UNIVERSITI PUTRA MALAYSIA

COMPARISON OF MEDIATING FACTORS ASSOCIATED WITH COGNITIVE FUNCTION BETWEEN NORMAL WEIGHT AND OVERWEIGHT/OBESE CHILDREN IN KUALA LUMPUR, MALAYSIA

SERENE TUNG EN HUI

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By

SERENE TUNG EN HUI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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Faculty : Medicine and Health Sciences

Recent research suggests that a negative relationship exist between adiposity and cognitive function in children. However, limited information is known on how they were related. The negative relationship between overweight/obesity with cognitive performance may be related both directly and indirectly via obesity-related behaviours, psychological well-being and cardiovascular disease risk factors. Hence, this study aimed to compare the mediating factors associated with cognitive function in normal weight and overweight/obese children aged 10-11 years in Kuala Lumpur, Malaysia.

This cross-sectional comparison study was conducted in twelve primary schools selected using multi-stage stratified random sampling method. A total of 1971 children were screened for BMI-for-age through measurement of height and weight. A total of 235 overweight/obese children were selected and matched for age, sex, and ethnicity with 226 normal weight children. Anthropometric measurements included weight, height, waist circumference (WC) and body fat percentage (BF%). Dietary intake and physical activity were assessed using a two-day 24 hour dietary intake and physical activity recall. A self-administered questionnaire was used to gather information on socio-demographic factors and assessed self-esteem, body image, disordered eating and depression. Blood pressure was measured and venous blood was drawn after an overnight fast to determine insulin, high-sensitivity C-reactive protein (hs-CRP), glucose and lipid profiles. Homeostasis model assessment-estimated insulin resistance (HOMA-IR) was calculated using glucose and insulin levels. Cognitive function such as perceptual reasoning, verbal comprehension, working memory and processing speed were measured by using Wechsler's Intelligence Scale for Children (WISC-IV).

Out of the 1971 children who were screened for BMI-for-age, 32.3% were found to be overweight/obese. Overweight/obese children had significantly higher energy intake (t=-

2.395; p=0.017), lower energy expenditure (t=-3.512; p<0.001), higher body image discrepancy scores (t=5.390; p<0.001) and disordered eating scores (t=-3.512; p<0.001) and poorer biochemical parameters (p<0.05) compared to their normal weight counterparts.

Ordinary Least Square (OLS) regression analysis was conducted to determine the direct and indirect relationships between weight status with cognitive function. Negative relationships were found between overweight/obesity with perceptual reasoning, verbal comprehension, working memory, processing speed and cognitive function scores (Full IQ scores). Overweight/obese children were on average 4.075 units lower in their cognitive function scores (Full IQ scores) compared to their normal weight counterparts. Such difference was found as a result of the mediators body image (β=-0.482; 95% CI [-1.374, -0.041], disordered eating (β= -1.021; 95% CI [-2.081, -0.329], depression (β= -0.565; 95% CI [-1.443, -0.071]), systolic blood pressure (β= 1.355; 95% CI [0.298, 2.864]), triglycerides (β=0.365; 95% CI [0.017, 1.087]), HOMA-IR (β= -1.089; 95% CI [-2.121, -0.425]) and hsCRP (β= -2.521; 95% CI [-4.111, -1.265]), contributing to 22.2% of the variances in cognitive function (Full IQ) of these children.

This study highlights the importance of psychological factors and cardiovascular disease risk factors as mediators of the relationship between overweight/obesity and cognitive function in children. Consequently, future interventions should not only target the reduction of weight but also target to reduce the cardiovascular disease risk factors through lifestyle modifications and improve psychological health for the prevention of poorer cognitive performance in overweight/obese children.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah

PERBANDINGAN FAKTOR PENGANTARA BERKAITAN DENGAN FUNGSI KOGNITIF ANTARA KANAK-KANAK BERAT BADAN NORMAL DAN BERAT BADAN BERLEBIHAN/OBES DI KUALA LUMPUR, MALAYSIA

Oleh

SERENE TUNG EN HUI

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Penyelidikan terkini menunjukkan bahawa hubungan yang negatif wujud antara adipositi dan fungsi kognitif kanak-kanak. Walau bagaimanapun, maklumat mengenai bagaimana ia berkaitan adalah terhad. Hubungan negatif di antara berat badan berlebihan / obesiti dengan fungsi kognitif mungkin berkaitan secara langsung dan tidak langsung melalui tingkah laku yang berkaitan dengan obesiti, kesejahteraan psikologi dan risiko penyakit kardiovaskular. Oleh itu, kajian ini bertujuan untuk membandingkan faktor pengantara yang berkaitan dengan fungsi kognitif di kanak-kanak berat badan normal dan berat badan berlebihan / obes, berumur 10-11 tahun di Kuala Lumpur, Malaysia.

Kajian keratan rentas ini dijalankan di dua belas sekolah rendah yang dipilih dengan kaedah pensampelan pelbagai peringkat berstrata secara rawak. Seramai 1971 kanak-kanak disaring indeks jisim badan *(BMI-for-age)* melalui pengukuran tinggi dan berat badan. Seramai 235 kanak-kanak berat badan berlebihan / obes dipilih dan dipadankan untuk umur, jantina, dan etnik bersama 226 kanak-kanak berat badan normal. Ukuran antropometri termasuk berat badan, ketinggian, lilitan pinggang (WC) dan peratusan lemak badan (BF%). Soalan kaji selidik yang diisi sendiri digunakan untuk mengumpul maklumat mengenai faktor-faktor sosio-demografi, harga diri, imej badan, pemakanan terganggu dan kemurungan. Maklumat pengambilan makanan dan aktiviti fizikal diperolehi dengan menggunakan dua hari ingatan makanan and aktiviti fizikal 24 jam. Tekanan darah diukur dan darah diambil selepas berpuasa semalaman untuk menentukan insulin, sensitiviti tinggi protein C-reaktif (hsCRP), glukosa dan profil lipid model homeostasis rintangan insulin penilaian dianggarkan (HOMA-IR) telah dikira menggunakan glukosa dan insulin. Fungsi kognitif seperti persepsi pemikiran, pemahaman lisan, memori kerja dan kelajuan pemprosesan diukur dengan menggunakan *Weschler's Intelligence Scale for Children (WISC-IV).*

Daripada 1971 kanak-kanak yang disaring indeks jisim berat (BMI-for-age), 32.3% didapati berlebihan berat/ obes. Kanak-kanak berlebihan berat/obes didapati mengambil tenaga yang tinggi (t = -2,395; p = 0.017), penggunaan tenaga yang rendah (t=-3.512; p<0.001), skor imej badan yang lebih tinggi (t = 5,390; p <0.001), skor pemakanan terganggu (t = -3,512; p <0.001) dan ukuran biokimia lebih tinggi berbanding dengan rakan-rakan berberat badan normal (p <0.001).

Analisis *Ordinary Least Square (OLS) regression* dijalankan untuk menentukan hubungan langsung dan tidak langsung antara status berat badan dengan fungsi kognitif. Perkaitan yang negatif wujud antara berat badan berlebihan / obesiti dengan persepsi pemikiran, pemahaman lisan, ingatan kerja, kelajuan pemprosesan dan skor fungsi kognitif (skor IQ Penuh). Kanak-kanak yang berlebihan berat badan / obes mempunyai secara purata 4.075 unit lebih rendah dalam markah kognitif fungsi (skor IQ Penuh) berbanding dengan kanak-kanak berat badan normal. Perbezaan ini telah ditemui akibat daripada kesan pengantara imej badan (β = -0,482; 95% CI [-1,374, -0,041], pemakanan terganggu (β = -1,021; 95% CI [-2,081, -0,329], kemurungan (β = -0,565; 95% CI [-1,443, -0,071]), tekanan darah systolik (β = 1.355; 95% CI [0,298, 2,864]), trigliserida (β = 0,365; 95% CI [0.017, 1.087]), HOMA-IR (β = -1,089; 95% CI [-2,121, -0,425]) dan hsCRP (β = -2,521; 95% CI [-4,111, -1,265]), yang menyumbang kepada 22.2% varians fungsi kognitif (IQ Penuh) dalam kalangan kanak-kanak.

Kajian ini menekankan kepentingan faktor-faktor psikologi dan risiko penyakit kardiovaskular sebagai pengantara hubungan berat badan berlebihan / obesiti dengan fungsi kognitif kanak-kanak. Kesannya, selain daripada mengubah berat badan, program intervensi harus mengurangkan risiko penyakit kardiovaskular melalui pengubahsuaian gaya hidup dan meningkatkan kesihatan psikologi untuk mencegah perubahan fungsi kognitif dalam kalangan kanak-kanak berat badan berlebihan / obes.

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

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LIST OF ABBREVIATIONS

BD	Block Design
BF%	Body fat percentage
BMI	Body Mass Index
BMR	Basal metabolic rate
BI	Body image
BIA	Bioelectrical Impedance Analysis
CDC	Center of Disease Control and Prevention
CD	Coding
CDI	Children Depression Inventory (CDI)
CHNS	China Health and Nutrition Survey
ChEAT	Children's Eating Attitude Test
CI	Confidence Interval
CRT	Combined Ravens Test
DBP	Diastolic blood pressure
DDSS	Diarrheal Disease Surveillance System
Diet	Energy intake per body weight
DS	Digit Span
DV	Dependent variable
EBQ	Eating Behaviour Questionnaire
EI	Energy Intake
FBG	Fating blood glucose
FIQ	Full Intelligence Quotient
HDL-C	High-density lipoprotein cholesterol
HOMA-IR	Homeostasis model assessment-insulin resistance
hsCRP	High sensitivity C-reactive protein
IDEFICS	Identification and prevention of dietary and lifestyle induced health effects in chidlren and infants study
IDF	International Diabetes Federation
IOTF	International Obesity Task Force
IQ	Intelligence quotient
IR	Insulin resistance
IV	Independent variable
K-ABC	Kaufman Assessment Battery for Children
K-NHANES	Korean National Health and Nutrition Examination Survey
LDL-C	Low-density lipoprotein cholesterol
M	Mediator
MET	Metabolic Equivalent
MetS	Metabolic syndrome
MINI-KID	Mini International Neuropsychiatric Interview for Children and Adolescents
NCEP/ATP III	National Cholesterol Education Program for Children
NHANES	National Health and Nutrition Examinination
NHBPEP	National High Blood Pressure Education Program
NHMS	National Health and Morbidity Survey
NAFLD	Non-alcoholic fatty liver disease
NCD	Non-communicable diseases
OLS	Ordinary Least Square Regression Analysis
OW/OB	Overweight/obese

PA	Energy expenditure per body weight
PIQ	Performance Intelligence Quptient
PRI	Perceptual Reasoning Index
PSI	Processing Speed Index
R-CPM	Raven's Coloured Progressive Matrices
RMR	Resting Metabolic Rate
RNI	Recommendend Nutrient Intake
RPM	Revolutions per minute
RSES	Rosenberg Sel-Esteem Scale
SBP	Systolic blood pressure
SD	Standard Deviation
SEANUTS	South East Asia Nutrition Survey
SI	Similarities
TC	Total cholesterol
TDEE	Total Daily Energy Expenditure
TG	Triglycerides
WAIS	Wechsler Adult Intelligence Scale
WC	Waist circumference
WHO	World Health Organization
WHtR	Waist-to-height ratio
WISC	Wechsler Intelligence Scale for Children
WMI	Working Memory Index
WRAT	Wide Range Achieveent Test
VCI	Verbal Comprehension Index
VIF	Variance Inflation Factor
VIQ	Verbal Intelligence Quotient
YRBSS	Youth Risk Behaviour Surveillance System

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Childhood overweight and obesity are defined as the accumulation of excessive adipose tissues that leads to various health consequences (WHO, 2012). Childhood obesity is a serious public health crisis globally in this 21st century. It was estimated that a total of 42 million children at the age of five are overweight. Out of the 42 million children, close to 31 million came from developing countries (WHO, 2012). Such a large number of overweight and obese children is concerning as this condition could persist into adulthood, leading to the development of various chronic diseases even at a very young age (WHO, 2012). In the year 2011, the South-East Asia Nutrition Survey (SEANUTS) revealed that the prevalence of overweight and obesity among children aged six months to 12 years was 21.6% (Poh et al., 2013). In the year 2015, NHMS study revealed that the prevalence of obesity among children aged 10-14 years was 14.4% (IPH, 2015).

Childhood obesity is associated with adverse health consequences such as hypertension, dyslipidaemia, atherosclerosis, inflammation, insulin resistance and metabolic syndrome, which used to be common among adults in the past (Reilly, 2005; Reilly et al., 2003; Weiss & Caprio, 2005). While the complications may still be in their early stages of development and may not be apparent until many years later, such conditions may continue to stress the body of the overweight and obese child. Other than the cardiovascular disease risks, long term overweight and obesity may also lead to other complications such as asthma, non-alcoholic fatty liver disease (NAFLD) and even obstructive sleep apnoea syndrome (Sanders et al., 2015; Harriger & Thompson, 2012). These non-communicable diseases (NCDs) not only cause premature death but also long-term health complications in the life of these children.

In addition, overweight and obese children more often experience weight related teasing, discrimination and social isolation, which result in greater risks of suffering from various psychological issues (Wardle & Cooke, 2005) . These psychological issues are such as lower self-esteem and confidence (Dreyer & Egan, 2008a; French, Story, & Perry, 1995; Griffiths, Parsons, & Hill, 2010; Miller & Downey, 1999; Wardle & Cooke, 2005), having depressive symptoms (Erermis et al., 2004; Reeves, Postolache, & Snitker, 2008; Wardle & Cooke, 2005), poorer body image (Schwartz & Brownell, 2004) and practice disordered eating behaviours (Goldschmidt et al., 2008) compared to normal weight children.

Recent meta-analysis and systematic reviews suggest that a negative relationship exists between adiposity and cognitive function in children and adolscents in Western and Chinese populations (Liang et al, 2013; Smith et al., 2011; Yu et al., 2010). Literature indicates that overweight and obese children have significantly lower intelligence scores

(Li, 1995; Yu et al., 2010), lower cognitive flexibility, shifting abilities (Cserjési et al., 2007) and lower performance in memory, reasoning and attention tests (Li et al., 2008) compared to their normal weight counterparts. A more recent review that examined the correlation of obesity with cognitive function in children concluded that there is a negative relationship with all aspects of cognitive functioning such as executive function, attention, visuospatial performance and motor skills (Liang et al., 2013).

1.2 Problem Statement

Although evidence from systematic reviews of and meta-analysis of case control and cohort studies show that obesity is associated with cognitive functioning in children and adolescents (Liang et al., 2013; Reinert et al., 2013; Smith et al., 2011; Yu et al., 2010), there is limited information on how they were related. The negative relationship between overweight/obesity with poorer cognitive performance may be related both directly and indirectly via obesity related behaviours, psychological well-being and cardiovascular disease risk factors. Some researchers suggest a direct relationship exists between obesity and cognitive decline as the relationship was reported among young subjects without serious metabolic complications (Smith et al., 2011; Yu et al., 2010). Others suggest an indirect relationship exists or the relationship is mediated via obesity-related behaviours such as dietary intake and physical activity (Liang et al., 2013); via psychological factors such as depression, lowered self-esteem and dieting (Brunstrom, Davison, & Mitchell, 2005; Kemps, Tiggemann, & Marshall, 2005; Wang & Veugelers, 2008) or through cardiovascular disease risk factors such as hypertension, dyslipidaemia or insulin resistance (Smith et al., 2011). However, it is unclear which of these indirect relationships or frameworks truly describe the pathway or mediate the relationship between obesity and cognitive function in children. Furthermore, it is also uncertain that the findings from the past examined among the Western and the Chinese populations are applicable to the Malaysian population due to the difference in socio-cultural backgrounds.

The prevalence of childhood obesity was reported to be the highest among children aged 10-11 years in Malaysia (IPH, 2015). Despite the high prevalence of childhood obesity in this age group, studies examining the cardiovascular disease risk factors and psychological well-being of overweight and obese children are limited in Malaysia. Despite the growing phenomenon of childhood obesity in this country, there were only few published studies that examined metabolic complications associated with obesity in children and adolescents (Fadzlina et al., 2014; Iwani et al., 2017; Ling et al., 2016; Narayana, Meng, & Mahanim, 2011; Quah, Poh, & Ismail, 2010; Wee et al., 2011). When examined further, these studies did not examine inflammation level, which is an important indicator of cardiovascular disease risk factors (Cook et al., 2000; El-shorbagy, 2010; Lambert et al., 2004; Yi et al., 2014). On the other hand, studies on psychological well-being related to obesity were mainly examined among adolescents and university students (Gan et al., 2011; Rezali, Chin, & Yusof, 2012; Rohayah et al., 2009; Yaacob et al., 2009) but rarely among children in Malaysia (Mohd Jamil, 2006; Rosliwati et al., 2008; Zalilah, Anida, & Merlin, 2003).

There were a few studies that examined the association between nutrition or weight status and cognitive function in Malaysia. These studies examined the associations of iron deficiency (Al-Mekhlafi et al., 2011; Hamid Jan et al., 2010), dietary patterns (Nurliyana et al., 2014) and lead concentrations (Zailina et al., 2008) with cognitive performance. Only a few examined the relationships between weight status and cognitive function in children (Anuar Zaini et al., 2005; Mohd Nasir et al., 2012; Sandjaja et al., 2013). Nevertheless, none of the aforementioned studies were designed specifically to examine the association of overweight/obesity with cognitive function.

With the rise in the prevalence of childhood obesity, the prevalence of cognitive problems among children is likely to increase (Yu et al., 2010). The link between obesity and poorer cognitive performance is a disadvantage as this may indicate early signs of cognitive impairment which could further lead to a more devastating epidemic, an earlier onset of dementia (Smith et al., 2011). On the other hand, academic performance is known to be an outcome of cognitive function (Hughes & Bryan, 2003). Consequently, it is very likely that childhood obesity is also associated with poorer academic achievement (Caird et al., 2011).

This study is designed to examine and compare the different mediating factors associated with cognitive function in normal weight and overweight/obese children. In doing so, the important research questions include:

1. What differences exist in obesity-related behaviours, psychological factors, cardiovascular disease risk factors and cognitive function between normal weight and overweight/obese children?

2. Is overweight/obesity directly or indirectly associated with cognitive function through obesity-related behaviours, psychological factors and cardiovascular disease risk factors in children?

1.3 Significance of the Study

Information pertaining to the relationship between childhood obesity and cognitive performance or education attainment may be useful to support arguments for obesity prevention initiatives especially in school settings since cognitive and academic performance are highly valued by parents and teachers in school. On the other hand, lower academic or educational attainment may be an economic disadvantage as it is associated with future employability, income and success. Hence, immediate action must be taken to tackle this issue to enable the full potential of children as future leaders that will eventually affect the country's productivity as well as to reduce the burden on healthcare systems.

To build a healthy nation and fuel economic growth, we must, therefore begin to test whether and to what extent childhood obesity is associated with cognitive performance in the crucial primary school years. An extensive understanding of the phenomenon of the link between obesity and cognition is important for the development of effective intervention programmes to reduce the association between childhood obesity and cognitive function or performance. Therefore, a framework that explain the relationship between obesity and cognition should be developed for the identification of possible mediators.

Identifying the key mediators between obesity and cognition can also help programme planners, health care professionals, researchers, nutritionists, dietitians as well as policy makers to design and implement intervention and prevention programmes that can help to reduce these key mediators. In addition, obesity-targeted interventions can be very costly. Therefore, it is essential to design interventions that are cost effective and successful, targeting both obesity and cognition at the same time. Successful interventions can also increase participation of the target population in the promotion programmes conducted by researchers and government agencies.

1.4 Objectives

1.4.1 General objective

To compare the mediating factors associated with cognitive function between normal weight and overweight/obese school children aged 10-11 years in Kuala Lumpur, Malaysia.

1.4.2 Specific objectives

1. To determine socio-demographic factors (age, gender, ethnicity, educational level, income status), obesity-related behaviours (dietary intake and physical activity), psychological factors (self-esteem, body image, disordered eating, depression), cardiovascular disease risk factors (blood glucose, lipid, high sensitivity c-reactive protein, insulin, blood pressure), weight status (BMI-for-age), body fat percentage, waist circumference and cognitive function (working memory, processing speed, language, perceptual reasoning/executive function) of the children.

2. To determine the differences in obesity-related behaviours, psychological factors, cardiovascular disease risk factors and cognitive function between the normal and overweight/obese children.

3. To examine the direct/indirect association between weight status and cognitive function through obesity-related behaviours, psychological factors and cardiovascular disease risk factors.

1.5 Null hypotheses

Ho 1: There are no significant differences in obesity related behaviours, psychological factors, cardiovascular disease risk factors and cognitive function between the normal and overweight/obese children.

Ho 2: There are no significant direct/indirect associations between weight status and cognitive function through obesity-related behaviours, psychological factors and cardiovascular disease risk factors.

1.6 Research Conceptual Framework

Figure 1 shows the conceptual framework of the relationship between weight status and cognitive function in children. The conceptual framework of the present study was based on multiple bodies of literature of the relationship between weight status and cognitive function in children (Liang et al., 2013; Martin et al., 2014; Smith et al., 2011; Yu et al., 2010). This conceptual framework was mainly designed to determine the mediators of the relationship between overweight/obesity with cognitive function in children. According to the literature, the relationship between overweight/obesity with cognitive function may be related both directly and indirectly via different mediators. In this study, the independent variable, weight status is associated both directly and indirectly with the dependent variable, cognitive function. Overweight and obese children were reported in the past to have significantly lower intelligence scores (IQ) and performance compared to normal weight children in Western and Chinese population (Yu et al., 2010). Such relationship was reported to exist among children who were not clinically diagnosed with cardiovascular conditions (Li et al., 2008), suggesting that the poorer cognitive performance reported may happen in overweight/obese children who were without pathophysiological vascular changes of aging.

Overweight/obesity in children is viewed to be related indirectly to cognitive function via multiple mediators: obesity-related behaviours, psychological factors and cardiovascular disease risks factors. The obesity-related behaviours (Liang et al., 2013) include dietary intake (Martin & Davidson, 2014; Riggs et al., 2010) and physical activity (Caird et al., 2011; Sibley & Etnier, 2003).

Psychological factors include self-esteem (French et al., 1995; Wardle & Cooke, 2005), depression (McDermott & Ebmeier, 2009), disordered eating (Brunstrom, Davison, & Mitchell, 2005; Green et al., 2003; Green, Elliman, & Rogers, 1995) and body dissatisfaction (Kemps & Tiggemann, 2005a; Vreugdenburg, Bryan, & Kemps, 2003).

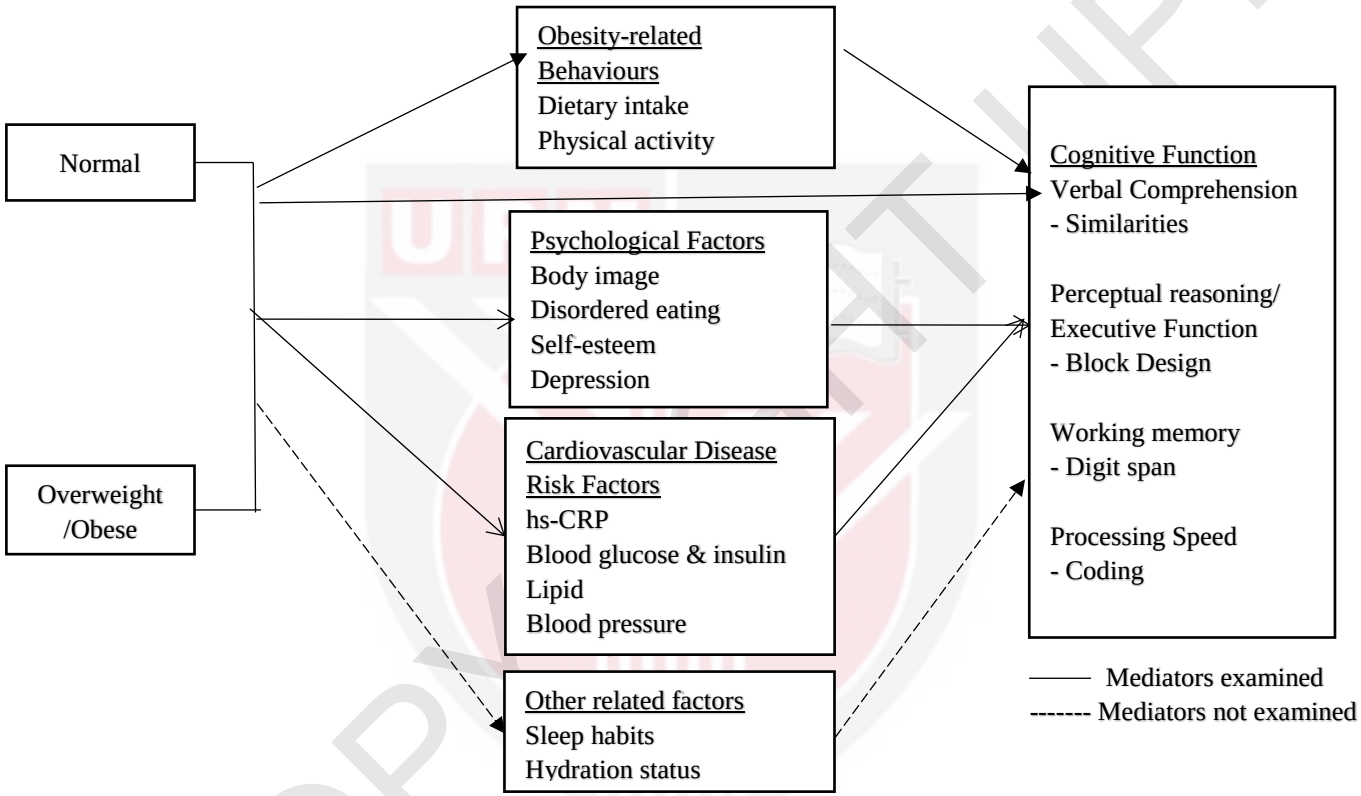

Figure 1.1: Conceptual framework of the relationship between weight status and cognitive function in children

Lastly, cardiovascular disease risk factors include lipid profiles (Taylor & MacQueen, 2007), an inflammation marker which is high sensitivity C-reactive protein (hs-CRP) (Brasil et al., 2007; Ford et al., 2001), insulin resistance parameters such as glucose, insulin (Convit, 2005; Lamport et al., 2009; Yates & Sweat, 2012) and systolic and diastolic blood pressures (Jennings & Zanstra, 2009; Jennings, 2003; Lande et al., 2003). Other related factors associated with weight status and cognitive function that were not examined in the present study include sleep habits and hydration status (Alloha & Plo-Kantola, 2007; de Bruin et al., 2017). These mediators are viewed to be the dependent variables of weight status and the independent variables of cognitive function in this research framework. Confounding factors controlled through the study design were age, sex and ethnicity. Differences in parent's education and household income were examined and no significant difference found between normal weight and overweight/obese children. However, puberty was not examined in the present study.

Obesity related behaviours, psychological factors and cardiovascular disease risk factors were tested as mediators of the relationship between weight status and cognitive function. A mediation model is an explanation of how or by what means the independent variable (X or IV) is related to the dependent variable (Y or DV) through one or more intervening variables known as mediators (M) (Baron & Kenny, 1986; Preacher & Hayes, 2004, 2008). In other words, a mediation model is a sequence of relationships in which an independent variable (X) is related to a mediator (M) which in turn is related to a dependent variable (Y), hence explaining how X is related to Y. As the multiple mediators are parallel, the mediators were tested together to determine indirect relationships of X on Y.

The mediation model in this study was tested using an SPSS macro known as PROCESS (Preacher & Hayes, 2008), where weight status acts as the predictor (X) in the model whereas obesity-related behaviours, psychological factors and cardiovascular disease risks factors are the mediators (M) and cognitive function acts as the outcome variable (Y). This hypothesized model was tested to determine the prediction of the independent variable (dummy coded normal weight as 0 and overweight/obese as 1) and the mediators (obesity-related behaviours, psychological factors and cardiovascular risk factors) on the dependent variable (cognitive function). The model was hypothesized to explain how much weight status (overweight/obesity) and the mediators explain the variation in cognitive function in children.

Four steps were taken to test the multiple mediation models. Firstly, the total indirect effects were examined; i.e. deciding whether the set of mediators explain the relationship of X on Y. Secondly, specific indirect effects were examined; i.e. deciding whether each mediator explains the relationship between X and Y. Thirdly, pairwise comparison between the mediators were examined to decide which mediator contributes the most in the relationship. Fourthly, the point estimates of the total indirect effects were examined; i.e. determine the direction of the relationship (positive or negative) and the mean difference in cognitive function between the normal weight and the overweight/obese children. It is expected that overweight/obesity is negatively related to cognitive function, and the mediators act as variables that explain the relationship.

1.7 Definition of Terms

1.7.1 Childhood Obesity

Conceptual definition: Childhood overweight and obesity are conditions of excessive adipose tissues accumulation leading to health consequences in life (WHO, 2012). Childhood obesity is viewed as one of the most serious public health problems in this 21st century as overweight and obese children were reported to develop into obese adults and even developing noncommunicable diseases such as type 2 diabetes and cardiovascular diseases at a very young age (WHO 2012).

Operational definition: The World Health Organization (WHO) growth reference for school aged children and adolescents age 5-19 years (de Onis, Onyango, Borghi, & Siyam, 2012) was used to assess overweight and obesity in this study. This growth reference is age- and sex-specific Body Mass Index (BMI-for-age). According to WHO growth reference, overweight is defined as one standard deviation body mass index for age and sex while obese is defined as two standard deviations body mass index for age and sex (WHO, 2012).

1.7.2 Cognitive function

Conceptual definition: Cognitive function is known as the functions and processes in relations to the brain (Schmitt, Benton, & Kallus, 2005). It encompasses executive function, memory, attention, perceptual reasoning, psychomotor and language (Schmitt et al., 2005) and such processes are often very much interlinked. The term cognitive function can also refer to as an act of gathering information from the environment and responding to it through internal processing and behaviours (Isaacs & Oates, 2008).

Operational definition: The Wechsler Intelligence Scale for Children version four (WISC-IV) was used to assess cognitive function in this study. This instrument consists of four domains namely verbal comprehension, perceptual reasoning, working memory, processing speed and executive function.

1.7.3 Verbal Comprehension

Conceptual definition: Verbal comprehension is the ability to comprehend or understand words or even sentences and be able to express thoughts, feelings, ideas and experiences using spoken language (Goldstein, 2011). Language and verbal processing is an important component of intelligence and cognition as it plays an important part to obtain knowledge, education and using this information gathered for problem-solving purposes (Isaacs & Oates, 2008).

Operational definition: The subtest "Similarities" of the Verbal Comprehension Index (VCI) domain from WISC-IV was used to measure language. Respondents were to state and expressed how two common objects or concepts are alike.

1.7.4 Working Memory

Conceptual definition: Memory is the process of keeping information observed through stimuli, images, events, ideas and skills and later retrieving and using information when original information is no longer present (Goldstein, 2011). On the other hand, working memory is a further elaboration of memory, which is defined as a combination of task performing or problem-solving that requires short term memory storage (Benton, Kallus, & Schmitt, 2005).

Operational Definition: The subtest "Digit Span" of the Working Memory Index (WMI) from WISC-IV was selected to measure auditory short-term memory, sequencing skills, attention and concentration. Digit span comprises of 8 items on "Digit Span Forward" where the numbers were to be repeated in the same order and another eight items on "Digit Span Backwards" where numbers were to be repeated in the reverse order.

1.7.5 Processing Speed

Conceptual definition: The speed of processing is the efficiency of the brain to process information which is measured through time. There are two types of tasks commonly used to measure processing speed is through inspection time tasks and reaction time tasks (Deary, 2001; Deary, Penke, & Johnson, 2010).

Operational Definition: The subtest "Coding" of the Processing Speed Index (PSI) from WISC-IV was selected to measure visual motor speed, complexity and motor coordination of the children. Children are required to complete the task by copying symbols that are paired with simple geometric shapes or numbers on boxes provided within the given 120 seconds time limit.

1.7.6 Perceptual reasoning/Executive Function

Conceptual definition: The ability to plan, implement goals and form strategies in an organized and thought through manner (Isaacs & Oates, 2008). In other words, problem-solving ability (Hughes & Bryan, 2003).

Operational Definition: The subtest "Block Design" of the Perceptual Reasoning Index (PRI) from WISC-IV was used to measure the ability to analyze and synthesize abstract visual stimuli. Respondents were required to view a constructed model or picture and re-create the design in a specified time limit using 3D blocks.

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