EF). EF refers to a group of high-order cognitive skills that underlie planning, organizing and self-regulation which are responsible for achievement of goal-directed behaviours. There are three dissociable yet interrelated domains of EF, namely inhibition, working memory (WM) and cognitive flexibility (CF). Proficiency of these domains affect multiple aspects of adolescents' well being. Given that considerable reorganization of EF in adolescence could be highly responsive to different biological and environmental factors, this study aimed to examine the factors associated with EF among adolescents aged 12 to 16 years in Petaling Perdana, Selangor.

A total of 513 adolescents (41.1% males, 58.9% females) with a mean age of 14.08 ± 1.32 years from two randomly selected government secondary schools in Petaling Perdana participated in this study. Mothers of the adolescents completed a self-administered questionnaire to obtain information on socioeconomic factors, while adolescents completed another set of self-administered questionnaire on their demographic information, meal consumption pattern, eating behaviours, physical activity (PA) and sleep quality. Anthropometric measurements (weight, height and waist circumference) and blood pressure of the adolescents were measured by the researcher. Physical fitness of the adolescents was assessed using a modified Harvard-step test. Three different neurocognitive tests were used to measure each domain of EF, including Stroop Colour-Word test, Digit-span test, and Trail-making test that measured inhibition, WM and CF, respectively.

Nearly one third of the adolescents were found to be overweight or obese (32.6%), while 14.0% and 18.5% were abdominally obese, based on their waist circumference and waist-to-height ratio, respectively. About one in ten of the adolescents were hypertensive (11.9%), while 19.1% were at pre-hypertensive stage. Birth data showed that one in ten

of the adolescents were born with low birth weight (11.4%) and more than half of them were pre-term births (56.5%). Unhealthy lifestyle behaviours were prevalent in adolescents in this study. Among all three main meals, the rate of breakfast skipping was the highest (69.0%), followed by dinner (47.4%) and lunch (47.2%). Although more than half of the adolescents had moderate PA level (55.0%), only 6.2% reported high level of PA. Likewise, only 9.0% of them attained good physical fitness level. Besides, majority of them were shown to have poor sleep quality (72.5%). In term of EF, the mean interference score (inhibition), WM score, and task-switching score (CF) of adolescents were 1.79 ± 6.68, 17.28 ± 3.74, and 27.92 ± 19.58, respectively. Based on the available categorization given, 7.6% and 13.3% of the adolescents had poor levels of inhibition and CF.

Results of multiple linear regression revealed that higher monthly household income ($\beta=0.078$, $p=0.048$) and lower A Body Shape Index ($\beta=-0.155$, $p=0.001$) significantly predicted better inhibition, in which these variables explained for 3.7% of variance in inhibition. Better WM was significantly predicted by older age of adolescents ($\beta=0.132$, $p=0.003$), higher monthly household income ($\beta=0.117$, $p=0.018$) and more years of father's education ($\beta=0.129$, $p=0.008$). It was also found that lower BMI-for-age ($\beta=-0.099$, $p=0.025$) and food responsiveness ($\beta=-0.096$, $p=0.029$), higher frequency of dinner intake ($\beta=0.105$, $p=0.017$), higher PA level ($\beta=0.084$, $p=0.045$) and better sleep quality ($\beta=0.192$, $p<0.001$) significantly predicted higher level of WM. Collectively, these variables explained for 12.7% of variance in WM. Lastly, female adolescents ($\beta=-0.107$, $p=0.017$), those who were at older age ($\beta=-0.166$, $p<0.001$), more regular dinner intake ($\beta=-0.090$, $p=0.042$), and lower emotional undereating ($\beta=0.097$, $p=0.032$) significantly predicted better CF. In relative to normal birth weight, very low birth weight significantly predicted poorer CF ($\beta=0.125$, $p=0.005$). These variables together explained for 7.5% of variance in CF.

In conclusion, a number of demographic and socioeconomic, physiological and lifestyle factors were found to be associated with EF among adolescents in this study. The proficiency of EF could be enhanced by improving socio-economic status such as parent's education and family income; while reducing risk of low birth weight via promotion of perinatal care and maternal health. Healthy lifestyle including regular meal intakes especially dinner, active in PA and good sleep quality should be advocated and established for life-long benefits and better EF. In view of the relatively small variance for EF found in this study, other factors such as dietary intakes, appetitive hormones, home environment and parent's mental health might possibly associated with EF of adolescents which required further investigations. The transition during adolescence appears as a valuable window for intervention to boost EF beyond preschool years. Therefore, a multidisciplinary approach involving parents, health professionals, government agencies, and school authorities should be established to foster healthy development of EF in adolescence and thereafter.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

FAKTOR BERKAITAN DENGAN FUNGSI EKSEKUTIF DALAM KALANGAN REMAJA BERUMUR 12 HINGGA 16 TAHUN DI PETALING PERDANA, SELANGOR, MALAYSIA

Oleh

JOYCE TEE YING HUI

Mei 2018

Pengerusi : Gan Wan Ying, PhD
Fakulti : Perubatan dan Sains Kesihatan

Remaja adalah peringkat peralihan paling dinamik dan berpengaruh dalam perkembangan manusia yang merangkumi perubahan dalam perkembangan fisiologi, kognitif dan psikososial. Perbezaan individu dalam transisi kejayaan remaja adalah ditentukan oleh kemampuan pengawalseliaan kendiri yang dinamakan sebagai fungsi eksekutif (EF). Fungsi eksekutif merujuk kepada sekumpulan kemahiran kognitif tinggi yang mendasari perancangan, pengurusan dan pengawalseliaan kendiri, dengan itu bertanggungjawab untuk pencapaian tingkah laku yang bertujuan dan berorientasikan matlamat. Terdapat tiga domain fungsi eksekutif yang berasingan tetapi saling berkaitan, iaitu *inhibition*, ingatan kerja, dan fleksibiliti kognitif. Kemahiran dalam domain ini mempengaruhi pelbagai aspek kesejahteraan hidup remaja. Penyusunan semula dan kematangan fungsi eksekutif berlaku pada peringkat remaja, di mana proses ini bertindak balas dengan faktor biologi dan persekitaran yang berlainan. Oleh itu, kajian ini bertujuan untuk menentukan faktor yang berkaitan dengan fungsi eksekutif dalam kalangan remaja yang berumur 12 hingga 16 tahun di Petaling Perdana, Selangor.

Seramai 513 remaja (41.1% lelaki, 58.9% perempuan) dengan purata umur 14.08 ± 1.32 tahun, dari dua buah sekolah menengah kebangsaan di Petaling Perdana yang dipilih secara rawak telah mengambil bahagian dalam kajian ini. Ibu remaja melengkapkan satu borang soal selidik yang merangkumi maklumat faktor sosioeconomi, manakala remaja melengkapkan satu lagi borang soal selidik tentang maklumat demografik, corak pengambilan makanan, tingkah laku pemakanan, aktiviti fizikal dan kualiti tidur. Ukuran antropometri (berat badan, ketinggian, dan lilitan pinggang) dan tekanan darah remaja diukur oleh penyelidik. Kecergasan fizikal remaja juga dinilai dengan menggunakan ujian langkah Harvard. Fungsi eksekutif terdiri daripada tiga domain, oleh itu, tiga ujian neurokognitif yang berbeza telah digunakan untuk mengukur setiap domain. Ujian neurokognitif ini termasuklah ujian *Stroop Colour-Word, Digit-span*, dan *Trail-making* yang masing-masing mengukur *inhibition*, ingatan kerja, dan fleksibiliti kognitif.

Hampir satu pertiga orang remaja mengalami masalah berlebihan berat badan atau obesiti (32.6%), manakala 14.0% dan 18.5% merupakan obesiti abdomen yang masing-masing berdasarkan lilitan pinggang dan nisbah pinggang-kepada-ketinggian. Satu daripada sepuluh orang remaja menghidapi tekanan darah tinggi, manakala 19.1% berada pada tahap pra-hipertensi. Data kelahiran menunjukkan bahawa satu daripada sepuluh

orang remaja mempunyai berat lahir yang rendah (11.4%) dan separuh daripada mereka merupakan kelahiran pramatang (56.5%). Gaya hidup yang tidak sihat adalah prevalen dalam kalangan remaja dalam kajian ini. Antara ketiga-tiga hidangan utama, kadar skip sarapan adalah tertinggi (69.0%), diikuti dengan makan malam (47.4%) dan makan tengahari (47.2%). Walaupun terdapat lebih daripada separuh remaja mencapai tahap aktiviti fizikal yang sederhana (55.0%), hanya 6.2% melaporkan tahap aktiviti fizikal yang tinggi. Hanya 9.0% remaja mencapai tahap kecergasan fizikal yang baik. Selain itu, kebanyakan mereka didapati mengalami kualiti tidur yang teruk (72.5%). Untuk fungsi eksekutif, min skor *interference (inhibition),* skor ingatan kerja dan skor pertukaran tugas (fleksibiliti kognitif) adalah 1.79 ± 6.68, 17.28 ± 3.74 dan 27.92 ± 19.58, masing-masing. Berdasarkan klasifikasi yang sedia ada, 7.6% dan 13.3% remaja mempunyai tahap *inhibition* dan fleksibiliti kognitif yang lemah.

Keputusan analisis regrasi pelbagai linear menunjukkan bahawa keluarga yang berpendapatan tinggi (β=0.078, p=0.048) dan indeks bentuk badan yang rendah (β=-0.155, p=0.001) meramalkan *inhibition* yang lebih baik, di mana faktor ini menjelaskan 3.7% varians dalam *inhibition*. Ingatan kerja yang lebih baik diramalkan oleh umur remaja (β=0.132, p=0.003), mereka yang berasal daripada keluarga yang berpendapatan tinggi (β=0.117, p=0.018), dan bapa yang mempunyai tahun pendidikan yang lebih banyak (β=0.129, p=0.008). Ia juga didapati bahawa indeks jisim tubuh mengikut umur yang rendah (β=-0.099, p=0.025) dan responsif makanan yang lebih rendah (β=-0.096, p=0.029), kekerapan makan malam yang lebih tinggi (β=0.105, p=0.017), tahap aktiviti fizikal yang lebih tinggi (β=0.084, p=0.045), dan kualiti tidur yang lebih baik (β=0.192, p<0.001) meramalkan ingatan kerja yang lebih tinggi. Faktor ini menjelaskan 12.7% varians dalam ingatan kerja. Akhirnya, remaja perempuan (β=-0.107, p=0.017), remaja yang berusia (β=-0.166, p<0.001), pengambilan makan malam yang lebih kerap (β=-0.090, p=0.042), dan kurang makan disebabkan oleh emosi (β=0.097, p=0.032) meramalkan fleksibiliti kognitif yang lebih baik. Berbanding dengan berat lahir yang normal, berat lahir yang terlalu rendah meramalkan fleksibiliti kognitif yang lebih teruk (β=0.125, p=0.005). Faktor ini menjelaskan 7.5% varians dalam fleksibiliti kognitif.

Kesimpulannya, sebilangan faktor demografik dan socioekonomi, fisiologikal dan gaya hidup didapati berkaitan dengan fungsi eksekutif dalam kalangan remaja dalam kajian ini. Memandangkan perkembangan fungsi eksekutif berlaku pada peringkat remaja, kecekapan fungsi eksekutif dapat ditingkatkan dengan memperbaiki status sosioekonomi seperti tahap pendidikan ibu bapa dan pendapatan keluarga, manakala mengurangkan risiko berat lahir yang rendah melalui promosi penjagaan perinatal dan kesihatan ibu. Gaya hidup yang sihat seperti pengambilan makanan pada tepat waktu terutamanya makan malam, aktif dalam aktiviti fizikal dan amalan tidur yang berkualiti patut dipupuk dan diamalkan bagi manfaat sepanjang hayat and fungsi eksekutif yang lebih baik. Memandangkan kajian ini memperolehi varians yang kecil dalam fungsi eksekutif, faktor-faktor lain seperti pengambilan makanan, hormon selera makan, persekitaraan rumah dan kesihatan mental ibu bapa mungkin berkaitan dengan fungsi eksekutif remaja yang memerlukan siasatan lanjut. Peralihan semasa remaja merupakan peluang yang baik untuk mengadakan intervensi untuk menggalakkan fungsi eksekutif selepas tahun prasekolah. Oleh itu, pendekatan multidisiplin yang melibatkan ibu bapa, profesional kesihatan, agensi kerajaan dan pihak berkuasa sekolah harus ditubuhkan untuk memupuk perkembangan fungsi eksekutif yang sihat dalam peringkat remaja dan peringkat yang seterusnya.

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I certify that a Thesis Examination Committee has met on 15 May 2018 to conduct the final examination of Joyce Tee Ying Hui on her thesis entitled "Factors associated with executive function among adolescents aged 12 to 16 years in Petaling Perdana, Selangor, Malaysia" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P. U. (A) 106] 15 March 1998. The committee recommends that the student be awarded the Master of Science.

Members of the Thesis Examination Committee were as follows:

Loh Su Peng, PhD
Associate Professor
Department of Nutrition and Dietetics
Faculty of Medicine and Health Sciences
Universiti Putra Malaysia
(Chairman)

Barakatun Nisak Mohd Yusof, PhD
Associate Professor
Department of Nutrition and Dietetics
Faculty of Medicine and Health Sciences
Universiti Putra Malaysia
(Internal Examiner)

Hamid Jan Jan Mohamed, PhD
Associate Professor
School of Health Sciences
Universiti Sains Malaysia
(External Examiner)

____
NOR AINI AB. SHUKOR, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

Gan Wan Ying, Ph.D
Senior Lecturer
Faculty of Medicine and Health Sciences
Universiti Putra Malaysia
(Chairman)

Chin Yit Siew, Ph.D
Senior Lecturer
Faculty of Medicine and Health Sciences
Universiti Putra Malaysia
(Member)

Tan Kit-Aun, Ph.D
Senior Lecturer
Faculty of Medicine and Health Sciences
Universiti Putra Malaysia
(Member)

____
ROBIAH BINTI YUNUS, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

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Signature: ______________________
Name of Chairman of
Supervisory Committee: Dr. Gan Wan Ying

Signature: ______________________
Name of Member of
Supervisory Committee: Dr. Chin Yit Siew

Signature: ______________________
Name of Member of
Supervisory Committee: Dr. Tan Kit Aun

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LIST OF ABBREVIATIONS

ABSI	A Body Shape Index
BMI	Body mass index
BP	Blood pressure
CF	Cognitive flexibility
CEBQ	Children Eating Behaviour Questionnaire
DBP	Diastolic blood pressure
DD	Desire to drink
EF	Executive function
EOE	Emotional overeating
EOF	Enjoyment of food
EUE	Emotional undereating
FF	Food fussiness
FR	Food responsiveness
IQ	Intelligence quotient
LBW	Low birth weight
PA	Physical activity
PFC	Prefrontal cortex
PSQI	Pittsburgh Sleep Quality Index
SBP	Systolic blood pressure
SE	Slowness in eating
SES	Socioeconomic status
SCWT	Stroop Colour-Word Test
SR	Satiety responsiveness
TFEQ	Three-Factor Eating Questionnaire

TMT	Trail-Making Test
VLBW	Very low birth weight
WHO	World Health Organization
WHtR	Waist-to-height ratio
WM	Working memory

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GLOSSARY OF TERMS

Cognitive function	A general term to describe all brain mediated functions and processes, which could be divided into six domains including psychomotor, language, perception, attention, memory and executive function (Schmitt, Benton, & Kallus, 2005).
Executive function	Encompasses a cluster of cognitive processes that underlie planning, organizing, self-regulating and decision-making, which are responsible for purposeful and goal-directed behaviours (Best, Miller, & Jones, 2009). It acts as the supervisory system of brain that coordinates thoughts and actions, thus enable us to adaptively respond to changing situations in everyday life.
Inhibition	Refers to the ability to resist distraction and supressing predominant mental presentations, while selectively maintain focus on the stimuli we choose to attend (Diamond, 2013; Nigg, 2000). Inhibition is measured using the Stroop colour word test wherein higher interference score indicates better inhibition (Golden & Golden, 2002).
Working memory	Refers to the ability to store, maintain, manipulate information to be retrieved within a brief period (Alloway, Gathercole, & Pickering, 2006; Diamond, 2013). Working memory is measured using the digit span test wherein higher total score indicates better working memory (Wechsler, 2003).
Cognitive flexibility	Refers to the ability to shift attention, select information, and alter response strategy in response to changing task demands (Lezak, 2012). It is measured by the trail-making test wherein higher task-switching score indicates poorer cognitive flexibility (Corrigan & Hinkeldey, 1987).

CHAPTER 1

INTRODUCTION

1.1 Background

Executive function (EF, also known as cognitive control or executive control) refers to a cluster of cognitive processes that underlie planning, organizing, self-regulating and decision-making, which are responsible for purposeful and goal-directed behaviours (Best, Miller, & Jones, 2009). As a supervisory system of brain that coordinates thoughts and actions, EF subserves the ability to adaptively respond to different situations, especially those unanticipated or non-routine encounters in daily life. In other words, EF enables ones to override habitual response and natural reflexes so that more deliberate behaviours are elicited. These abilities are named "executive" because they play a significant role in the integration of information across different areas of brain (Sheridan, 2012). As such, EF can potentially influence the proccessing and development trajectories of other cognitive domains including language, memory and visual perception (Diamond, 2014; Scanlan, 2004).

There has been a great deal of theorectical controversy about the construct of EF, where it is a unitary contruct or as a set of multiple, distinct domains (Best et al., 2009). However, increasing evidence from behavioural and neuroimaging studies have provided much support that EF is multi-faceted in nature (non-unitary) (Huizinga, Dolan, & van der Molen, 2006). This was in line with the "unity and diversity" framework, in which different domains tapped on some common underlying abilities, thus, they correlate with each other (unity), but at the same time they are separable (diversity) (Teuber, 1972). There are three distinct but intercorrelated domains of EF, namely inhibition (inhibitory control), working memory (updating), and cognitive flexibility (set shifting) (Miyake et al., 2000). Inhibition refers to the ability to resist distraction and selectively maintain focus on the stimuli we choose to attend (Diamond, 2013; Nigg, 2000); working memory (WM) refers to the ability to store, maintain, manipulate information to be retrieved within a brief period (Alloway, Gathercole, & Pickering, 2006; Diamond, 2013); cognitive flexibility (CF) is the ability to shift attention, select information, and alter response strategy in response to changing task demands (Lezak, 2012).

EF is predominantly governed by prefrontal cortex (PFC), the last region of brain to achieve maturity (Diamond, 2002). Thus, the full functional capacity will not be reached until mid to late adolescence (Luna, Garver, Urban, Lazar, & Sweeney, 2004). Although EF emerged during first few years of life, considerable enhancement and refinement happen in adolescence which in line with the substantial remodeling and reorganization of PFC (Best & Miller, 2010). Compared to the early development, maturation process involved more subtle changes and sophistication of EF. Hence, adolescence has been denoted as the sensitive period of EF development, where EF is maximally responsive to environmental influences due to the increased plasticity of PFC (Mackey, Raizada, & Bunge, 2012). The interactions of these morphological and functional transformation of brain, along with other biological changes as well as cultural and psychosocial factors would determine how adolescents perceive, feel and behave (Spear, 2000).

Adolescence is defined as the period between ages 10 and 19 years (WHO, 2001). This period encompasses remarkable physical, cognitive, social and emotional changes, thus presents new health risks but also great opportunities for health promotion (Sawyer et al., 2012). Optimal development of EF essentially support the increasing social and cognitive demands on self-regulatory capabilities and individual autonomy among adolescents (Luna, 2009). With growing drive for independence, EF plays an important role in shaping their abilities to control impulses, to delay gratification, to modulate emotional expression, to value risk and reward and to make right decisions. On the contrary, many intuitive abilities would be hindered without EF, such as controlling impulses and resisting temptations, taking time to think before making a decision and finding alternative solutions (Diamond, 2013). Thus, changes in EF development could have tremendous effects on adolescents' behaviours, learnings and well-being.

One of the significant aspects that is affected by EF is social and mental health. Poor EF has been implicated in emotion dysregulation, which was responsible for the heightened risk of emotional volatility, risk-taking, and instability among adolescents (Lee et al., 2014; Paus, Keshavan, & Giedd, 2008; Powers & Casey, 2015). Deficits in EF were accounted for a wide range of psychosocial issues such as antisocial behaviours, aggression, anxiety, and depression (Hughes & Ensor, 2011; Poland, Monks, & Tsermentseli, 2016). These problems have been found increasingly apparent during adolescence (Kessler et al., 2005). Taken together, EF plays vital roles in adaptive emotional regulation and proper behavioural control, which have long term impacts on future regulatory success and mental health of adolescents (Wekerle, Waechter, Leung, & Leonard, 2007).

EF is essential for regulating daily-life behaviours, even mild impairments in these functions could have adverse effects on different aspects of life. It appeared to predict academic achievements even over and above Intelligence Quotient (IQ) (Miller, Nevado-Montenegro, & Hinshaw, 2012), school performance and career success (Bailey, 2007; Morrison, Frederick, Ponitz, Claire Cameron, & McClelland, 2009; Titz & Karbach, 2014), physical and mental health (Fairchild et al., 2009; Gross et al., 2016), as well as social and psychological aspects in life (Davis, Marra, Najafzadeh, & Liu-Ambrose, 2010; Eakin et al., 2004). Besides, EF serves as a ground support for adolescents' learning, including time management, self-discipline, switching focus between different tasks, memorizing information, managing school assignments and coping with stress (Best, Miller, & Jones, 2009). All these capabilities have substantial influences on their academic and career success in future (Bailey, 2007; Titz & Karbach, 2014). As evident from previous findings, long-term stability of EF may have meaningful consequences for people's lives (Moffitt et al., 2011). Since adolescence has been regarded as the critical stage for development of EF where its related skills are most easily learned and retained, the identification of factors associated with EF in this group of population could be particularly prominent for its broad implications on the formation of positive adult health outcomes.

1.2 Problem Statement

Adolescence is a period marked by dynamic developmental changes and transition towards independence and autonomy (Curtis, 2015). One of the most significant changes during adolescence is the neurocognitive development, particularly relating to the substantial reorganization of PFC that governs EF (Luna, 2009). As such, adolescence is regarded as a sensitive period for EF in which different physiological and environmental factors could be associated with the neurological changes of EF that either improve or impair it.

The hypothesis of biological programming suggested that exposure to adverse conditions during early development may have life-long consequences on subsequent health (Gluckman & Hanson, 2006). During prenatal period, prematurity and increased medical complications could be the potential risk factors of poor neurodevelopment outcomes including impaired EF (Vladar, Lee, Stearns, & Axelrod, 2015). However, previous studies mostly focused on cases of very preterm or extremely low birth weight (LBW) among children (Aarnoudse-Moens, Smidts, Oosterlaan, Duivenvoorden, & Weisglas-Kuperus, 2009; Anderson & Doyle, 2004; Baron, Kerns, Müller, Ahronovich, & Litman, 2012), while it is not known whether these neurological effects persist into adolescence.

Besides, emerging literature has documented that socioeconomic and demographic indicators such as family income, parents' education level, and household size were correlated with the development of EF in young children (Blair et al., 2011; Raver, Blair, & Willoughby, 2012; Rhoades, Greenberg, Lanza., & Blair, 2011). Despite the enduring association of early socioeconomic status (SES) with EF, evidence revealed considerable plasticity in EF in later development (Hallin, Hellström-Westas, & Stjernqvist, 2010). Since both SES and EF are independently associated with a variety of health outcomes, examining their relationship among adolescents would provide opportunities to lower the disparities of SES and EF for better well-being of adolescents.

In light of the rising rates of childhood obesity, accumulating evidence revealed significant association of high BMI-for-age and poor inhibition in school children (Guxens et al., 2009; Huang et al., 2015; Kamijo, Pontifex, et al., 2012; Verbeken, Braet, Claus, Nederkoorn, & Oosterlaan, 2009; Wirt, Hundsdörfer, Schreiber, Kesztyüs, & Steinacker, 2014). Abdominal obesity as determined by waist circumference (WC) and visceral fat volume were also found to predict poorer inhibition among adolescents (Schwartz et al., 2013). Nevertheless, limited studies examined other domains of EF such as WM and CF as more focus were given to the role of inhibition in poor self-control and impulsive behaviours as often found in obese individuals (Reinert, Po, & Barkin, 2013). Even across the studies of WM and CF, the findings were inconsistent and their sample sizes were rather small (Cserjési, Molnár, Luminet, & Lénárd, 2007; Gunstad, Spitznagel, Paul, et al., 2008; Maayan, Hoogendoorn, Sweat, & Convit, 2011; Verdejo-García et al., 2010).

As one of the common obesity comorbidities, hypertension in adults was shown to have its root at a much younger age (Narchi, 2011). Previous studies revealed a clear association between hypertension and cognitive deterioration among adult population (Kuo et al., 2004; Manolio, Olson, & Longstreth, 2003), but the neurological effect of hypertension in younger population is yet to be determined (Sharma et al., 2010). A study done by Adams, Szilagyi, Gebhardt, and Lande (2010) found that hypertensive adolescents were more likely to have learning disabilities than normotensive controls. These findings suggested the potential impact of elevated blood pressure on neurocognition of adolescents particularly EF. Given the rapid rise in the prevalence of hypertension among Malaysian children and adolescents (Chong, Soo, & Rasat, 2012; Sreeramareddy et al., 2013), more studies are urged to ascertain this relationship.

Besides, high level of maladaptive eating behaviours such as emotional eating, disinhibited eating and other food-approach eating styles observed in obese adolescents were associated with executive dysfunction (Groppe & Elsner, 2014, 2015). Yet, many studies focused on single facet of EF, namely inhibition and a limited range of eating styles (Elfhag & Morey, 2008; Fischer, Smith, & Cyders, 2008; Jasinska et al., 2012). Hence, examining associations between broader aspect of eating behaviours and EF would be of particular significance.

Due to the increasing demands from peer pressure with influences of media and society, unhealthy lifestyle behaviours often begin in adolescence, such as meal skipping, sedentary behaviours and sleep deficit (Sawyer et al., 2012). These lifestyle factors could possibly affect EF development of adolescents. A great deal of research has considered the importance of breakfast consumption to specific cognitive processes mainly on attention and memory, but less had assessed EF (Cooper, Bandelow, Nute, Morris, & Nevill, 2012; Mahoney, Taylor, Kanarek, & Samuel, 2005; Wesnes, Pincock, Richardson, Helm, & Hails, 2003). In view of the high tendency of breakfast skipping among Malaysian adolescents (Chin & Mohd Nasir, 2009; Chong, Wu, Noor Hafizah, Bragt, & Poh, 2016), more local studies are needed to examine the association between meal consumption pattern and EF.

Sedentary lifestyle has been increasingly reported in children and adolescents, due to the advancement in technology such as easy access to internet and use of digital gadgets. While the cognitive benefits of physical activity (PA) is shown across lifespan (Verburgh, Königs, Scherder, & Oosterlaan, 2013), previous studies demonstrated that higher levels of PA and aerobic fitness can potentially enhance brain structure and function such as hippocampal and basal ganglia volume, as well as memory performance (Chaddock et al., 2010; Hillman, Castelli, & Buck, 2005; Khan & Hillman, 2014). In contrast, the association of PA, aerobic fitness and EF from behavioural evidence remained inconsistent (Booth et al., 2013; Pindus et al., 2014; van der Niet et al., 2015). Therefore, more studies are needed to ascertain the findings in light of the pandemic of physical inactivity.

Sleep deprivation is a commonplace among adolescents as they undergo a variety of sleep-pattern changes (Millman, 2005). Neuroimaging evidence suggested that PFC may be particularly susceptible to the effects of sleep loss (Killgore, 2010). Based on a systematic review among adult population, extreme sleep duration affected multiple cognitive domains, including EF, verbal memory as well as processing speed (Lo, Groeger, Cheng, Dijk, & Chee, 2016), while poor sleep quality coupled with increased daytime sleepiness could also contribute to poorer EF and decision making (Chuah, Venkatraman, Dinges, & Chee, 2006; Drummond, Paulus, & Tapert, 2006; Killgore, Balkin, & Wesensten, 2006). However, the association of sleep quality and EF is still underexplored among adolescent population.

Undeniably, adolescence is a critical stage for cognition since its stability was shown to predict several health aspects in adulthood (Gale et al., 2012). Evidence from both structural neuroimaging studies and behavioural research have proven that considerable reorganization of PFC and the corresponding executive processes continue well in adolescence, which is likely to be susceptible to environmental influences (Blakemore & Choudhury, 2006; Luna, 2009; Luna, Garver, Urban, Lazar, & Sweeney, 2004). This indicates that the transition to adolescence could be another period of relative plasticity of EF beyond preschool years. Therefore, better examination of the possible associated factors would be prominent to foster healthy development of EF thereafter.

In acknowledgement of the great need for research, no local study has been done to explore factors associated with EF in adolescents. Therefore, the present study aimed to determine the factors associated with EF among adolescents aged 12 to 16 years. This age range encompassed the early to middle stage of adolescence, in which profound reorganization of PFC takes place, supporting the refinements of EF skills (Best & Miller, 2010). This study addressed a few important research questions as follows:

1. What are the levels of EF among adolescents aged 12 to 16 years?
2. Are demographic and socioeconomic factors, physiological factors (body composition, blood pressure, birth weight and gestational week), and lifestyle factors (eating behaviours, meal consumption pattern, PA, aerobic fitness and sleep quality) associated with EF among adolescents aged 12 to 16 years?

1.3 Significance of the Study

Since EF underlies planning and regulating behaviours, it could be particularly important to adolescents who often exposed to situations marked by novelty, distractions and stress. This study serves as the pioneer study that provides valuable findings on the possible factors associated with EF among adolescents in Malaysia, while also contributes to the body of knowledge regarding the importance of neurodevelopment during this transitional period of life. This study can also be used as reference for future research on EF. Since evidence of great potential for brain plasticity are becoming clearer especially among children and adolescents, better approaches to prevent executive dysfunction or reverse the stage of deterioration could be known.

On the other hand, findings of this study can be used by health professionals especially public health nutritionists to create awareness regarding the importance of EF for adolescent's health. Effective interventions can be planned and implemented to promote optimal development of EF by intervening healthy lifestyles in adolescents, including eating behaviours, meal consumption patterns, PA, and sleep habits. These efforts would help to reduce problems of overweight and hypertension, while also enhance EF which in turn reinforced the sustainability of health behaviours in adolescence and thereafter. Lastly, policy makers could benefit from the findings to establish better guidelines to promote healthy lifestyle practices in order to prevent deteriorating effects of executive dysfunction in adolescents.

1.4 Objectives

1.4.1 General objective

To determine factors associated with EF among adolescents aged 12 to 16 years in Petaling Perdana, Selangor.

1.4.2 Specific objectives

a) To examine demographic and socioeconomic factors (age, sex, ethnicity, parent's education level, marital status, monthly household income, household size), physiological factors (body composition, blood pressure, maternal age, birth weight, and gestational week), and lifestyle factors (eating behaviours, meal consumption pattern, physical activity, aerobic fitness and sleep quality) among adolescents.
b) To assess EF (inhibition, working memory, and cognitive flexibility) of adolescents.
c) To determine the associations between demographic and socioeconomic, physiological factors, and lifestyle factors with EF among adolescents.
d) To determine the contributions of demographic and socioeconomic, physiological factors, and lifestyle factors towards EF among adolescents.

1.5 Research Hypotheses

a) There are significant associations between demographic and socioeconomic factors, physiological factors, and lifestyle factors with EF among adolescents.
b) There are significant contributions of demographic and socioeconomic factors, physiological factors, and lifestyle factors towards EF among adolescents.

1.6 Conceptual Framework

Figure 1.1 depicts the conceptual framework of this study. Several independent variables including demographic and socioeconomic, physiological and lifestyle factors were examined for their associations with EF, the dependent variable of this study. The three distinct but interrelated domains of EF, namely inhibition, WM and CF were assessed using Stroop Colour Word test, Digit Span test, and Trail-making test, respectively.

Previous studies have documented associations between socioeconomic factors such as household income, parent's education level and occupational status with EF among children and adolescents (Noble, Norman, & Farah, 2005; Raver et al., 2012; Rhoades et al., 2011). Adverse perinatal outcomes such as low birth weight (LBW), pre-term birth, and small size for gestational age were also correlated with poor EF (Baron et al., 2012; Duvall, Erickson., MacLean., & Lowe., 2015; Vladar et al., 2015). A growing number of studies revealed significant associations between anthropometric measures including BMI, waist circumference with different domains of EF in adults, adolescents as well as children (Cserjési et al., 2007; Guxens et al., 2009; Liang, Matheson, Kaye, & Boutelle, 2014; Pauli-Pott, Albayrak, Hebebrand, & Pott, 2010; Schwartz et al., 2013), but the results were inconsistent (Gunstad et al., 2008).

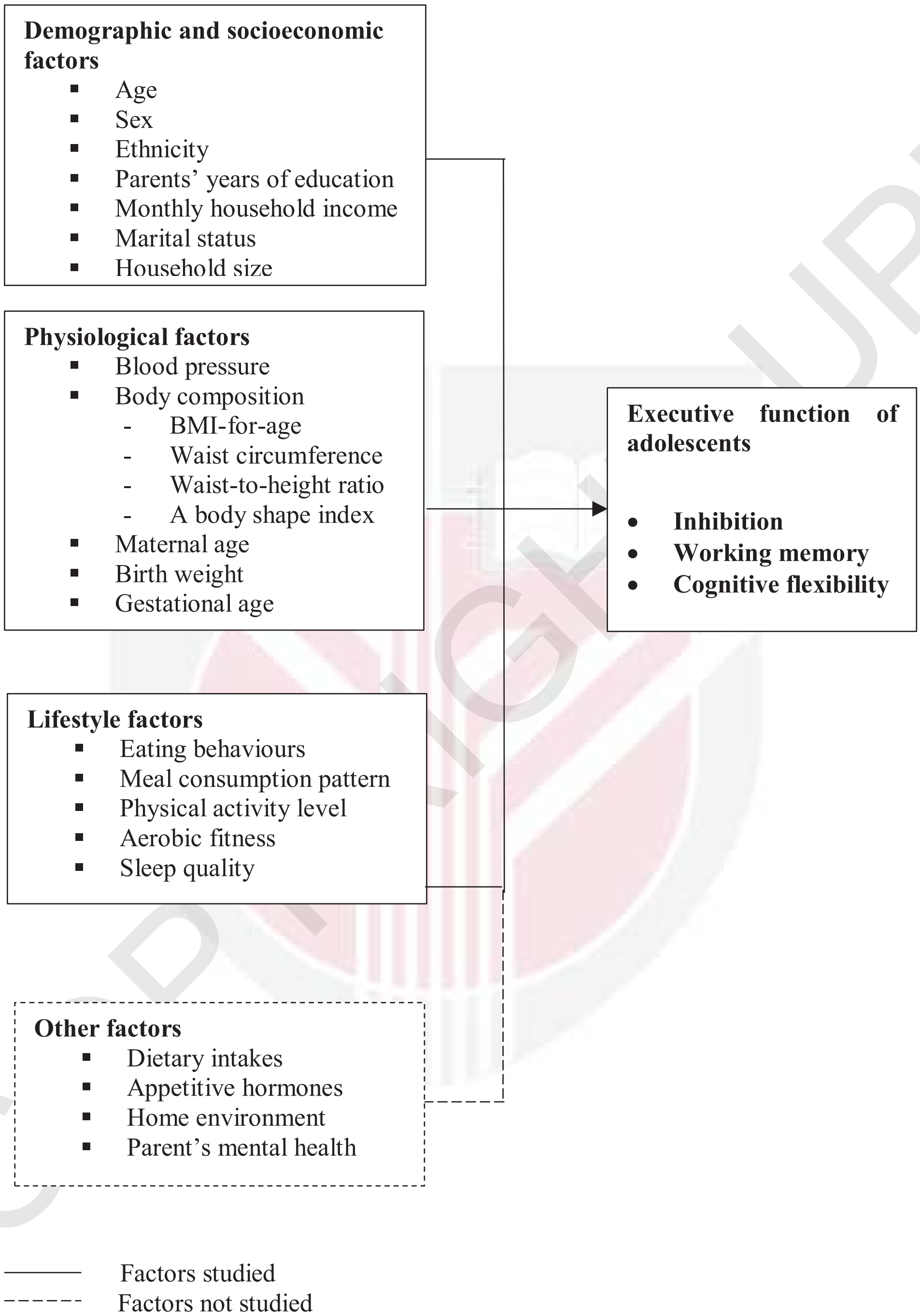

Figure 1.1: Conceptual Framework

As for lifestyle factors, several studies explored the correlation between maladaptive eating behaviours and EF, with more focus on inhibition (Calvo, Galioto, Gunstad, & Spitznagel, 2014; Jasinska et al., 2012). Few recent studies showed that poor EF were correlated with different eating styles such as desire to drink, food responsiveness and restrain eating, yet the results were inconsistent (Groppe & Elsner, 2014, 2015). Meal consumption particularly breakfast intake was shown to improve performance on tests measuring attention, WM, memory, inhibition but some studies did not find significant associations between these variables (Cooper, Bandelow, & Nevill, 2011; Mahoney et al., 2005; Widenhorn-Müller, Hille, Klenk, & Weiland, 2008). Other lifestyle factors were also found to have positive associations with EF, including PA level (Booth et al., 2013; Daly, McMinn, & Allan, 2014), aerobic fitness (Chaddock, Hillman, Buck, & Cohen, 2011), and sleep quality or duration (Anderson, Storfer-Isser, Taylor, Rosen, & Redline, 2009; Benitez & Gunstad, 2012).

Past literature also documented associations of other factors that were not examined in this study with EF. In term of diet, greater intakes of saturated fats and cholesterol were correlated to poorer EF (Khan, Raine, Drollette, Scudder, & Hillman, 2015), while other studies found positive association between consumption of dietary fibers (Khan et al., 2014) and ratio of omega 6 to omega 3 (Sheppard & Cheatham, 2013) with EF in children. Few studies also dicovered significant correlation of appetitive hormones (serum leptin and ghrelin) with EF among different groups of adults (Alosco et al., 2015; Chen et al., 2017; Gunstad, Spitznagel, Keary, et al., 2008). Besides, parent's mental health and home environment including learning resources, family companionship and enrichments were significantly associated with EF among children (Hackman, Gallop, Evans, & Farah, 2015; Piccolo, Salles, Falceto, Fernandes, & Grassi-Oliveira, 2016; Sarsour et al., 2011).

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