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Child and adolescent obesity prevalence in the Gulf Cooperation Council countries and its impact on adolescent females in Kuwait

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Declaration of authenticity and author's rights

This thesis is the result of the author's original research. It has been composed by the author and has not been previously submitted for examination which has led to the award of a degree.

Signed:

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Abstract

Background: Obesity is a global problem that has become very prevalent in children and adolescents in the six Gulf Cooperation Council countries (GCC), with Kuwait being in the forefront. However, there is lack of evidence on the current impact of obesity among school-age children adolescents in Kuwait and the other GCC countries.

Aims and objectives: This thesis aimed to assess the impact of child and adolescent obesity in Kuwait and the GCC countries through (a) testing how well child and adolescent obesity is monitored in the GCC states, (b) assessing the extent to which surveys and studies of obesity using the BMI might be underestimating the prevalence of obesity, and finally (c) investigating associations between adolescent obesity and educational attainment and cognitive inhibition.

Methods: This thesis presents four manuscripts (studies 1-4). The first is a systematic review on the recent prevalence of obesity among school age children and adolescents in the GCC countries. The second, third, and fourth studies were based on a prospective study of 400 healthy Kuwaiti female adolescents. Study 2 examined the ability of BMI-for-age to define high body fatness (defined by ≥30 %) by comparing BMI-for-age defined obesity against body fatness measures from bioelectrical impedance (BIA). Study 3 examined cross-sectional associations between obesity (defined by both BMI-for-age and high body fatness) and educational attainment using Grade Point Average (GPA). Study 4 tested for an association between obesity (defined as both BMI-for-age and high body fatness) and cognitive inhibition, measured by the Stroop Colour Word Test (SCWT), the first computerised SCWT in the Arabic language.

Results: The systematic review (Study 1) included 11 eligible studies from the six GCC countries that showed a high prevalence of obesity as defined by BMI-for-age among school-age children and adolescents, and prevalence seemed to increase consistently with age according to these 11 studies. Evidence on obesity prevalence in the GCC countries was quite limited e.g. Bahrain, Oman, and Qatar had no recent data on prevalence, and nationally representative surveys of prevalence are scarce. Kuwait was the only country from the GCC countries that had a national survey for obesity prevalence. The second thesis study found a higher prevalence of obesity based on high body fatness (62% of the sample had body fat percentage above ≥30) than the prevalence of obesity based on BMI-for age (42%). The sensitivity of BMI-for-age was moderate (66%) but specificity was high (96%). In the third study, obese students (defined by BMI and body fatness) had significantly lower academic attainment (measured by Grade Point Average) compared to their non-obese individuals, and BMI-defined obese individuals were more likely to be in the lowest quartile for the GPA than the non-obese individuals (OR 3.03, 95% CI 1.90-4.85, $P < 0{\cdot}001$). In the fourth study, the performance on the Stroop Colour Word Test (SCWT) was significantly lower in obese (defined by BMI and body fatness) than non-obese individuals. BMI-defined obese individuals were at significantly higher risk of being in the lowest quartile of SCWT compared to non-obese individuals (OR 2.05, 95% CI 1.30 – 3.25, $P <0.001$). Both GPA and SCWT performance were not affected by the confounding variables considered (student age and socio-economic status as measured by parental educational level).

Conclusion: Based on the findings of this thesis, obesity is having a significant impact on the six GCC countries; it is very prevalent using BMI-based definitions, and even more prevalent than BMI-based definitions of obesity suggest. This thesis also suggests that obesity may impair the academic attainment of adolescents and may impair cognitive inhibition. This thesis adds to the evidence that obesity is having a range of impacts in Kuwait and the GCC countries.

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Dedication

This thesis is dedicated to my late father Abdullah Al Hammadi (may ALLAH bless his soul) who died recently from ***Covid-19****. I did not have the chance to see him, he was not only my father but my friend and supported me all the way from the beginning of my PhD and inspired and encouraged me throughout my education and my life. I miss you father so much and I will never forget your beloved soul and your concern. I promise you that I will continue to achieve success in my life and career as you wished and as you were proud.*

List of abbreviations

ADP	Air Displacement Plethysmography
ALSPAC	Avon Longitudinal Study of Parents and Children
AMSTAR	A Measurement Tool to Assess Systematic Reviews
ASPB	American Society of Bariatric Physicians
AUC	Area Under the Curve
BDNF	Brain-Derived Neurotrophic Factor
BF%	Percent body fat
BIA	Body Impedance Analysis
BMI Z Score	Body Mass Index standard score
BMI	Body Mass Index
BPNRC	Brain, Performance and Nutritional Research Centre
CDC	Centres for Disease Control and prevention
CI	Confidence Intervals
COMPASS	Computerised Mental Performance Assessment System
COSI	Childhood Obesity Surveillance Initiative
CRD	Centre for Reviews and Dissemination
CT	Computer tomography
CVR	Altered Cerebrovascular Reactivity
DALYs	Disability-Adjusted Life Years
DEXA	Dual-Energy X-Ray Absorptiometry
ECOG	European Childhood Obesity Group
EF	Executive Function
EMR	Eastern Mediterranean Region
GBD	Global Burden of Disease
GCC	Gulf Cooperation Council Countries
GNI	Gross National Income
GPA	Grade Point Average
GSHS	Global School-based Student Health Survey
HRQL	Health-related Quality of Life
ICD-11	The International Classification of Diseases, Eleventh Revision
IOTF	International Obesity Task Force
IQ	Intelligence Quotient
IQR	Interquartile Range
JBI	Joanna Briggs Institute
Kg	Kilogram
KISR	Kuwait Institute for Scientific Research
KNSS	The Kuwait Nutrition Surveillance System
KSA	Kingdom of Saudi Arabia
KU	Kuwait University
MD	Mean difference
MGRS	Multicentre Growth Reference Study
MOE	Ministry of Education
MOH	Ministry of Health
MOO	Ministry of Oil
MRI	Magnetic Resonance Imaging

NCD	Non–Communicable Disease
NCD-RisC	Non-Communicable Disease Risk Factor Collaboration
NCHS	National Centre for Health Statistics
NHANES	National Health and Nutrition Examination Survey
OB	Obese
OR	Odds ratio
OSAS	Obstructive Sleep Apnoea Syndrome
PE	Physical Education
PECO	Population, Exposure, Comparison, Outcome Framework
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PROSPERO	International Prospective Register of Systematic Reviews
QOL	Quality of Life
ROC	Receiver Operating Characteristics
SCWT	Stroop Colour Word Test
SD	Standard Deviation
SDS	Standard Deviation Score
SES	Socioeconomic status
SFT	Skinfold Thickness
SOP	Standard Operating Procedures
SPSS	Statistical Package for Social Sciences
STARD	Standards of Reporting for Diagnostic Accuracy Studies
TNF	Tumour Necrosis Factor
UAE	United Arab Emirates
UK	United Kingdom
USA	United States of America
WC	Waist Circumference
WHO	World Health Organisation

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1. Publications and manuscripts from thesis

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Chapter 5

Al Hammadi, H., & Reilly, J. J. (2020). Classification Accuracy of Body Mass Index for Excessive Body Fatness in Kuwaiti Adolescent Girls and Young Adult Women. *Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy, 13, 1043*.

Chapter 6

Al Hammadi, H. H., Alaslawi, H. A., Hewitt, A., & Reilly, J. J. (2020). Differences in educational attainment between obese and non-obese Kuwaiti female university students. *Journal of Nutritional Science*, *9*.

Chapter 7 (unpublished)

Al Hammadi, H. H., Alaslawi, H. A., Hewitt, A., & Reilly, J. J. (2021). Associations between obesity and cognitive function in Kuwaiti female university students.

2. Conference presentations from thesis

Al Hammadi, H., & Reilly, J. (2019). Prevalence of obesity among school-age children and adolescents in the Gulf cooperation council (GCC) states: a systematic review. International Conference on Nutrition and Growth, Valencia, Spain. March 2019.

Al Hammadi, H., & Reilly, J. J. (2019). Classification Accuracy of Body Mass Index for Excessive Body Fatness in Kuwaiti Adolescent Girls and Young Adult Women. 29th Annual Congress of European Childhood Obesity Group, Katwice, Poland November 2019.

Al Hammadi, H., & Reilly, J. J. (2020). Classification Accuracy of Body Mass Index for Excessive Body Fatness in Kuwaiti Adolescent Girls and Young Adult Women. International Conference on Nutrition and Growth, London, UK. August 2020.

Chapter 1: Introduction and literature review

1. Introduction

Obesity is a main public health concern in most parts of the globe and has substantial impacts on both psychosocial and physical health (Summerbell *et al.*, 2009; Rey-Lopez *et al.*, 2019; WHO, 2000). The prevalence of obesity has been on the rise worldwide with some variation in the rates and trends across different countries. The World Health Organization (WHO) described this as a “global pandemic” over 20 years ago (WHO, 1998).

Obesity is a condition where the adipose tissue begins to grow abnormally due to the enlargement of fat cell size and the increase in fat cell number (Park, 1995). The excess of body fat in adults is a risk factor for many comorbidities (Hruby *et al.*, 2016; WHO, 2000), including diabetes mellitus, hyperlipidaemia, hypertension, coronary heart disease and some cancer types, such as endometrial, oesophageal, colorectal, postmenopausal breast, prostate, and kidney cancer (Muller *et al.*, 2001; Bray, 2004; Colditz & Peterson, 2018; De Pergola & Silvestris, 2013). A matter of concern is that several studies have indicated that childhood obesity tends to lead to adverse impacts on health during childhood and adolescence (Reilly *et al.*, 2003; Reilly, 2005; Han *et al.*, 2010; Kelishadi *et al.*, 2015) as well as adulthood (Reilly, 2010; Reilly & Kelly, 2011; Kelsey *et al.*, 2014), partly because obesity in children tends to persist into adolescence and adulthood (Biro & Wien, 2010; Reilly, 2010; Reilly & Kelly, 2011; Kelsey *et al.*, 2014). More details about the health consequences of obesity are given in section 5 of this chapter.

As in many other nations, obesity is a real concern in Kuwait and in the other five member states of the Gulf Cooperation Council (GCC), including the Kingdom of Saudi Arabia (KSA), the United Arab Emirates (UAE), Qatar, Oman, and Bahrain. The prevalence of obesity in the Gulf region seems to be very high among children, adolescents, and adults (Musaiger & Gregory, 2000; Sorkhou *et al*., 2003; Naser Al-Isa, 2000; Al Yazeedi & Berry, 2019; Nahhas *et al*., 2018; Alshaikh *et al*., 2017). In Kuwait, for example, some older studies suggested that the prevalence of overweight and obesity in children and adolescents ranged from 25% to 40% (El-Bayoumy *et al*., 2009; Musaiger, 2011; Ng *et al*., 2014; Zaghloul *et al*., 2013). In addition, the prevalence of obesity among Kuwaiti adults has been on the rise, and this rise might have been more marked in women than men (Al-Awadhi *et al*., 2013; Weiderpass *et al*., 2019).

Some research has highlighted the need for more studies of obesity prevalence within the GCC countries as the number of such studies is low compared to western countries (AlMarri *et al*., 2017). The dramatic increase in the prevalence of obesity in the GCC is associated with the rise in socio-economic status (SES) (ALNohair, 2014; Elkum *et al*., 2016; Rey-Lopez *et al*., 2008; Rey-Lopez *et al*., 2019; Musaiger *et al*., 2012; Rabeea *et al*., 2019). The Non-Communicable Disease Risk Factor Collaboration (NCD-RisC) showed that obesity prevalence in the GCC population is higher than many other Middle Eastern populations in all age groups (NCD-RisC, 2017). More details about the international and national prevalence of obesity are given in section 4 of this chapter.

This thesis has a focus on the potential of obesity to impair educational attainment. Systematic reviews have pointed to the possibility of obesity having negative impacts on educational attainment (Martin *et al*., 2017; Booth *et al*., 2014; Santana *et al*., 2017; Hill *et al*., 2018) as well as on the vital cognitive processes necessary for educational attainment (Favieri *et al*., 2019; Yang *et al*., 2018; Reinert *et al*., 2013; Liang *et al*., 2014; Martin *et al*., 2017; Booth *et al*., 2014). This thesis focuses on adolescent girls as a population potentially highly sensitive to such impacts on education attainment, partly because educational attainment is important to adolescents (e.g. in university education), and partly because there is some evidence that adolescent females might be the group most sensitive to any effects of obesity on educational attainment and/or cognitive function and quality of life (Martin *et al*., 2017; Booth *et al*., 2014). More details about obesity and educational attainment are given in section 6, and obesity and cognition in section 7 of this chapter.

The first thesis chapter provides an overview of obesity in children and adolescents, its definition, a description of the international epidemiology and a brief summary of obesity determinants. The problems under investigation in this thesis include the prevalence of obesity, and how well this is measured by BMI and BMI-for-age, and how well this is being monitored in the GCC states. The thesis then goes on to examine associations between obesity and educational attainment, and some aspects of cognitive function.

2. Definitions of obesity

Obesity is a condition where the level of body fatness is high enough to pose increased risk of morbidity and/or premature mortality (WHO, 2000; Reilly *et al*., 2003; Reilly & Kelly, 2012). The International Classification of Diseases, Eleventh Revision (ICD-11) defines obesity as “a chronic complex disease defined by excessive adiposity that can impair health. It is in most cases a multifactorial disease due to obesogenic environments, psycho-social factors and genetic variants" (WHO, 2020).

Body fat content can be measured by direct methods including computer tomography (CT) scans, dual-energy X-ray absorptiometry (DEXA), underwater weighing, magnetic resonance imaging (MRI), and air displacement plethysmography (ADP), among others (Wells & Fewtrell, 2006; Marshall *et al*., 1991; Dietz & Bellizzi, 1999; Butcher *et al*., 2019). Further information on these methods is found in chapter 4.

The gold standard for measuring body composition is multicomponent models that include three or four models, which generate sufficiently accurate information about the body fat mass, fat-free mass, and water (Wells & Fewtrell, 2006). One of the low-cost methods that is frequently used in research is bioelectrical impedance analysis (BIA). Systematic review evidence has reported that it is practical, easy to use with children and adolescents, and has reasonably high reproducibility making it a good option for measuring body composition changes over time (de Castro *et al*., 2018). However, there are conflicting results regarding its accuracy due to the variety of BIA methods used in studies (Talma *et al*., 2013; de Castro *et al*., 2018). Comparing different BIA models (tetrapolar BIA, finger-to-finger, hand-to-hand, and leg-to-leg), the leg-to-leg model was found to be the most accurate among these models (Peterson *et al*., 2011). In addition, the leg-to-leg model was shown insensitive to drink and food consumption before measurement (Androutsos *et al*., 2015). In a recent study that assessed body fat in adolescents using BIA, they found that BIA was accurate, highly specific and sensitive in classifying participants based on their body fat percentage (BF%) (Butcher *et al*., 2019).

With regards to the BF% measured by these methods, a variety of cut-off values to identify high fatness have been used in studies due to the lack of reference data on BF% cut-offs (Javed *et al*., 2015; Gallagher *et al*., 2000; Shah & Braverman, 2012). However, a cut-off of body fat ≥25% in males, and ≥30% in females are commonly used (Neovius *et al*., 2004; Okorodudu *et al*., 2010; Shah & Braverman, 2012; Anzolin *et al*., 2017; Diouf *et al*., 2018) because these values were found to be associated with increased cardiometabolic risk factors among children and adolescents (Williams *et al*., 1992). In addition, the guidelines of the American Society of Bariatric Physicians (ASBP) have used these cut-offs to identify individuals for the treatment of obesity with anorectic agents (Shah & Braverman, 2012).

Overall, these methods for measuring body fat content are reasonably reliable, informative, sensitive and specific in assessing body fat (Reilly *et al*., 2005; Reilly *et al*., 2007). However, these methods are not commonly used because they are expensive and not readily available for routine practice (Wells & Fewtrell, 2006). In addition, they are technically complex and require trained individuals to use them (Deurenberg & Yap, 1999). In large epidemiological studies and surveys and in low-income countries, body composition is rarely measured and simpler measures are all that is possible to define obesity (Deurenberg & Yap, 1999). Therefore, more practical proxy methods are widely used in both clinical and field studies (Dietz & Bellizzi, 1999; Deurenberg & Yap, 1999; McCarthy *et al*., 2003).

One of the most commonly used body fatness proxies is the body mass index (BMI), calculated using the expression: weight kg/height m^2 (WHO, 2000; WHO, 1995). It is internationally agreed that in adults (except Asian adults who have different cut-offs as discussed later), having a BMI of <18.5 is considered underweight, 18.6-24.9 normal, 25-29.9 overweight, and ≥30 obese, and these ranges were determined based on their association with risks of mortality and morbidity in adults (WHO, 2000; Cole *et al*., 2000; WHO, 2007). Waist circumference (WC) is another proxy for body fatness in adults. According to the WHO, the risk of metabolic complications increases with a WC>94 cm in men, and WC>80 cm in women. The risk is substantially increased with WC>102 cm in men and >88 cm in women (WHO, 2008).

The aforementioned cut-off points of BMI and WC in adults are not applicable for children and adolescents because they are undergoing rapid growth, and both BMI and WC vary substantially with age and differ between males and females during the developmental stages (WHO, 2000; Cole *et al*., 2000; De Onis & Lobstein, 2010). Therefore, there was a need to develop age- and sex-specific cut-off points for those under the age of 20 years old (WHO, 2000; Cole *et al*., 2000; De Onis & Lobstein, 2010). According to WHO, children are defined as individuals aged between 5.0-9.9 years old, whereas adolescents are those between 10.0-19.9 years old (WHO, 2013; WHO, 2016).

National and international BMI cut-off points were developed for children and adolescents. Statistics were applied on reference data distribution of body weight and height to represent the BMI data either in centiles or standard deviation scores (SDS) (WHO, 2007; WHO, 1995). The centile charts divide the reference data into 100 equal parts to produce groups or curves (such as 5, 10, 25, 50, 85, 95) that indicate normality and give an approximation of the normal weight per age and sex (WHO, 2007; WHO, 1995). Alternatively, the measurements of reference data can be presented using the SDS, known as z score, from the population mean. If the z score is positive, it is above the mean, and if it is negative, it is below the mean (De Onis *et al*., 2007; WHO, 2007; WHO, 1995).

There are different reference data and different cut-off points in the reference data distribution that are in use to determine obesity in children and adolescents (De Onis & Lobstein; 2010). Three of the most used international references are described in this section, and the BMI-based definitions of obesity in each reference are summarised in **Table 1**.

World Health Organization child growth reference for children and adolescents

This reference was first developed using a Multicentre Growth Reference Study (MGRS) that included 8,500 children from six countries (India, Oman, Ghana, Brazil, Norway and the United States) through a longitudinal study of children aged 0 to 24 months as well as a cross-sectional study of children aged 18 to 71 months (De Onis *et al*., 2004). As this reference included only preschool children, it was necessary to develop a reference for school-aged children and adolescents. Therefore, the data from the previous cross-sectional sample (18–71 months) were combined with data from 1977 US National Centre for Health Statistics (NCHS) (1–24 years) to construct the currently used WHO child growth reference (De Onis *et al*., 2007; WHO, 2007). This data reference was developed in 2007 in alignment with the previous cut-points for age 5 years and the BMI cut-off points of adults at age 19 years. BMI-for-age z score ≥ 1 is used to define overweight, and BMI-for-age z score ≥ 2.00 is used to define obesity in school-aged children and adolescents (aged 5-19 years) as this value correlates with the cut-off point of adult obesity BMI ≥30 kg/m^2 (De Onis *et al*., 2007; WHO, 2007).

The International Obesity Task Force (IOTF) reference for children and adolescents

This reference was published in 2000 based on six representative cross sectional studies that took place in Hong Kong, Singapore, the Netherlands, Brazil, Great Britain, and the United States (Cole *et al*., 2000). This international survey included 97,876 males and 94,851 females from birth to 25 years old. The centile curves from each study were drawn to pass through the adult cut-off points of overweight and obesity at age 18 years. The IOTF reference provides age- and sex-specific BMI cut-off points for ages 2 to 18 years (Cole *et al*., 2000).

The Centres for Disease Control and Prevention (CDC) reference for children and adolescents

The CDC Growth Charts were developed in 2000 after revising the 1977 NCHS growth charts using five national surveys with the aim of a more representative US reference for children and adolescents. This reference consists of a set of charts for infants (0-36 months) and a set of charts for the older ages (2 to 20 years) (Kuczmarski *et al*., 2000). The BMI-for-age CDC charts are sex-specific and classify BMI ≥ 95^{th} percentile as “obese” and BMI≥ 85^{th} percentile as “overweight” (Kuczmarski *et al*., 2000).

Table 1. Summary of the definitions of obesity in children and adolescents

Organization	Age range (years)	Growth reference	Obesity
World Health Organization (WHO, 2007)	0-5	WHO child growth Reference	3 *SD* above median
World Health Organization (WHO, 2007)	6-19	National Center for Health Statis-tics/WHO growth reference	2 *SD* above median
U.S. Centers for Disease Control and Prevention (Kuczmarski *et al.*, 2000)	2-20	CDC growth reference	≥ 95° percentile
International Obe-sity Task Force (Cole *et al.*, 2000)	2-18	IOTF international reference	Correspond to adult BMI of 30

Overall, age and gender-specific percentile charts based on international and national representative data have been commonly applied in both the clinical and epidemiological settings (Reilly, 2005; Reilly *et al.*, 2010; De Onis & Lobstein, 2010). However, the question of the most appropriate definition and diagnosis for childhood obesity remains. Cole *et al*. (2000) reported trends in childhood obesity and acknowledged that trends may be difficult to quantify due to the many defini-tions available on childhood obesity (Cole *et al.*, 2000). In addition, the variety of BMI national and international references and the different cut-off points that are in use across all these references make it difficult to compare between studies, which may result in over or underestimation of obesity prevalence (Must & Anderson, 2006; Javed *et al.*, 2015; Deurenberg & Yap, 1999). Therefore, the accuracy of BMI definition relative to specific reference data should be taken into account when used for clinical and epidemiological purposes (Reilly *et al.*, 2010).

3. Classification accuracy of BMI: sensitivity and specificity

This section will introduce the concept of classification accuracy and the definitions of its statistical measurement in general and then discuss in detail the classification accuracy of BMI for high body fatness.

The accuracy of a diagnostic test reflects its capacity to detect those who have a disease/condition and those who do not have that disease/condition (Akobeng, 2006; WHO, 1995). This diagnostic accuracy is measured by sensitivity, specificity, and positive and negative predictive values (Akobeng, 2006; WHO, 1995). The sensitivity of a test determines only the proportion of individuals who have the disease and have a positive result, while the specificity determines only the proportion of individuals who do not have the disease and have a negative result (Akobeng, 2006; WHO, 1995). Therefore, the test with a high sensitivity helps exclude the disease when having a negative result, and that with a high specificity helps “rule in” the disease when having a positive result (Akobeng, 2006; WHO, 1995). However, sensitivity and specificity are not useful to determine the probability of a condition in an individual patient (Akobeng, 2006). Instead, predictive values can be used for that purpose. The positive predictive value is defined as “the proportion of people with a positive test result who actually have the disease” (Akobeng, 2006), and the negative predictive value is defined as “the proportion of people with a negative test result who do not have the disease” (Akobeng, 2006). The predictive values are limited to a specific population as they vary with disease prevalence (Akobeng, 2006; WHO, 1995).

Numerous systematic reviews dealing with classification accuracy of BMI for high body fatness in children, adolescents, and adults have reported that BMI has high specificity and low to moderate sensitivity (Javed *et al*., 2015; Reilly *et al*., 2010; Okorodudu *et al*., 2010). This can be explained by the fact that BMI is based on body weight, rather than body composition. Thus, BMI does not distinguish between fat mass and lean mass (Trang *et al*., 2019; Wellens *et al*., 1996; Deurenberg & Yap, 1999; Rothman, 2008), leading to inaccuracy in the classification of obesity at the individual level (Rothman, 2008; Deurenberg & Yap, 1999). The implication is that a considerable number of people apparently having healthy BMI-for-age or BMI, in reality, have high body fatness. Such a low-moderate sensitivity problem may be more serious in some populations than in others (Javed *et al*., 2015; Reilly *et al*., 2010; Okorodudu *et al*., 2010; Rothman, 2008). For instance, in one of the recent studies on African adolescents and children, obesity as defined by high body fatness measured accurately using total body water was three times more prevalent than obesity defined using the BMI for age (Diouf *et al*., 2018). In adults, the misclassification of BMI is more frequently reported in women than in men and increases with the advanced age of women (Rothman *et al*., 2008). A study on American adults found that 48% of women had false-negative BMIs, while they were found to be obese (high body fatness) using DEXA (Shah & Braverman, 2012). In contrast, 25% of men had false positive BMIs while they were found to be non-obese by DEXA. This misclassification results from the fact that BMI does not consider the muscular body morphology and that men lose less muscle than women with ageing (Shah & Braverman, 2012).

Moreover, research on non-European population has shown ethnic and racial differences in body fat distribution that may affect the accuracy of proxy measures of obesity (Chen & Wang, 2010; WHO, 2004; Deurenberg & Yap, 1999; Wang *et al*., 1994). There has been a considerable debate over the applicability of the international BMI cut-off points in some Asian populations that have shown higher fat percentage and thus higher health risk at a given BMI compared to western populations (Chen & Wang, 2010; Lear *et al*., 2007; WHO, 2004). Comparing data for children (aged 8-10 years) from China, Malaysia, The Philippines, Lebanon and Thailand, ethnic differences in the relationship of BMI and BF% were reported among these subgroups (Liu *et al*., 2011). Asian children were found to have 3-6 units lower BMI values at a given BF% compared to Caucasian children. Therefore, both WHO and IOTF references failed to identify obese children, while the use of Chinese classification (cut-offs based on Chinese reference data) had a higher sensitivity (Liu *et al*., 2011).

The WHO has endorsed lower BMI cut-off points for use with adults of south-east Asian populations (WHO, 2004). Considering these adjusted cut-off values, a study done in south Asia (Pakistan) showed a high prevalence (total 50%) of overweight (BMI 23.1-27.5 kg/m^2) and obesity (BMI $>$27.5 kg/m^2) among adult participants, and the prevalence was even higher using the BF% (Amin *et al*., 2015). Although lower cut-off points are in use, there is still much variation among Asian ethnic groups in regards to the relationship of BMI, BF%, and health outcomes. A recent study that included representative data from India, Nepal, and Bangladesh reported that BMI-defined obesity using the lower cut-off values was associated with high odds of hypertension (Hossain *et al*., 2019). While some other Asian studies have not found any significant associations between higher BMI and mortality risk (Sauvaget *et al*., 2008; Pierce *et al*., 2010).

Nonetheless, the bias arising from the use of BMI is not widely referred to in studies (Reilly *et al*., 2018; Reilly, 2017). The two recent global estimates of obesity prevalence (NCD-RisC, 2017; GBD 2015 Obesity Collaborators, 2017) and some others failed to refer to this source of bias that seems to vary substantially between populations (Hruschka & Hadley, 2016). Regarding Arab countries in Asia, there is lack of studies on the classification accuracy of BMI in children, adolescents, or adults. Additionally, none of the studies on the prevalence of obesity in the GCC region has reported BMI as a source of bias when estimating obesity prevalence (AlMarri *et al*., 2017; Alsharif *et al*., 2018; Nahhas *et al*., 2018; Musaiger *et al*. 2016; Mirmiran *et al*., 2010; Musaiger and Gregory, 2000; Sorkhou *et al*., 2003; Naser Al-Isa, 2000; Al Yazeedi & Berry, 2019; Alshaikh *et al*., 2017). Therefore, there is a need for evidence regarding the BMI classification accuracy in the Arab population in order to assess the extent of bias these surveys and studies would have and so to avoid any delay in addressing this epidemic issue.

The misclassification of the obesity (high fatness) problem due to the application of BMI extends beyond the potential bias in obesity prevalence estimation (Rothman, 2008). In most studies, BMI has been applied as a proxy exposure variable for body fatness in testing for associations between obesity and educational attainment, cognition, and health outcomes (Booth *et al*., 2014; Martin *et al*., 2018). In other studies, BMI has been used to test links between obesity as an outcome and some potential exposures such as sedentary behaviour and physical activity (Janssen *et al*., 2019; Basterfield *et al*., 2012). In one study, they measured a 2-year change in sedentary behaviour and physical activity in a UK representative sample of 403 children aged 6 to 7 years and the concurrent change in adiposity measured by BIA as well as the BMI Z-score according to the UK 1990 population reference data (Basterfield *et al.*, 2012). They found that the decline in physical activity and the increase of sedentary behaviour were significantly associated with an increase in body fatness, but not in the BMI-Z score (Basterfield *et al.*, 2012). These findings consistently indicate that the measurement of body composition would provide more sensitivity than proxy measures when assessing associations (Rothman, 2008; Jiménez-Pavón *et al.*, 2010). Therefore, the extent to which BMI misclassifies high fatness affects the extent to which research can recognise obesity as a vital outcome or exposure in epidemiological studies (Rothman, 2008).

The low sensitivity of BMI should be considered where prevalence estimates and comparisons are made to reduce bias (Reilly *et al.*, 2010; Reilly *et al.*, 2018; Hruschka and Hadley, 2016). In addition, both specificity and sensitivity of BMI are vital for identifying the fattest children and adolescents and those who are at greatest risk of the comorbidities of obesity. (Reilly, 2005; Reilly, 2006; Reilly, 2010; Rothman, 2008; WHO, 1995). High specificity is preferable in the clinical setting to be sure that anyone defined obese by BMI has high body fatness and to avoid the diagnosis of non-obese as obese and the unnecessary treatment (Reilly *et al.*, 2002; Reilly, 2005; Reilly *et al.*, 2006; Reilly *et al.*, 2010; WHO, 1995). However, high sensitivity is important for public health monitoring and surveillance of obesity as low-moderate sensitivity means that the prevalence of those with high fatness is underestimated (WHO, 1995; Reilly *et al.*, 2002; Reilly, 2005). Improving sensitivity by using a lower BMI cut-off might be a better option to avoid prevalence underestimation, e.g. in national surveys, the overweight cut-off might be a better option than the obesity cut-off (Diouf *et al*., 2018; Javed *et al*., 2015; Reilly *et al*., 2010; Okorodudu *et al*., 2010; Reilly *et al*., 2002).

Finally, the use of appropriate BMI cut-off points that provide a balance between specificity and sensitivity is essential for making reliable comparisons between studies and populations, measuring obesity trends, revealing the relationship between adiposity and health outcomes, and evaluating public health intervention for obesity surveillance, prevention, and treatment (Hruschka & Hadley, 2016).

4. Prevalence of obesity – worldwide

Child and adolescent obesity prevalence has been on a dramatic rise over the last thirty years, with marked variations in the levels and trends across nations and potential stabilisation in western high income countries in the last decade or so (Hruby & Hu, 2015; Ng *et al*., 2014). According to the WHO, 38 million children (<5 years) were overweight or obese in 2019, and over 340 million children and adolescents (5.0-19.9 years) were overweight or obese in 2016 (WHO, 2020). Ng *et al*., (2014) reported the change in the prevalence of overweight and obesity between 1980 and 2013 in 188 countries by developmental status. In developed countries, the prevalence of overweight and obesity in children and adolescents had increased from around 17% in boys and 16% in girls to 24% in boys and 23% in girls (Ng *et al*., 2014). While in the developing countries, the prevalence of overweight and obesity in children and adolescents had increased from 8% to 13% in boys and from 8% to 13% in girls (Ng *et al*., 2014).

In the United States of America (USA), the prevalence of obesity in children and adolescents aged 2-19 years using the CDC reference was 19% in 2016 and affected about 14 million children and adolescents (Hales *et al*., 2017). Importantly, during a period of 10 years, there was no significant change in childhood obesity in the USA (Hales *et al*., 2017). In Europe, the data on childhood obesity (6-9 years) are reported by the WHO European Childhood Obesity Surveillance Initiative (COSI) study. In the first round (2007-2008) of COSI study, the prevalence of obesity using the WHO reference ranged from 6% to 27% among boys and from 5% to 17% among girls (Wijnhoven *et al*., 2014). In the COSI round (2012-2013), the prevalence of obesity in 19 countries was 6%–28% among boys and 4%–20% among girls (WHO Regional Office for Europe, 2018). Whereas in the 2015-2016 round, the prevalence of obesity in 14 countries was 5–21% among boys and 5–15% among girls, with the highest prevalence of childhood obesity in southern Europe (WHO Regional Office for Europe, 2019).

In the past 15-20 years, stabilisation of childhood obesity has been shown in some parts of the world as mentioned earlier (Rokholm *et al*., 2010; Wabitsch *et al*., 2014). Olds *et al*., (2011) reported high quality evidence, including data for close to half a million children and adolescents between the ages of 2-19 years old from the USA, Switzerland, Sweden, New Zealand, the Netherlands, France, England, China, and Australia indicating that the prevalence of overweight and obesity in children and adolescents seems to be plateauing at different levels. However, the rate of change in obesity prevalence across these nations is influenced by age, sex, ethnicity, and socioeconomic status (Olds *et al*., 2011).

The prevalence patterns and trends of obesity in the developing countries might be different from those shown in developed countries where the prevalence of obesity is usually higher in groups with lower socioeconomic status and in rural areas (Popkin *et al*., 2012; Wang & Lim, 2012; Popkin & Gordon-Larsen, 2004). The developing nations that have been experiencing fast economic transformation show rapidly increasing childhood obesity, especially among the urban populations in higher socioeconomic groups (Wang & Lim, 2012). In addition, while many low- and middle-income countries are still dealing with the burden of undernutrition and infectious diseases, overnutrition and its associated noncommunicable diseases have emerged causing a double burden of malnutrition, affecting population at the individual, household, and country levels (Caballero, 2005; Popkin & Gordon-Larsen, 2004). This double burden is especially prevalent in countries with the lowest income due to rapid increases in the prevalence of overweight and obesity along with a slower drop in the prevalence of undernutrition in these countries, namely south and east Asia, sub-Saharan Africa, and the Pacific (Popkin *et al*., 2020a). Although urbanisation has been associated with increased prevalence of obesity in low- and middle-income countries, new evidence suggests that the burden of obesity seems to shift from urban to rural areas (NCD-RisC, 2019; Popkin, 2019; Jaacks *et al*., 2015). The NCD-RisC (2019) reported that more than 55% of the global rise in obesity from 1985 to 2017 was in rural areas, mainly among women in low- and middle-income countries (NCD-RisC, 2019).

In summary, childhood and adolescent obesity prevalence has been on the rise globally with a potential stabilisation in the western world recently. The rate of change in obesity prevalence varies between countries and from one region to another. While the rate of increase is rapidly rising in some countries, the rate is slowing down or staying at a high level in other parts of the world.

4.1 Prevalence of obesity in the GCC and some Middle East countries

High prevalence of obesity, compared to most of the world, seems to exist among children, adolescents, and adults in the Gulf region (Musaiger & Gregory, 2000; Sorkhou *et al*., 2003; Naser Al-Isa *et al*., 2000; Al Yazeedi & Berry, 2019; Nahhas *et al*., 2018; Alshaikh *et al*., 2017). It has been estimated that 25–40% of children and adolescents and two-thirds to three-quarters of adults were overweight or obese in the GCC countries in the late 2000's (Ng *et al*., 2011). A systematic review of the prevalence studies in the Gulf region between 1990 and 2009 found that the prevalence of obesity among adolescents (10-18 years) in the Gulf region was higher than that in their American counterparts, and Kuwait had the highest prevalence of adolescent obesity (40–46%) among the GCC countries (Ng *et al*., 2011). The prevalence of obesity among female adolescents was especially pronounced in Kuwait, Qatar, and UAE. In addition, Kuwait and Saudi Arabia showed a higher rate of obesity increase in the Gulf region (Ng *et al*., 2011).

In the WHO Mediterranean region, the GBD 2015 Eastern Mediterranean Region Obesity Collaborators reported that the prevalence of obesity increased from 15% to 21% among adults in the period 1980-2015. Besides, the burden of obesity associated death and disability-adjusted life years (DALYs) for all age groups accounted for 10% and 6% of total deaths and DALYs, respectively (GBD 2015 Eastern Mediterranean Region Obesity Collaborators, 2018). Musaiger *et al*., (2016) compared the prevalence of overweight and obesity among adolescents (15-18 years) in eight Arab countries (Palestine, Jordan, Iraq, Kuwait, Saudi Arabia, Sudan, Libya and Tunisia). The highest prevalence of overweight and obesity among these countries was reported in Kuwaiti adolescents, both males and females (Musaiger *et al*., 2016). In addition, Kuwait, Qatar, and Libya were among the world countries where the prevalence of obesity in adult females exceeds 50% (Ng *et al.*, 2014). Among the GCC countries, Kuwait, Saudi Arabia and Qatar had the highest prevalence of overweight and obesity in adults (Ng *et al.*, 2011) as well as the highest prevalence of type 2 diabetes (Samara *et al.*, 2019). The overall prevalence of obesity in adult women in the GCC countries is very high as shown in **Table 2**. It has been consistently higher in women than in men and it would be worse now if obesity prevalence has continued to rise.

Table 2. Prevalence of obesity in adults in Gulf countries (WHO, 2010)

Country	Gender	
	Male (%)	Female (%)
Kuwait	36	48
Saudi Arabia	28	44
UAE	25	42
Bahrain	21	38
Qatar	19	32
Oman	8	17

Despite the evidence of the obesity epidemic above, there is still insufficient data using the most recent definitions of obesity in most of the Middle East countries (De Onis *et al.*, 2012). In addition, the comparison between childrens' data is very difficult due to the different obesity definitions used in each study (Mirmiran *et al.*, 2010). On the other hand, there have been a limited number of studies and surveys targeting obesity in Arab children and adolescents compared to other countries (AlMarri *et al.*, 2017; Alsharif *et al.*, 2018; Nahhas *et al.*, 2018; Rabeea *et al.*, 2019). Further, there is a lack of systematic reviews that summarise and synthesise conclusions about the overall picture in the region so that more thoughtful steps can be taken to improve both the physical and mental health of the targeted population (AlMarri *et al.*, 2017). More details about this issue are provided in chapters 2 and 3.

4.2 Prevalence and trends of obesity in Kuwait

So far, this section has dealt with global obesity prevalence, then GCC prevalence, and now a closer look will be taken at the prevalence of obesity in Kuwait since the present thesis focuses on Kuwait. As noted in section 4.1, the prevalence of obesity is very high in the GCC countries and possibly the highest prevalence in the GCC is in Kuwait (Musaiger & Gregory, 2000; Sorkhou *et al*., 2003; Naser Al-Isa, 2000; Ng *et al*., 2011; Al Yazeedi & Berry, 2019; Nahhas *et al*., 2018; Alshaikh *et al*., 2017).

The Kuwait Nutrition Surveillance System (KNSS) is a national sentinel surveillance system coordinated by the Kuwait Ministry of Health (KNSS, 2016). It was developed in 1995 in collaboration with CDC and WHO (Global Health Data Exchange, 2020). Anthropometric data and key indicators of health and nutrition are collected on a regular basis from various age groups and reports are sent annually to WHO (KNSS, 2016). In 2007, KNSS started using the reformed WHO child growth reference to define obesity (De Onis *et al*., 2012). According to the data provided by the KNSS (2010) shown in **Figure 1**, the prevalence of obesity is higher among adults and adolescents than in children, and the prevalence increases with increasing age.

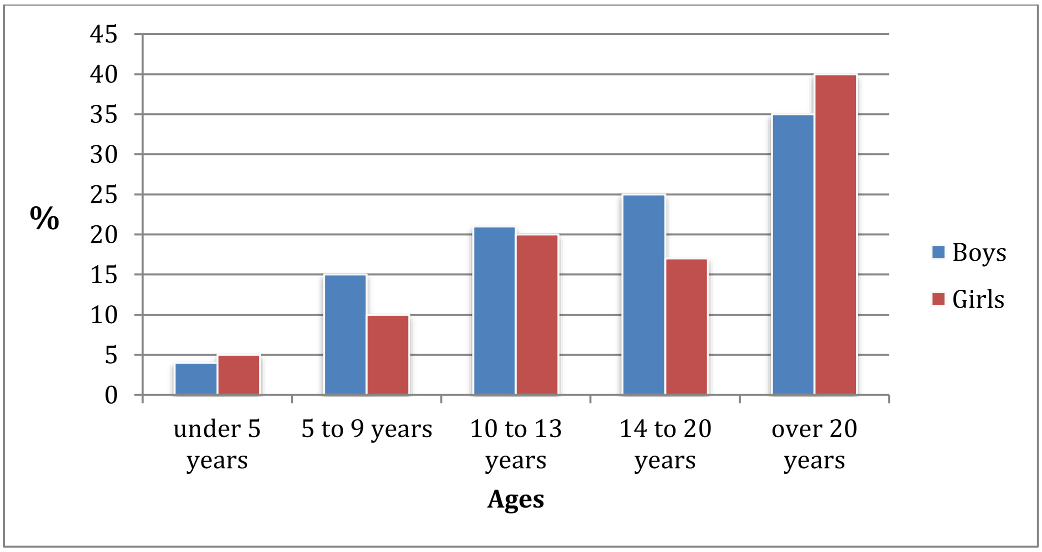

Figure 1. Prevalence of WHO-defined obesity in Kuwait (Adapted from KNSS, 2010)

In 2013, the prevalence of obesity in a sample aged 6-18 years was reported using the three different references: CDC = 34%, IOTF = 28%, WHO = 31% (Elkum *et al.*, 2016). Rey-López *et al.*, (2019) conducted a cross sectional study on data from the Study of Health and Activity among Adolescents in Kuwait (2012-2013). They reported that over half of the adolescents (N=591) were overweight or obese based on IOTF BMI cut-offs. The prevalence of overweight was found to be higher in boys, while the prevalence of obesity was higher among male adolescents (Rey-López *et al.*, 2019). In 2015, the Global School-based Student Health Survey (GSHS) based on WHO reference reported the overall prevalence of obesity in 3637 students (13-17 years) to be 23%, with 28% in males, and 18% in females (WHO, 2015). According to national reports of KNSS using WHO definitions, the prevalence of overweight and obesity in children and adolescents (5-19 years) in 2016 was 20% and 26%, respectively, given that the prevalence of obesity was higher in males than females starting from age 9 to 17 years (KNSS, 2016). In 2018, the estimates of overweight and obesity in the same age group increased to 21% and 27%, respectively (KNSS, 2018; World Obesity Federation, 2019) [unpublished KNSS data reported in the World Obesity Federation/ Global Obesity Observatory].

In adults, a review article which included 18 studies with representative samples reported that the overall prevalence of obesity in Kuwaiti adults ranged from 24% to 48% with an increasing trend between 1980 and 2009 (Karageorgi *et al*., 2013). Ahmed *et al*., (2012) analysed the data from the KNSS from 1998 and 2009 and reported that obesity prevalence in adult females exceeded that in males for all years and age groups, and the prevalence had increased by 11% in males and 15% in females over that time (Ahmed *et al*., 2012). In 2014, the prevalence of overweight and obesity (defined by WHO BMI and WC cut-off points) in a sample of 3,915 Kuwaiti adults was 37% and 40%, in males and females respectively (Weiderpass *et al*., 2019) – see more details in chapter 4 . According to the KNSS in 2016, the overall prevalence of overweight and obesity among Kuwaiti adults (N=1540, age >19 years old) was 78% and 44%, respectively, without specifying the estimates by gender (KNSS, 2016). While in 2018, the annual report of KNSS showed that the prevalence of obesity in men was 36% and 49% in women (KNSS, 2018; World Obesity Federation, 2019) [unpublished KNSS data reported in the World Obesity Federation/ Global Obesity Observatory].

Overall, the prevalence of obesity in children, adolescents, and adults has reached alarming levels in Kuwait. The estimates provided by the national surveys as well as the cross-sectional studies in such a small country with a homogenous population exceed those reported in other big countries with a heterogeneous population, such as the USA. The effects of socioeconomic, cultural, and environmental factors on the prevalence of obesity in Kuwait are given in section 8 of this chapter.

5. Health consequences of obesity

Most of the evidence on adverse effects of high BMI is based on obesity, but not overweight, so obesity is the focus of this thesis.

Obesity is associated with multiple physical and psychological comorbidities (Dietz, 1998; Reilly, 2005). Therefore, the definitions of obesity in children, adolescents, and adults aim to identify those who are at the greatest risk of these comorbidities associated with obesity (Reilly, 2010). As noted briefly earlier, childhood obesity has both short- and long-term health effects, which leads to serious complications affecting different life stages; i.e. both the obese child and the adult who suffered childhood obesity (Reilly, 2010; Reilly, 2005; Bridger, 2009). Systematic reviews have shown that obesity in childhood and adolescence tends to persist into adulthood (Parsons *et al*., 1999; Reilly *et al*., 2003; Reilly, 2005; Singh *et al*., 2008). If the child by the time of adolescence is obese, there is usually a high probability to stay obese as an adult (Reilly, 2010; Reilly, 2005; Bridger, 2009). In addition, the onset of obesity-related disorders at an early age predicts worsening of health complications that usually start later in life and that means earlier morbidity and mortality, which in turn affects both life quality and life span (Dietz, 1998; Kelsey *et al*., 2014).

In this section, both the short- and long-term impacts of obesity are discussed briefly.

5.1 Health consequences of obesity in children and adolescents

There has been a vast body of evidence on the association of obesity with impaired indicators of cardiometabolic health in children and adolescents (Reilly, 2005; Bridger, 2009; Cote *et al*., 2013). Several systematic reviews have reported that obese children and adolescents had at least one of the following cardiovascular risk factors - abnormal lipid profile, high blood pressure, abnormalities in left ventricular and endothelial function, and chronic low-grade inflammation (Reilly *et al*., 2003; Reilly, 2005; Kelishadi *et al*., 2015). In addition, obesity in childhood and adolescence has a detrimental impact on glucose metabolism and insulin resistance (Bridger *et al*., 2009; Weiss & Caprio, 2005; Hannon *et al*., 2005). Impaired glucose tolerance has shown to progress gradually over time into insulin-dependent Type 2 diabetes, and the rapid transition into diabetes was shown to be associated with significant increases in weight in children and adolescents, while the transition from impaired to normal glucose tolerance was associated with weight loss (Weiss *et al*., 2005; Wiegand *et al*., 2005). A study conducted in the US to determine the prevalence of overweight and obesity among children and adolescents between ages 3 and 19 years reported that the prevalence of overweight and obesity among those diagnosed with type 2 diabetes was 10% and 79%, respectively (Liu *et al*., 2010). In addition to diabetes, both non-alcoholic fatty liver disease and metabolic syndrome have been shown to be prevalent in obese children (Gupta *et al*., 2012; Bridger, 2009; Weiss & Caprio, 2005).

Childhood obesity may contribute to implications in the respiratory system. Asthma has been noted to be prevalent among adolescents and children who are overweight and obese (Reilly, 2005; Beuther *et al*., 2006; Boulet, 2013; Sansone *et* *al*., 2020). In one meta-analysis by Chen *et al*., (2013), rates of asthma among children also increase as their weight becomes higher (Chen *et al*., 2013). In addition, the association between the degree of obesity and asthma has been shown to substantially vary by race/ethnicity. A population-based cross-sectional study done in the US reported that youths with moderate and extreme obesity (defined as BMI-for-age > 95^{th} percentile, and BMI-for-age ≥1.2 times the 95^{th} percentile, respectively, according to CDC reference) had a 37% and 68% higher asthma frequency, respectively, and the prevalence of asthma was higher in non-Hispanic white and Asian/Pacific Islander youth than in black or Hispanic youth (Black *et al*., 2012). Moreover, higher child body weight has been associated with lower lung volume that may, in turn cause impaired lung function (Davidson *et al*., 2014). Further, children with obesity showed increased risk of sleep apnoea represented by a diminished apnoea-hypopnea index and minimum oxygen saturation in obese children as compared to underweight and normal-weight children (Kang *et al*., 2012).

Childhood obesity has been also associated with other implications, including orthopaedic, gastrointestinal, renal, and psychosocial complications (Han *et al*., 2010; Dietz, 1998). The relationship between obesity and mental health in children and adolescents is discussed in section 5.3.

5.2 Health consequences of obesity in adults

Paediatric obesity appears to persist over time, and this constitutes a warning for a rising incidence of obesity among adults in the future besides the current high prevalence of adult obesity (Reilly, 2010; Reilly, 2005; Reilly *et al*., 2018). A study revealed that being obese at the age of five raised the risk of suffering from diabetes at twenty-one years of age when compared to those children having a normal weight at age five (Al Mamun *et al*., 2009). Reilly and Kelly (2011) conducted a systematic review on the long-term impacts of being obese and overweight in childhood and adolescence on the person's health in adulthood. They found a significant increased risk of cardiometabolic morbidity, including coronary heart disease, stroke, hypertension, ischaemic heart disease, and diabetes (Reilly & Kelly, 2011). Moreover, they reported increased risk of polycystic ovary syndrome, asthma, premature disability and premature death, and reliance on sickness and early retirement benefits during adulthood (Reilly & Kelly, 2011). In line with these findings, other health implications, including non-alcoholic fatty liver disease, obstructive sleep apnoea, orthopaedic complications, psychiatric disease, infertility, and increased risk of hormone-influenced cancer, were also reported in adults who were obese as children (Kelsey *et al*., 2014).

Moreover, the GBD 2015 Obesity Collaborators (2017) reported that obesity accounted for about 4 million deaths and 120 million DALYs worldwide in 2015, with cardiovascular disease, followed by diabetes, being the leading causes of death among obese individuals (GBD 2015 Obesity Collaborators, 2017). More recently, studies have been conducted to determine the impact of obesity and overweight on the risk of contracting COVID-19. With increased risk of hospitalization among obese adults and adolescents, they have a higher chance of exposure to COVID-19, among other life-threatening infections that could easily be spread within the hospital or general environment (Kassir, 2020). In addition, a systematic review of 75 studies showed that obesity increases the risk of individuals contracting COVID-19 by up to 50% (Popkin *et al*., 2020b). Some of the obesity effects that have been reported included inadequate mechanical ventilation response and diminished lung function, hence placing obese individuals at a greater risk of mortality and severe sickness from COVID-19 (Caci *et al*., 2020). Some information from New York City indicates that obesity can be a risk factor for intensive care unit admission among individuals who have contracted COVID-19, specifically in individuals 60 years of age and below (Lighter *et al*., 2020). In one of the French studies, the risk of mechanical ventilation use among COVID-19 patients admitted at the ICU was seven times higher for individuals with BMI >35 when compared to those with lower BMI (Simonnet *et al*., 2020). In Kuwait, one study revealed that diabetes and obesity in individuals suffering from COVID- 19 was connected to ICU admission, making such individuals at higher risk of poor health outcomes (Al-Sabah *et al*., 2020).

In addition to the health effects of obesity, obesity in adolescence has been shown to affect social and economic outcomes in early adulthood, such as the level of income and educational attainment. These effects might be more marked in women than in men (Reilly *et al*., 2003, Reilly, 2005).

5.3 Impact of child and adolescent obesity on mental health

Many studies have tried to determine the relationship between obesity and psychological/mental health challenges in children and adolescents (Luppino *et al*., 2010; Tiffin *et al*., 2011; Small & Aplasca, 2016). Systematic reviews have reported a large body of evidence that children with obesity are at a higher risk of experiencing psychological complications than those without obesity, and that risk is greater in girls than in boys and the consequences increases with age (Reilly *et al*., 2003; Sanders *et al*., 2015). In addition, research has shown that obesity in children and adolescents is associated with several psychosocial factors, including anxiety, depression, body dissatisfaction, lower self-esteem, eating disorder symptoms, and emotional problems (Russell-Mayhew *et al*., 2012, Sahoo *et al*., 2015). However, the extent to which these factors would affect obese children and adolescents may vary by age and gender (Russell-Mayhew *et al*., 2012). A systematic review by Griffiths et al., included 17 self-esteem and 25 quality of life studies showed a significant decline in self-esteem and quality of life among obese children and adolescents, with no clear differences of the effects between children and adolescents (Griffiths *et al*., 2010).

A full discussion on the effects of obesity on mental health is beyond the scope of the thesis, except for what might explain mechanisms relating obesity to educational attainment and cognition as discussed below.

Behavioural problems and low self-esteem are probably the most frequently experienced comorbidities among obese children and adolescents (Strauss, 2000; Reilly, 2005; Franklin *et al*., 2006; Griffiths *et al*., 2010; Gow *et al*., 2020). The relationship between obesity and psychosocial health could be further explained through their association with a number of behavioural mechanisms, such as stigmatisation, teasing, victimisation, and bullying (Russell-Mayhew *et al*., 2012). Obesity has been considered as one of the most stigmatising issues during childhood and adolescence, and obese girls seem to be more stigmatised than obese boys (Tang-Péronard & Heitmann, 2008). In addition, obese children and adolescents are at a higher risk of being victimised by bulling and teasing compared to non-obese peers (Jansen *et al*., 2014; Lampard *et al*., 2014). Puhl and Latner (2007) reported that children tend to show weight bias by linking obesity with negative traits and preferring to make friendships with non-obese peers. Besides, the children who have more negative attitudes towards obesity tend to bully and tease obese peers (Puhl & Latner, 2007).

Moreover, children who have faced obesity at the age of five are more likely to suffer from depression in their adulthood (Sánchez-Villegas *et al*., 2010). Further, obese children and adolescents are more likely to be exposed to various mood disorders when they become adults, and the risk of depression was higher in females who were obese in either childhood or adolescence (Sanderson *et al*., 2011; Korczak *et al*., 2013). More details about the mental health (related) consequences of obesity on educational attainment and cognitive function are found in section 6.2 of this chapter.

In conclusion, most of the studies about the relationship between obesity and mental health and their effects in childhood and adolescence were conducted in western high-income countries, which may not be applicable to the low-middle income countries or the non-western world (Sahoo *et al*., 2015; Griffiths *et al*., 2010). Therefore, more research is needed to fill this gap and better understand the direction and resolution of such relationships.

6. Association between child/adolescent obesity and educational attainment

The relationship between health and educational attainment is well established and intensively studied (Haas & Fosse, 2008; Silles, 2009; Basch, 2011; Eide & Showalter, 2011; Braveman *et al*., 2011; Shankar & Park, 2016). Studies based on links between educational attainment and health have concluded that there is a bi-directional relationship and that generally healthier children and adolescents tend to obtain better educational outcomes and those who achieve educational success tend to have better health outcomes (Currie, 2009). Further, these influences are likely to be confounded by parental SES. In addition, studies have been undertaken on whether educational success may be of benefit with regard to the psychological and social factors associated with health (Egerter *et al*., 2009, Topitzes *et al*., 2009), or whether poor educational attainment could possibly lead to anxiety and/or depression causing potential mental health issues at a later date (Dadaczynski, 2012; van Lier *et al*., 2012).

Obesity is one complex health condition that is associated with a variety of interrelated physical and psychological factors, which have to be considered when assessing the association between obesity and education (Cohen *et al*., 2013, Preiss *et al*., 2013). Booth *et al*., (2014) examined the longitudinal association between obesity and subsequent academic attainment in adolescents using a large UK cohort (N=5966), the Avon Longitudinal Study of Parents and Children (ALSPAC). They found that girls, but not boys, with obesity (defined by BMI z-score ≥ 1.64, equivalent to ≥ 95^{th} percentile relative to UK 1990 population reference data) at 11 years old had lower academic attainment (assessed by national tests at 11, 13, and 16 years old) compared with heathy weight peers. Importantly, this association was independent after controlling for potential mediators, including intelligence quotient (IQ), depressive symptoms, and age of menarche in females, which may suggest a causal relationship between obesity and poor academic attainment in female adolescents (Booth *et al*., 2014). These results may also suggest gender difference or different underlying mechanisms mediating the relationship between adolescence obesity and academic attainment. These mechanisms are discussed in more detail in section 6.2.

Two older literature reviews on the relationship between obesity and academic attainment in children and adolescents concluded that obese individuals performed less well than their healthy counterparts did (Taras & Potts-Datema, 2005; Caird *et* *al*., 2011). Since then, more evidence has emerged. In the following section, recent systematic reviews on obesity-attainment associations are discussed.

6.1 Recent systematic reviews on obesity, educational attainment, and aspects of cognitive function

Santana *et al*., (2017) conducted a systematic review of 34 studies (23 cross-sectional studies and 11 longitudinal studies), sample size from 37 to 18,746 participants, on the association between obesity and educational attainment in school children and adolescents between 1990 and 2016. They reported that 11/23 cross-sectional studies and 4/11 longitudinal studies showed a significant negative association between obesity and academic performance. However, this association became uncertain after controlling for SES, parental education, and other health-related risk factors. Overall, due to insufficient data, Santana and colleagues concluded that there is no strong evidence to support a direct link between obesity and low academic performance in children and adolescents (Santana *et al*., 2017).

Martin *et al*., (2017) carried out a systematic review of 31 studies with a focus on longitudinal studies (17 cohorts), sample size from 405 to 21,260 participants aged 3-18 years old. The findings suggested that the association between childhood obesity and academic attainment may differ by age, sex, and school subject. There was no strong evidence of an association between obesity and reading/language, composite attainment, and science achievement in boys and girls. However, a significant negative association between obesity and maths achievement was found in adolescent girls, while this association was not evident in obese boys or preschool obese girls. With regards to the plausible mediating factors for obesity-academic achievement associations, psychosocial factors such as weight-based bullying and poor executive functions were suggested (Martin *et al*., 2017).

Most research studies and systematic reviews on obesity-education association have focused on school children. However, obesity has been shown to have long-term impact on social and economic status of adolescents and young adults (Reilly *et al*., 2003, Reilly, 2005). Similarly, poor academic achievement may possibly have subsequent social and economic implications (Deary & Johnson, 2010). In addition, obesity at a young age tends to persist into adulthood, therefore, the influence of obesity on academic attainment needs to be captured beyond primary and secondary school. With a limited evidence base, Hill *et al*., (2018) conducted a systematic review on the association between obesity and tertiary education using 16 studies (6 cross-sectional studies and 10 longitudinal studies), sample size from 77 to 752,283 participants aged 16 years old and above. All cross-sectional studies and 8/10 longitudinal studies (with low risk of bias) showed convincing evidence that obese students had poorer educational achievement at college and university compared to normal weight peers (Hill *et al*., 2018). The evidence was stronger regarding the impact of obesity on the completion of the degree rather than the likelihood of enrolment. Considering gender differences, females were more likely to be affected with weight bias than males in higher education (Hill *et al*., 2018). In addition, tertiary attainment is likely to be affected to a lesser extent than school attainment by socioeconomic disadvantage, which may offer an opportunity to detect the direct influence of obesity on educational attainment (Hill *et al*., 2018).

In conclusion, the evidence of the impact of childhood and adolescence obesity on educational attainment is inconsistent. While obesity in children and adolescents was negatively associated with academic achievement in several studies, in some studies this negative relationship was shown to be weakened after adjusting for other factors that are associated with both obesity and education (i.e. confounding and mediating variables), indicating that part of the association between obesity and education attainment might be indirect, i.e. obesity may affect educational attainment indirectly through the mediating variables, such as psychosocial factors and patho-physiological factors that are discussed in more detail in the next section (6.2).

On the other hand, clearer evidence on the negative association of obesity and academic performance was shown in higher education, with females being more affected than males. Moreover, the majority of studies in the 3 reviews discussed above took place in western high income countries (N of studies in USA=44, Canada=4, Australia=4, UK=4), with lack of evidence from the GCC countries and thus more research addressing this association in a different cultural context is needed. More discussion on the cultural differences that may affect obesity-educational attainment association in the GCC countries are given in section 8.

6.2 Mechanisms of any effect of obesity on educational attainment

As indicated above, it was not possible to detect causality between obesity and educational attainment in children and adolescents due to the use of observational studies (Caird *et al*., 2011; Martin *et al*., 2017; Santana *et al*., 2017, Hill *et al*., 2018). In addition, the evidence from lifestyle intervention studies was unclear, except that physical activity may improve some aspects of cognitive function in children and adolescents (Martin *et al*., 2018). Given the complexity of obesity development and its consequences (Reilly *et al*., 2007), the negative association between obesity and academic attainment and its associated outcomes was shown to be partly explained by a number of mechanisms that may have direct or indirect effects as discussed below.

Pathophysiological factors

Obesity may affect child and adolescent academic performance indirectly through its impact on their physical health. Chronic physical diseases associated with obesity, such as asthma, OSAS, and orthopaedic problems, may cause student frequent absenteeism or less productivity (Pan *et al*., 2013). Children and adolescents with frequent school absences are at risk of poorer academic achievement, social problems, non-completion of school, and non-enrolment in university (Gottfried, 2011; Allen *et al*., 2018). An *et al*., (2017) conducted a systematic review on the relationship between obesity and school absenteeism in children and adolescents. Among the 13 studies, 11 of them reported a significant association between overweight/obesity and absenteeism. The meta-analysis also showed that the odds of being absent from school among overweight and obese students were 27% and 54%, respectively, higher than among their normal weight counterparts (An *et al*., 2017). A cross-sectional study (N=3812, age 8-17 years) reported that students with asthma experienced more absence days compared with other students, and that absenteeism was significantly inversely associated with test level performance (Moonie *et al*., 2008).

Moreover, obese children and adolescents are more likely to have sleep deprivation and interrupted sleep due to disordered breathing (Chen *et al*., 2008; Beebe *et al*., 2007). Tan *et al*., (2013) found that children and adolescents with obstructive sleep disorders reported significantly more school problems than those without obstructive sleep disorders (Tan *et al*., 2013). In addition, obese adolescents (N=163, age 10-17 years) with increased severity of sleep disordered breathing had more learning and attention difficulties (Beebe *et al*., 2010). Nocturnal asthma in children and adolescents was associated with reduced school attendance and performance (Diette *et al*., 2000). Reynolds *et al*., (2018) examined the combined associations of common comorbidities, including obesity, allergic rhinitis, and sleep disordered breathing, on sleep and academic performance among children (N= 249, age 7-9 years) with persistent asthma. The results of this small study suggested that children with multiple comorbid conditions were at greater risk for shorter sleep duration and more frequent school absences (Reynolds *et al*., 2018). In addition, poor sleep negatively affects the ability of children to focus in school, which in turn affects their educational attainment adversely (Tan *et al*., 2013; Spruyt & Gozal, 2012). Daytime sleepiness was associated with increased odds of failing mathematics and languages in children and adolescents (Perez-Chada *et al*., 2009). Spruyt and Gozal (2012) assessed the relationship between sleep disordered breathing and cognitive function in obese children (N=351, age 6-10) and found that sleep disordered breathing was responsible for one third of the lower cognitive performance in obese children (Spruyt & Gozal, 2012).

Psychosocial factors

Obesity related pathophysiological factors have also been associated with psychosocial consequences in children and adolescents (Clarke & Currie, 2009). There is a growing evidence linking OSAS and sleep disordered breathing with internalising problems (such as anxiety, emotion dysregulation, and depression) and externalising behaviour problems (such as impulsivity, aggression, and hyperactivity) as well as diminished neurocognitive and academic functioning (Blechner & Williamson, 2016). Independent of the degree of obesity, obesity-related sleep difficulties in a sample (N=150, age 6-12 years) were associated with increased symptoms of depression and reduced quality of life (QOL) (Whitaker *et al*., 2018).

In addition, having mental health (related) conditions and behavioural problems are associated with increased absenteeism among students (Allen *et al*., 2018). In one study including 423 high school students, absenteeism was shown to be negatively related to academic achievement as well as to personal factors such as academic self-perception, goal valuation, motivation/ self-regulation, and attitudes towards teacher and school (Balkıs *et al*., 2016). Among female university students in Canada, overweight and obese students reported lower Grade Point Average (GPA), lower sense of academic self-efficacy, and higher depressive symptoms compared to normal-weight peers, with no differences in sociodemographic variables (Aimé *et al*., 2017). Importantly, depressive symptoms were significantly associated with BMI, but not with GPA, indicating the detrimental impact of obesity associated mental health consequences on academic performance (Aimé *et al*., 2017).

As mentioned in section 5.3, obesity in children and adolescents has been associated with behavioural problems, such as discrimination, teasing, and weight bias, which may mediate obesity-attainment associations. Obese children and adolescents are more likely to experience weight related distress and social rejection (Krukowski *et al*., 2009), which are proposed to affect academic performance (Caird *et al*., 2011). Assessing the association between psychological behaviours and academic performance in obese students (N=84, Age 7-13 years), teasing/social rejection was significantly highly reported by students and their parents in one study in Iceland (Gunnarsdottir *et al*., 2012). After controlling for demographics, parental depression and life-stress, and students' physical activity, teasing/social rejection was a significant contributor to poor psychological adjustment as well as low academic competencies among obese students (Gunnarsdottir *et al*., 2012). In addition, some studies have shown that obese girls are more likely to experience stigmatisation than boys (Tang-Peronard & Heitmann, 2008), which may explain why the association between obesity and educational attainment may be stronger in girls than in boys (Palermo & Dowd, 2012; Booth *et al*., 2014; Martin *et al*., 2017). However, Martin *et al*., (2017) further explored the psychosocial factors that may explain the association between obesity and academic achievement in focus groups with four obese adolescent girls (aged 12–15 years) and their parents, who perceived that, although body weight did not necessarily influence their academic achievement, body weight did influence their school experiences. They also reported negative weight-related experiences including peer stigmatisation and teasing, especially during Physical Education, which in turn caused them to perform less well in that class. However, the adolescent girls and their parents perceived that social isolation and lack of friends due to weight bias experienced at school could be a reason for their good overall academic performance since they are less distracted with peer relationships (Martin *et al*., 2017).

In addition to peer weight-related bias and stigmatisation, teacher bias has been suggested as a potential pathway in the obesity-attainment association. MacCann and Roberts (2013) compared the school grades (GPA) and test scores of students from middle-schools (N=383, age 12-15 years) and community colleges and universities (N=1036, age 18-25 years) drawn from five regions in the United States. Although there was no significant difference in test scores for intelligence (in middle-school students) or achievement (in college and university students) between obese and normal-weight students, obese students received significantly lower grades than their non-obese peers in middle school, community college, and university even after controlling for demographic and personality variables (MacCann & Roberts, 2013). A recent study compared the attitudes and stereotypes towards obesity between Physical Education (PE) teachers (N=81) and mathematics teachers (N=75) and evaluated the association between the teacher bias and the level of physical activity of their students (N=1792, age 12-16 years) (Carmona-Márquez *et al*., 2021). There were no statistically significant differences in the biases between PE teachers and mathematics teachers. About 80% of the teachers showed implicit negative attitudes, however, the PE teachers had stronger bias towards the association between laziness and obesity. Moreover, the PE teacher bias was a significant predictor of the lack of physical activity in adolescents (Carmona-Márquez *et al*., 2021).

Neurocognitive effects of obesity

Several studies have shown that cognitive function may predict academic performance (Spinath *et al*., 2006; Bull *et al*., 2008; Bathelt *et al*., 2019). A recent study aimed at assessing the relationship between cognition, education, and white matter network organisation in a sample (1) of normal children and adolescents (N = 63, age 6-12 years) and in a sample (2) of struggling learners (N = 139, age 5-13 years), independently (Bathelt *et al*., 2019). They reported that cognitive ability (measured by Wechsler Abbreviated Scale of Intelligence and the Automatic Working Memory Assessment in both samples) was significantly correlated with educational attainment (measured by Woodcock-Johnson Test of Achievement in sample 1, and Wechsler Individual Achievement Test in sample 2), and that cognition explained over 35% of the variance in educational attainment in both samples (Bathelt *et al*., 2019). In addition, the MRI of the whole brain showed that the white matter network was significantly positively associated with both cognition and educational attainment in both samples, with a mediating effect of cognition in the relationship between white matter organisation and educational attainment (Bathelt *et al*., 2019).

As mentioned in section 5.1, obesity in childhood and adolescence is associated with several comorbidities, including metabolic syndrome, hypertension, inflammation and insulin resistance (Reilly *et al*., 2005; Reilly *et al*., 2003; Kelishadi *et al*., 2015; Bridger, 2009; Weiss & Caprio *et al*., 2005; Hannon *et al*., 2005). These comorbidities were shown to negatively affect cognitive function and educational attainment (Lande *et al*., 2012; Yau *et al*., 2012), and the potential mechanisms underlying these comorbidities are discussed in more detail in section 7.2. Reviewing 11 observational studies of cognition and hypertension, Lande and Kupferman (2015) reported that hypertension in children and adolescents has been associated with decreased performance on neurocognitive testing, increased prevalence of learning disabilities compared to non-hypertensive counterparts, and altered cerebrovascular reactivity (CVR) (Lande & Kupferman, 2015). The CVR reflects the ability of brain blood vessels to respond to a vasoactive stimuli, and thus CVR dysfunction impairs the delivery of blood to brain regions and results in neurocognitive problems (Catchlove *et al*., 2018). In addition, adolescents with metabolic syndrome showed significantly lower cognitive function and academic achievement (mathematics and spelling scores) than those without the metabolic syndrome (Yau *et al*., 2012).

Systematic reviews have suggested that executive functions are more likely to be impaired by child and adolescent obesity than other cognitive functions (Liang *et* *al*., 2014; Smith *et al*., 2011; Lande & Kupferman, 2015). Several definitions have been used to describe executive functions such as "higher cognitive processes that allow forethought and goal-directed action" (Reinert *et al*., 2013; Pearce *et al*., 2018; Esteban-Cornejo *et al*., 2020) or "the ability to think before acting, retain and manipulate information, reflect on the possible consequences of specific actions, and self-regulate behaviour" (Tomporowski *et al*., 2015). Overall, the term executive function involves a range of mental processes, including reasoning, working memory, mental flexibility, inhibition control, problem-solving, and planning (Chan *et al*., 2008; Diamond *et al*., 2013; Booth *et al*., 2014; Tomporowski *et al*., 2015; Yang *et al*., 2018).

There has been substantial evidence that executive function plays an important role in learning during childhood and adolescence (Zelazo *et al*., 2016). In addition, relationships have been identified between specific executive functions, namely inhibition, cognitive flexibility, and working memory, and scholastic achievement (Miyake *et al*., 2000; Baggetta & Alexander, 2016). According to the model developed by Miyake *et al*., (2000) the aforementioned three domains are considered core interrelated but separable components of executive function (Miyake *et al*., 2000; Miyake & Friedman, 2012). These three core processes constitute the basis of academic performance. In an academic context, inhibition refers to the skill of suppressing automatic and dominant responses in favour of more appropriate responses (Miyake *et al*., 2000). Working memory (or updating) is the skill required to update task-relevant information by retrieving or replacing the old information in the memory (Miyake *et al*., 2000). Cognitive flexibility (or shifting) is the skill required to switch between task goals or mental sets (Miyake *et al*., 2000). In addition, inhibition was shown to support the development of shifting and updating as well as higher-order skills such as planning and goal-setting (Blair & Razza, 2007; Borragan *et al*., 2018), suggesting that inhibition may not be only a subcomponent but a common cognitive ability that partially explains performance across the host of executive function tasks (Miyake & Friedman, 2012; Butterfuss & Kendeou, 2018; Borragan *et al*., 2018).

Inhibition is generally defined as the "capacity to control one's attention, thoughts, behaviour, and/or emotions to override inappropriate actions in a given context" (Reinert *et al*., 2013; Diamond *et al*., 2013). The most frequently used tests/tasks for assessing inhibition include the Stroop test, Stop Signal task, and Go/No-Go task. The Stroop test is a neuropsychological test that has been widely in use since it was proposed by Stroop in 1935 (Stroop, 1935; Jensen, 1965; Scarpina & Tagini, 2017, Deng *et al*., 2018; Kulendran *et al*., 2017). The Stroop test is preferable over other choices since it requires suppressing an automatic but inappropriate response in order to provide a subordinate response, while Go/No-Go or Stop Signal tasks only require suppressing the dominant response without providing a response at all (Gilmore *et al*., 2015; Mason & Zaccoletti, 2020).

Inhibitory processes have shown to be implicated in reading comprehension (Butterfuss & Kendeou, 2018) as well as in bilingual speech production (Borragan *et al*., 2018) since inhibition reduces the effects of distraction and activation of irrelevant information in the memory and prevents them from interfering with comprehension (Butterfuss & Kendeou, 2018; Borragan *et al*., 2018). In addition, inhibition was associated with attainment in science, English, and mathematics in adolescents (age 11-12 years) (St Clair-Thompson & Gathercole, 2006). Mason and Zaccoletti (2020) reviewed 18 studies on the association between inhibition and science achievement at different educational levels from primary to higher education. Of the 11 studies in primary and secondary school students (age 9-18 years), 7 studies found a significant association between inhibition (measured by Stroop task in 5 studies) and science attainment (Mason & Zaccoletti, 2020). Among the university students (age 18-24 years), 6/7 studies found a significant association between inhibition and science achievement, given that inhibition was detected by brain imaging in all except one study that used Stroop task (Mason & Zaccoletti, 2020). Kamijo *et al*. (2012) measured inhibition control in preadolescent children (n =126, age 7-9 years) by completing Go/NoGo tasks and academic achievement by completing Wide Range Achievement Test 3rd edition (which measures arithmetic, reading, spelling). They reported that obese children (obesity defined by both high BMI and DEXA measured body fatness) had significantly lower inhibitory control as well as poorer academic achievement compared to the normal weight children (Kamijo *et al*., 2012).

Collectively, the effects of obesity on the neurocognitive function may be a direct mechanism explaining obesity-educational attainment association. More details about the association between obesity and executive function and inhibition are given in the next section.

7. Association between child and adolescent obesity and executive function

This section provides an overview of the empirical evidence on the association between obesity and executive function, with a focus on inhibition, and concludes with potential mechanisms for the association between obesity and executive function.

7.1 Recent systematic reviews on obesity, executive function, and inhibition

Reinert *et al*., (2013) carried out a systematic review of 31 studies on cognitive executive function in BMI-defined obesity in children and adolescents (age 2-20 years). Inhibitory control was the domain most examined in childhood studies (76.9%) as well as in adolescent studies (72.7%) included in the review. In children, obesity was significantly associated with poorer inhibitory control, and some studies reported that poorer inhibitory control at a younger age was a predictor of high BMI at a later age. In adolescents, obese individuals performed worse than healthy weight adolescents on inhibitory control tasks (Stroop task in 4 studies) as well as on attention/mental flexibility tasks (Reinert *et al*., 2013).

Yang *et al*., (2018) conducted a meta-analysis of 72 observational studies on executive function performance in obese (65 studies) and overweight (24 studies) individuals (Total N= 4904, mean age 7.9-76.9 years, using BMI definitions). Obese individuals exhibited lower executive function than normal weight counterparts across all the domains including inhibition, working memory, cognitive flexibility, planning, decision-making, and verbal fluency. Overweight individuals only exhibited significant deficits in inhibition and working memory, probably due to the smaller number of studies targeting the effects of overweight on the other domains of executive function (Yang *et al*., 2018). Of the 72 studies, 39 studies assessed inhibition in obese individuals (N=1782), and 10 studies assessed inhibition in overweight individuals (N=641). Obese as well as overweight individuals showed significantly worse performance on inhibition tasks (Stroop used in 18 studies) than the normal weight counterparts. The association between obesity and impaired inhibition was independent of age, gender, and the tasks used to measure inhibition in each study (Yang *et al*., 2018).

A systematic review by Favieri *et al*., (2019) reviewed 88 studies on the relationship between obesity (defined by BMI) and executive function in individuals aged 5-70 years, 63 were cross sectional and 28 were longitudinal studies, given that 3 studies used both designs (Favieri *et al*., 2019). Regarding the overall evidence from the cross-sectional studies, the majority of studies (50/63) reported a significant difference between the obese and non-obese in executive functioning, confirming a negative association between obesity and executive function (Favieri *et al*., 2019). Of the 63 cross-sectional studies, 45 studies examined the association between inhibitory control and obesity, with the majority of studies using the Stroop task. A lower inhibitory control in obese individuals compared to normal-weight ones was reported in 28 studies, while the rest found no significant difference (Favieri *et al*., 2019). The evidence from the longitudinal studies (28) showed that 13/28 studies showed a negative association between obesity (defined by BMI) and inhibition. The interventions aimed at reducing body weight demonstrated a general improvement in executive function in all age groups (Favieri *et al*., 2019). More specifically, some studies showed improved inhibitory control after bariatric surgery or weight loss programmes, while other studies showed that improved inhibition predicted a reduction in body weight. However, the direction of the relationship between obesity and executive function or its specific domains is still unclear due to the variability in assessment methods used in studies. More longitudinal studies with a uniformity of measurement methods are needed (Favieri *et al*., 2019).

7.2 Plausible mechanisms underlying obesity-cognitive function association

Most of the literature concerning cognitive impairments associated with obesity point to a cyclic model including a range of plausible mechanisms that might link cognitive function and obesity, although full understanding of these mechanisms is still lacking. The theoretical model on obesity developed by Brownell and Walsh (2017) (**Figure 2**) shows that obesity, defined as high body fat, causes physiological variations (A), which may impair cognitive function (B), which may cause cognitive deficit contributing to diminished abilities of self-regulation (C) that is defined as the "ability to control inner states or responses with respect to thoughts, emotions, attention, and performance" (Bell & Deater-Deckard, 2007).

Childhood and adolescence are critical periods where the brain grows, matures, and creates connections, making children and adolescents sensitive to changes in the brain structure and function and in executive function (Lenroot & Giedd, 2006). Accordingly, obese children and adolescents are exposed simultaneously to both the potential effects of biological changes associated with obesity as well as to brain developmental changes that may affect behaviour (Esteban-Cornejo *et al*., 2020).

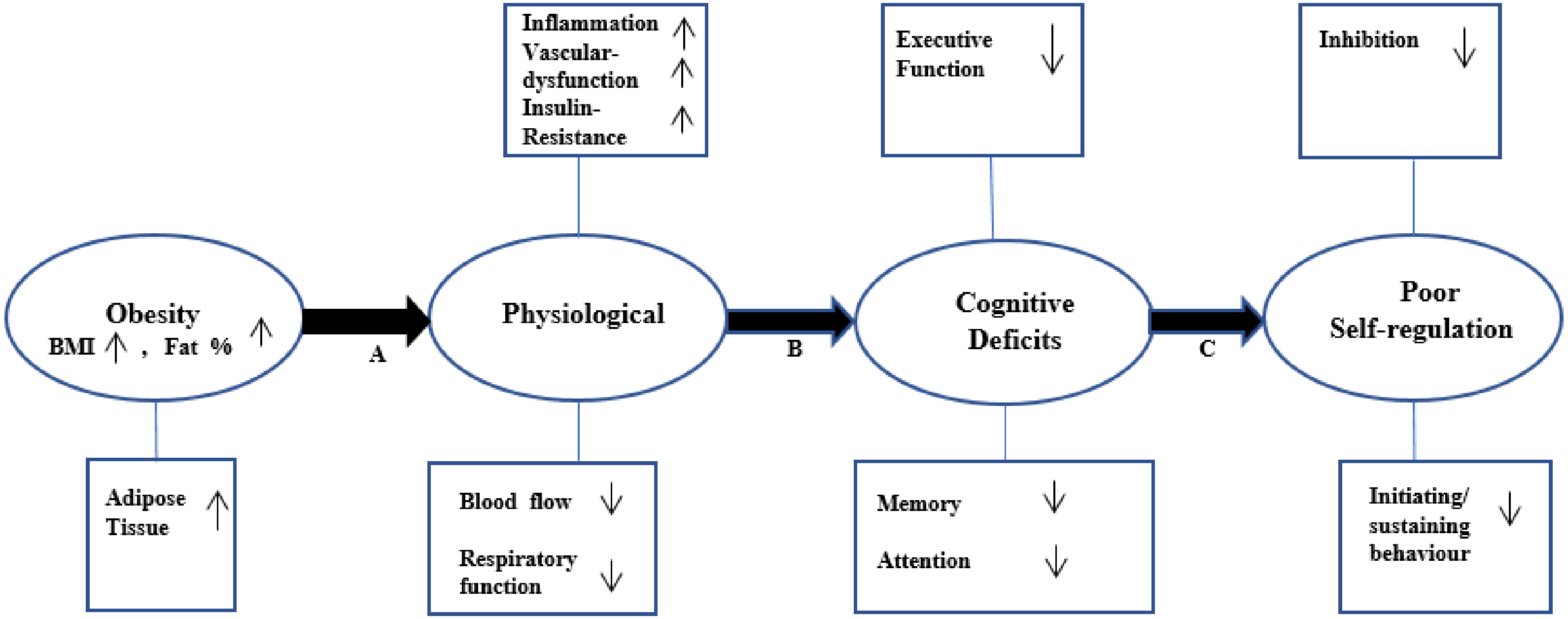

Figure 2. Cyclical model of obesity and cognitive function (redrawn from Brownell and Walsh, 2017)

Possible effects of obesity on brain function

Obesity-related inflammation may constitute a major biological pathway involved in the link between obesity and poor cognitive executive function (Favieri *et al*., 2019). Obesity is associated with chronic low-grade inflammation as the accumulation of white adipose tissue as well as the enlargement of adipocytes augment the production of pro-inflammatory cytokines, including tumour necrosis factor (TNF)-α, C-reactive protein and interleukins IL-1β and IL-6 (Reilly & Saltiel, 2017). This systemic inflammation was shown to affect cognitive function in humans and animal models by spreading into the brain and impairing key components of cognition (Favieri *et al*., 2019; Boitard *et al*., 2014). In a mouse model of metabolic syndrome, the levels of pro-inflammatory cytokines (IL-1β, TNF-α, and IL-6) were shown to increase in the hippocampus with a decrease in the levels of brain-derived neurotrophic factor (BDNF), resulting in impaired spatial working memory performance (Dinel *et al*., 2011). In addition, obese adults with high concentrations of pro-inflammatory cytokine (C-reactive protein) exhibited impaired cognitive flexibility and shifting abilities in comparison to obese individuals with lower levels of this cytokine as well as to non-obese individuals, indicating that low-grade inflammation may be a major contributor to reduced cognitive function associated with obesity (Lasselin *et al*., 2016).

In addition, excess adipose tissue and chronic inflammation are associated with hormonal dysregulation. Insulin and leptin are considered as brain adiposity signals since their circulating levels increase with food intake and decrease during fasting (Hallschmid & Schultes, 2009). Accordingly, both insulin and leptin signalling in the hypothalamus modulates energy homeostasis (Hallschmid & Schultes, 2009; Morrison, 2009). Further, insulin and leptin have shown activity in other areas of the brain related to cognitive function (Hallschmid & Schultes, 2009; Morrison, 2009). From animal studies, rats were trained on a memory task, in which they were shocked after entering a dark cage. The rats that received insulin 24h after the shock showed increased latency in entering the cage compared to those that had received either deactivated insulin or saline, indicating a role of insulin in enhancing memory, presumably by acting on the hippocampus (Park *et al*., 2000). Further, leptin has a role in neuron structure and function and its neuroprotective effects has improved cognition and mood in animal models (Paz-Filho *et al*., 2010). In human studies, enhanced insulin sensitivity in Alzheimer's patients improved their performance in memory tests (Craft *et al*., 1996). Similarly, optimal levels of leptin have shown to be protective against Alzheimer's disease (Paz-Filho *et al*., 2010). However, excess adipose tissue is associated with both insulin resistance and leptin resistance, meaning that the circulating levels of both insulin and leptin are high in obese individuals (Kern *et al*., 2006). Although the levels of these two hormones in blood are high, the concentration of these hormones in the brain is reduced, probably due to obesity-related dysfunction of the blood-brain barrier (Kern *et al*., 2006; Hallschmid & Schultes, 2009; Morrison, 2009). As a result, the altered levels of both insulin and leptin in the brain have been linked to impaired neurocognitive function (Kern *et al*., 2006; Morrison, 2009).

Possible effects of obesity on brain structure

The obesity-cognition underlying mechanisms may be further understood from neuroimaging research. The negative impact of obesity on brain structure was evident not only in adulthood and in dementia, but also in the developing brain during childhood and adolescence (Liang *et al*., 2014). The neurostructural deficits associated with obesity included a smaller orbitofrontal cortex (grey matter) volume observed in obese children and adolescents compared to their normal-weight counterparts (Maayan *et al*., 2011; Yokum *et al*., 2012; Ou *et al*., 2015), and this was associated with poor inhibitory control among the obese group (Maayan *et al*., 2011). In addition, the study by Yau *et al*., (2012) reported a significantly smaller hippocampal volume and thus increased cerebrospinal fluid, along with a loss of the microstructural integrity of white matter in adolescents with metabolic syndrome (Yau *et al*., 2012). These brain complications were in parallel with impaired cognitive function represented by a trend for lower overall intelligence and significant reduction in arithmetic, spelling, attention, and mental flexibility (Yau *et al*., 2012). Similarly, obesity in children and adolescents (age 8-10 years) was associated with differences in white matter microstructures mainly in frontal and temporal brain regions (Ou *et al*., 2015). A large study in US children and adolescents (N= 3190, age 9-10 years) found that higher BMI was associated with lower cortical thickness in 18 cortical regions, especially in the prefrontal cortex (Laurent *et al*., 2020). Additionally, the prefrontal cortex thickness was found to partially mediate the association between BMI and working memory (Laurent *et al*., 2020). Moreover, global functional connectivity studies identified that obese adolescents showed reduced functional connectivity in the brain regions involved in cognitive control (the dorsolateral prefrontal cortex) as well as in emotional memory (the middle temporal cortex) (Moreno-Lopez *et al*., 2016).

Animal studies have also contributed to the evidence base on the potential effects of obesity on brain structure. Juvenile male mice fed high-fat diet for 18 weeks showed lower cerebral blood flow and reduced white matter integrity along with adipose tissue inflammation (Jacobs *et al*., 2019). Similarly, 15 weeks of high-fat diet was associated with reduced cerebral blood flow, functional connectivity, and white and grey matter integrity in mid- and late-adult mice (Arnoldussen *et al*., 2017). White and grey matter integrity refers to the structural integrity of the brain network that is composed of two types of tissues, grey matter that process neuronal information, and white matter that connect and transfer signals between grey areas (Radetz *et al*., 2020; Mercadante & Tadi, 2020). In addition, obese mice showed poorer learning performance and lower hippocampal synaptic plasticity than their normal counterparts (Hwang *et al*., 2010). Moreover, juvenile mice showed increased loss of relational memory flexibility (the flexible ability of memory to relate and generalise previously acquired experiences to new situations) as well as decreased hippocampal neurogenesis than adult mice fed high-fat diets for the same duration, indicating that the consumption of a high-fat diet at an early age may lead to detrimental effects on hippocampal structure and function (Boitard *et al*., 2012).

Possible effects of obesity on inhibition and energy balance behaviours

The metabolic disturbances associated with obesity may accelerate the decline in cognitive function, which in turn may lead to adopting poor health habits (Spyridaki *et al*., 2016). Ineffective inhibitory control has been proposed to increase disinhibited eating (i.e. the tendency to overeating in response to different cues) (Maayan *et al*., 2011; Guerrieri *et al*., 2012; Kulendran *et al*., 2017; Zhou *et al*., 2017; Preuss *et al*., 2019). A study employing cognitive, neurostructural, and eating behaviour measures in obese (n=54) and lean adolescents (n=37) found that obese adolescents had significantly lower volume of orbitofrontal cortex, lower inhibitory control (lower Stroop colour-word score), and higher ratings of disinhibited eating compared to lean adolescents (Maayan *et al*., 2011). Disinhibition has been associated with obesity, high food intake, less healthy food choices, and eating disturbance (Lawson *et al*., 1995; Lindroos *et al*., 1997; Bryant *et al*., 2008; Bryant *et al*., 2019). In addition, disinhibition has been implicated in reduced success at weight loss regimes as well as weight regain after weight loss (Bryant *et al*., 2008; Amundsen *et al*., 2017), which may promote maintenance or increases in obesity.

In conclusion, the rise of child and adolescent obesity is of particular concern as it seems to affect the developing brain. Although the directionality between childhood and adolescence obesity and executive function has not been confirmed, some aspects of executive function such as inhibition have been shown to be implicated in obesity as well as academic achievement. Given the complexity of obesity development and academic achievement, further research on the mechanisms underlying obesity-educational impairment in children and adolescents is warranted.

The European Childhood Obesity Group (ECOG) has recently recommended that obesity related impairments of brain structure and function, executive function and academic performance in children and adolescents should be considered as important, not only secondary, complications of obesity (Esteban-Cornejo *et al*., 2020).

8. Kuwait in context and potential risk factors for obesity

Kuwait is a Middle Eastern country that has a small geographical area of approximately eighteen thousand square kilometres. It is located on the Arabian Gulf coast and bordered by the Arabian Gulf in the east, Saudi Arabia in the south and west, and Iraq in the north. The state has six provinces, namely, Al-Ahmadi, Mubarak Alkabeer, Farwaniya, Hawalli, Jahra, and Al Asimah (Kuwait Central Statistical office, 2020; Ministry of Oil (MOO), 2020). **Figure 3** is a Map of Kuwait showing the geographical location and countries with borders (source: Kuwait Government Online, 2019). The country has a desert climate characterised by short winters coupled with occasional rain while the summer is usually long, hot, and dry, with sandstorms often experienced (MOO, 2020)

Figure 3. Geographical location of major town/cities (Kuwait Government, online)

Kuwait is an Islamic Arab democracy where members of the national parliament are elected every four years. Arabic is the official language of the country and English is widely used as a second language in Kuwait (MOO, 2020). Until 2020, the total population was 4,464,521, of which 1,365,171 are Kuwaiti nationals, and 3,099,350 are non-nationals (Kuwait Central Statistical Office, 2020). The majority of the population is concentrated in Kuwait city, the capital, with increased rate of internal migration to urban areas (Alghais *et al*., 2018). Kuwaiti has a young population and the birth rate is very high among both nationals and non-nationals. Kuwait is composed of a homogenous population of Kuwaiti nationals descending from Arabs of the Arabian Peninsula. The non-nationals population includes Arabs, non-Arabs (mainly Asian), and stateless (Kuwait Central Statistical Office, 2020).

8.1 Economy

Kuwait is wealthy and has a moderately open economy with 10% of the world's reserves of unrefined petroleum. Oil represents about 50-60% of the gross domestic product (Kuwait Central Statistical Office, 2019). Kuwait, like other GCC countries, has experienced rapid economic and social changes upon the discovery of oil reserves between 1940 and 1970. People started to leave the traditional work in agriculture and fishing and join the oil industry jobs (Musaiger, 1987). The growth in the socioeconomic status has been paralleled with dietary and lifestyle changes with a shift towards overconsumption of fast foods and adoption of westernised lifestyle, which may have contributed to the obesity epidemic in Kuwait and the Gulf region (Musaiger, 1987; Elkum *et al*., 2019).

The connection between socioeconomic status (SES) and obesity prevalence is complex and inconsistent across various populations. In high income western countries, obesity has been shown to be more prevalent in groups with lower SES (Newton *et al*., 2017). However, it has not been the case in the low-middle income countries, where obesity is usually associated with higher SES, such as income, education, and place of residence (Dinsa *et al*., 2012; Vazquez & Cubbin, 2020).

In addition, most previous studies on socio-economic differences in obesity prevalence have taken place in high income western countries (Newton *et al*., 2017), which are usually characterised by a good deal of socio-economic inequality and quite a lot of poverty, i.e. unequal societies dominate the literature (Benabou, 2000). Kuwait is a high income country with a more socio-economically equal society (for the nationals). In general, the ratio of employment to population is 71.9, the income index (gross national income (GNI) per capita) is 0.963, and the human development index (education, lifespan, and income per capita) is 0.806, indicating that the levels of employment, income, and human development are high to very high based on these standard global economic indices (The World Bank, 2021; UNDP, 2020). Although there are no recent data on inequality and poverty indices, Kuwait is a relatively equal society with almost no socioeconomic hierarchy as compared to that seen in other high-income countries (The World Bank, 2021; UNDP, 2020), and therefore assumptions about SES and confounding of obesity-outcome relationships by SES might not apply to the same extent in Kuwait. A recent study found that familial SES defined by parental education was not associated with obesity (defined by BMI-IOTF) in Kuwaiti children and adolescents (Rey-López *et al*., 2019). However, in one recent study of Kuwaiti adults, the prevalence of obesity (defined as BMI ≥30 kg/m^2) was inversely associated with the education level in females aged between 18-69 years old, while the prevalence of obesity was significantly higher in women who were homemakers than those in other occupational categories (Weiderpass *et al*., 2019). Of note, these associations between obesity and higher level of education as well as the occupational status were not detected in men (Weiderpass *et al*., 2019). Therefore, the impact of SES on obesity could be age- and sex-specific and more studies targeting this association in Kuwaiti population may be warranted. More details about obesity and the SES in Kuwaiti population are found in chapter 4.

8.2 Culture and Environment

As Kuwaiti people descended from Arabs of the Arabian Peninsula, they have similar cultural and historical backgrounds (Musaiger, 1987). Extended families tend to live together or in the same neighbourhood and share meals, which may create a social environment that promotes high-energy intake or low energy expenditure. In addition, the hot climate plays a role in increasing consumption of soft drinks and carbonated beverages (Musaiger, 1987; Al-Haifi *et al.*, 2016; Al Yazeedi and Berry, 2019).

The social and environmental factors have been implicated as potential major contributors to the growing obesity trend in the GCC countries along with the improvements in income (Farrag, 1983; Musaiger, 1987). The latter was accompanied by increased working mothers and thus increased dependence on uneducated house cleaners to help with house and children with a decline in breast-feeding and early introduction of formula feeding (Farrag, 1983; Musaiger, 1987). In addition to the widespread availability of fast food (Musaiger *et al*., 2012), other environmental factors for obesity in Kuwait and the other Gulf states include high reliance on motorised transport, rapid urbanisation, high access to internet and technology devices and increased screen time. Less access to playgrounds and out-door activities due to the climate have contributed to reduced physical activity among children and adolescents (Farrag, 1983; Musaiger, 1987).

Unlike western culture, having a high body weight has long been an indicator of health and wealth in the traditional culture of Gulf regions (Musaiger, 1987). However, this belief may be becoming less acceptable among many people nowadays. In addition, it is well established in western societies that obesity negatively affects health-related quality of life (HRQL) in children and adolescents (Griffiths *et al*., 2010; Kolotkin & Andersen, 2017). However, this association was not found in Kuwaiti adolescents, indicating that cultural differences may influence the perception and attitudes towards obesity (Boodai & Reilly, 2013). Similarly, a recent study conducted in the United Arab Emirates found no significant impact of obesity measured by BMI on self-esteem in adolescents aged 11–17 years (Khadri *et al.*, 2020). On the other hand, the prevalence of disordered eating attitudes was the highest in obese Kuwaiti adolescents in both genders compared to their counterparts in the other six Arab countries (Musaiger *et al*., 2013). Collectively, most of the research on effects of child and adolescent obesity on aspects of psychosocial health, such as HRQL and self-esteem, has taken place in high income western countries, and the findings of these studies might well not apply to different cultural contexts such as Kuwait. There is therefore a need to do more research to better understand age and sex-specific effects of obesity on various psychosocial health aspects in Kuwaiti children and adolescents. The influence of obesity on psychosocial health is important, and it might explain or help us understand relationships between obesity and outcomes, such as educational attainment and cognitive function in the Kuwaiti youth.

8.3 Education system

The general Kuwaiti education system includes 5 years at the elementary level, 4 years at the intermediate, and 3 years at the secondary level. Education is mandatory for children and adolescents between the ages of 6–14 years (Ministry of Education [MOE], 2015). Private education is growing fast and exceeds public education. The Ministry of Education regulates both public and private schools. All levels of state education, including higher education, are offered to Kuwaiti citizens free of charge (MOE, 2015). The literacy rate among youth aged 15–24 years is 98.7%, one of the highest rates among the Arab world (Kuwait Central Statistical Office, 2019). The MOE oversees two state-supported institutions of higher education: the Kuwait University and the Public Authority for Applied Education and Training (MOE, 2015). Kuwait University (KU) is the largest and oldest public university in the country with 16 colleges offering various academic programmes at different levels (KU, 2018). More information about KU is found in chapter 4. A number of private universities have emerged recently to provide the labour market with required skills, such as business, engineering, and project management (MOE, 2015).

The school year runs from mid-September to mid-June, and the school week is Sunday through Thursday. The school day usually starts at 7:15 a.m. and ends at 1:30 p.m., although the timing varies between winter and summer and in some international private schools (MOE, 2015). The short length of the school day compared to countries with comparable income level has been considered one of the inefficiencies within the public education system (Burney & Mohammed, 2002). During the month of fasting, Ramadan, different time schedules and shorter business days (9 a.m. -1 p.m.) are applied in most of the institutes across the country. Following Ramadan, there are two important religious holidays (Eids) that each last from 4 to 7 days (MOE, 2015).

9. Aims of the thesis

High levels of obesity have been reported amongst children and adolescents in the six Gulf countries compared to other countries (Ng *et al.*, 2011; GBD 2017). Obesity has been associated with severe health consequences and may also be a risk factor for poor educational attainment and/or cognitive function problems as noted above (Booth *et al*., 2014; Martin *et al*., 2017; Santana *et al*., 2017; Hill *et al*., 2019).

Therefore, the overall aim of this thesis was to assess the impact of obesity among school-age children and adolescents in the six GCC states and Kuwait as one of the GCC states. To address the impact of child and adolescent obesity in Kuwait and the other GCC states, a systematic review (study 1) was used to summarise and synthesise the evidence on prevalence of obesity and the major gaps in the evidence base on obesity prevalence in the GCC. The second aim was to assess to what extent the prevalence data from the systematic review might not be giving a full picture of the prevalence of obesity (high body fatness; study 2). Given the high prevalence of obesity among adolescents in Kuwait, and emerging evidence that obesity related deficits in education attainment or cognitive function might be worse in females than males (Booth *et al*., 2014; Martin *et al*., 2017; Hill *et al*., 2018), evidence on whether obesity has educational impacts in female adolescents (study 3) and/or cognitive function impacts (study 4) was collected. Having both BMI and body fatness measures in assessing the associations between obesity and educational/cognitive outcomes might add to the previous literature. Evidence from Kuwait would be especially important because obesity may be unrelated to socioeconomic status, and Kuwaiti nationals make up a relatively homogenous population with low levels of poverty and less extreme variation in socioeconomic status than in western countries.

10. Structure of the thesis

The thesis consists of eight chapters. Chapter 1 gives a brief introduction and literature review of the study and provides information on the research setting of this thesis, particularly the geographical location, population, education system, and economic status of the state of Kuwait and also sheds light on the significance of the study. Key components of the current study are introduced in the first chapter, including the statement of the problem and research questions to be addressed.

The thesis includes four manuscripts - three have been published (Chapters 3, 5, 6) and the fourth unpublished (Chapter 7). Chapter 2 expands on the methods not covered in detail in Chapter 3, which has the systematic review that was the first study I conducted during my Ph.D. Chapter 4 expands on the methods not covered in detail in chapters 5 to 7 since they were based on published papers and therefore had brief methods sections. Chapter 5 includes the second publication (study 2) and chapter 6 the third publication (study 3). The final manuscript for study 4 (chapter 7) is unpublished and will be submitted later.

The thesis concludes with a discussion (chapter 8) of the major findings of the thesis in the context of the literature, and presents the important strengths, weaknesses, limitations, conclusions, and recommendations for Kuwait's current policy as well as future research.

Chapter 2: Methodology of systematic review

1. Preface

The systematic review "Prevalence of obesity among school-age children and adolescents in the Gulf cooperation council (GCC) states: a systematic review" (chapter 3) was published in *BMC Obesity* in January 2019. This chapter will explain in detail the methods used to conduct the systematic review which is not available in the publication because the number of words is limited by author guidelines.

Professor John Reilly (JJR), an expert in systematic reviewing, guided the present systematic review, and the author also had input from the Librarian Ms Sarah Kevill (SK). The lead author was Hanouf Hasan (HH) and she participated in all aspects of the systematic review. JJR and SK supported various aspects of the review including study selection, data extraction, and the assessment of quality. HH attended a workshop on systematic reviewing at the Nutrition Society in London in 2017. She learned more about systematic reviews in the public health areas and what would be the guidance available and methods used throughout the process. Search strategies were advised by SK at Strathclyde University, see section 3.1. Both authors contributed to and approved the final submitted manuscript.

2. Introduction and context

Before starting the systematic review search, novel research questions were developed based on the fact that obesity in the GCC countries (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates) had apparently reached an alarming level. The primary research question was 'what was the prevalence of obesity among school age children and adolescents in GCC states?' The secondary research question was ‘does obesity prevalence vary by the following variables - age, gender, time of the survey or the study definition of obesity used in these nations?’ Research on obesity in the GCC countries is limited and studies have called for more research to explore the reason why obesity is increasing and the extent to which obesity prevalence is increasing (AlMarri *et al*., 2017).

Previous estimates of prevalence in the GCC states and elsewhere tended to combine overweight and obesity (Alsharif *et al*., 2018; Nahhas *et al*., 2018). So there is a need to estimate current/ recent obesity prevalence not combined with overweight. Chapter 1 explained the different outcomes between obesity and overweight and higher health risks of obesity comorbidity. Some studies of obesity prevalence in the GCC have mixed child, adolescent and adult data, and some studies have had a focus on the wider Arab world (including some low-and middle-income countries) rather than the GCC countries. As described in Chapter 1, GCC countries have a high prevalence of overweight and obesity but research on prevalence seemed to be quite limited and there is a lack of a systematic review covering prevalence in the GCC countries.

The well-publicised global surveys by the Global Burden of Disease and NCD Risk Factors Collaboration included prevalence data from Kuwait and Bahrain which were >10 years old; 10 years is a long time over which obesity prevalence might be increasing rapidly (NCD, 2017; Ng *et al*., 2014; GBD 2015 Obesity Collaborators, 2017). The other problem with older evidence is the fact that definitions of child and adolescent obesity have evolved over the past 10-15 years. Specifically, the WHO definition of child and adolescent obesity based on BMI-for-age was not published until 2007 and was not in widespread use until sometime after that (WHO, 2007; WHO, 2013).

As explained earlier, obesity prevalence data among the GCC states is limited; however, a further problem with existing obesity prevalence data is that systematic reviews have demonstrated limitations of BMI-for-age as a surveillance tool as described in systematic reviews (Reilly & Kelly, 2011; Javed *et al*., 2015). So there was a need to examine whether any studies or surveys in the GCC countries used other definitions of obesity (e.g. based on high body fatness), see Chapter 1.

3. Planning research

3.1 Literature search and inclusion

A search for both published and ongoing systematic reviews was conducted to determine whether ongoing or previous reviews answered the questions highlighted earlier in section 2. The review was registered in PROSPERO (International Prospective Register of Systematic Reviews) registration number CRD42010739210 in September 2017 (see Appendix A). PROSPERO is managed by the Centre for Reviews and Dissemination (CRD) at the University of York. Registering systematic reviews on PROSPERO helps to reduce the potential for bias, fosters transparency, and serves to avoid unintended duplication of reviews (Stewart, Moher & Shekelle, 2012).

The next step was to determine inclusion and exclusion criteria for the PECO framework (Population, Exposure, Comparison, Outcome). Search terms concerning the PECO framework (see Chapter 3) were then created with the help of SK, which involved formulating keywords related to the research questions (see section 2); for example, P, Population, was children and adolescents aged between 5.0-19 years old.

The World Health Organization (WHO) defines individuals aged between 5.0-9.9 years old as “children” whereas those between 10.0-19.9 years are defined as “adolescents” (WHO, 2013). WHO identifies childhood obesity as one of the greatest challenges for public health of the 21st century (WHO, 2011). This review was restricted to children and adolescents to keep the workload manageable and consistent with the rest of the thesis.

E refers to exposure, obesity based on BMI-for age, with measured height and weight. C refers to a comparator, any appropriate BMI for age reference data using an accepted reference dataset such as IOTF, CDC and WHO, as explained in chapter 1. O refers to outcome, i.e. prevalence of obesity among the general population since January 2007. Any published data before that date were excluded.

Inclusion study criteria: Prevalence data were collected from studies published from Jan 2007 to the end of October 2018 from one of the GCC countries (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates) published in the English language. All study designs were accepted, using the following search terms: “Obesity prevalence”, “Children”, “Child’’, “Adolescent” or “teen” or “youth’’, Gulf Countries” or “Arabian Gulf”, “Bahrain”, “Kuwait”, “Oman”, “Qatar”, “Saudi Arabia” or “United Arab Emirates”.

Exclusion study criteria: Studies were excluded if participants were not children and adolescents, as defined above, or if data were from other nations and not from the GCC countries, if obesity was based on self-reported BMI, or if the prevalence of overweight and obesity were combined; data from clinical populations were excluded.

4. Conducting and reporting a systematic review

4.1 PRISMA

In this research PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analysis) was used – this is a tool to improve the reporting of systematic reviews. PRISMA items are categorized into five main sections in a checklist: title, abstract, introduction, methods and results. The PRISMA checklist was used to ensure that all relevant items were included in the review and the page number on which specific item is reported is given in the PRISMA checklist (Moher *et al*., 2009; Higgins *et al*., 2011; Muka *et al*., 2020). The PRISMA checklist for study 1 is given in Chapter 3 in the additional materials.

4.2 AMSTAR

AMSTAR (A Measurement Tool to Assess Systematic Reviews) is a useful tool for ensuring the methodological quality of Systematic Reviews. It has been widely used to assess the quality of systemic reviews (Shea *et al*., 2017). It has been critiqued extensively and joins several published instruments designed for this purpose (Kung, 2010; Dahm, 2017). In this research, the AMSTAR guideline was used to compile the systematic review -to both carry the review out and to help write it up. The original AMSTAR was provided as a checklist of 16 items. The purpose of using the AMSTAR was to try to ensure that our systematic review would be of high quality, by addressing all of the points in the AMSTAR checklist.

AMSTAR 2, was available online in 2017, therefore AMSTAR 2 was used in this study. AMSTAR 2 consists of 16 items, each item was categorized into four possible responses: “yes,”, “no,” “can’t answer,” or “not applicable”. The items addressed included the literature search, grey literature, including and excluding studies, study features, conclusions/ results, bias, and conflicts of interest. The full AMSTAR 2 checklist is detailed in study 1, **Table 3** (Chapter 3).

5. Literature search for identification of studies

5.1 Databases

Moher *et al*., (2009) published an article that suggested a minimum of 2-5 databases was recommended to conduct a systematic review; similarly, Muka *et al*., (2020) suggested a minimum of 3-4 databases. In this present research, the five most relevant electronic databases have been used. SK suggested that Medline, Google Scholar, Physical Education Index, SCOPUS and WHO Global Database on Child Growth and Malnutrition - were the most relevant to this research. Also, JJR suggested searching in the grey literature as well as forward and backward citation searching on the eligible studies. The choice of the above databases rested on their authoritativeness and relevance to the research e.g. public health, epidemiology, physical activity, education. Previous reviews on different aspects of obesity in the GCC countries have used similar databases, using three or four (AlMarri *et al.*, 2017; Alshaikh *et al*., 2017). We limited the search from 2007 to the present because of the high probability that obesity prevalence had been increasing in the GCC in recent years, and as the widely used and recommended by WHO definition of obesity only became available in 2007, as noted above (WHO, 2007). The full search terms used in the strategy (keywords) are in chapter 3.

5.2 Grey Literature

Grey literature has had increasing importance in systematic reviews because of its perceived benefits (Cook, Mulrow & Haynes, 1997). Grey literature includes: research and committee reports, theses and dissertations, conference papers, government reports, academics and ongoing research. Grey literature can escalate the comprehensiveness and timeliness of reviews, reduce publication bias, and promote a more balanced picture of evidence available (Paez, 2017). Important obesity prevalence data may have been published in grey literature rather than academic journals (Paez, 2017).

The diverse formats of grey literature can present a challenge in systematic reviewing. Nonetheless, a grey literature search strategy that is carefully thought out can be a useful component of the systematic review (Paez, 2017). Hence, a grey literature search was added to the database search in study 1 chapter 3. The researchers HH and JJR created a list (see Chapter 3) of relevant contacts from researchers and academics, Health Ministries, and other organizations in the six GCC countries, with at least one named contact per organization. This totalled 22 authors, experts and officials. These individuals were contacted by email and phone to seek any further published or unpublished sources of prevalence data. A formal letter was sent by email from HH and JJR to the experts and researchers (**Appendix B**). There were some obstacles in getting some of this information such as they were busy and did not respond immediately. The authors contacted these individuals again for the second time by email. Then HH followed up by phoning three colleagues for further information. Only 14 responses were received from the 22 contacts. Information about the contacts is attached also in the additional file of Chapter 3.

5.3 Assessing the quality of eligible studies

Joanna Briggs Institute (JBI) Quality Appraisal

The JBI is an international organization within the Faculty of Health Sciences at the University of Adelaide. The Institute has specialized in fostering and supporting evidence-based healthcare through offering access to resources for midwifery, nursing, allied health, and medicine (Joanna Briggs Institute, 2017). The JBI provides checklists for assessing the quality of published studies. The JBI checklists are provided for many different kinds of studies including prevalence studies and diagnostic tests accuracy as well as mixed methods studies (Munn *et al*., 2014). In this research, the quality of eligible studies was assessed using the Joanna Briggs Institute (JBI) tool for assessing the quality of prevalence studies (assessment of the risk of bias). The JBI checklist was selected as the tool for assessing study quality (risk of bias) because it was the only quality assessment tool for prevalence studies at that time (2017) and it came from a trusted source in evidence-based medicine (Munn *et al*., 2014). The JBI tool asks nine questions which are summarized below. In this research the Quality assessment was undertaken independently by both reviewers HH and JJR. We discussed and agreed the rating for each of the nine questions and these are shown below and in **Appendix C**. The nine questions from the JBI checklist are summarized and explained below.

1. Was the sample frame appropriate to address the target population?

This question focuses on the knowledge of the features of the population. Sample frame is defined as the set of source materials from which the sample is selected, a means for selecting the specific members of the target population. The differences between population and the sample frame is that population is general and the sample frame is specific. A good sample frame for any project first of all includes all individuals in the target population, secondly it excludes all individuals not in the target population and finally it includes accurate information about the target sample such as gender, age range, morbidities, and other possibly important factors such as the geographic area. This means that the sample frame is a list of characteristics for the target sample and is used to frame the research and make it specific. For example, if the research population is Kuwaiti nationals, the sample frame here should include all the six governates of Kuwait: Al Ahmadi, Al Farwaniyah, Al Jahrah, Al Kuwait (Capital City), Hawalli and Mubarak Al-Kabeer. So, if the sample frame in each eligible study was stated clearly, that was good and considered as a positive response (Yes) and scored one. If the sample frame was not stated clearly the score is unclear and it received zero as a score.

2. Were research participants recruited appropriately?

This question concerns those who participated in the research and how the recruitment occurred, including if the sample was randomly selected, the sample frame was stated and if the recruitment was appropriate and was reported. Appropriate recruitment should include ethical approval, signed consent, the location of the research stated clearly. Also important is that there is no bias. For example, avoiding asking the participants to agree or not with measurements or having only obese participants take part in the research, respect of participant privacy and lack of pressure, and retaining participants until the end of the research. So, if this information was considered and stated then it is considered as acceptable for item 2 (recruitment) and scored as a positive (Yes) response and scored as 1. If all the above-mentioned information was not considered, it was a negative (No) response, scored as 0. For example, if an eligible study selected the sample randomly, and stated what strategy they used to recruit the participants that was scored as 1. If the strategy used to sample and recruit was not clearly stated, then this was considered as unacceptable, negative, and scored zero.

3. Was the sample size adequate?

This question refers to the number of participants involved in the study and highlights the importance of having an adequate sample size to represent the population. The researchers should calculate the sample size using the most appropriate formula to ensure that it is adequate and should report the power calculation with the confidence interval around the prevalence estimate. If the sample size and 95% CI were estimated and reported then this was considered acceptable/ low risk of bias and a positive response (Yes) received scored as 1. If not, then it was considered as being of high risk of bias and (No) and scored as 0. For example, if eligible studies calculated the sample size and included all the information related to the sample size and how they calculated power and provided a confidence interval, then that was a positive response (Yes) and scored 1. If the power calculation was not included and the sample size not mentioned, this consideration was not considered good practice and scored zero; if the papers mentioned the sample size without mentioning the power calculation and confidence intervals then we scored them unclear (0).

4. Were the study subjects and settings described in detail?

This question deals with the study subjects' characteristics, such as health conditions or diseases across populations and geographic regions. The information provided should be sufficient and cover all the socio-demographic information, and so give the opportunity to other researchers to compare their published work to any other work. So, any study should provide information about gender, age, relevant diseases, including marital status, habits, education, and income if relevant. If the study did not provide sufficient details on these issues, then that was a negative (No) and considered bad practice and scored zero. If the study included sufficient information, then we considered it as good practice (Yes) and scored 1.

5. Was data analysis conducted with sufficient coverage of the identified sample?

The question deals with biased coverage of any relevant subgroups in the sample - this effectively means whether all relevant subgroups had been included or not. For example, if a study was conducted on 5-19 years old and the response rate for each group included in this study was not the same for each age group. So it was considered here as bias as the response rate was not the same and there was a big difference between the groups. For example, if one of the subgroups was less representative and the response rate less than the others, this was considered as a negative response (No) and scored as zero. If the response rate for the subgroup is acceptable then it was considered positive (Yes) and scored 1. Also, if the study had any dropout, there were questions: What was the dropout percentage? Is it acceptable or not? Has it been stated clearly or not? For example, if there is no dropout that means a positive answer and so it had a (Yes) positive response and a score of 1. If there is a dropout and the percentage is not high, so 2-5 %, then this was also considered a positive (Yes) response and scored 1. If there is a high dropout, more than 5%, then this was considered not acceptable and had a negative response (No) and scored 0. If it was not clear from the study, then it was considered unclear and received 0.

6. Were valid methods used for the identification of the condition?

This question checks the accuracy of a method used and defined whether it measures what it is intended to measure. Since BMI-for-age is regarded as an acceptable measure of obesity, as described in chapter 1, studies that used measured BMI for age with any acceptable BMI reference data, such as WHO, CDC, or IOTF, were scored as one.

7. Was the condition measured in a standard, reliable way for all participants?

This question explains that the same method should be used in all participants for example used obesity definition BMI for age. The same method should be used in all participants. Also, the experts or researchers e.g. (nurses, dietitians, researchers trained to take measurements) should follow standard methods to measure the BMI for age (WHO, CDC, or IOTF). If the answer is (Yes) that is considered as a positive response and scored one; if it was not clear or negative response (No) then the score is zero.

8. Was there appropriate statistical analysis?

The eighth question concerned the method section of the study analysed in detail by researchers (HH and JJR) to be clear about the variables and how they were measured. For example, if the Confidence Interval, (% CI) or numerator/denominator, was explained and the analytical strategy carried out was clearly stated. If any were mentioned CI was given the response as positive (Yes) and scored one. If 95% CI was not mentioned, the answer to this question was negative (No) and scored a zero.

9. Was the response rate adequate, and if not, was the low response rate managed appropriately?

This question highlights the importance of the study response rate, as well as indicating that it is important to manage the response rate throughout the study. For example, if the study mentioned the response rate with reasons why the response rate was low, and managed appropriately, then this was acceptable. For example, if there were only adolescent female participants and the data were collected throughout a year, and clearly mentioned in the study were reasons for the response rate, including reasons of absentees (if they stated they were ill or had an injury) then it received a positive response (Yes) and scored one . If the study did not provide all this for the response rate, it had a negative response (No) and scored zero. If the response rate was low initially then a large dropout happened, then this was considered as not acceptable and scored zero.

After completing the assessment, the total response score was measured to assess the quality of the studies, with a range of scores from 0-9. Since total scores might not be that informative, the response for each item was provided too.

6. Data collection and analysis of systematic review

6.1 Narrative synthesis and meta-analysis

The narrative synthesis was detailed in Chapter 3 and it was the appropriate analysis method in the case of study 1 (Chapter 3) (Higgins & Green, 2011). A meta-analysis of review findings was deemed desirable if practical and is explained further below. If enough studies were available which are considered methodologically homogenous/similar, they could be pooled statistically, for example in meta-analyses. In study 1 (chapter 3) few similar/comparable studies were available – the minimum number of similar studies for meta-analysis is suggested to be 10 (Valentine, Pigott

& Rothstein, 2010). Not all reviews are suitable for meta-analysis due to heterogeneity between studies. Heterogeneity can include differences in sex or age of study participants, or differences in their socio-economic status, or nationality. It can also include differences between studies in the definition of obesity which was used, and differences in time period when the study collected data (when obesity was probably increasing rapidly in the Gulf States). Data from eligible studies in study 1 were considered probably unsuitable for meta-analysis due to high heterogeneity (large differences between studies in the factors listed above). No formal test of heterogeneity, for example, the I^2, "which describes the percentage of total variation across studies due to heterogeneity rather than chance" (Higgins *et al*., 2003), was carried out.

7. Conclusion

The present chapter has provided additional details on the methods that were used in chapter three, as well as the reasoning for some of the decisions made.

Chapter 3: Prevalence of obesity among school age children and adolescents in the gulf cooperation council (GCC) states: a systematic review

Published in *BMC Obesity* in January 2019

1. Preface

The literature review showed gaps the evidence base on the prevalence of obesity among school-age children and adolescents in the GCC states. The present chapter aimed to systematically review recent evidence on the prevalence of obesity among school-age children and adolescents in the GCC states. The current systematic review study was published in BMC Obesity in January 2019. The paper is presented in a similar format as was published in the journal, and therefore the reference list presented at the end of this chapter is not APA as the other non-manuscript chapters in this thesis.

Professor John J Reilly (JJR), a renowned expert in systematic reviews guided the present systematic review. The lead author was HH and participated in all facets of the systematic review. JJR supported the assessment of quality. Finally, the review design, revision as well as approval of the final review was supported by all authors.

2. Abstract

Background: The Gulf Cooperation Council (GCC) countries have amongst the highest prevalence of adult obesity and type 2 diabetes in the world. This study aimed to estimate the recent prevalence of obesity among school-age children and adolescents in the GCC States.

Methods: The literature search for obesity prevalence data was carried out in July 2017 in Google Scholar, Physical education index, Medline, SCOPUS, WHO, 2007-2017, and updated in November 2018. In addition, 22 experts from the GCC were contacted to check the search results, and to suggest studies or grey literature which had been missed. Eligible studies were assessed for quality by using the Joanna Briggs Institute (JBI) tool for prevalence studies. Conduct of the systematic review followed the Assessment of Multiple Systematic Reviews Tool (AMSTAR) guidance. A narrative synthesis was conducted.

Results: Out of 392 studies identified, 41 full-text reports were screened for eligibility; 11 of which were eligible and so were included, from 3 of the 6 GCC countries (United Arab Emirates, Kuwait, Saudi Arabia). Surveillance seems good in Kuwait compared to other countries, with one recent national survey of prevalence. Quality of the eligible studies was generally low-moderate according to the JBI tool: representative samples were rare; participation rates low; power calculations were mentioned by only 3/11 studies and confidence intervals around prevalence estimates provided by only 3/11 eligible studies; none of the studies acknowledged that prevalence estimates were conservative (being based on BMI-for-age). There was generally a very high prevalence of obesity (at least one quarter toone third of study or survey participants were obese according to BMI-for-age), prevalence increased with age, and was consistently higher in boys than girls.

Conclusions: The prevalence of obesity among school-age children and adolescents appears to have reached alarming levels in the GCC, but there are a number

of major gaps and limitations in obesity surveillance in the GCC states. More national surveys of child and adolescent obesity prevalence are required for the GCC states.

Trial registration: PROSPERO registration number CRD420107392

Keywords: Children, Adolescents, Obesity, Body mass index, Systematic review, Gulf Cooperation council (GCC).

3. Background

The Gulf Cooperation council countries include Kuwait, the United Arab Emirates (UAE), Qatar, Bahrain, the Kingdom of Saudi Arabia (KSA), and Oman. The GCC countries have among the highest adult obesity and type 2 diabetes prevalence in the world [1-4] with rapidly increasing prevalence of adult obesity and diabetes in the past two decades [1]. Several factors have contributed to the high prevalence of obesity in the GCC countries [2], notably the very large and rapid increases in household income, with associated lifestyle changes that include reduced physical activity and increased consumption of obesogenic foods and drinks [5,6].

Surveillance of childhood obesity is considered central to tackling the obesity epidemic [7], but there may be a number of important limitations in surveillance of child and adolescent obesity prevalence in the GCC at present. Specifically, we were unable to find a recent systematic review of obesity prevalence of children and adolescents in the GCC, so prevalence of the problem is unclear. Our initial scoping review also suggested that many previous studies combined the prevalence of overweight and obesity, and so the prevalence of obesity could not be determined. In addition, many previous studies in the GCC collected data over 10 years ago and these studies may now be out of date given the rapid increases in prevalence in the region [8, 9]. The recently published global estimates of obesity prevalence [10, 11] used data from the GCC countries which were also over 10 years old for example, so there is a need for prevalence data from more recent studies and surveys. An additional problem with older evidence is the fact that definitions of child and adolescent obesity have evolved over the past decade. Specifically, the WHO definition of child and adolescent obesity based on BMI-for-age was not published until 2007, and was not in widespread use until some time after that. A further problem with existing obesity prevalence data is that systematic reviews demonstrating limitations of BMI-for-age as a surveillance tool (high specificity for excessive fatness, but only low-moderate sensitivity) have become available only relatively recently [12, 13] and recent obesity prevalence studies or surveys from the GCC countries may not have made allowances for this important source of bias in prevalence estimates.

The primary aim of the present study was therefore to establish the recent (last 11 years) prevalence of obesity among school-age children and adolescents in the GCC states. Secondary aims were: to identify differences in prevalence between countries and between groups (e.g. by gender, age); to identify major gaps and weaknesses in the evidence base on obesity prevalence in the GCC. The study was intended to help improve child and adolescent obesity surveillance in the GCC in future, so that public health action aimed at tackling the obesity epidemic in the GCC can be better informed [7].

4. Methods

4.1 Registration and reporting of the systematic review

This systematic literature review was reported in accordance with the Pre-ferred Reporting Items for Systematic Reviews (PRISMA) guidelines [14]. The review protocol was registered on PROSPERO on the 10th September 2017 (registration number CRD420107392), the international prospective register for systematic reviews (http://www.crd.york.ac.uk/ NIHR_PROSPERO). The search strategy followed the PECO (population, exposure, comparator and outcome) format: population=school-age children and adolescents in the GCC countries; exposure=obesity as defined using BMI-for-age; comparator=any appropriate BMI-for-age reference data; outcome=prevalence of obesity among the general population since 2007.

4.2 Literature search

The literature search was originally conducted on 17 July 2017. The manuscript was submitted to this journal on 28th February 2018 and reviews were not received until October 2018, so the original searches were repeated on 2nd November 2018. Searches used the five most relevant electronic databases: Medline, Google Scholar, Physical education Index, SCOPUS and WHO. The search terms used in Medline are provided in **Additional File Table 1,** as required by the PRISMA checklist; terms were very similar in the other databases, though with small differences in syntax between databases. The electronic database searching was complemented by reference citation tracking (forward and backward) of the included studies and of previous reviews, consultation with GCC-based experts in the field, and a search for 'grey literature' among the GCC experts (summarised in **Additional File Table 2).**

Table 1. AMSTAR Self-assessment of the process used in the present study

Table 1 AMSTAR Self-assessment of the process used in the present study

Questions	Yes/ NO	Answers in detail
1) Did we have a PICO/PECO	Yes	Population = children and adolescents of school-age as defined by WHO (5-19 yrs) from GCC countries; E = exposure = obesity defined using an acceptable method based on BMI-for-age; Comparator = any appropriate reference data; Outcome = prevalence of obesity rather than overweight and not overweight/obesity combined, from 2007 onwards.
2) Did we specify review methods in advance of doing the review?	Yes	Registered in PROSPERO ref. CRD42017073692
3) Did we explain/justify inclusion criteria (based on study design)?	Yes	We did not exclude any study design, but RCT not likely to be that relevant (though RCT could contain relevant data and so not excluded)
4) Did we have a comprehensive lit search strategy?	Yes	Electronic databases from 2007 to 2018: See Methods and Additional file 1.
		We were resourced to search for English language publications only, though literature suggested by expert contacts in the GCC (including grey literature) in Arabic would have been considered eligible.
		Searched reference lists of eligible studies? Yes, both forward and backwards citation searching was carried out.
		Consulted experts? Yes-list of $n = 22$ expert contacts in all GCC countries was consulted in October–November 2017.The experts from the GCC were asked to check on the results of the literature search and if they were aware of any grey literature which was relevant (e.g. national surveys)
		Search within 24 month of planning the search - Yes, within 2 months
5) Did review authors agree on inclusions/exclusions of full text potentially eligible studies?	Yes	Both authors agreed on inclusions/exclusions of the full text articles screened
6) Data extraction from eligible studies- did both review authors do this/check this?	Yes	Both authors agreed on data extraction from the eligible studies
7) Is a list of all excluded studies provided, including the reasons for exclusion?	Yes	Appendix of excluded studies and reasons for exclusion is provided (Additional file 3).
8) Does the data extraction and narrative (Evidence tables and text) provide enough detail about the eligible studies?	Yes	Text summarises the eligible studies, and details of eligible studies are provided in Evidence Tables (Results section)
9) Did the review authors consider risk of bias?	Yes	Results section (Evidence Tables) contains data on possible sources of bias including: sample size; representativeness of sample; bias arising from definition of obesity used.
10) Did the review authors report sources of funding of their review?	Yes	Kuwait Cultural Office and Scottish Funding Council
11. & 12 Did the review authors do a meta-analysis? (Was this appropriate?)	No	No meta-analysis possible dues to degree of differences in study design and methods: different nations; differences in factors which create differences in prevalence estimates- different definitions of obesity, different age groups, different sex distributions in studies
13) Did the review authors consider sources of bias in eligible studies?	Yes	As above- the evidence tables deal with representativeness, sample size/power calculations, and biases in the definitions of obesity used by the studies
14) Did review authors consider sources of heterogeneity in eligible studies?	Yes	Different times, different obesity definitions, different ages and sexes, different countries and places all considered
15) Did review authors consider other sources of bias (in particular publication bias)	N/A	No formal testing for publication bias was possible due to small number of eligible studies.
		Main sources of bias in prevalence studies were considered: sample size and representativeness; use of BMI to estimate obesity prevalence is biased (underestimates obesity prevalence) as noted in the manuscript
16) Did review authors consider any conflicts of interest which arose when doing their review?	Yes	No conflicts to declare

4.3 Study selection

Inclusion criteria

Studies were included if they satisfied all of the following inclusion criteria: Prevalence data were collected in the last 11 years, i.e. from Jan 2007 to the end of October 2018; from a GCC country (Bahrain, Kuwait, Qatar, Oman, KSA, UAE); they provided prevalence of obesity rather than overweight prevalence, or prevalence of overweight/obesity combined; they must have defined obesity using an accepted method for children and adolescents based on BMI-for-age; BMI must have been based on measured height and weight (rather than self-report or parental report); age of study participants between 5-19 years; study participants from the general population (e.g. not from clinical samples).

Exclusion criteria

Studies were excluded if they addressed prevalence of obesity in middle Eastern countries that are not members of the GCC, with study participants outside the range 5-19 years; if prevalence data were collected earlier than 2007; if prevalence estimates from BMI-for-age were based on self-reported height or weight, or which combined prevalence of obesity and overweight so that obesity prevalence could not be ascertained. Studies that sampled from specific populations (e.g. clinical populations) were also excluded.

All literature search hits, and all potentially eligible studies identified by forward and backward citation searching, were examined for eligibility independently by both authors. The two authors resolved differences of opinion over eligibility by discussion, and in a few cases, by asking for clarification of methods from the authors of the original studies (e.g. over the precise data collection period where this was unclear in a few cases). A list of studies excluded at the full-text screening stage, with reason(s) for exclusion is provided in the supplementary material (**Additional File Table 3)**.

Data extraction

A data extraction form was devised in advance of the process of data extraction and used to populate the evidence tables given in the Results section below, with summary data on prevalence of obesity (with 95% CI where possible) overall, and by subgroup as reported (e.g. by age, gender, definition of obesity). Both authors independently populated the data extraction forms, and they resolved any differences of opinion by discussion.

Quality assessment-appraisal of eligible studies

The quality of individual eligible studies was assessed by both authors independently using the Joanna Briggs Institute (JBI) checklist for assessment of the quality of prevalence studies [15]. Two additional aspects of prevalence study quality which are specific to obesity were also considered and added to the data extraction forms: the timing of data collection given recent rapid increases in obesity prevalence in the GCC; [8,9]; whether biases arising from use of the BMI-for-age to estimate obesity prevalence [12,13] had been considered by the authors (e.g. reported in the Discussion and/or used to adjust prevalence estimates in the Results).

Guidance on maintaining the quality of the systematic review

In an attempt to ensure high quality of the present review process the authors planned and conducted the review by addressing each of the items in the Assessment of multiple systematic reviews tool (AMSTAR [16]) checklist - the process is summarised in Table 1.

Synthesis of study findings

A meta-analysis of review findings was considered desirable if practical, but it was recognised that marked gaps in the evidence and/or differences between studies, e.g. differences in age or sex, ethnicity or socio-economic status of the samples, differences in time period [17], differences arising from differences in the definition of obesity used, which would be expected to be marked [12],might preclude meta-analysis. Publication bias assessment was also considered desirable if possible.

5. Results

5.1 Eligible studies and study selection process

The PRISMA flow diagram is provided in **Figure 1**. In the original search 22 potentially eligible papers were identified for full-text eligibility screening by both authors by conventional literature searching and a further 17 papers/surveys from the grey literature were suggested by expert contacts in the GCC and all of those were full-text screened by both authors. The search update in November 2018 identified further studies for full-text screening but no additional eligible studies, so only 11 eligible papers/survey reports were identified, reporting 13 separate prevalence estimates, from 3 of the 6 GCC countries (UAE, Kuwait, KSA): there were no eligible studies from Oman, Bahrain, and Qatar. In summary, the number of eligible studies in the GCC countries was limited and the studies/surveys themselves differed substantially by time, sample age and sex, ethnicity, and by definitions of obesity used.

No formal assessment of publication bias was possible given the small number of eligible studies, and so a narrative synthesis, by nation, is provided below.

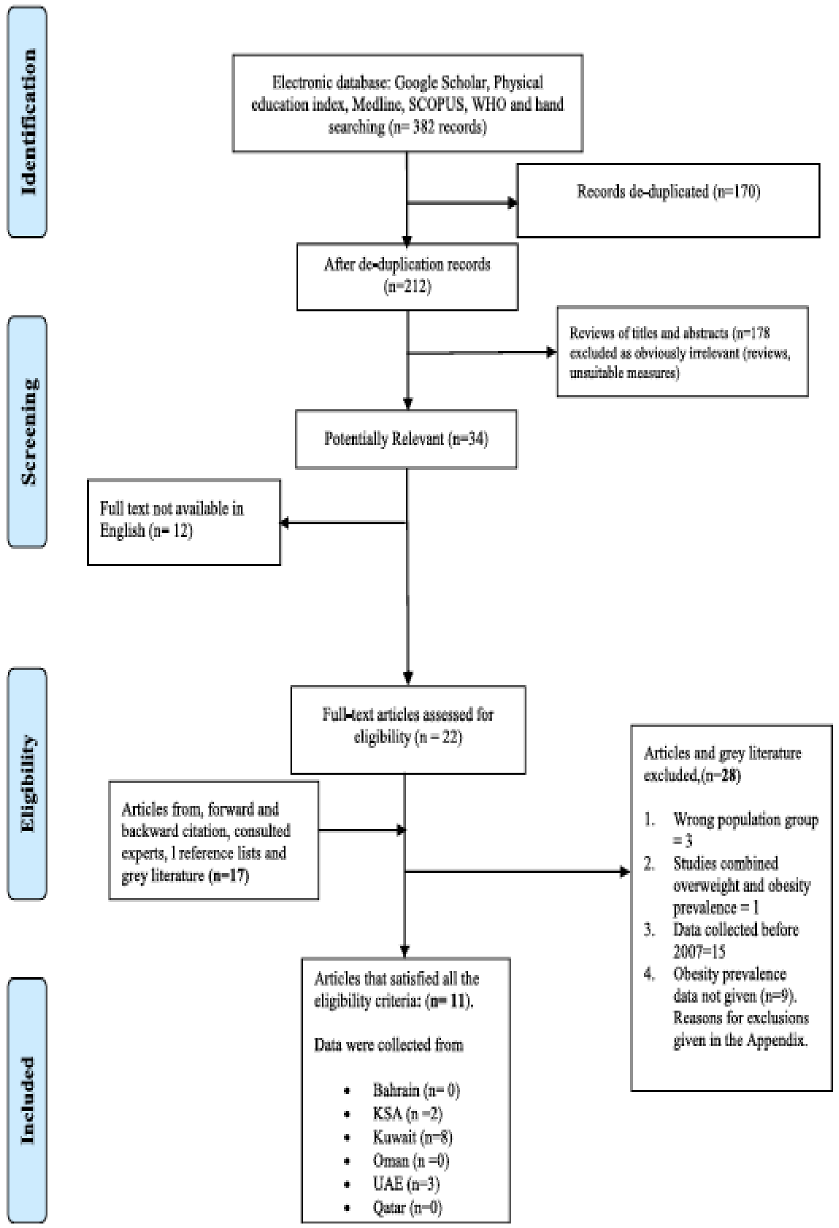

Fig. 1 PRISMA Study Flow Diagram. Footnote: search updates in November 2018 identified 10 additional potentially eligible studies, of which 6 were excluded from Abstract screening and four were deemed ineligible after full-text screening (see Additional file 3)

Figure 1. PRISMA Study Flow

5.2 Study quality appraisal

The formal appraisal of study quality for the 11 eligible studies/surveys is summarised in **Table 2**. A number of the quality assessment items were not reported or not carried out, in particular the use of nationally representative samples was rare (1/11 eligible studies), and few studies reported power calculations or confidence intervals for their prevalence estimates (only 3/11 provided confidence intervals). In addition, few of the eligible studies/surveys were recent: 9 out of 11 studies collected data over 7 years ago. Finally, consideration of biases arising from use of BMI-for-age was not carried out (0/11 eligible studies referred to this major source of bias).

Table 2. Study Quality Appraisal

Table 2 Study quality appraisal summary using the Joanna Briggs Institute, JBI, tool [15]

Criteria-Paper	AlBlooshi, 2016 [18]	AlJunaibi, 2013 [20]	Musaiger, 2012 [19]	Al-Hazzaa, 2014 [21]	Musaiger, 2016 [22]	Al-Awadhi, 2013 [2]	Al-Haifi, 2013 [5]	Alrashidi, 2015 [26]	El-Ghaziri, 2011 [27]	Elkum, 2016 [28]	KNSS,[a] 2016 [29]
1. Sampling frame appropriate?	No	No	No	No	No	No	No	No	No	No	No
2. Sample appropriate?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Unclear
3. Sample size adequate?	Unclear	No	Yes	Yes	Yes	Unclear	Unclear	Unclear	Unclear	No	Yes
4. Subjects & settings described?	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
5. Analysis conducted to ensure coverage?	No	No	No	No	No	Yes	Unclear	No	No	No	No
6. Valid methods used to define obesity?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
7. Obesity defined in same way for all subjects?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
8. Appropriate analysis? (numerator, denominator, %, CI)	No	Yes	No	No	No	Yes	No	No	Yes	No	No
9. Response rate adequate/dealt with?	No	Yes	No	No	No	Yes	No	No	No	No	No
Total/9	4	5	5	5	5	7	4	4	5	4	3

[a]Kuwait Nutrition Surveillance System

5.3 Narrative synthesis by GCC nation

UAE

Table 3 summarises the three eligible studies from the UAE [18-20]. None of the three studies used representative samples, though one study [18] was very large (n = 44,942), relatively recent (data collection 2013-2015), included both nationals and non-nationals, and included a wide age range (3-18 years). In this study [18] by prevalence of obesity according to the WHO definition exceeded one third of the sample in the secondary school-age participants, and there was clear evidence of increasing prevalence with increasing age. The highest prevalence was recorded for age 11-14 years. In two of the three studies from the UAE [19, 20] obesity prevalence estimates were provided using more than one definition of obesity, and in both cases prevalence was substantially lower using the International Obesity Task Force (IOTF) compared to the alternative definitions (from the US Centers for Disease Control and WHO respectively). In the one study which considered differences in obesity prevalence between the sexes, prevalence was much lower among girls than boys [19] .

KSA

Table 4 summarises the evidence from the two eligible studies in the KSA [21, 22]. Neither of these studies were based on nationally representative samples. Both studies included adolescents only, and in both studies prevalence of obesity was much higher in boys than girls.

Kuwait

Table 5 summarises the eight eligible studies from Kuwait. A number of the eligible studies were not based on representative samples, were not very recent, and had relatively small samples. The most informative of the data sources from Kuwait was the large and recent nationally representative survey from 2016 [28]. In this survey there was clear evidence of increasing prevalence of obesity with increasing age, and by adolescence one-quarter to one third of participants were obese according to the WHO definition. Among the other seven eligible studies from Kuwait (**Table 5**), three reported comparisons between prevalence estimates according to the definition of obesity used. Prevalence estimates were generally lower with the IOTF definition than the CDC and WHO BMI-for-age definitions (Table 5). Four studies compared prevalence between the sexes, and in all cases found that prevalence was lower among girls than boys, though prevalence was still high among the girls (typically ranging between 20% and 45% of girls in the samples studied).

6. Discussion

This systematic review showed that evidence on the prevalence of obesity among school age children and adolescents in the GCC states is limited. Only one nationally representative survey was identified, and only 3/6 GCC states had any eligible data from the past 11 years, with multiple gaps in the evidence (e.g. for certain age groups) and weaknesses in the evidence (e.g. reliance on non-representative samples, lack of national surveys). More extensive and higher quality surveillance of obesity among school age children and adolescents in the GCC is required in future if the GCC states are to address the obesity epidemic effectively [7]. Regular high quality surveillance is essential to assess the scale of the obesity problem, to identify trends and inequalities, to drive obesity prevention and control measures, and to assess the impact of policy measures aimed at obesity prevention and control [7].

Despite limitations in the evidence base on obesity prevalence in the GCC nations noted above, some trends were apparent from the 11 eligible studies. First, the prevalence of obesity according to BMI-for-age was very high. For example, prevalence of obesity in the UAE, according to the WHO definition, exceeded one third of the sample in the secondary school-age participants, and increased with increasing age. One-quarter to one third of participants were obese according to the WHO definition in the Kuwaiti national survey. Moreover, BMI-for-age substantially underestimates the prevalence of obesity (excessive fatness) in children [12,13] so 'true' prevalence of obesity in these studies in the GCC would have been even higher if this bias arising from the use of BMI had been accounted for. None of the eligible studies or surveys acknowledged that their prevalence estimates were subject to this source of bias, or attempted to adjust for it. A large recent study [29] across Africa found that the WHO-BMI-for-age definition of obesity only identified around one third of children with excessive body fatness measured by a reference method (Total Body Water). Second, in most of the eligible studies the prevalence of obesity was higher in boys than girls, suggesting that this is a real difference in susceptibility to paediatric obesity in the GCC states. It should be noted that prevalence of obesity among the girls would also be regarded as very high relative to other nations [10,11]. Third, the eligible studies and surveys which compared prevalence estimates by the different definitions based on BMI-for-age consistently found that prevalence was substantially lower when the IOTF definition of obesity was used compared to definitions based on the CDC or WHO, consistent with previous evidence [12].

There are no previous systematic reviews of the prevalence of child or adolescent obesity from the GCC, and so the results of the present study cannot easily be compared with other evidence. Comparisons of prevalence of obesity among children and adolescents in the GCC with those living in other countries is also difficult because of differences in the timing of the studies, differences in the definitions of obesity used, and whether or not obesity prevalence estimates (as distinct from overweight prevalence estimates, or prevalence of overweight and obesity combined) can be found in published studies.

The present review found major limitations of obesity surveillance in the GCC, notably the apparent lack of any recent surveillance data from three of the six 6 GCC countries, the availability of nationally representative sample data from only 1/6 GCC countries, the small sample sizes and scarcity of power calculations (and confidence intervals around prevalence estimates), and the fact that bias in the use of BMI-for-age to generate prevalence estimates was not considered by any of the 11 eligible studies/surveys. In addition, eligible study and survey response rates were often very low (under 50%), and not reported in all of the eligible studies and surveys. It should be noted that many of the studies did not set out to obtain nationally representative samples, and estimating obesity prevalence was not a primary aim of all of the eligible studies. In addition, a checklist for guiding/assessing the quality of prevalence studies [15] only became available after many of the eligible studies were conducted. Future studies and surveys of child and adolescent obesity prevalence in the GCC states and elsewhere may find it useful to refer to the checklist for assessment of prevalence study quality used in the present study [15].

This review had a number of strengths. First, it focused on obesity-rather than overweight and obesity. While obesity and overweight are often combined somewhat casually in paediatric prevalence studies they are not equivalent clinically or biologically in children, as in adults: there is currently a very large body of consistent evidence of adverse health effects of obesity in childhood and adolescence [30, 31], but the adverse health impact of overweight in childhood and adolescence is much less clear at present. Second, the present review attempted to provide evidence of most relevance and highest quality, by including only relatively recent studies, and only those which used acceptable objective measures of obesity (rather than self-or parent reports), and by formal appraisal of study quality. The conduct of the present systematic review was also intended to follow best practice, by using the AMSTAR tool as a guide to the process, and reporting of the review followed PRISMA guidance. Finally, by making use of extensive expert contacts in all of the six GCC states, the probability that eligible studies and surveys (including grey literature) were not identified by the conventional literature search was reduced.

The present review also had a number of limitations. The number of eligible studies was relatively small due in part to our decision to exclude studies which collected data prior to 2007. The rationale for this is that we included only recent studies to provide up to date information, especially important given likely recent rapid increases in obesity prevalence in the GCC [1-4, 8,9]. Including older studies would have increased the size of the evidence base, but also made it much less generalisable to contemporary GCC populations. The literature search was limited to the English language for practical reasons, but any grey literature or other studies suggested by expert contacts in the GCC published in Arabic would also have been considered if identified. The first author is from Kuwait, which may have biased the grey literature searching towards Kuwaiti sources of evidence. However, author connections in relevant institutions in the rest of the GCC are good, and responses from those contacts were generally informative (**Additional File 2**). It therefore seems unlikely that useful sources of evidence from the other GCC states, such as recent nationally representative surveys, were missed.

7. Conclusions

There is a major gap in the literature on the childhood and adolescent obesity prevalence in the GCC states, with the exception of Kuwait. New research/surveys are needed for those countries in the GCC apparently not doing surveillance of child and adolescent obesity prevalence. For those countries where studies and surveys have been carried out, greater attention could be paid to the quality appraisal issues identified by the present review.

Table 3. Obesity Prevalence, UAE

Table 3 Obesity Prevalence, UAE

Author and Year	Sample Size and age (n)	Data Collection (Years)	Definition of Obesity Used	Obesity Prevalence (%) by Definition	Comments on Obesity Prevalence Estimates
Al Blooshi et al., 2016) [18]	44,942 (Males and females) age 3–18 years This study was conducted in two phases; the first phase was in 2013–2014 (*n* = 15,532) age 4–12 years. The second phase was in 2014–2015 (*n* = 29,410) *n* = 27,078 nationals and 2332 non-nationals age 3–18 years .	2013–2015	International Obesity Task Force (IOTF), World Health Organization 2007 (WHO), and Centers for Disease Control (CDC)	Prevalence estimates for the nationals only Age / IOTF / WHO / CDC 3-6 / 5.2 / 11.2 / 7.4 7-10 / 12.4 / 27.0 / 16.7 11-14 / 18.9 / 37.5 / 24.3 15-18 / 19.3 / 33.8 / 22.2	The sample was apparently not representative of the UAE. CIs given for prevalence estimates: No Biases considered: No Prevalence higher in boys than girls and generally higher in older than younger individuals
Musaiger et al., 2012) [19]	605 adolescents aged from 15 to 18 years (*n* = 262 males, 243 females)	2010–2011	IOTF and CDC	SEX / IOTF / CDC Male / 19.1 / 22.5 Female / 6.6 / 7.0	The sample was apparently not representative of the UAE. Biases considered: No CIs given for prevalence estimates: No Prevalence higher in boys than girls
Al Junaibi et al 2013 [20]	1541, aged 6–19 years (*n* = 1770 males, *n* = 770 females)	January–December 2011	IOTF and CDC	SEX / IOTF / CDC Male / - / 21.4 Female / - / 18.1	The sample was representative of Abu Dhabi but not the entire UAE. CIs given for prevalence estimates: No Biases considered: No The authors used IOTF to define obesity prevalence but data using IOTF not shown. Prevalence higher in older individuals and slightly higher in boys than girls

Table 4. Obesity Prevalence, KSA

Table 4 Obesity Prevalence, Kingdom of Saudi Arabia

<table>
<tr><th>Author and year</th><th>Sample size (n) and age of sample</th><th>Data collection (Years)</th><th>Definition of obesity used</th><th>Obesity prevalence by methods</th><th>Comments on obesity prevalence estimates</th></tr>
<tr><td>Al-Hazzaa et al., 2014) [21]</td><td>2908 (n = 1401 males, n = 1507 females) aged 14 to 19 years</td><td>2009–2010</td><td>IOTF</td><td><table><tr><th>SEX</th><th>IOTF</th></tr><tr><td>Male</td><td>24.1</td></tr><tr><td>Female</td><td>14.0</td></tr></table></td><td>The sample was apparently representative of Al-Khobar, Jeddah and Riyadh, but not representative of KSA

CIs given for prevalence estimates: No

Biases considered: No

Prevalence higher in boys than girls</td></tr>
<tr><td>Musaiger et al., 2016) [22]</td><td>968 adolescents aged 15–18 years (n = 518 males, n = 450 females)</td><td>2013–2014</td><td>IOTF, WHO</td><td><table><tr><th>SEX</th><th>IOTF</th><th>WHO</th></tr><tr><td>Male</td><td>24.3</td><td>35.5</td></tr><tr><td>Female</td><td>15.3</td><td>8.0</td></tr></table></td><td>The sample represents Dammam city but was apparently not representative of KSA.

CIs given for prevalence estimates: No

Biases considered: No

Prevalence higher in boys than girls</td></tr>
</table>

Table 5. Obesity Prevalence, Kuwait

Table 5 Obesity Prevalence, Kuwait

Author and year	Sample size (n) and age	Data collection (Years)	Definition of obesity used	Prevalence by methods	Comments on obesity prevalence estimates
Al-Haifi et al., 2013) [5]	906 (males *n* = 463, females 443) aged between 14 and 19 years	2009–2010	IOTF, WHO	SEX / IOTF / WHO Male / 25.5 / - Female / 21.0 / -	The sample was from Kuwait city, but apparently not representative of Kuwait CIs given: No Biases considered: No WHO method used for age 18–19 years; but data not included. Prevalence slightly higher in boys than girls
El-Ghaziri et al.,(2011) [27]	499 10–14-years (males *n* = 317, girls *n* = 182).	2009	IOTF,WHO, CDC	IOTF / CDC / WHO 44.1 / 44.9 / 50.5	The sample was from Kuwait city but apparently not representative of Kuwait Biases considered: No Prevalence differences between the sexes not given
Elkum et al., 2016) [28]	6574 6–18 years (females *n* = 3973, *n* = 2601 males)	2012–2013	IOTF,WHO,CDC	Age / IOTF / WHO / CDC 6 / 20.0 / 16.2 / 24.7 10 / 29.7 / 30.2 / 36.0 13 / 31.9 / 33.9 / 39.9 18 / 27.3 / 19.9 / 28.0	The sample was from Kuwait city apparently not representative of Kuwait Biases considered: No Prevalence not given for the sexes separately.
Musaiger et al., 2016) [22]	706 aged 15–18 years (*n* = 343 males, *n* = 363females)	2013–2014	WHO, IOTF	SEX / IOTF / WHO Male / 28.6 / 40.5 Female / 21.1 / 31.2	The sample was from Kuwait city, apparently not representative of Kuwait CIs given: No Biases considered: No Prevalence higher in boys than girls
Musaiger et al., 2012) [19]	4698 age 15 to 18 years (*n* = 2240 males, *n* = 2458 females).	2010–2011	IOTF, CDC	SEX / IOTF / CDC Male / 34.8 / 42.1 Female / 20.6 / 21.1	The sample was apparently representative of Kuwait city, but not representative of Kuwait CIs given: Yes Biases considered: No Prevalence higher in boys than girls.
Alrashidi et al 2015 [26]	960 11-14 years females(*n* = 480) and males (n = 480	February–June 2013	WHO	SEX / Prevalence Male / 37.6 Female / 35.6	The sample was from Kuwait city, apparently not representative of Kuwait CIs given: No Biases considered: No
Al-Awadhi et al 2013 [2]	1273 females, age 15–19 years	2010	CDC	18.3% (95% CI: 16.2–20.6%)	The sample was apparently representative of Kuwait, CIs given: Yes Biases considered: No
The Kuwait Nutrition Surveillance system:2016 Annual report,Ministry of Health [29]	12,396, age 5-17 years. (*n* = 6251 males and *n* = 6145 females)	2016	WHO	Overall prevalence of obesity was 25.9% Age / Prevalence 5 / 13.5 9 / 20.0 11 / 33.1 15 / 29.6 17 / 26.7	The sample was representative of Kuwait CIs given: No Biases considered: No Prevalence not given for the sexes separately.

Footnotes: There were no eligible published data or grey literature for 3 of the GCC countries: Bahrain, Oman and Qatar
Where authors acknowledged biases in prevalence estimation with BMI this has been noted. Where authors reported CIs for their prevalence estimates these have been provided in the Tables. *CDC* Centers for Disease Control and Prevention, *BMI* Body mass index, *IOTF* International Obesity Task Force, *WHO* World Health Organisation, *KSA* Kingdom of Saudi Arabia, *UAE* United Arab Emirates

8. Additional files

8.1 Additional File 1 Title. Literature search terms in Ovid Medline.

Description. Search terms and syntax in Medline.

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1. "Obesity prevalence."
2. "Children" , ''Child''
3. "Adolescent" or "teen" Or ''youth''
4. "Gulf Countries" or "Arabian Gulf"
5. "GCC" or "Middle East"
6. "Saudi Arabia", "Kuwait", "Oman", or "Bahrain", "Qatar",
7. "United Arab Emirates", or "UAE"
8. "Reviews", "Literature", or "Systematic"
9. #(1)&#(2)#(4).
10. #(1)&#(3)#(5)
11. #(1)&#(2)#(6)
12. #(1)&#(2)#(6).
13. Limit to English language

The search strategy was replicated in the other databases, but with minor changes of syntax as required by each database.

8.2 Additional File 2 Title. GCC experts consulted on search findings and missing studies.

Description. Summary of experts contacted to check on search results, their affiliations, and their responses.

Contact No	GCC Country	Location	Response
1	Kuwait	Sport Section, Kuwait Ministry of Health	No
2	Kuwait	Kuwait University	Yes
3	Kuwait	Kuwait University	Yes
4	Kuwait	Ministry of Education	Yes
5	Kuwait	Public Authority for Food and Nutrition	Yes
6	Kuwait	Ministry of Education	No
7	Kuwait	Ministry of Health	Yes
8	Kuwait	Ministry of Education	Yes
9	Kuwait	Public Authority for Food and Nutrition	No
10	Kuwait University	Kuwait University	No
11	UAE	College of Medicine & Health Science	Yes
12	UAE	Emirates University	No
13	UAE	Ministry of Health	Yes
14	Bahrain	Arabian Gulf University	No

15	Bahrain	Ministry of Health	Yes
16	Qatar	Aspetar Sports Medicine Hospital	No
17	Qatar	Hamad Hospital	No
18	KSA	Al Majamaa University	Yes
19	KSA	King Saud University	Yes
20	KSA	Dammam University	No
21	Oman	Ministry of Health	Yes
22	KSA	Ministry of Health	Yes
23	KSA	Ministry of Health	Yes

8.3 Additional File 3 Title. List of excluded studies.

Description. Summary of full-text screened studies excluded, with reasons for exclusion.

Authors, year	Study title	Reason for exclusion
Abdul-Rasoul, 2012	Obesity in children and adolescents in Gulf countries: Facts and solutions.	Old data before 2007
Al-Dossary *et al.*, 2010	Obesity in Saudi children: a dangerous reality	Old data before 2007
Al-Kilani *et al.*, 2012	Trends of obesity and overweight among college students in Oman: A cross sectional study	Wrong population group
Al-Refaee *et al.*, 2013	The rising tide of overweight among Kuwaiti children: study from Al-Adan Hospital, Kuwait.	Overweight data, no obesity data
Al Shehri, 2013	Obesity among Saudi children.	Old data before 2007
Bader *et al.*, 2008	Overweight and obesity among adolescents in Bahrain	Combined overweight and obesity prevalence
Boodai *et al.*, 2014a	Prevalence of cardiometabolic risk factors and metabolic syndrome in obese Kuwaiti adolescents	Metabolic syndrome study; No obesity prevalence data
Boodai *et al.*, 2014b	National Adolescent Treatment Trial for Obesity in Kuwait (NATTO): project design and results of a randomised controlled trial of a good practice approach to treatment of adolescent obesity in Kuwait.	No relevant obesity prevalence data
El-Bayoumy *et al.*, 2009	Prevalence of Obesity Among Adolescents (10 to 14 Years) in Kuwait.	Old data before 2007
El Mouzan *et al.*, 2010	Prevalence of overweight and obesity in Saudi children and adolescents	Old data before 2007
Farrag Nesrine S., 2017	A systematic review of childhood obesity in the Middle East and North Africa (MENA) region: Prevalence and risk factors meta-analysis.	Old data before 2007
Gharib and Rasheed, 2008	Obesity among Bahrani children and adolescents: Prevalence and associated factors	Old data before 2007
Hammad and Berry, 2016 [3]	The Child Obesity Epidemic in Saudi Arabia: A Review of the Literature.	Old data before 2007
Jackson *et al.*, 2011	Waist circumference percentiles for Kuwaiti children and adolescents.	No prevalence data
Mandeya and Kridli, 2014	Childhood overweight and obesity in Qatar: A literature review.	Old data before 2007
Mirmiran *et al.*, 2010	Childhood obesity in the Middle East: a review	Old data before 2007
Musaiger,	Overweight and obesity in eastern Mediterranean	Old data before

2011	region: prevalence and possible causes.	2007
Musaiger *et al.*, 2012	Body weight perception among adolescents in Dubai, United Arab Emirates.	Old data before 2007
Musaiger and Al-Mannai, 2013	Role of obesity and media in body weight concern among female university students in Kuwait.	Body Image, No obesity prevalence data
Musaiger *et al.*, 2013	Risk of disordered eating attitudes among adolescents in seven Arab countries by gender and obesity: a cross-cultural study.	Eating Attitudes , No obesity preva-lence data
Musaiger *et al.*, 2014	Social, dietary and lifestyle factors associated with obesity among Bahraini adolescents	Old data before 2007
Musaiger *et al.*, 2016	Disordered Eating Attitudes Among University Students in Kuwait: The Role of Gender and Obesity.	Wrong population group
Ng *et al.*, 2014 [6]	Global, regional, and national prevalence of over-weight and obesity in children and adults during 1980-2013: a systematic analysis for the Global Bur-den of Disease Study 2013	Old data before 2007
Rizk and Yousef, 2012	Association of lipid profile and waist circumference as cardiovascular risk factors for overweight and obesity among school children in Qatar.	Old data before 2007
Shaban *et al.*, 2017	Corrigendum to Perceived Body Image, Eating Behavior, and Sedentary Activities and Body Mass Index Categories in Kuwaiti Female Adolescents	Self-image, no obe-sity prevalence data.
Suraya *et al.*, 2017	Effect of obesity on academic grades among Saudi female medical students at College of Medicine	Wrong population group
Zaal *et al.*, 2011	Anthropometric characteristics and obesity among adolescents in the United Arab Emirates.	No obesity preva-lence data

The updated search in November 2018 identified a further four studies which were full-text screened but ineligible, details as follows: Garemo *et al*., (2018) studied an ineligible population group (Pre-school children); Al Omar *et al*., (2018) used an ineligible means of defining obesity in adolescents (BMI rather than BMI-for-age); Nanhas *et al*., 2018 did not present any prevalence data (protocol paper); Rey-Lopez *et al*., 2019 did not present obesity prevalence data.

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Chapter 4: General methods for studies 2, 3 and 4

1. Preface

The present section expands on the methodology for chapters 5, 6 and 7 highlighting and justifying the various methods used in the three studies, which could not be presented in the manuscripts because of the restriction on word limits for each journal.

1.1 Author Contribution

The cross-sectional study was designed and conducted by the leader author HH. JJR assisted with the study design and choosing the appropriate exposure, co-variates, and outcome measures. JJR and AH (Dr. Allan Hewitt) supported the study design and data analyses. HA (Dr. Hamad Alaslawi) facilitated the process of data collection at the Kuwait University, all authors read and approved the final manuscripts.

When collecting data, HH was assisted by a Dietitian SA (Shyima Alqatan) from AlAdan Hospital during the fieldwork and she recorded field notes. HA (Hasan Alttaer) from KISR trained HH how to set-up the equipment for BIA to measure the body fat in participants. For the cognitive test, CHR (Dr. Crystal Haskell) from Northumbria University trained and advised on the inhibition test outcome.

2. Introduction

The systematic review (Study 1, Chapter 3) showed that the prevalence of obesity seems very high in Kuwaiti children and adolescents. However, the evidence was limited as there are few recent studies of prevalence in Kuwait and the Gulf states. In addition, the evidence was typically based on BMI definitions, which have been shown to underestimate the true scale of prevalence as discussed in chapter 1. Moreover, none of the previous systematic reviews on the classification accuracy of BMI (Reilly *et al*., 2010; Okorodudu *et al*., 2010; Javed *et al*., 2015), which included n=18, n= 25, and n=37 studies, respectively, had any studies from the Arab world or the GCC population.

Study 2 (Chapter 5) aimed to test the classification accuracy of BMI for high body fatness in female Kuwaiti late-adolescents (17-19.9 years) at university to assess the impact of BMI-defined obesity compared to that based on body fat percent. Study 3 (chapter 6) and study 4 (chapter 7) aimed to further explore the impact of obesity in Kuwait by assessing associations and possible effects of obesity on educational attainment (Study 3) and cognitive inhibition (Study 4) in female adolescent university students.

3. History of studies 2, 3 and 4 from exploratory to full studies

Studies 2, 3, and 4 (see chapters 5, 6 and 7) were initially planned to be feasibility studies with exploratory analyses because of logistic and time limitations considered at the planning stage. The researcher HH had to obtain approval from the Kuwait University for collecting data from the students, and to borrow the equipment from Kuwait Institute for Scientific Research (KISR) that required the equipment being in custody of one of the university staff and returning them within three months of moving to Kuwait University campus. In addition, HH had to obtain approval from Kuwait University for an allocated area to store the equipment and undertake the assessment for participants. As for time constraints, the university academic year begins in mid-September and ends at the end of May and is further divided into two semesters of between 15 and 17 weeks' duration. The first semester is from mid-September until the end of December. The second semester starts from the end of January until the end of May, and June is exams period for the end of the semester. Therefore, the most eligible time to have the most participants accessible was during the 2^{nd} semester from February until end of May, but there was also a need to avoid the exam period and the month of fasting (Ramadan) that started in mid-May that year as well as the holidays. In addition, the researcher HH had visa restrictions that prevented her from staying out of the country of study (UK) for more than 90 days.

In summary, the combination of the issues described above (having to get approval and borrow equipment for data collection, the university term time, Ramadan, the visa restrictions) meant that the time window available for data collection for studies 2, 3, and 4 was limited to approximately 12 weeks.

Accordingly, power calculations were not considered as these studies were novel and were originally determined based on what would be feasible in Kuwait, and that was not clear until HH collected the data over the period between March and May 2019 during the academic year of 2018/2019 at Kuwait University. Since it was feasible to recruit a reasonably large sample size with all measurement data, the studies seemed to be more than feasibility studies and became cross sectional studies and were all based on the same protocol/data collection described later in this chapter.

4. Sample characteristics and recruitment

4.1 Participants

Studies 2, 3 and 4 were all based on a convenience sample due to the reasons described above. Convenience sampling is defined as nonprobability sampling where subjects are sampled simply because they are convenient without using random selection (Jager *et al*., 2017). Although probability sampling has better generalisability than nonprobability sampling, the use of homogeneous convenience samples provides clearer generalisability than heterogeneous convenience samples for understanding population effects and subpopulation differences (Jager *et al*., 2017). For example, homogeneous convenience sample was suitable for assessing the impact of obesity on educational attainment and inhibition in Kuwaiti individuals. Therefore, only Kuwaiti nationals were considered, a move that was undertaken to provide a relatively homogeneous sample for reducing the number of potential confounders (e.g. non-Kuwaiti nationality).

This sample was restricted to female late adolescents in the first and second year of university as this age group corresponds to the WHO definition of adolescents. Based on the general definition by WHO, adolescent is aged between 10 and 19.9 years old (WHO, 2007; WHO, 2015) as described in chapter 1. This age group was chosen due to practical and scientific reasons. For practicality, having permission from the Ministry of Education for collecting data from school-aged children under the age of 16 years would have taken more time than was available for data collection within a maximum of 12 weeks due to visa restrictions mentioned earlier in this chapter. In addition, gaining approval for the study from the Ministry of Health in Kuwait would have taken more than 12 weeks. Furthermore, it would be difficult to transfer the equipment from each school and class to others, which would require obtaining further permission. Additional consideration was that adolescents are more mature and would be more responsive when invited to participate in the study. Having a female researcher HH involved meant that it would be more practical to collect data from the same sex, especially due to cultural and religious aspects of the Kuwait environment

In addition, targeting female adolescents was based on the emerging evidence of the higher impact of obesity on self-esteem and quality of life in females than in males (Al-Sabah *et al*., 2015; Al Khalaf *et al*., 2012; Korczak *et al*., 2013; Reilly *et al*., 2003). Other systematic reviews (Hill *et al*., 2018; Martin *et al*., 2017; Santana *et al*., 2017) showed that obesity was more likely to be negatively associated with education attainment and/or cognitive function in girls than in boys. Most studies in these reviews were conducted in western societies, which may not be applicable in the GCC countries. Furthermore, to date, no study has investigated the association between obesity and educational attainment and/or cognitive function in female adolescents in Kuwait.

4.2 Ethical permissions and clearance

Studies are expected to strictly adhere to a set of ethical guidelines. This study was conducted in accordance with the Declaration of Helsinki (Goodyear *et al*., 2007). In addition, ethical approval was provided in December 2018 by the ethics committee of the School of Psychological Sciences & Health, Faculty of Humanities and Social Science of the University of Strathclyde. The approval to conduct the study at Kuwait University followed a formal procedure. The letter from the ethics committee (**Appendix D**) as well as a letter from the supervisor JJR (**Appendix E**) were presented to the Dean of Social Science College at Kuwait University to get their permission for conducting the study on campus. Kuwait University also made sure that there was no need for a permission from the Kuwait Ministry of Health because the study did not include participants under the age of 16 years old or a collection of blood samples. Additionally, the Social Science College formally reached out to KISR for an agreement to borrow and move the study-required equipment to their campus for two months (**Appendix F**). The Research and Statistical Consultation Unit provided allocated area for storing the equipment and collecting data. The researcher HH was trained on the use of the equipment by KISR staff and the equipment was returned back to them at the end of May 2019.

The Researcher HH collected the data with assistance of her female colleague, who has an M.Sc. degree in Dietetics and is specially trained for working with children and adolescents at Al Adan Hospital in Kuwait. The ethical considerations were addressed by seeking consent from the participants before they were allowed to be involved in the study. The consent form (**Appendix G**) provided participants with adequate information, such as the purpose of the study, details of the researcher, information on the voluntary nature of participation, the participant's ability to withdraw from the study at any time, the participant's role, the duration of the experiment and the confidentiality and anonymity of the data. Consent was provided in Arabic and English, and all participants or parents of those under the age of 18 years gave informed written consent to participation.

4.3 Sample recruitment

Information about the students in the 1st and 2nd year in all departments of the College of Social Sciences for the academic year 2018/2019 was provided by the Vice Dean of Academic Affairs (**Appendix H**). This information included the nationality (Kuwaiti or non-Kuwaiti), the gender, the specific department, and the total number of students in each category. The total number of students was 3024; 855 students were excluded because they were either male or non-Kuwaiti, leaving n=

2169 female Kuwaiti students who were invited by emails to participate in this study. Additionally, the researcher HH reached out to female students in the College of Social Sciences by giving presentations and displaying posters (**Appendix I**) about the research topic, aim of the study, and contact information. Those who were interested in participating in the study had to register by emailing or calling the secretary of Research and Statistical Consultation Unit, and they had to provide their student ID number and choose the appropriate date and time slot to participate. Of the 2169, n=525 agreed to participate in the study, and of the 525, n=125 were excluded as ineligible due to having issues which might affect their weight status and body composition (such as pregnancy, chronic illness, injury or fracture which may affect body weight). **Figure 1** summarises the recruitment process at the College of Social Sciences.

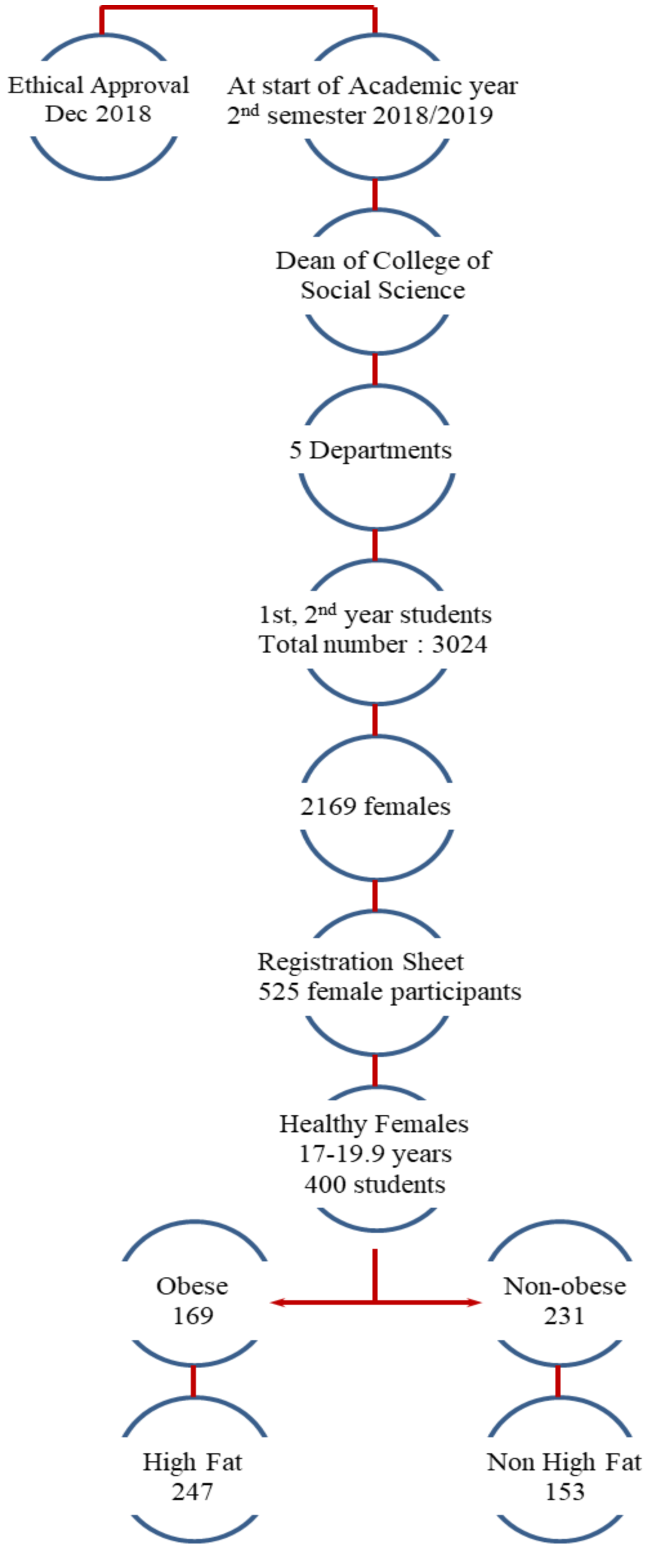

Figure 1 Flow diagram of the recruitment process [1]

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[1] Obese: WHO BMI-for-age Z score≥ 2 for students aged (17.0-19 years), BMI ≥30 kg/m^2 for those aged (19.1-19.9 years). High body fat: Fat % ≥ 30%.

4.4 Sample size

The sample sizes for studies 2, 3 and 4 were fixed due to practical issues mentioned earlier in this chapter, and initially the studies were intended as feasibility studies as described earlier in this chapter. Power calculations were not carried out in advance of the study due to the fixed sample size, as discussed previously.

Study 2: Classification accuracy

In classification accuracy studies for obesity, the main requirement is to have a wide range of body fatness and BMI-for-age since the classification accuracy of BMI-for-age for body fatness was shown to vary considerably according to the degree of body fatness (Freedman & Sherry, 2009). In addition, the accuracy of BMI-for-age was shown to be inaccurate in underweight and normal-weight children and adolescents- the accuracy of BMI increases with the degree of body fatness (Freedman & Sherry, 2009). The sample for study 2 had a wide range of BMI-for age and body fatness, from 15.1 to 54.0 kg/m^2 and from 5.0 to 54.0%, respectively.

In the systematic review by Reilly *et al* on the classification accuracy of BMI-for-age, the largest study (Ng *et al*., 2007) had a female sample size n=1144, mean age 15.8 years, and the smallest study had a female sample size n=57, age 15-18 years (Oliveira *et al*., 2006). The other two studies reported in the same age group included n=659, mean age=16.1 years (Kelishadi *et al*., 2006) and n= 523, mean age 16.1 years (Misra *et al*., 2007). Another systematic review (Javed *et al*., 2015) included a Brazilian study (Da Veiga *et al*., 2001) with a female sample size n=823 (age 10-17.9 years) with only n=68 females in the age (17-17.9 years), and the largest female sample size (n=1603, mean age 15.2 years) was reported in a Swedish study (Neovius & Rasmussen, 2008). A recent Chinese study (Chen *et al*., 2018) included a female sample size n=999, age 9-19 years, with a mean age 13.9.

Overall, the sample size for study 2 was fairly comparable to most studies assessing the classification accuracy of BMI in adolescents covering a wide age range. The sample size for study 2 was even higher than most studies that covered the specific age group (17-19.9 years old).

Studies 3 and 4: Association studies

A recent systematic review (Hill *et al*., 2018) assessed the association between obesity and educational attainment in college and university students (+16 years old) in 6 cross-sectional studies that had a female sample size that ranged from n=45 with a mean age of 21.7 (Franz & Feresu, 2013) to a female sample size of n=1020 with a mean age of 22.6 (Odlaug *et al*., 2015), but the latter study collected self-reported data through an online survey. All the cross-sectional studies included in the review by Hill *et al*., (2018) were conducted in the USA, except one study that was conducted in a single university in Saudi Arabia and had a female sample size n=199 with a mean age of 21.3 years (Suraya *et al*., 2017). The other USA studies included in the review reported a female sample size of n= 866, age 18-19 years (Canning & Mayer, 1966), n= 204, mean age 21.1 years (Anderson and Good, 2017) and n=1036, including males and females, aged 15-85 years (MacCann & Roberts, 2013).

Santana *et al*., (2017) reviewed the association between obesity and educational attainment in 23 cross-sectional studies with a sample size ranged from n=45, age 7-12 years (Ramaswamy *et al*., 2010) to a sample size of 1172 females with a mean age of 10.5 (Leblanc *et al*., 2012). The second largest study (Abdelalim *et al*.,

2012) in this review was conducted in Kuwait on males only with a sample size of n=999, and a mean age of 10.3 years. Of note, this study included Kuwaiti and non-Kuwaiti male students.

Martin *et al*., (2017) systematically reviewed longitudinal studies (n=31) on the association between obesity and educational attainment in children and adolescents. All studies, except one study, started either in childhood or in early adolescence and followed up to middle adolescence (< 17 years old). The only longitudinal study (Roberts and Hao, 2013) that included participants aged 11-17 years at baseline and followed up to 12-18 years had a sample size of n=3134 including males and females (Martin *et al*., 2017).

Regarding the association between obesity and cognitive function, a recent systematic review (Favieri *et al*., 2019) included 20 cross-sectional studies on adolescents with a sample size that ranged from n=18 to n=108, including males and females. While the sample size in the longitudinal studies (n=6) ranged from n=22 to n=62, including males and females. More specifically, all adolescent inhibition studies, including cross sectional and longitudinal designs, had a female sample size n= <100.

In summary, the majority of studies on the association between obesity and educational attainment and inhibition included early and middle adolescents, with a very limited number of studies that had data on late adolescents. In addition, most of the samples in previous studies were mixed by both genders and had wide age ranges so they were quite heterogeneous, so the present thesis studies had a fairly large sample size for a homogenous sample of late adolescents.

5. Data collection

5.1 Location of data collection

Kuwait University was first established in 1966. At that time, it was comprised of 418 students and 31 faculty members in both the Arts and Sciences colleges (Safi, 1986). The University has not only expanded but has also diversified to fulfil the demands of Kuwait's trained workforce. Its establishment marked an important milestone in the state of Kuwait because it represented the first public institution of higher education and research in the state.

Kuwaiti nationals are provided free registration (tuition free) and each registered Kuwaiti student receives an allowance for four years of study with a stipend of around 500 pounds each month. In addition, graduate students have to study full time as the government does not allow part-time degree studies as a policy of the higher education system.

College of Social Science

The research for studies 2-4 was done in the College of Social Science, one of the more renowned areas of the university. The College is located in Kuwait City Shuwaikh Campus **(Figure 2**), the largest campus at Kuwait University. The college consists of five (**Figure 3**) academic departments, including Information Science, Geography, Psychology, Political Science, and Social Work. The campus also includes a library, language unit, and the Global Centre. They are supported by instructional facilities, college administration, labs, research spaces all of which are equipped with smart teaching technology.

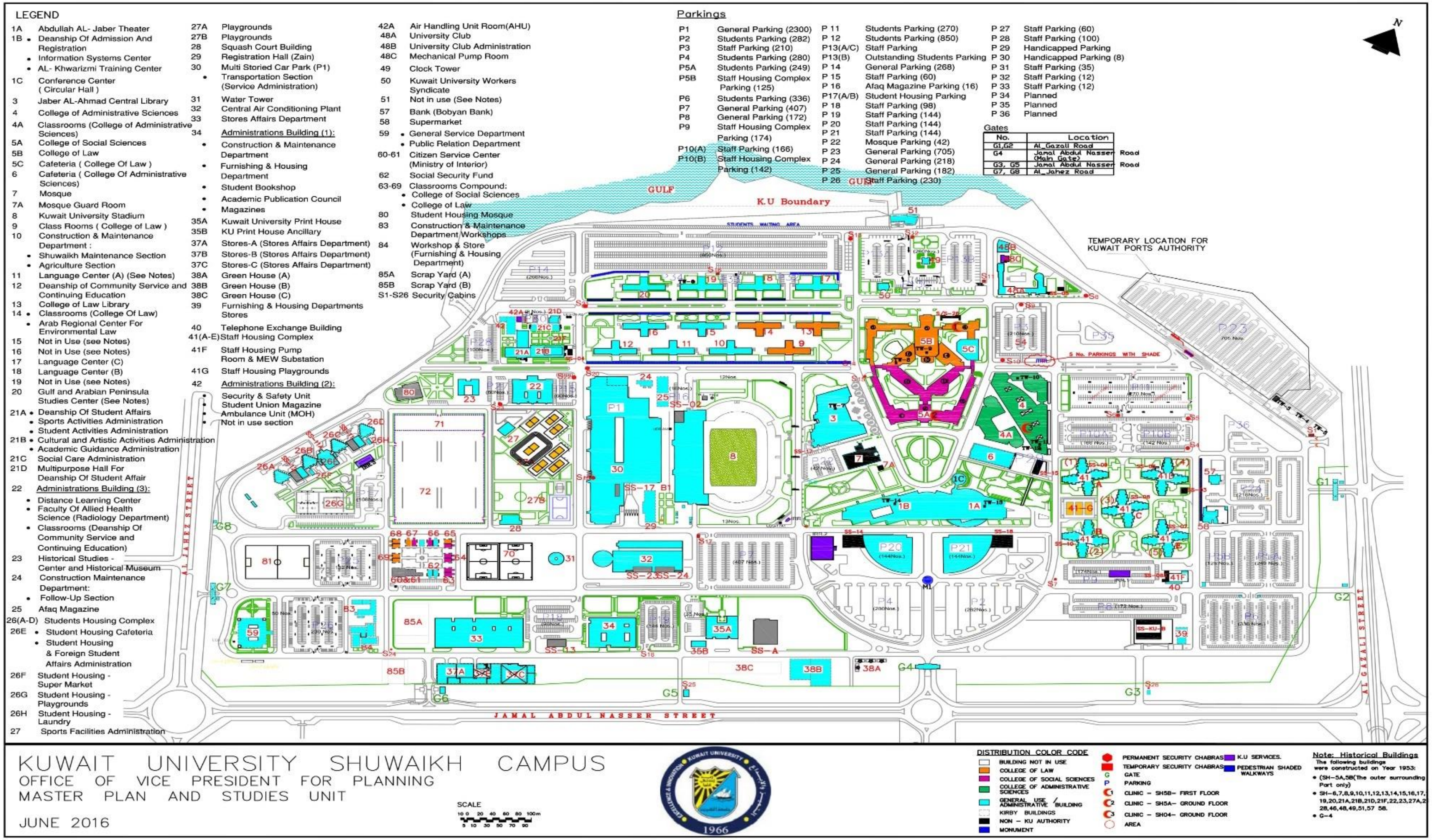

Figure 2. The College of Social Science (shown in pink) is located in Shuwaikh Campus (Kuwait University, 2020)

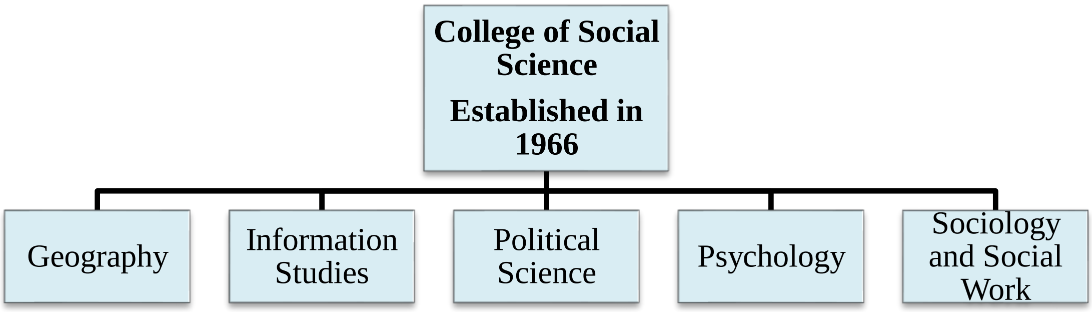

Figure 3. College of Social Science academic departments (Kuwait University, 2020)

5.2 Procedure of data collection

The data were collected from students over a twelve-week period, from 8 am until 7 pm on Sunday-Thursday, and from 9 am to 1 pm on Saturdays in a private room with a temperature of 25C. **Figure 4** below shows the steps for collecting the data from students; **1-** Student ID and information sheet, **2-**height measured by stadiometer, **3-** BMI and BF% measured by Tanita, and **4-** cognitive function computerized test.

Data were entered using the student ID entry codes on an SPSS data file (**Appendix J**) to guarantee anonymity. In addition, there was a detailed description of Standard Operating Procedure (SOPs) for each measure (**Appendix K**).

Figure 4. Steps for collecting data for studies 2-4

6. Justification of methods used in studies 2, 3 and 4

The aim of this section is to detail the methods used to assess the exposure and outcome measurements in studies 2, 3 and 4.

6.1 Measuring exposure variables in studies 2, 3 and 4

The main exposure measures were obesity as defined by BMI-for-age and high body fat (expressed as a percentage of body weight) see chapter 1 that explains in detail these measurements of obesity. The BMI in adults and BMI-for-age in children and adolescents are considered a standard metric used as a proxy for classifying who is overweight, normal weight, and obese (WHO, 2007). In general, the body anthropometry measurements refer to a series of quantitative measurements of the bone, muscle, and adipose tissue primarily used as proxies for body composition (Cole *et al*., 2000). They are proxies for body composition rather than direct measurements of body composition; these measures generally do not produce measures of body fatness, while body composition techniques in contrast do measure body fatness, e.g. body fat percentage. For the body composition measurements, there is no one single method that gives information on overall body tissue, therefore there are various methods that differ in cost effectiveness and simplicity and these methods can range from simple field-based methods e.g. BIA to highly technical challenging laboratory based methods (DEXA, MRI) as mentioned in Chapter 1. **Table 1** shows the advantages and disadvantages of most common methods for body composition and proxy measures of body composition.

Table 1. Advantages and disadvantages of direct measures of body composition and proxy measures for body composition

Direct measures of body composition:

Method	Advantage	Disadvantage
Dual Energy x-Ray Absorptiometry (DEXA)	High measurement precision (Wells & Fewtrell, 2006; Krugh & Langaker, 2019).	The lack of standardization in both bone and soft tissue measurements and expensive equipment (Gibson, 2005; Krugh & Langaker, 2020).It is not Portable
Densitometry	Body density Offers a two-compartment model (underwater weighing and air displacement plethysmography) that measures both FFM and FM. (Pupim *et al*., 2004; Wells & Fewtrell, 2006)	The process calls for a special facility The method can be uncomfortable for the subject because it requires them to remain underwater-particularly difficulty for the elderly, obese, children, and debilitated subjects when they try to get either into or out of the water tank. (Pupim *et al*., 2004; Wells & Fewtrell, 2006)
Isotope dilution	Usable in any population High accuracy	Very expensive (Bila *et al*., 2017)
Magnetic resonance imaging (MRI)	High reproducibility Provide precise measurement of subcutaneous and visceral fat (Wells & Fewtrell, 2006)	Extremely expensive equipment (Gibson, 2005; Krugh & Langaker, 2020)
Bio-Impedance (BIA)	Safe, practical (Talma *et al*., 2013), and inexpensive in terms of analysing body composition (Barreira *et al*., 2013). Commonly used in the estimation of body composition in muscle and fat mass (Peterson *et al*., 2011)	Strict protocol for children under 10 years old as they must fast. Also could be affected by hydration status, drink and food intake, air temperature, physical activity. (Barreira *et al*., 2013; Talma *et al*., 2013)

Table 1. Advantages and disadvantages of direct measures of body composition and proxy measures for body composition cont./

Proxy measures for body composition:

Method	Advantage	Disadvantage
Skinfold Thickness (SFT)	Simple Inexpensive Provides invaluable information about body fat distribution (Wells & Fewtrell, 2006)	Difficult or challenging to take data in an individual who is extremely obese. Prediction of body fat depends on certain equation assumptions. (Gibson, 2005; Wells & Fewtrell, 2006)
Body Mass Index (BMI)	Simple Inexpensive Appropriate for large-scale studies (Wells & Fewtrell, 2006)	Fails to account for muscle mass differences Shorter people are likely to overestimate their height when allowed to self-report., and problems of low to moderate sensitivity Obese people often tend to underestimate their body fat weight when allowed to self-report. (Reilly *et al*, 2010: Wells & Fewtrell, 2006)
Waist circumference (WC)	Simple and cheap (Wells & Fewtrell, 2006).	Might cause pain or embarrassment for some people if they were sensitive; problems of low to moderate sensitivity (Gibson, 2005; Wells & Fewtrell, 2006).

The exposure measurements were BMI-for-age and body fat percent measured by BIA. For each participant in study 2, 3 and 4, weight was measured to the nearest 0.1kg using the BIA TBF 310 (Tanita™). Before taking the weight, the height was measured to the nearest 0.1 cm, using SECA, UK, with shoes removed. Each measurement was conducted twice and the average was taken from these two readings. The BIA electrode was cleaned with Isopropyl alcohol after each participant. More details about each measurement are explained below.

Body mass index (BMI-for-age) is a commonly used index for nutritional status and generally accepted in children and adolescents to classify them as obese and non-obese (WHO, 2007; de Onis *et al*., 2007; Cole *et al*., 2000) as discussed in Chapter 1. The WHO BMI cut-off points are commonly used in studies to define obesity. In studies 2-4, obesity was defined based on WHO BMI-for-age Z score ≥2.0 in participants aged 17.0-19.0 years old, and BMI ≥30 kg/m^2 in participants aged 19.1-19.9 years old (WHO, 2007; Cole *et al*., 2000). BMI Z scores were calculated using Anthroplus software (Appendix K), which is a software designed to enable the global application of WHO Reference 2007 for children and adolescents aged between 5 and 19 years old (WHO, 2007; WHO, 2009). Anthroplus software calculates Z score up to 19.0 years old, and if the age was 19.0 and 1 day from date of birth it would not calculate the BMI z score, therefore the adult BMI was calculated for those aged 19.1-19.9 years old (Cole *et al*., 2000).

Body fat percentage (BF%) by Bioelectric Impedance Analysis (BIA)

The second measure of obesity was BF %. In the current studies 2, 3 and 4 (chapters 3, 5 and 7) body composition was measured using BIA, which is a relatively simple and inexpensive technique and does not require much training and practice unlike other methods (Burns *et al*., 2019) as discussed in chapter 1, section 2. In addition, BIA is used in large population-based studies especially cross sectional studies (Javed *et al*., 2015; Reilly *et al*., 2010) and large scale epidemiological surveys for both children and adults e.g. the US National Health Examination Survey (NHANES III) (Chumlea & Guo, 2000). Moreover, the BIA model used is Tanita TBF 300, which is one of the most accurate methods and can be done alone with the participants, if compared with the skinfold assessment that cannot be done alone and requires a skilled person for accuracy (Peterson *et al*., 2011). A systematic review of 50 studies, with 7 studies of Tanita TBF 300 model, supported BIA as a reliable method to estimate body fat % in children and adolescents (Talma *et al*., 2013). In addition, Kabiri *et al*., (2015) reported excellent reliability for Tanita TBF 300 model in university students. However, the validity of BIA was not clear due to the variety of BIA devices and prediction equations used in studies (Talma *et al*., 2013).

As discussed in chapter 1, section 5, numerous studies have established that high levels of body fatness during childhood and adolescence can cause a vast range of adverse health consequences (Reilly, 2010), mainly the cardiometabolic consequences, as summarised in the systematic reviews (Reilly *et al*., 2003; Reilly & Kelly, 2011). For this thesis, the term “high body fatness” is used rather than “excessive fatness” that was used in the published paper (Chapter 5) based on the reviewers’ suggestion.

Determining the cut-off point that defines high fat, i.e. the body fat content which escalates the risk of developing cardiometabolic risk factors, is more problematic in adolescents than it is in adults due to normal (and sometimes large) changes in body composition that naturally occur with age and growth. Williams *et al*., (1992) aimed to develop cardiovascular health-related % body fat standards that can be used in epidemiological investigations of the prevalence of obesity in children and adolescents. The sample included 3320 White and African American children and adolescents aged 5-18 year old to determine the critical level of body fatness associated with increased risk of cardiometabolic variables, namely elevated blood pressure, total cholesterol, and serum lipoprotein. A significant increase in the cardiometabolic risk profile was found for body fatness of ≥30% in girls and ≥25% in boys (Williams *et al*., 1992).

According to Williams *et al*., (1992), the BF cut-off of 30% for females was used in the present thesis studies. This cut-off is widely used and accepted to define high body fatness in girls and female adolescents in studies. A recent study evaluated the classification accuracy of BMI in 1516 children aged 8-11 years old from eight African countries using the Williams cut-off (Diouf *et al*., 2018). In adolescents, these cut-off values were used in a Swedish cross-sectional study (Neovius *et al*., 2004) of 477 adolescents aged 17 years old, as well as in two Brazilian studies in female adolescents aged 10-17.9 years old (Veiga *et al*., 2001) and in male adolescents (Anzolin *et al*., 2017). In addition, some studies used Williams cut-off values in American adults aged >18 years old (Shah & Braverman, 2012; Frankenfield *et al*., 2001) as well as in Australian adults aged 19-77 years old (Piers *et al*., 2000).

Overall, there is lack of reference data on BF% cut-offs to define high fatness and therefore a variety of cut-off values have been used in studies (Javed *et al*., 2015; Okorodudu *et al*., 2010; Reilly *et al*., 2010). Accordingly, the BF cut-off of 30% used in these studies was a working definition, and the accuracy of this definition for detecting adolescent females with high fatness is still uncertain.

6.2 Measurement of potential confounders in studies 3 and 4

Confounding is defined as mixing of effects when investigating an association between an exposure and an outcome (Miettinen, 1974; Jager *et al*., 2008). The confounder is a variable that has to satisfy the three properties as follows:

1) "the variable must be associated with the exposure, i.e., it must be unequally distributed between the exposed and nonexposed groups" (Jager *et al*., 2008).

(2) "it must be associated with the outcome, i.e., it should be a risk factor for the outcome" (Jager *et al*., 2008).

(3) "it must not be an effect of the exposure, nor be a factor in the causal pathway of the outcome" (Jager *et al*., 2008).

The outcome variables in this study are educational attainment (GPA) and cognitive inhibition. Confounding of obesity-educational outcomes may be influenced by socioeconomic status (SES) in western societies. A systematic review by Santana *et al*., (2017) showed that the association between obesity and academic attainment in school children and adolescents became uncertain for most studies after controlling for potential confounders, including SES and parental education (Santana *et al*., 2017). Additionally, Walk *et al*., (2020) emphasized that there was a strong possibility that confounding by SES might at least partly explain the association between obesity and lower education attainment and cognitive function in children (9-10 years) (Walk *et al*., 2020). On the other hand, the systematic review of Hill *et al*., (2018) indicated that SES (including parental education or earnings) was considered as a potential confounder in all the longitudinal studies but none of the cross-sectional studies (Hill *et al*., 2018). Hill and colleagues concluded that educational attainment in university students may be less impacted by SES than that in school students, suggesting that university could provide a better opportunity for studying the association between obesity and educational attainment (Hill *et al*., 2018).

As discussed in chapter 1, low SES in high income countries is associated with higher obesity risk, while in contrast in low-middle income countries, low SES is associated with lower obesity risk. Since low SES affects both the exposure and the outcome, then it is a possible confounder in western societies, and it may be a potential confounder in GCC countries. The confounding potential in this case could explain the associations between obesity and educational outcomes and cognitive inhibition, which are investigated in studies 3 and 4 (i.e. poorer attainment in the obese might simply be because they are poorer). Therefore, the relationship between obesity and these outcomes requires an understanding of the cofounding properties of SES in the context of Kuwait. **Figure 5** Illustrates the confounding variable (SES) examined in the association between adolescent obesity and educational attainment and cognitive function (inhibition).

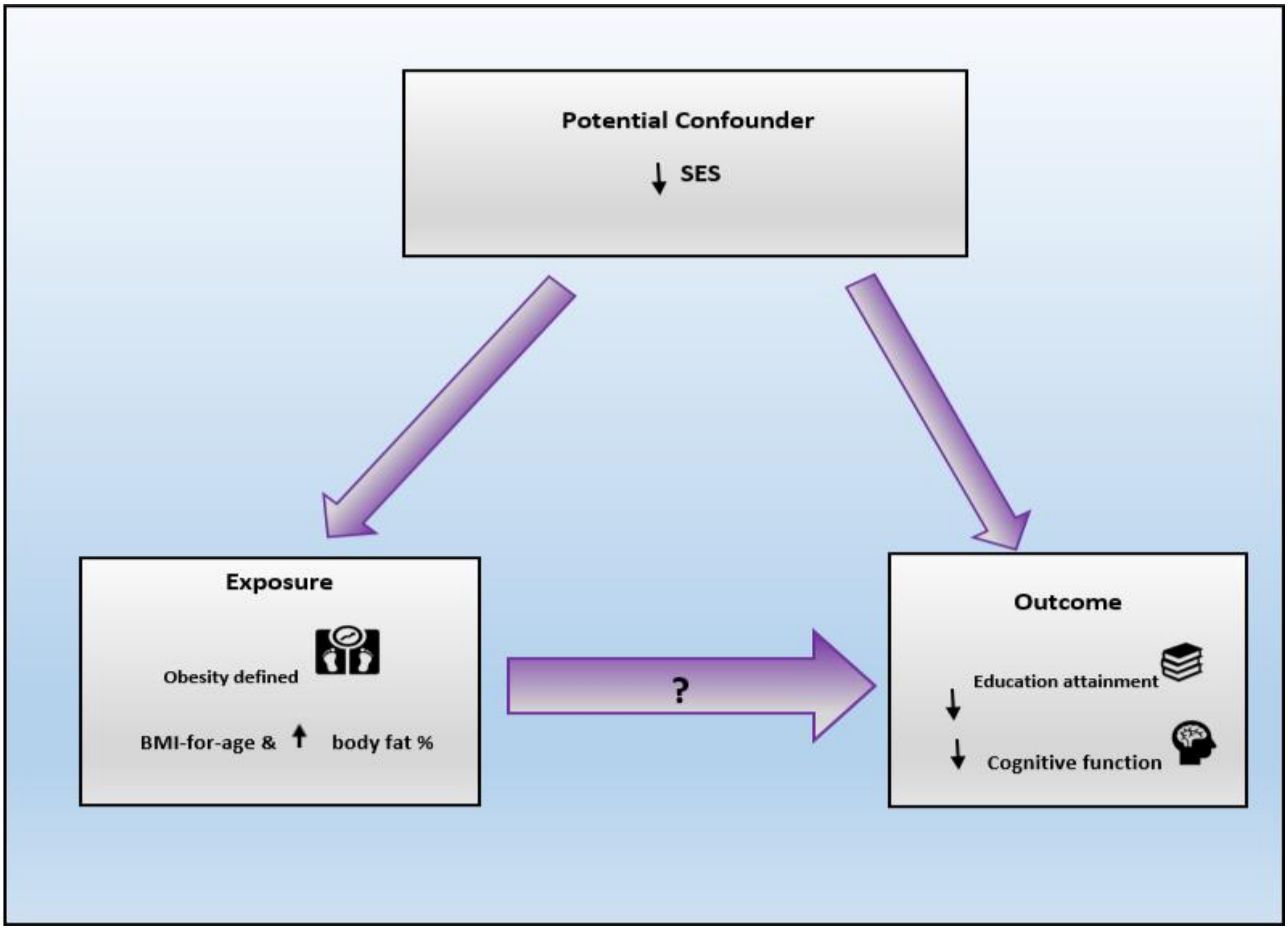

Figure 5. Association between exposure and outcome for studies 3-4

As discussed in chapter 1, section 8, Kuwait is a relatively equal society with almost no socioeconomic hierarchy as that seen in other high-income countries. However, there is limited previous evidence on obesity-educational and obesity-inhibition outcomes in Kuwait, therefore, the potential confounding of obesity-educational and obesity-inhibition associations by SES is not that clear and may not be the same as in studies in western countries.

Rey-Lopez *et al.*, (2019) indicated that no evidence was found for an association between SES and adolescent obesity risk in Kuwait. Their cross-sectional study assessed the prevalence of overweight and obesity among 591 Kuwaiti adolescent students (males and females 11.0-19.0 years old) from only three out of the six Kuwaiti governorates due to time and resource constraints (Rey-Lopez *et al*., 2019). The study concluded that over half of school age Kuwaiti adolescents were overweight/obese (combined) using IOTF cut-off points. The SES was based on parental education using the following response categories: “illiterate, read and write, intermediate, secondary, university or higher” (Rey-Lopez *et al*., 2019). For analysis, these categories were recoded into two levels: High, if parents achieved at least university, and Low, if parents achieved below university studies (Rey-Lopez *et al*., 2019). The study found no significant association between SES represented by parental education and obesity risk in adolescents, given that this study was one of the very few studies that addressed the potential confounding of SES with regards to obesity prevalence in Kuwait

However, a more recent cross-sectional study analysed data from STEPS survey on NCD risk factors in Kuwait. The study investigated the association between obesity (defined as BMI $\geq$30 kg/m^2) and several sociodemographic factors among 3589 Kuwaiti individuals, males and females, aged 18-69 years old from the 6 governorates (Weiderpass *et al*., 2019). The SES factors assessed in this study were education level and work status. The prevalence of obesity was inversely associated with the education level in females, while the prevalence of obesity in men with primary education only was less than that in men with post-graduate education (Weiderpass *et al*., 2019). For work status, the prevalence of obesity was significantly higher in women who were homemakers than those in other occupational categories (employed, student, retired), while no association between obesity and the occupational status was detected in men (Weiderpass *et al*., 2019).

Accordingly, it seems there is lack of consistent evidence regarding the role of SES in the risk of obesity in Kuwait and more investigation is needed (Abdelalim *et al*., 2012; Al-Kandari, 2006; Musaiger, 2011). The SES in the present thesis was defined by parental education as a relevant indicator of individual variation in Kuwaiti population. Other SES measures, such as income and place of residence, were not considered in the present thesis due to limited disparity in the income between Kuwaiti nationals, and the urban concentration of population as discussed in chapter 1. On the other hand, education and SES may be less related in Kuwait than in some other countries as the education at Kuwait University is free. In addition, every Kuwaiti student at Kuwait University receives a stipend of around 500 pounds monthly from the Government of Kuwait.

6.3 Justification of methods used for outcomes in studies 3 and 4

For studies 3 and 4 (chapters 6 and 7), the outcome measures were educational attainment (GPA) in study 3 and inhibition in study 4. The justification for methods and measurements of the outcomes are explained below.

Outcome measurements for study 3- chapter 6

Educational attainment outcome:

The measurement used for educational attainment was the grade point average (GPA). The GPA is widely used to determine progress or achievement in the performance of university students worldwide (Hill *et al*., 2018). The choice of GPA rests on the fact that it is the most common measure used to assess the success of undergraduate students, and it is meaningful to students and colleges/universities, and it is relatively easy to obtain (Alhazmi & Al Johani, 2019).

The GPA is widely used in the GCC and Kuwait for schools and universities (Al-Isa *et al*., 2010; Suraya *et al*., 2017). Previous studies of associations between obesity and educational attainment in undergraduates have used GPA as an outcome as shown by several systematic reviews (Hill *et al*., 2018; Martin *et al*., 2017; Santana *et al*., 2017). GPA is used to give a composite score across all classes and is a reliable measurement (Martin *et al*., 2017; Sabia *et al*., 2009). However, some studies of the possible effects of obesity on educational attainment measured education attainment in individual subjects, such as maths, reading, and language, rather than the overall GPA across multiple classes/subjects (Martin *et al*., 2017). Martin *et al*., (2017) suggested that associations between obesity and maths outcomes might be stronger than that for obesity and other outcomes. In this thesis study, it might not matter because the students were from the college of Social Science and most students would not register for maths or a reading module at the college. Moreover, the choice of GPA was made partly because this is such an important/meaningful measure for students and universities (Hill *et al*., 2018), and so it makes sense to test for associations with the most meaningful outcome to stakeholders.

GPA measurement at Kuwait University: the GPA was provided as a continuous variable (from 1.00 to 4.00). The student ID was used to look at the GPA of each student for the academic year of 2018/2019. The Kuwait University used the formulae of dividing the total number of points (for each module) acquired by the student by the credit hours attempted by the student to arrive at the overall GPA for each student at Kuwait University. **Table 2** shows the GPA categories used at Kuwait University. For instance, for students to attain grade A in a three credit-hour module, they must get twelve points. In this case, if a student attends four classes and attains twelve points in each, then the GPA for that student is as follows: 4X12=48 points, 4X3=12 credit hours, **GPA**=48/12=4. Therefore, the overall point (GPA) for that student in the whole semester is 4. HA (Hammad Alaslwai), the Head of Research and statistical consulting unit at College of Social Science at Kuwait University, provided the GPA for each student, with confidential access to identifiable data only by the researcher HH.

Table 2. GPA values & categories used at Kuwait University, College of Social Science

Appreciation	Degree		Points (GPA)
Excellent	Normal	A	4
	Low	A-	3.67
Very good	High	B+	3.33
	Normal	B	3.00
	Low	B-	3.67
Good	High	C+	2.33
	Normal	C	2.00
	Low	C-	1.67
Satisfactory	High	D+	1.33
	Normal	D	1.00

Outcome measurements for study 4- chapter 7

Inhibition outcome:

Chapter 1 noted that cognitive function mattered and was potentially affected by obesity according to the model by Brownell and Walsh (2017) (**Figure 2** in chapter 1). The majority of studies measured specific cognitive domains (e.g. Executive function (EF)) rather than the general intelligence (Booth *et al*., 2014; Martin *et al*., 2017; Santana *et al*., 2017). There are many different dimensions of EF and so many choices of cognitive tasks for EF dimensions (e.g., Stroop task, Stop Signal Task, Iowa Gambling Task, Span Task, Maze task); some of which are more sensitive to test aspects of executive functions than others (Diamond, 2013; Vainik *et al*., 2013) as discussed in chapter 1. As aspects of executive functioning have been measured using different tasks, the Stroop task (Stroop, 1935) is the most common one that has been used to measure response inhibition, selective attention, short-term memory, and cognitive flexibility (Favieri *et al*., 2019; Scarpina & Tagini, 2017). In study 4, selective attention (the ability to suppress an automated/uninhibited response and focus attention) and response inhibition were assessed by the Stroop Colour Word Test (SCWT). The SCWT is widely used to measure inhibition because it is based on colours and easy to translate and so it has been used in different languages (Marian *et al*., 2013). The SCWT is easily understood by adolescents and well-educated university students (Suarez *et al*., 2014). In addition, a study by Deng *et al*., (2018) suggested that computerised SWCT is a reliable test of brain function in the young aged between 18-25 years old (Deng *et al*., 2018), and the computerized version of Stroop test is applicable in brain-imaging studies in both children and adults (Penner *et al*., 2012). A review of nine studies supported the validity of the computerised Stroop test and the reliability of the tool (Che Din & Tat Meng, 2019). Moreover, the choice of SCWT was because the researcher was familiar with it as she used it in her MSc project at Northumbria University at Newcastle-upon-Tyne.

However, the Arabic version of computerised SCWT was not available in Kuwait. The first time that SCWT was used in Arabic, it was a paper-based test in a small study conducted in Saudi Arabia (Al-Ghatani *et al*., 2010). As Arabic is the first language for the students in the College of Social Sciences, there was a need to develop the Arabic version of the computerised SCWT. The license for the SCWT was purchased in the form of the Computerised Mental Performance Assessment System (COMPASS) version 5 (Haskell *et al.*, 2010; Dodd *et al.*, 2015). Dr. Crystal Haskell from Northumbria University's Brain, Performance and Nutrition Research Centre (BPNRC), with the assistance of the researcher HH, translated the SCWT to Arabic written colours, which makes this task the first specialised version in Arabic language in the world. However, using COMPASS software on healthy participants provides a fairly simple solution to alleviate some of the complexities of cognitive testing. COMPASS is an easy system that allows selecting a number of tasks from a wide range of pre-programmed standard cognitive tests in various languages. As it is automated, it easily retrieves data and saves time. Furthermore, the outcome data for each assessment that are completed by each participant are automatically saved and downloaded and the raw data are readily available for quality and fine-grained analysis.

Administration of the Stroop task:

The first step entailed closing all applications for installing COMPASS version 5. The installation folder was selected before clicking next. After the installation was done, the COMPASS icon appeared on the screen. The license key obtained from the vendor was entered, and then COMPASS was configured for the Stroop test only. Configuration of the SCWT was done by dragging and dropping the desired task from the list on the left to the task order on the right, right clicking the task name and selecting configure, changing the default setting for the Stroop test only and then clicking ok to save the configuration. After configuration, the COMPASS was run by double-clicking its icon on the desktop, selecting load on the study design screen, and navigating to a folder where the study configuration had been stored. Then, the study configuration was opened, and followed by clicking next to display the module configuration screen, clicking next again to display the study details screen before inputting the specific session details, and finally clicking next to commence the task.

A pilot test for SCWT was undertaken using 19 students from the original 525 cohort. Prior to taking the weight and height measurements of these 19 students they were individually asked to sit in front of the computer while the process was explained to them and a full description of the task involved was given to them (in Arabic). They then undertook the SCWT test to demonstrate that they fully understood the process. These 19 students undertook the tests twice and the best results were used for the scores. The students included in the pilot study were also included in the main study.

When the SCWT was administered, each participant was again instructed to perform the test as accurately and quickly as possible. It was again explained to them that they would see words written in different colours in Arabic where they have to match the written (word) colour and one of the coloured boxes on the right-hand side of the screen.

The words presented on the laptop screen were either congruent, meaning the colour of the word and the Arabic name of the colour was the same, or incongruent, meaning that the colour of the word and the name of the colour were different as shown in the figure below. On the screen, the words appeared randomly and the SCWT consisted of twenty tasks. Two trials were done for each student; the first trial as a standard practice for the student and the second trial where the results were recorded, as advised in the COMPASS manual (COMPASS, 2019). See **Figure 6** below. More detailed explanation on the SCWT S.O.P.s are provided in **Appendix**

K. Every student was given between 1-2 minutes to complete the test, and both the % of correct answers and the total reaction time (RT) (in milliseconds) were automatically computed and recorded for every student. Stroop effect is defined as the delay in the reaction time between congruent and incongruent stimuli (Gluck *et al*., 2013) and therefore RT is used to assess the mental response speed. The RT is important because if the participants did not have to produce a timed response, then they could simply study the colour word for as long as they liked and would be very unlikely to produce an incorrect response. In addition, the RT is also useful as sometimes it is more sensitive than accuracy, so the participants may perform extremely well on accuracy but at the expense of speed and therefore RT allows you to assess both speed and accuracy (Burle *et al*., 2004).

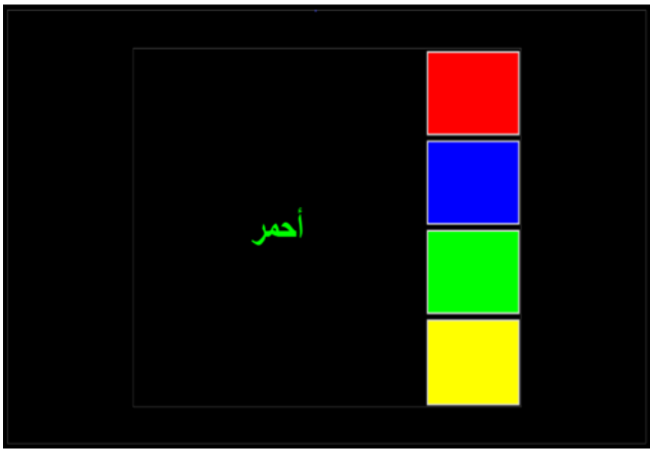

Figure 6. On Screen layout of the Stroop Color-Word tasks. Reaction time (RT) and overall correct answers generated for every task.

7. Data handling and statistical analysis

BMI-for-age Z score was calculated for individuals aged 17.0-19.0 years old using AnthroPlus **Appendix L** (WHO, 2009) as mentioned earlier in this chapter.

The BMI-for-age Z score data were divided into non-obese and obese based on the cut-off points of WHO 2007 reference. For individuals aged ≥ 19.1 years, the BMI was calculated according to the formula (weight kg/height² m²), and the BMI data were divided into non-obese and obese according to adult cut-off point (WHO, 2000; Cole *et al*., 2000). The body fat % data were divided into non-high body fat and high body fat based on the cut-off points developed by Williams *et al*., (1992) as explained earlier. Obesity is the exposure variable based on BMI-for-age (none-obese coded=1, obese coded =2) and body fatness (non-high body fat coded =1, high body fat coded =2). The analyses in studies 3 and 4 were run with both BMI-for-age defined obesity and high body fat % defined obesity. The potential confounder variables were SES (Parental education as described earlier in this chapter). For the SES, parents without university degree coded=1, parents with university degree coded= 2. Although the age range was limited, the age decimal range (17.0-19.9) was considered in the confounding analysis as the risk of obesity was shown to increase with age, and age may affect educational attainment or cognitive inhibition.

Descriptive data and normality testing:

All data analysis was done for studies 2, 3 and 4 using Statistical Package SPSS version 26.0 (SPSS Inc; Chicago.IL) and MedCalc. Demographic statistics were conducted to provide descriptive data for the characteristics of the sample population, including the number of participants, weight (kg), height (cm), age (decimal years), BMI (kg/m^2) (range), fat percentage (%), all to 1 decimal place.

Characteristics of study participants were checked for normal data distribution. For normality, D'Agostino–Pearson test is a powerful overall test for normality. D'Agostino (1971) describes a "normality test based on the skewness coefficient, √b

1 and kurtosis *b*2 coefficients. For the normal distribution, the theoretical value of skewness is zero, and the theoretical value of kurtosis is three". Subgroup analysis was performed to determine the normal distribution of variables, which was assessed by plots of the data, D'Agostino-Pearson test, and the nonparametric test Kolmogorov-Smirnov (K-S) to help make a decision on the next steps of measurements and statistical methods for data analysis (Ghasemi & Zahediasl, 2012).

The inter quartile range (IQR) is defined as "a measure of spread given by the difference between the "1st quartile (the value below which 25% of the cases lie) and the 3rd quartile (the value below which 75% of the case lie)" (Harris & Taylor, 2008), and the IQR contains the middle half of the sample. Continuous variables were summarised as mean (SD) if normally distributed or median (range or IQR) if not normally distributed.

7.1 Study 2 statistical analysis

Classification accuracy statistics

The sensitivity, specificity, and positive and negative predictive values are statistical measures of the performance of a binary classification test that are widely used for evaluating clinical tests as discussed in detail in chapter 1, section 3. These values were calculated and expressed in percentages according to the definitions (for definitions see Chapter 1, section 3 and chapter 5) to measure the accuracy of BMI-for-age to define high fatness. High body fatness was defined as a body fat of ≥30.0% derived from bio-electrical impedance.

The receiver operating characteristic (ROC) curve and the area under the curve (AUC) of ROC analysis were not done because the aim of study 2 was not to identify the optimal BMI cut-off points. However, study 2 aimed to estimate the extent to which BMI-for-age estimates of obesity prevalence from study 1 might be underestimating the true prevalence of obesity (i.e. high body fatness). In addition, the sample size was not sufficient for doing ROC analysis since sensitivity and specificity depend on the sample size and the true prevalence (true positives) of obesity (Habibzadeh *et al*., 2016), therefore, the lack of reference or criterion measure of body fatness (e.g. TBW) in this study was another reason for not doing ROC analysis.

7.2 Studies 3 and 4 statistical analysis

In study 3, the grade point average (GPA) was used in two ways: as a continuous variable (from 1·00 to 4·00) and as a categorical variable with the GPA distribution divided into quartiles (Q1-Q4), with n=100 students per quartile, where Q1 is the highest, and Q4 is the lowest quartile. Using more than one way of considering GPA was done for several reasons: the analyses were regarded by the author and supervisors as exploratory; academic attainment outcome data have been treated as categorical variables in many previous studies; it permitted the use of logistic regression which extended the experience of statistical analysis for the author. The data were categorised to define a bad outcome since it was not clear what would be a low GPA for university students in the 1st and 2nd year using the continuous variable. It was reasonable to use four quantiles with a sample size of 400 so that there is the same number of individuals in each group. The splitting of data into four equal groups was done following the grading system at Kuwait University mentioned earlier in this chapter.

A significant difference level of 5 % was used with a confidence interval of 95% for all tests.

Tests of differences between obese and non-obese (by BMI and body fat %):

The mean GPA was compared between students categorised as obese versus non-obese by BMI and the same was done for those categorised as high body fat versus non-high body fat by fat percentage using two-sample t-test because the variables were normally distributed. The null hypothesis for t-test: "there is no statistically significant difference in the mean GPA between obese and non-obese individuals".

Chi-squared ($\chi 2$) tests were used to estimate the association between two categorical variables (GPA quartiles and obesity defined by BMI or high fatness). The null hypothesis for chi-squared test was "there is no statistically significant association between GPA quartile and obesity defined either by BMI or high fatness".

Logistic regression is used to examine the association of (categorical or continuous) independent variable with one dichotomous/binary dependent variable or to predict a binary outcome based on a set of independent variables. When the GPA data were categorised into quartiles, with the lowest quartile considered as a bad outcome, linear regression was used to estimate the odds of having a bad outcome by weight status (having obesity or not having obesity; having high body fatness or not having high body fatness). Linear regression was not used because it is suitable for predicting an outcome that is continuous and the outcome variable in this study was binary. The potential confounding by participant age or by socio-economic (parental education level) was considered in this analysis. The null hypothesis for logistic regression in study 3 was "there is no statistically significant association between GPA lowest quartile and obesity defined either by BMI or high fatness".

For study 4 (Chapter 7), the SCWT performance data were not normally distributed, therefore, Mann Whitney U, which is a non-parametric test, was used to compare median SCWT performance between groups (obese versus non-obese by BMI or high fatness). The null hypothesis for Mann Whitney U: “there is no statistically significant difference in the median SCWT performance between obese and non-obese individuals”.

The reaction time (RT) data were normally distributed, and the two sample t-test was used to compare the mean RT between groups (obese versus non-obese by BMI or high fatness). The null hypothesis for t-test: “there is no statistically significant difference in the mean RT between obese and non-obese individuals”. Appendix M

Chi-squared (χ^2) tests were used to analyse the differences between median SCWT performance categorised by quartile (Q1-Q4 highest-lowest performance as explained above for GPA quartiles) and obesity status (either by BMI or high fatness). The null hypothesis for chi-squared test was “there is no statistically significant association between median SCWT performance and obesity defined either by BMI or high fatness”.

Logistic regression was used to investigate the association between SCWT performance and both BMI status and high fatness status. The null hypothesis for logistic regression was “there is no statistically significant association between median SCWT performance and obesity defined either by BMI or high fatness”.

The results of logistic regression were presented as odds ratio (OR) with the 95% confidence intervals (CI). The ORs are widely used to measure associations in epidemiology and defined as a measure of association between an exposure and an outcome. The OR represents the odds that “an outcome will occur given a particular exposure, compared to the odds of the outcome occurring in the absence of that exposure" (Szumilas, 2010). The ORs and their 95% CI for the associations between GPA/Stroop performance and obesity defined by BMI and high fatness were estimated.

8. Conclusion

This chapter aimed to provide a more detailed explanation and justification for the methods used in the three studies done in Kuwait and information on the location and procedures. Chapter 5, 6 and 7 will present the papers of three studies.

Chapter 5: Classification Accuracy of Body Mass Index for Excessive Body Fatness in Kuwaiti Adolescent Girls and Young Adult Women

Published in *Journal of Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy in April 2020*

1. Preface

The systematic review findings from chapter 3 have shown that evidence on the prevalence of obesity among school-age children and adolescents in the GCC states is limited outside Kuwait sate. This chapter aims to present the published paper, Classification Accuracy of Body Mass Index for Excessive Body Fatness in Kuwaiti Adolescent Girls and Young Adult Women, Published *in Journal of Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy Science in April 2020.*

The paper is presented in a similar format as was published in the mentioned journal. Therefore, the referencing system is not APA as used in the other chapters of this thesis. As mentioned previously, HH was the lead author and collected the data with a Dietitian. JJR and HA (Allan Hewitt) advised and supported the assessment of analysing and all the aspects of the study. HA (Hamed alaslawi) supported with the private space to set up the equipment borrowed from KISR and provided the students GPA. Finally, the review design, revision as well as approval of the final manuscript was supported by all authors

2. Abstract

Purpose: Adolescent obesity, as defined by BMI, is amongst the highest in the world in Kuwait. This study aimed to determine the extent to which BMI might be underestimating obesity as defined by excessive fatness in Kuwaiti female adolescents and young adults.

Methods: 400 apparently healthy Kuwaiti female university students (mean age 18.0 SD 0.6) were recruited. Excessive fatness was defined as body fat % ≥30, measured using the Tanita model TBF-310 Bio-impedance system with the manufacturer's equation. Obesity was defined as recommended by WHO in adult participants - those age ≥19.1 years- as a BMI ≥30 kg/m^2. In the adolescent participants (age <19.1 years) obesity was defined as recommended by WHO as BMI-for-age Z score of ≥2.00. The accuracy of BMI-defined obesity to identify excessively fat individuals was determined by estimating prevalence of obesity using high BMI, prevalence of excessive fatness, and by calculating sensitivity and specificity and predictive values.

Results: Median BMI was 27.8 kg/m^2 (range 15.1 to 51.2) and median body fat% was 32.0 (range 5.0 to 54.0). Prevalence of excessive fatness was 62% (247/400 individuals were excessively fat), while the prevalence of obesity according to BMI was 42% (169/400 individuals were obese according to their BMI). The sensitivity of BMI to identify the excessively fat individuals was moderate (66%) but specificity was high (96 %). The positive predictive value of BMI was 96% and negative predictive value was 64%.

Conclusion: BMI-based measures substantially underestimate the prevalence of excessive fatness in Kuwaiti adolescent females. Obesity is even more prevalent, and requires more urgent attention, than is apparent from BMI-based measures used

in most research and national surveys. The BMI may also be too crude for use as an exposure or outcome variable in many epidemiological studies of Arab adolescent girls and adult women.

3. Introduction

Prevalence of child, adolescent, and adult obesity are very high in the Gulf Co-operation Council (GCC) states, among the highest in the world[1-4]. Our recent systematic review found that obesity prevalence estimates for the GCC countries, like many other countries around the world, are currently based entirely on BMI[1]. The World Health Organization (WHO) defines obesity as body fat accumulation to the extent which poses a health risk[1]. However, since body fatness is difficult to measure, simpler proxies for body fatness are usually preferred for defining obesity in studies and national surveys[1,5,6]. WHO recommends that the best simple proxy for obesity prevalence is the BMI, with obesity defined as BMI$\geq$30.0 kg/m^2 in adults, or a BMI-for-age Z score $\geq$2.00 in adolescents (up to and including age 19.0 years as defined by the WHO).

Several systematic reviews[7-9] of the classification accuracy of the BMI in children, adolescents, and adults have concluded that using BMI is a conservative way of determining obesity prevalence, i.e. that sensitivity is low-moderate. This means that a relatively high proportion of individuals with an apparently healthy BMI or BMI-for-age are actually excessively fat. The problem of low sensitivity of BMI seems to be particularly serious in some populations, e.g. in a recent study of African children and adolescents the prevalence of obesity as defined by excess fat-ness was over three times higher than the prevalence of obesity as defined by the BMI-for-age[6]. Despite this concern about the BMI this source of bias when using

BMI is not widely known. For example, our recent systematic review found 11 eligible published studies and surveys of obesity prevalence from the GCC states and none of these made any reference to biases in the estimation of obesity prevalence using BMI[1]. The two most recent global estimates of obesity prevalence[10,11] also failed to refer to this source of bias when using BMI and BMI-for-age.

While an underestimate of obesity prevalence when using the BMI to define obesity might therefore be expected, it is not widely appreciated, and the extent of the underestimate seems to vary substantially between human populations[12]. At present the extent of the bias when using BMI in Arab countries is unknown - none of the systematic reviews published to date found any studies of diagnostic accuracy of BMI from any Arab countries in children, adolescents, or adults[7-9]. There is therefore a need for new evidence on the diagnostic accuracy of BMI in Arab populations so that the extent to which studies and surveys which have used it are biased can be assessed.

The problem of misclassification of obesity (excessive fatness) when using BMI goes beyond implications for estimating obesity prevalence. In many studies BMI is being used as a proxy exposure variable, to test for associations between obesity and various adverse health and other outcomes, such as cognitive and educational attainment for example[13,14]. In many other studies BMI is being used as a proxy outcome variable, to test for associations between various potential exposures (e.g. physical activity and sedentary behaviour) and obesity[15,16]. The extent to which BMI misclassifies excessive fatness will determine the extent to which these studies can identify obesity as an important exposure or outcome. The ability to examine obesity as an outcome or exposure in our future studies in the GCC countries depends on the extent to which BMI misclassifies excessive fatness. If the degree of misclassification of excessive fatness by BMI is substantial in Arab populations, then body fatness should be measured directly in future studies, rather than using BMI as a proxy[17].

The aim of the present study was therefore to assess the extent to which BMI might underestimate obesity (excessive fatness) in Kuwaiti adolescent girls and young adult females at university.

4. Methods

4.1 Study Design, Participants, Consent and Ethics Approval

The present study was part of a wider prospective investigation of the impact of obesity on educational outcomes in a convenience sample of Kuwaiti female university students. Data collection took a place at Kuwait University College of Social Science in February-May 2019 and was restricted to adolescents and young adults only (students in 1st and 2nd year), and to Kuwaiti nationals only so as to obtain a relatively homogenous sample. Of the 3024 students in the College, 855 students were excluded as they were male or non-Kuwaiti, leaving 2169 students who were potentially eligible and so were invited to participate in this study. Students with issues which might affect their weight status and body composition were excluded (pregnancy, chronic illness, injury which affected body weight e.g. limb in cast following a fracture). The study was approved by the ethics committee of the School of Psychological Sciences & Health, Faculty of Humanities and Social Science, Strathclyde University (See Appendix-D for approval letter; no ethics reference numbers were issued by the ethics committee back in 2018) and all study participants gave informed written consent to participation. For study participants under the age of 18 years a parent also provided informed written consent. This study was conducted in accordance with the Declaration of Helsinki. Additionally, Kuwait University provided approval to carry out this study at the College of Social Science.

4.2 BMI-Defined Obesity- the Index Test of Obesity

Height was measured using a Seca Stadiometer to 0.1cm (Seca, London, England), and weight to 0.1kg with study participants in light indoor clothing with the Tanita TBF-310 leg-leg bioimpedance system (Arlington Heights, Illinois, USA). Both height and weight were measured by two trained and experienced observers and both observers followed WHO guidance on anthropometric measurement using standard operating procedures. Since adolescents are still growing and BMI increases until growth has stopped, the BMI cut-offs recommended by WHO to define obesity for adolescents and adults are different[5]. For the adolescents (17.0 to 19.0 years of age) who took part we defined obesity as a BMI Z score of ≥2.0 relative to WHO 2007 reference data[5] using Anthroplus software. For those from 19.1 years we used the adult cut-off point of BMI ≥ $30kgm^2$ to define obesity.

4.3 Body Fatness-defined Obesity, the Reference Standard

Body fat percentage was measured by the Tanita TBF-310, using the manufacturer's equation for estimation of body fatness which is commercially sensitive and not available publicly. The device was used by two trained researchers on the same day as the height and weight measures, and they followed standard operating procedures based on the manufacturer's instructions. Study participants were asked to avoid strenuous exercise and eating and drinking for at least 2 h prior to the bio-impedance measure. Leg–leg bio-impedance estimates of body fatness are relatively insensitive to the timing of eating and drinking, and to the composition of the food and drink consumed, making the technique particularly practical for field and clinical applications.[18,19] The purpose of using bio-impedance in the present study was based partly on practical grounds as it is quick, cheap, and painless, and poses little or no burden for researchers as well as the participants of the study, and so is especially suitable for field studies of this kind.[20] Additionally, the Tanita device with the manufacturer's equation has been validated against alternative measures of body fatness in a number of studies in adolescents and young adults, and has been reported to provide acceptable estimates of fatness.[21–24] .

Previous studies of the diagnostic accuracy of BMI against body fatness measurement have used a variety of cut-offs for excessive fatness in adolescent females, but a cut-off of ≥ 30% has been used widely according to systematic reviews[7-9]. This cut-off originated from a major study which found that there was a sharp increase in cardiometabolic risk factors at 30% body fat in girls and women[25]. Therefore, body fat ≥ 30% was used in the present study to define excessive fatness.

4.4 Classification Accuracy Statistics and Reporting

The sensitivity, specificity, positive and negative predictive values were calculated to measure the accuracy of BMI to define over-fatness[26]. Sensitivity was defined as "proportion of people with the disease with a *positive* result"; specificity was defined as "the proportion of people without the disease with a *negative* result"; positive predictive value was defined as "the proportion of people with a positive test result who actually have the disease"; negative predictive value was defined as "the proportion of people with a negative test result who do not have disease" [26]. Continuous variables were summarized as mean (SD) or median (range) as appropriate after checking for normality using plots and D'Agostino-Pearson tests.

Classification accuracy and diagnostic accuracy studies should follow STARD[27] (Standards for Reporting of Diagnostic Accuracy Studies) guidance, and so conduct and reporting of the present study followed this guidance.

5. Results

5.1 Characteristics of Study Participants

Recruitment into the study is summarised in a flow diagram (**Figure 1**). Of 2169 potentially eligible Kuwaiti female students, 525 agreed to participate, but 125 were ineligible (age 20 or over, with chronic disease, injury, or pregnant): 400 eligible participants took part and among these 400 there were no missing data. Anthropometric and bio-impedance data were collected on the same day. Mean weight was 68.8 kg (SD 17.2), and mean height was 158.1 cm (SD 5.1), while median body fat percentage was 32.0 (range 5.0 to 54.0): see **Table 1.**

Table 1. Characteristics of Study Participants

Table 1 Characteristics of Study Participants, Mean (SD) or Median (Range)

Variable	Total
Number of participants (n)	400
Weight (kg)	68.8 (17.2)
Height (cm)	158.1 (5.1)
Age (decimal years)	18.3 (0.6)
BMI (kg/m^2)	27.8 (range 15.1–54.0)
Fat percentage (%)	32.0 (5.0–54.0)

5.2 Prevalence of BMI-Defined Obesity and Prevalence of Excessive Fatness

Prevalence of excessive fatness was 62% (247/400 individuals were excessively fat) while the prevalence of obesity according to BMI was 42% (169/400 individuals were obese according to their BMI).

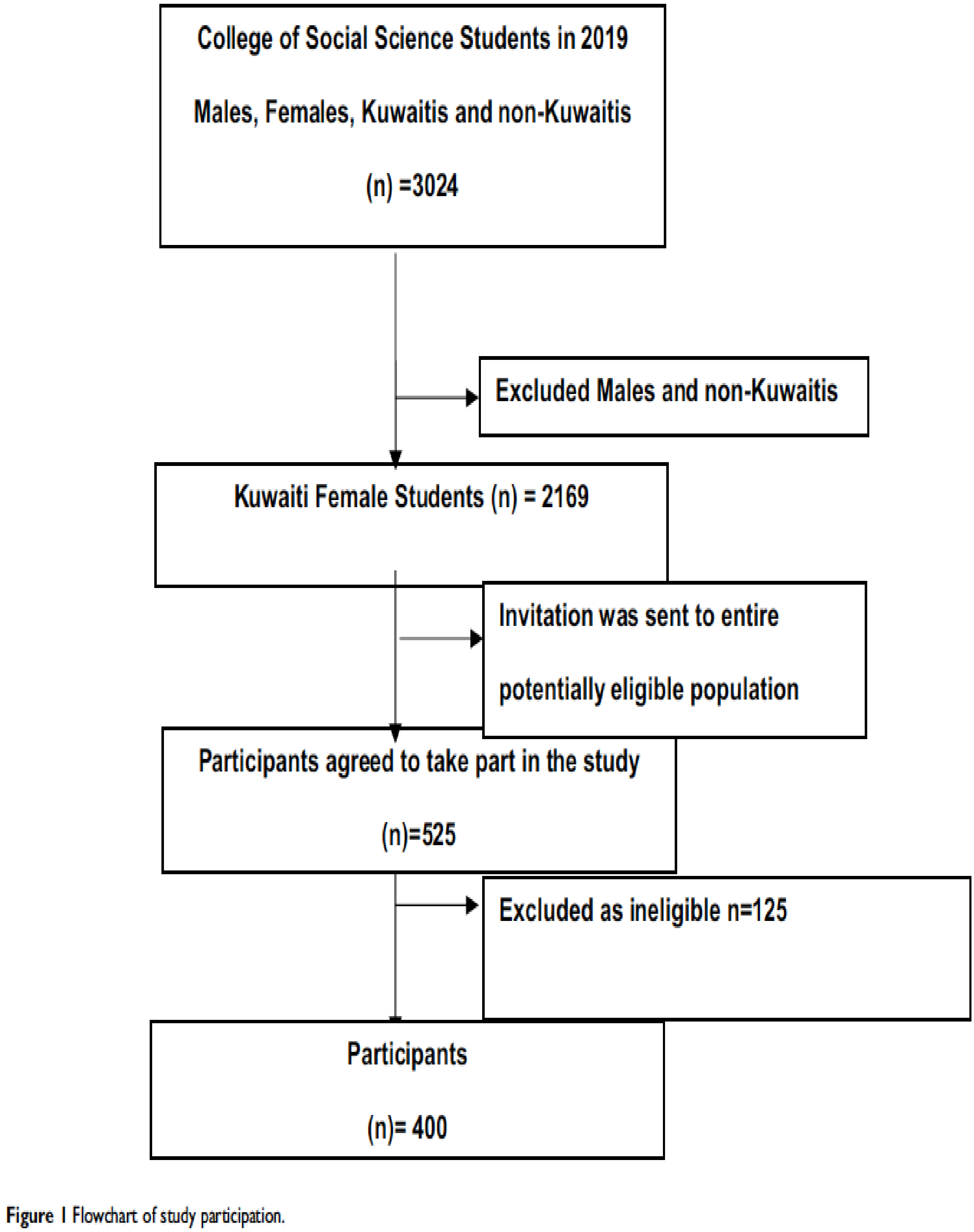

Figure 1. Flowchart of Study participation

5.3 Classification Accuracy Statistics

The STARD checklist summarising adherence to conduct and reporting guidance for studies of this kind is summarised in **Table 2.** Sensitivity of the BMI for age definition of obesity was 66% (163/247 excessively fat individuals had a positive test for obesity according to their BMI; **Table 3**). The specificity of the WHO BMI for age was 96% (147 out of 153 individuals not excessively fat had a negative test for obesity tests according to their BMI). The positive predictive value was 96%: 163 out of 169 individuals with positive tests for obesity were excessively fat. The negative predictive value was 64%: 147 out of 231individuals with negative tests for obesity were not excessively fat.

Table 2. Summary of Required Items for Reporting of Diagnostic Accuracy Studies

Table 2 Summary of Required Items for Reporting of Diagnostic Accuracy Studies, Adapted from[27]

Title, Abstract	Identify as diagnostic or classification accuracy study
Introduction	Make aim of classification accuracy clear
Methods	Describe design, prospective or retrospective
	Describe participant eligibility criteria
	Explain participant's identification and recruitment sequence
	Describe the index test and reference method
	Provide a rationale for the reference method
	Provide a rationale for the test cut-offs chosen
	Test and reference measures known at time of measurement
	Describe methods of assessing classification accuracy
	Describe how index and reference measures were handled
	Consider sample size
Results	Describe participant flow in a diagram (Figure 1)
	Provide summary characteristics of participants (Table 1)
	Describe time between index and reference measures
	Provide estimates of classification accuracy (Table 3)
Discussion	Discuss limitations, uncertainty, generalizability
	Discuss policy or practice implications
Funding	Provide funding source and conflicts

Table 3. Diagnostic Accuracy Summary (N=400)

Table 3 Diagnostic Accuracy Summary (N=400)

Over Fatness (Defined as Body Fat percentage ≥30 in Girls)	Yes, n=247	No, n=153	Total, n=400
Obese according to BMI	163	6	169
Non-obese according to BMI	84	147	231

6. Discussion

The main finding of the present study is that BMI substantially underestimated the prevalence of excessive fatness: BMI had high specificity but only moderate sensitivity for excess fatness in the present study. The finding that BMI was conservative is consistent with previous studies as summarised by systematic reviews[7-9], though previous studies have almost all involved participants of white European ethnic origin. Previous systematic reviews found no eligible studies of the accuracy of BMI in Arab children, adolescents, or adults and so the presence of an underestimate and extent of the underestimate inherent with BMI were unknown prior to the present study. The degree of bias associated with BMI seems to be population-specific and so there was a need for a study in an Arab population[7-9,12]. Even lower sensitivity of BMI when compared to body fatness has been reported in some previous studies. In one study of US adult women for example, the BMI defined obesity prevalence was 35% while it was 79% according to a measure of body fatness based on dual-energy x ray absorptiometry[28].

The present study suggests that obesity (excessive-fatness) is a much more common problem than it appears when BMI is used to define obesity in adolescent females in Kuwait. The present study findings have implications for obesity surveillance. Obesity in adolescent girls may be even closer to a crisis point in the GCC states than it appears from national surveys of BMI[1]. The present study also has implications for studies which use BMI as a proxy for obesity as either an exposure or outcome variable, testing the impact of obesity on health outcomes or the impact of risk factors on obesity as an outcome. The present study found that BMI was a very crude proxy for obesity (excessive fatness) in Kuwaiti adolescent and young adult women, and so where possible it would be more informative to have a direct measure of body fatness rather than a crude proxy such as BMI in future epidemiological studies which aim to understand the causes or consequences of obesity[17].

The present study had a number of strengths, in particular the novelty of the sample and setting since it seems that no previous studies of the accuracy of BMI to define obesity had been carried out in any Arab sample[7-9]. There were also some study limitations, including generalisability. The university sample, limited age range, and exclusively female sample recruited, mean that results should be generalised to other samples and setting with caution, though our findings were consistent with previous systematic reviews as noted above. Sensitivity and specificity depend on the prevalence of true positives in the sample, and the present study did not attempt to estimate obesity prevalence in Kuwait, rather to examine the extent to which obesity prevalence estimates using BMI might be biased, e.g. in national surveys. An additional limitation was that no 'gold standard' measure of body fatness was available. The only gold standard methods of measuring body fatness at present are the multicomponent models[29] but these are not practical for field studies such as the present study[6]. However, the field technique of impedance chosen is practical and has acceptable accuracy[21-24]. A final limitation is the fact that the sample size of the present study was fixed at around 400 participants, because the present study was part of a separate study which aimed to test for associations between obesity and academic attainment in university students. The power of the present study is therefore unclear, though it was larger than many previous studies of the diagnostic accuracy of BMI in children and adolescents as reported in previous systematic reviews of the diagnostic accuracy of BMI[7-9]. In the absence of a gold standard method of measuring body fat, the present study findings did not extend to further analyses such as Area Under the Curve, and did not attempt to identify the optimal BMI cut point for identification of those with excessive fatness [6,26].

7. Conclusion

The standard method of defining obesity based on BMI substantially underestimated the prevalence of obesity (excess fatness) in Kuwaiti adolescent females. Further studies are required to ascertain the extent to which obesity prevalence in Kuwait is being underestimated by use of BMI in males and in other age groups, but BMI should be considered as a highly conservative proxy for body fatness. BMI should also be considered as a crude proxy for body fatness which may be unsuitable for epidemiological studies where obesity is used as either an exposure or an outcome variable.

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Chapter 6: Differences in educational attainment between obese and non-obese Kuwaiti female university students

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1. Preface

This cross-sectional study assessed the association between obesity and educational attainment in Kuwaiti female students. The data collection was explained in detail in chapters 4 and 5. This paper has been presented in the same format as was published in the Journal. Hence, the reference system used is not APA as used in the other non-published chapters in this thesis.

As previously mentioned, HH was the lead author. JJR and AH guided and supported with data analysis. HA facilitated the process of data collection at the Kuwait University. Finally, the review design, revision as well as approval of the final manuscript was supported by all authors.

2. Abstract

Individuals with obesity tend to perform less well than their non-obese peers in tertiary education, but there is little evidence from non-western countries and recent studies. The present study aimed to test whether academic attainment differed between female undergraduates with obesity (defined by BMI) and those who were non-obese in Kuwait, a country with very high obesity prevalence. In 400 female Kuwaiti 1st and 2nd year Social Science students (mean age 18.0 SD 0.6 years) educational attainment was defined as the Grade Point Average (GPA) across all subjects (from 1.00-4.00). Mean GPA (2.51 SD 0.53) among students defined as obese by BMI (n 163) was significantly lower than among the students defined as non-

obese by BMI (n 237; 2.80 SD 0.63; p<0.001), and those defined as obese were more likely to be in the lowest quartile for GPA (OR 3.03; 95% CI 1.90 to 4.85), independent of socio-economic status. Similar differences were observed between students defined as having high versus normal body fatness. Female undergraduates in Kuwait with obesity have lower academic attainment than their non-obese peers, and universities should consider measures to mitigate reduced attainment among their female undergraduates.

3. Introduction

In Kuwait more that 40% of adults have obesity as defined by the BMI[1–5]. Prevalence of obesity is also extremely high among Kuwaiti children and adolescents[6,7] Obesity rates are still rising amongst Kuwaiti adults and children, costing the country a minimum of 2.8 billion dollars annually in both direct and indirect costs[8], and with a Kuwaiti population of only 1.1 million[9] Kuwait has around 5,000 bariatric procedures each year[10].

Obesity in childhood, adolescence, and adulthood increases the risk of a large number of medical problems[11-13]. If obesity impairs educational attainment this could provide new arguments for obesity prevention and treatment[14-17]. In the UK for example, a large cohort study by Booth, *et al*[14] found that obesity in adolescence was associated with markedly poorer academic attainment, independent of confounders, but in girls only. Recent systematic reviews have disagreed on the quality, quantity, and consistency of the evidence on differences in academic attainment between individuals with obesity and those who do not have obesity: Santana *et al.*, concluded that deficits in academic attainment in individuals with obesity might be explained largely by confounding (with obesity much more prevalent in individuals with lower socio-economic status in high-income western countries) and called for more research on the issue [15] . Hill *et al* [16] concluded that deficits in academic attainment in undergraduates with obesity were fairly well established, particularly in women, and might be explained largely by weight-related bias. The Cochrane review by Martin *et al*., (2016)[17] highlighted plausible mechanisms relating obesity to lower academic attainment including social mechanisms such as stigma/bias and impaired quality of life associated with obesity, biological mechanisms (such as cognitive effects of inflammation)[18,19] and mechanisms related to poor health associated with obesity (such as illness related absenteeism). An additional systematic review[20] concluded that impaired academic attainment associated with obesity was most likely in adolescent girls and young adult women.[20]

Since systematic reviews on the topic have not reached consistent conclusions, other than the likelihood that obesity-related deficits in attainment may be worse in females than males, and almost all research included in those reviews comes from older studies in high-income western nations, there is a need for new research from a wider range of settings. The primary aim of the present study was therefore to test whether educational attainment in Kuwaiti undergraduates was lower in individuals with obesity. We studied female undergraduates because of the previous evidence that obesity-related deficits in attainment might be worse in females than males.

4. Methods

The present study recruited a convenience sample of first and second-year Kuwaiti University College of Social Science students between March and May 2019. Sampling and recruitment have been described in detail elsewhere [21]. In brief, all 1st and 2nd-year Social Science undergraduates were invited to take part by the researcher. Students were considered suitable for inclusion if they were female, Kuwaiti nationals, <20.0 years of age and did not have any condition or illness which would have altered their weight status (e.g. pregnancy, long-bone fracture). Students were excluded if they were male, non-Kuwaiti nationals, 20.0 years or older, and had any condition or illness affecting their weight status, or reported any other chronic disease. The aim of these inclusion and exclusion criteria was to provide a relatively homogenous sample, and one which was relatively free of a number of potential confounders (e.g. non-Kuwaiti nationality, age). Of the 2169 students contacted, 525 expressed an interest and 400 of these were eligible and were entered into the study. All participants gave informed written consent to participation and the study was approved by the University of Strathclyde Psychological and Health Sciences Ethics Committee.

4.1 Measures of exposure (BMI and body fatness)

Anthropometric measurements and BMI calculations were carried out as described by Al Hammadi and Reilly(21). A Seca Stadiometer (Seca, London, England) was used to measure the Height to the nearest 0.1cm. Weight was measured to 0.1kg with study participants in light indoor clothing by the Tanita model TBF-310 (2625 South Clearbrook Drive Arlington Heights, Illinois 60005, USA). A BMI z score of ≥2.0 relative to WHO 2007 (22) reference data was used to define obesity in the adolescents (17 to 19.0) years of age (n= 275) and for those over 19.0 years old the adult cut off point of BMI ≥ 30kgm^2 was used (n= 125)(23).

4.2 Educational attainment measurement

The measure of educational attainment outcome used in the present study was the Grade Point Average (GPA) for all university subjects. The GPA was provided in anonymised form from the university authorities. The GPA was used in two ways: as a continuous variable (from 1.00 to 4.00); a categorical variable, with the GPA distribution divided into quartiles from highest (Q1) to lowest (Q4); further details can be found in Chapter 4

4.3 Potential confounders

In high-income Western countries, socioeconomic status is a potential confounder of obesity-educational attainment relationships because it is associated with both higher risk of obesity and lower educational attainment[15,20]. Socioeconomic status was considered as a potential confounder in the present study using parental educational attainment (degree education versus education to high school level). Despite the relatively narrow age range we also considered student age as a potential confounder.

4.4 Statistical analysis

Data were analysed with SPSS version 26 (IBM Corp, Armonk, NY, USA) and Medcalc (Belgium). The data was tested for normality and summary data were described as mean (standard deviation (SD) or median (range) depending on the distribution of variables which was assessed by plots of the data and D'Agostino Pearson tests in MedCalc (more details in Chapter 4). We compared GPA between students categorised as obese by BMI versus those considered non-obese by BMI, using two-sample t-tests. We also compared the percentage with obesity among the GPA quartiles using both chi-squared tests, and used logistic regression to estimate the odds ratios for risk of being in the lowest GPA quartile (in the obese vs non obese and in the high fat vs lower fat groups). P values of <0.05 were used to indicate statistical significance.

Power of the present study was difficult to assess at the outset - power was fixed as this was part of a wider study of the ability of BMI to identify excessive fatness among female Kuwaiti adolescents[(21)].

5. Results

5.1 Characteristics of study participants

A total of 525 students agreed to take part in the study, 125 were excluded as they did not meet the inclusion criteria (age over 20.0 years, pregnancy, injury e.g. long-bone fracture in cast, presence of chronic diseases). Therefore, 400 actually took part, and all 400 provided data for all variables. A total of 163/400 participants were defined as obese based on BMI and 247/400 were defined as excessively fat based on the bio-impedance measure.

5.2 Educational attainment differences between individuals with obesity and those who did not have obesity

The mean GPA in the overall sample of 400 was 2.68 (SD 0.62). Mean GPA in the sample with obesity defined by BMI (n= 163) was 2.51 (SD 0.53; 95% CI 2.42-2.59) and in participants defined as not having obesity according to their BMI (n=237) was 2.80 (SD 0.65; 95% CI 2.71-2.88). This difference was statistically significant (t 3.29, df 398, P<0.001; 95% CI for difference in means = 0.17 to 0.41).

A chi-squared test on the distribution of GPA quartiles by obesity versus non-obesity status using BMI was statistically significant (x^{2} *28.9, df 6,* P<0.001; **Table 1**)**.** The odds ratio, unadjusted, for risk of being in the lowest quartile of GPA in the individuals with obesity according to BMI was 3.03 (95% CI 1.90-4.85; P<0.001). Student age and parental educational attainment were not associated with the exposure and outcome values, and did not confound the relationship between BMI defined obesity and GPA. Including these values in the analysis produced an Adjusted odds ratio of 2.97 (CI 1.86-4.99; P<0.001).

Table 1. GPA quartiles by weight status

Table 1. Grade point average (GPA) quartiles by weight status

	Quartile 1 Highest	Quartile 2	Quartile 3	Quartile 4 Lowest
GPA range	4·00–3·00	3·00–2·70	2·70–2·10	2·10–1·00
Mean GPA (SD)	3·44 (0·32)	2·92 (0·11)	2·48 (0·16)	1·88 (0·27)
Obese by the BMI *n* 163	28	35	39	61
Non-obese *n* 237	72	65	61	39

6. Discussion

6.1 Main findings and study implications

The present study found that undergraduates with BMI-defined obesity had poorer overall academic attainment than those who did not have obesity, and this difference could not be explained by socio-economic status. The impact of obesity on educational attainment might be helpful in both obesity prevention and treatment[(14)]. Individuals and families may be motivated to change weight status or health behaviours for cognitive or educational benefits**.** The very high prevalence of obesity in Kuwait, combined with the importance of educational attainment, might therefore provide new/additional arguments for obesity prevention and treatment in Kuwait and the other Gulf States. Universities should also be more aware of the increased risk of poorer attainment among undergraduates with obesity, and have a particular responsibility to do so if at least some of this poorer attainment relates to bias or stigmatization from peers and/or university staff[16]. The magnitude of the difference in GPA between groups in the present study might also be sufficient to motivate universities to address the issue in future, even if only to raise student attainment.

6.2 Comparisons with other studies

Recent systematic reviews[15-17, 20] have generally concluded that obesity predisposes to lower academic attainment, particularly in girls and women. However, some of these reviews have questioned whether this might be explained by confounding by socio-economic status, with poverty being associated with both lower academic attainment and obesity in high-income western countries. Systematic reviews and original studies have identified a number of plausible mechanisms by which obesity might impair educational attainment. Potential mechanisms[15-17,20,24-27] include increased absenteeism from university or school associated with the co-morbidities of obesity; cognitive deficits associated with cardiometabolic co-morbidities; impaired quality of life and the psychosocial co-morbidities of obesity; the impact of obesity on brain structure and/or function particularly in the pre-frontal cortex and hippocampus; the impact of obesity on behaviours known to be associated with educational attainment such as reduced moderate-vigorous intensity physical activity or less healthy diet; weight stigmatization by peers or teachers. The present study was designed to test whether academic attainment was lower in female undergraduates with obesity, and was not designed to identify mechanisms underlying this difference. However, some cultural and socio-economic differences between Kuwait and high-income western countries might help in the development of future research aimed at understanding why the differences observed in the present study exist. First, poverty is almost non-existent among Kuwaiti nationals, and income inequality is extremely low in Kuwait compared to high-income western countries(28,29). There is also some evidence that obesity is not confounded by socio-economic status in Kuwait, in contrast to western countries(30). Weight stigmatization and psychosocial impacts of obesity among adolescent girls and adult women may also differ between Kuwait and other nations. There is limited evidence on such differences to date, but impaired quality of life is the norm among adolescents with obesity in western countries, but not present in Kuwaiti adolescents(31).

6.3 Study Strengths and Weaknesses

The present study had a number of strengths. First, the focus on adolescent girls and women, the groups most likely to experience obesity-related impairment of educational attainment was important. Second, novelty of the study was high because of the non-western setting and contemporary sample (with most of the previous literature from undergraduates from an era when obesity prevalence and access to tertiary education were very different(16)). Third, we examined potential confounding by socio-economic status, considered crucial by a number of previous reviews, notably Santana *et al*(15).

The present study used BMI to define obesity (obesity is a high level of body fatness rather than a high BMI)(21) – while the BMI is a convenient proxy for high body fatness, it has only moderate sensitivity for high body fatness in Kuwait and in other populations(21). In an attempt to address this potential weakness we also tested for differences in academic attainment between individuals defined as having high body fatness (≥30% of body weight, as estimated by bio-electrical impedance) vs those with lower body fatness in the present study. This analysis is summarized in **Supplementary Table 1,** but results and conclusions were very similar to those from the analysis based on BMI-defined obesity. Power of the study was difficult to assess at the outset, but the sample size was sufficient to detect significant associations. The present study sample of 400 undergraduates was derived from a potentially eligible population of around 1800, and the extent to which biases in recruitment to the study affected study findings are unclear. Defining socio-economic status by income is problematic in Kuwait with such limited variation in income relative to western countries[(28-30)] – the present study used parental educational attainment as a convenient and relevant individual-level indicator of socio-economic status, but there is probably no ideal single measure. The present study was not designed to identify the mechanisms of any associations and further studies will be required to do so. The generalisability of the findings is also unclear and will need to be tested in other studies. Finally, the present study had a cross-sectional design and so is restricted to identifying differences in academic attainment between individuals with obesity versus those who did not have obesity, and cannot confirm that obesity is a cause of lower academic attainment. However, the present study findings were consistent with a good deal of other evidence, there are plausible biological and social causal mechanisms, and reverse causality (lower educational attainment causing obesity and excessive fatness) is possibly unlikely in this case.

7. Conclusion

This research suggests that having obesity may impair academic attainment in Kuwaiti female students. Further studies will be needed to test the generalisability of these findings, and to identify the underlying mechanisms of any effect of obesity on educational attainment.

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Supplementary Table 1.

Differences in Educational Attainment (Grade Point Average, GPA) Between Individuals with High Body Fatness vs Those With Lower Body Fatness

High body fatness was defined as a body fat % of ≥30.0 derived from bio-electrical impedance[21].

Mean GPA in the sample with high body fatness (n= 247) was 2.59 (SD 0.59; 95% CI 2.52-2.67) and in participants defined as not having high body fatness (n=153) was 2.81 (SD 0.64; 95% CI 2.70-2.91). This difference was statistically significant (t 3.03, df 398, P<0.001; 95% CI for difference in means = 0.08 to 0.33).

A chi-squared test on the distribution of GPA quartiles by high fatness versus non-high fatness was statistically significant (x^2 *21.9, df 6*, P<0.001)**.** The odds ratio, unadjusted, for risk of being in the lowest quartile of GPA in the individuals with high fatness according, was 2.39 (95% CI 1.43-3.99; P<0.001). Student age and parental educational attainment were not associated with the exposure and outcome values, and did not confound the relationship between body fatness and GPA.

Chapter 7: Associations between obesity and cognitive function in Kuwaiti female university students

1. Preface

The present thesis has shown that there is limited evidence on the prevalence of obesity among school age children and adolescents in the GCC states (chapter 3), and that the prevalence based on BMI could be underestimating the true prevalence in Kuwait (chapter 5). In addition, there could be an impact on educational attainment in obese students (chapter 6). The present manuscript aimed to assess the impact of obesity on cognitive inhibition of these students. This peer review manuscript will be submitted to the Journal of Nutritional Science. This paper is presented in the same format of the mentioned journal, and therefore the reference system used is not APA as used in the other non-published chapters in this thesis.

As previously mentioned, HH was the lead author. JJR and AH supported and advised on data analysing. CRH (Crystal Haskell) trained for the cognitive test at Northumbria University. Finally, the review design, revision as well as approval of the final manuscript was supported by all authors.

2. Abstract

Obesity has adverse cognitive effects, but which cognitive functions are impaired by obesity remains unclear. The present study aimed to test for associations between obesity (defined by BMI) and high body fatness (>30.0% body fat based on bio-electrical impedance) and performance in the Stroop Colour Word Test (SCWT) in Kuwaiti adolescent and young adult females. Confounding of associations between obesity and cognition by socioeconomic status is problematic in western countries but probably not in Kuwait[4]. Participants were 400 female Kuwaiti 1st and 2nd year Social Science students (mean age 18.0 SD 0.6 years). SCWT performance was significantly lower in the obese (median 60% correct answers; IQR 45-75) vs non obese (median 75% correct; IQR 55-90). SCWT performance was significantly lower in the high fat (median 60% correct; IQR 45-80) vs non high-fat individuals (median % correct 80 IQR 60-90) by Mann-Whitney Tests. Those defined as obese by BMI were more likely to be in the lowest quartile for SCWT performance (odds ratio 2.05; 95% CI 1.30 – 3.25, P <0.001). High fat individuals were also at significantly higher risk of being in the lowest quartile for SCWT (odds ratio 1.95; 95% CI 1.19-3.22, P <0.001). SCWT performance was not affected by confounding variables considered (student age; socio-economic status as measured by parental educational level). In conclusion, obesity may impair Stroop Colour Word Test performance in adolescent females but evidence from the present study is tentative and this suggestion needs to be confirmed by future studies.

3. Introduction

Worldwide obesity has dramatically increased in the last few decades[1–3]. Obesity is a major concern for public health due to high prevalence[1, 4] combined with increased risk of many medical problems[5–7]. In Kuwaiti children and adolescents, obesity rates are growing[8,9] and a recent systematic review highlighted that the prevalence of obesity in school-age children and adolescents has reached alarming levels in Kuwait[10]. Systematic reviews and other reports have also indicated that obesity may have a negative impact on educational attainment[11–13] and on cognitive processes relevant to educational attainment[12–14].

Obesity may impair multiple aspects of cognitive function such as executive functions[15–18]. A longitudinal study conducted recently found that cognitive ageing was exacerbated in individuals with higher BMI[16]. A systematic review concluded that there is a need to answer the question "what is the relationship between executive function and obesity in children and adolescents?"[19] Executive functions have been defined as the "higher cognitive processes that allow forethought and goal-directed action", this set of mental skills includes cognitive inhibition, cognitive flexibility and working memory[20,21]. There are differing definitions of executive function, for example it has also been defined as "the capacity to think before acting, retain and manipulate information, reflect on the possible consequences of specific actions, and self-regulate behaviour"[22].

Scientific reports and systematic reviews have suggested that executive functions are more likely to be impaired by obesity than other cognitive functions [19,23]. A systematic review reported that obese and non-obese individuals may perform differently in performance tasks which measure inhibitory control[24]. Inhibition was decreased in obese young women in one study[22]. Disinhibited eating in obese adolescents was associated with orbitofrontal volume reductions and executive dysfunction in another study[25]. Another report indicated that high BMI has a significant effect on cognitive flexibility in young adults, with associated frontal lobe dysfunction and deficits in cognitive control[26].. A number of studies have reported that high BMI and visceral fat and total body fatness in adulthood may impact on cognitive performance[27–29]. Overall, these studies have indicated that obesity in adulthood may speed up cognitive ageing and may increase the later life risk of Dementia[28]. Additionally, the risk of lower cognitive performance related to obesity may be gender related and females may be at greater risk compared to males[29]. The physiological mechanisms underlying the relationship between visceral fat and executive function may also differ by sex[30]. While many reports have linked obesity to poorer executive functions[10, 21, 30–32], several reports have recommended more research to have a better understanding of the mechanisms behind the reduction of executive function, e.g. which specific cognitive processes are impaired by obesity[19, 31, 33]. Understanding the specific processes which might be impaired by obesity may help in providing more information about the cognitive mechanisms of effect, and might also be useful in future strategies which aim to reduce the effects of obesity on executive function.

Aspects of executive function have been measured by using many different tools, but one common tool is the Stroop Test, which can be used to measure selective attention, response inhibition, cognitive flexibility, and short-term memory[34–37]. However, in this current study we have used the Stroop Colour Word Test (SCWT) to evaluate selective attention and cognitive inhibition, as there was some previous evidence that obesity might impair these processes[38]. In addition, variables such as inhibition might be important to the maintenance of obesity as described in chapter 1 of this thesis and performance on the Stroop Test may be relevant to academic attainment[11, 39, 40].

Most previous human studies on associations between obesity and cognitive function in humans have used BMI as a proxy for obesity (high fatness). As noted earlier in this thesis the BMI is a crude proxy for obesity and so there is a need to test for associations between high body fatness and cognitive function. Also there is some scepticism about the possible effects of obesity on cognitive processes because most human studies have taken place in high-income western countries. In such countries relationships between obesity and cognitive outcomes may be confounded by socioeconomic status (low socio-economic status likely to be associated with both obesity and impaired cognition) [11, 12]; and so there is a need to test for associations where confounding of this kind is reduced or absent, such as in Kuwait[10].

The present study therefore aimed to test for associations between obesity (BMI-defined), high body fatness, and Stroop test performance in a sample of late adolescent and young adult females in Kuwait.

4. Methods

4.1 Sampling, recruitment, and ethics

All participants gave informed written consent to participation and the study was approved by the University of Strathclyde Psychological and Health Sciences Ethics Committee. First and second-year Kuwait University, College of Social Science students were recruited to take part in this research between February and May 2019. Sampling and recruitment have been described previously[41]. Briefly, all 1st and 2nd-year Social Science undergraduates were requested to participate in this study. The inclusion criteria were: students should be female, Kuwaiti nationals, under 20.0 years old, and without any condition or illness which would have changed their weight status (e.g. pregnancy, long-bone fracture). Students were therefore excluded from participation if they were male, non-Kuwaiti nationals, aged 20 years old or more, or affected by the conditions indicated. The research invitation was sent by the College of Social Science to 2169 students via direct recruitment by talking to students directly. After getting permission from the Dean of the Social faculty, the author went to their lecture room and delivered 20 talks for 15 mins over a period of a week; to invite students to participate in the research. In addition, posters were distributed in the faculty to help with recruitment. As a result, 525 students responded, and 400 students met the inclusion criteria as described previously in chapter 3 and 5[41]. All collected data were saved under the ID code; only the researcher was able to access that information[41].

4.2 Measures of exposure (BMI defined obesity and high body fatness measured by bio-electrical impedance)

Anthropometric measurements and BMI calculations were carried out as described by Al Hammadi and Reilly[41]. Briefly, height to the nearest 0.1cm was measured by Seca Stadiometer (Seca, London, England). Weight was measured without shoes to nearest 0.1kg for participants in light indoor clothing by the Tanita model TBF-310 (2625 South Clearbrook Drive Arlington Heights, Illinois 60005, USA).

BMI measurements

Two BMI-based definitions of obesity were used in this study, to deal with differences in participant age, following Al Hammadi and Reilly [5,41] . A BMI z score of ≥2.0 relative to WHO 2007[5] reference data was used to define obesity in the adolescents (17 to 19.0) years of age (n= 275) and for those over 19.0 years old the adult cut off point of BMI ≥ 30kgm^2 was used to define obesity (n= 125)[41]. In practice, the actual BMI values for the two definitions were similar: at age 18.5 years for example a BMI Z score of 2.0 is equivalent to a BMI of 29.6 kg/m^2, and at 19.5 years of age the BMI cut-off which defined obesity was 30.0.

4.3 High body fat measurements

The method of measurement of body fatness and cut-offs for defining high body fatness were as described in our previous publication[41]: ≥ 30% of body weight defined high body fatness following previous studies[4,42,43]. The estimation of body fatness for participants was carried out by using the TANITA TBF-310 with the manufacturer's equation used to predict body fatness. The Tanita device was used as it is a practical option for body composition measurement in field studies of this kind[44–46] e.g. is inexpensive and quick and painless. In addition, it has been established that the Tanita device has reasonable accuracy relative to reference methods in adolescents and young adults[44–46]. In this study, duplicate measurement of bioelectrical impedance was carried out for each participant and the mean of the duplicates was calculated and used. All relative information related to students' age, height, clothes weight (standard weight of 1.0 kg) and sex were entered into the TANITA TBF-310 to obtain the body fatness estimate. All ethical measures were taken into consideration while handling the data for each participant. Students were requested to fast at least 2 hours without food or drinks prior to the Tanita measurements.

4.4 Potential confounding variables

It seems unlikely that socio-economic status is a confounder of associations between obesity and educational or cognitive outcomes in Kuwait since obesity and socioeconomic status are not related in Kuwait[(4)]. In addition, our previous study also showed that relationships between obesity and educational attainment were not confounded by socioeconomic status[(4, 41)]. However, we considered student age and socio-economic status (parental education) as potential confounders and so included them in analyses.

4.5 Cognitive function measurement

Al Ghatani indicated that there is a need for a computerised Stroop Test in the Arabic language[(47)]. Computerised tests of cognitive function are preferable to alternatives such as traditional pencil and paper tests because they are more practical, reliable and valid[(34, 48, 49)]. Therefore, we worked with the Brain Performance and Nutrition Research Centre (BPNRC) at Northumbria University in the UK to develop an Arabic Version of the SCWT, part of the Computerised Mental Performance Assessment System (COMPASS) Version 5.0[(35)]. COMPASS software in English was modified with the help of the thesis author, and an Arabic language set of instructions was added to make it easier for the participants to understand the SCWT[(35)]. The present study is therefore the first research with the computerised SCWT in the Arabic language.

4.6 Stroop Colour-Word Test

The SCWT is a widely used assessment of many aspects of cognitive function. There are many different variants of SCWT, and a recent systematic review found that even for components of the SCWT which aim to measure the same cognitive process there is a great deal of variation in how tests are administered and how they are scored, making performance on the SCWT hard to compare between studies[36]. This systematic review suggested that, as a minimum, researchers should report the % of correct answers and the reaction time (RT). The SCWT has been used to measure a range of cognitive processes including selective attention, response inhibition, cognitive flexibility, and short-term memory[34–37]. In the present study, we focused on using the SCWT to measure selective attention (the ability to suppress an automated/uninhibited response and focus attention) and response inhibition. These were operationalised by using the % of correct answers and RT in milliseconds (ms).

In our SCWT, words were presented on a laptop screen which were either 'congruent' (name of colour and colour of word the same) or 'incongruent' (name of colour and colour of word different) see (**Figure 1**). The words appeared randomly on the screen. Participants were asked to respond as quickly and as accurately as possible by using the trackpad on the laptop.

Twenty tasks made up the SCWT- a series of colour names in Arabic appearing in different coloured fonts on the laptop screen, one by one. Participants were requested to use the trackpad on the laptop to match the colour font to the name of that colour. The words were presented in two different ways, with the colour name and colour the same (congruent) or different (incongruent). All the tasks were randomly presented.

As described in chapter 4, study 4 followed a pilot study which was conducted on 19 students from the 525 students who originally agreed to undertake the test. The pilot study suggested that the protocol was feasible, and that the students understood what was required of them. The best score from two attempts was taken from students' SCWT performance in the pilot study and for the rest of study 4.

Figure 1 On screen layout of the 'Stroop Colour-Word' tasks. Reaction time (RT) and overall correct answers are generated for each task, the SCWT diagram in the Arabic Language, the word in the centre means Red.

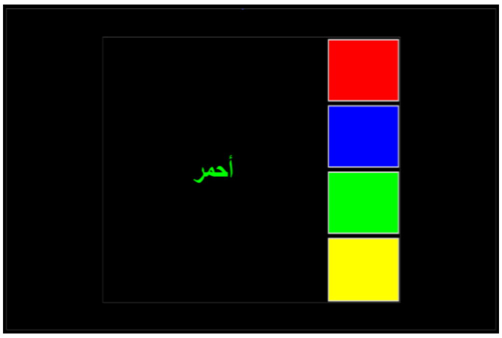

Figure 1. On Screen layout of Stroop Colour Word Tasks

4.7 Statistical analysis

Duplicate measures of BMI and Fat percentage were taken and mean of the two measures of BMI and body fat percentage was used in analysis. The data were analysed by using Medcalc and SPSS version 26. All data were tested for normality using the Kolmogorov-Smirnov (K-S) test in SPSS and the D'Agostino Pearson test in Medcalc. Descriptive data were provided as Mean (SD) or median (IQR) as appropriate. SCWT performance was not normally distributed (D'Agostino-Pearson Test, the data were not normally distributed Skewness= -0.33 and Kurtosis = -0.46 P< 0.0001) and so was summarised as median (IQR), and the Mann Whitney U test was used to compare median performance on the SCWT between groups (the obese versus non obese and the high fat vs non high-fat). Differences in the distribution of Stroop test performance by obesity status and high body fatness status were also tested for significance using Chi-squared tests, with SCWT performance categorised by quartile (Q1-Q4 highest-lowest performance) as described in chapter 6[(50)] and the odds of being in the lowest quartile by obesity status (obese vs non-obese by BMI) and by fatness status (high body fatness vs healthy body fatness) were calculated using logistic regression, along with 95% CI. Reaction time data were normally distributed (D'Agostino-Pearson Test p=0.14, Skewness= 0.18 and Kurtosis = 0.34) and so have been summarised as mean (SD) and between-group differences tested for significance using independent sample t-tests.

The possibility that relationships between SCWT performance and both obesity status and fatness status were confounded by participant age or by socio-economic (parental education level) status was assessed using logistic regression as described in our previous publication[(41)] .

The power of the present study was unknown, and this study was considered exploratory research. The sample size of this study was larger than that of many previous studies which tested for associations between obesity and cognitive function in adolescence females though, for example the largest study included in a number of systematic reviews was 299[(17,19,51,52)].

5. Results

5.1 Characteristics of study participants

The participants' characteristics are shown in Table 1. Of 525 participants 400 participants fitted the inclusion criteria and completed the SCWT and also had BMI measures and estimates of their body fatness. The average of the age of the participants was 18.0 (SD 0.6) years, see **Table 1**.

5.2 Stroop Colour Word Test (SCWT) performance and BMI defined obesity

Stroop Test performance is summarised in Table 2 Median % correct answers in the sample with obesity defined by BMI (n= 163) was 60 (IQR 45-75) and in participants defined as not having obesity according to their BMI (n=237) median was 75 (IQR 55-90.)

The difference in median % correct answers between obese and non-obese groups was significant (Mann Whitney U 14.8, p<0.001, Table 2).

The odds ratio, unadjusted, for risk of being in the lowest quartile of Stroop Test performance for individuals with obesity according to BMI, was 2.05 (95% CI 1.30 – 3.25, P <0.001). Logistic regression results indicated that student age and parental educational attainment were not associated with obesity or with SCWT performance and did not confound the relationship between BMI defined obesity and Stroop Test performance.

The chi squared test on the distribution of SCWT by obesity status was also significant (x^2 *21.9, df 6,* P<0.001).

5.3 Stroop Test performance and high body fatness

Stroop Test performance (median % correct answers) among those participants defined as having high body fatness (n= 247) was 60 (IQR 46-80) and in the non-high fat (n=153) the median was 80 (IQR 60-90). The Mann-Whitney U test on differences in median % correct answers by high fatness versus non-high fatness was statistically significant (Mann Whitney U= 14.2, $P<0.001$; Table 2). The odds ratio, unadjusted, for risk of being in the lowest quartile of SCWT performance in the individuals with high fatness was 1.95 (95% CI 1.19-3.22, $P<0.001$). Student age and parental educational attainment were not associated with fatness and with SCWT performance and did not confound the relationship between body fatness and SCWT performance

5.4 Stroop Reaction Time and BMI defined obesity

Mean RT in the overall sample of 400 was 2397ms (SD 32). Mean RT in the sample with obesity defined by BMI (n= 163) was 2264ms (SD 513, 95% CI 2185-2343) and in participants defined as not having obesity according to their BMI (n=237) was 2396ms (SD 497, 95% CI 2333-2460). The difference in RT between obese and non-obese groups was significant by independent sample t-test (t 3.01, df 398, 95 % CI 32-234ms; P <0.001).

5.5 Stroop Reaction Time and high body fatness

Mean RT in the sample with high body fatness (n=153) was 2391ms (SD 525, 95% CI 2307-2475) and in participants defined as not having high body fatness (n=247) was 2396 (SD 497, 95% CI 2250-2374). This difference in RT between the body fatness groups was not significant by t-test (t 1.98, df 398, P = 0.13).

6. Discussion

6.1 Main findings and study implications

This study is one of the very few that addressed the issue of the potential impact of obesity in the Gulf States beyond the usual impacts such as cardio-metabolic co-morbidities of obesity. Possible cognitive impacts of obesity are important because our previous systematic review showed that obesity in adolescents in the Gulf States is very prevalent(10), and it is well established that adult obesity is very prevalent in the Gulf States(3,9,53,54). However, some authors have argued that associations between obesity and cognitive function are still not clear and studies in western countries may have been confounded by socio-economic status(11,55) so there is a need for studies in countries where confounding of this kind is less of a problem. There is also a need for more studies which identify the specific cognitive processes which might be affected by obesity - the present study aimed to expand our knowledge on specific cognitive impacts by examining associations of obesity with Stroop Test performance, a specific measure of aspects of executive function, selective attention and inhibition. Finally, the present study added to the literature by going beyond using the BMI as the measure of obesity- by adding a more direct and specific measure of body fatness as the exposure variable.

The present study indicated that being obese (BMI z score of ≥2.0 or BMI ≥ 30kgm^2)(41) may possibly impair performance on the Stroop Colour Word Test in adolescent females, but results from the present study cannot be considered definitive for reasons discussed in the limitations section of this discussion below. A previous systematic review provided evidence that obesity is likely to impair some aspects of executive function in children and adolescents(56), and another systematic review(13) suggested that cognitive impairments associated with obesity might be more marked in females than in males.

A systematic review[33] of studies which included over 30, 183 participants found that obesity was associated with poorer performance various aspects of executive function, and 10 studies found poorer performance on various tests and aspects of attention in obese participants[33], however, this study did not use Stroop Colour Word testing.

The present study finding of possibly poorer cognitive performance associated with obesity was similar to those published previously in some western studies[15,57,58] but confounding by socio-economic status is a concern for such western studies as noted above. Additionally, the current research found that high body fat percentage may have been associated with poorer SCWT performance and this adds confidence that if there is any 'effect' of obesity on this aspect of cognition it may be related to high body fatness.

While few studies have included both BMI and body fatness as exposure measures in studies of the effect of obesity[11,55,59], another study suggested that visceral fat is associated with lower executive functioning in adolescents[28] and that any mechanisms might depend on effects of visceral fat accumulation on brain function. Some other studies have suggested that reducing body fatness might have cognitive benefits in obese individuals. For example, one study found that losing weight improves aspects of cognitive function in children[60]. They found that excess adiposity in children has negative impact on cognitive function (attentional inhibition, assessed using a modified version of the Eriksen flanker task)[60].

The present study suggests that SCWT performance might be impaired by a high BMI and high level of body fatness in adolescent and young adult females, and that this association might be independent of confounding variables considered (student age; socio-economic status as measured by parental - mother and father - educational level). The present study therefore suggests that the impact of the very high prevalence of adolescent and adult obesity in the Gulf States may possibly go beyond the more obvious consequences for cardio-metabolic health, but further studies will be needed to confirm whether Stroop Colour Word Test performance is really impaired by obesity in adolescent females. The finding of a possible negative association between obesity and executive function supports our previous published results that obesity may impair academic attainment [(12-14)]. The present study results may also help explain the findings of our previous study that educational attainment might be impaired by obesity. Reduced selective attention or reduced inhibition (present study) may contribute to reduced performance in educational assessments[(50)] chapter 6. However, further investigation is needed to have a clearer understanding as to how impaired educational attainment might arise from obesity-there are other potential mechanisms of effect as discussed earlier in this thesis. These possible mechanisms include increased absenteeism associated with obesity, poorer mental health associated with obesity, biological mechanisms (such as cognitive effects of inflammation also has been reported previously[(13,14)]. Another plausible mechanism that has recently been suggested includes depressive symptoms and obesity leading to absenteeism[(61)]. Nutritional mechanisms and eating behaviour disorders related to obesity have also been suggested[(62)]; other indirect mechanisms have also been suggested including stigmatisation and weight bias by teachers[(63)].

Although different mechanisms have been investigated to understand the possible effect of obesity on cognition in human studies, animal models have also been used to explore the possible mechanisms further[64]. Animal studies have generally been supportive of the hypothesis that obesity impairs learning and cognitive processes related to learning. For example, one study on rats investigated obesity related impairment of cognitive function via a possible role for cytokine-mediated inflammation in the hippocampus. Their results indicated that cognitive decline was associated with a hippocampal inflammatory response[64] which may be due to proinflammatory cytokine-dependent activation of glial cells[64].

Other human studies have found that chronic diseases, and the cardio-metabolic co-morbidities of obesity can impair cognitive processes. For example, Gluck *et al*[65] and Catoira *et al*[22], reported that impaired glucose metabolism may impair performance on the SCWT[22,63]. Another study indicated an association between smaller brain volumes and higher BMI and % fat in adolescents[19]. High body fatness may also affect brain blood flow which may impact cognitive functioning[66]. Finally, human obesity may provoke chronic low grade inflammation which may spread into the central nervous system and alter cognitive performance, and this may also encourage cognitive decline later in life[38].

Existing literature on obesity -related cognitive impairment suggests a mechanism as cyclical model of obesity (Figure 2) in which obesity (high body fatness) lead to physiological changes (pathway A) that impair cognitive function (pathway B) which may affect cognitive deficits that contribute to decrease self-regulation abilities (pathway C)[67]. Obesity is known to be associated with dysregulation of many physiological system, including vascular structure and function, blood flow, inflammatory, and neurohormonal process. In combination or individually, these physiological changes could impair many cognitive functions.

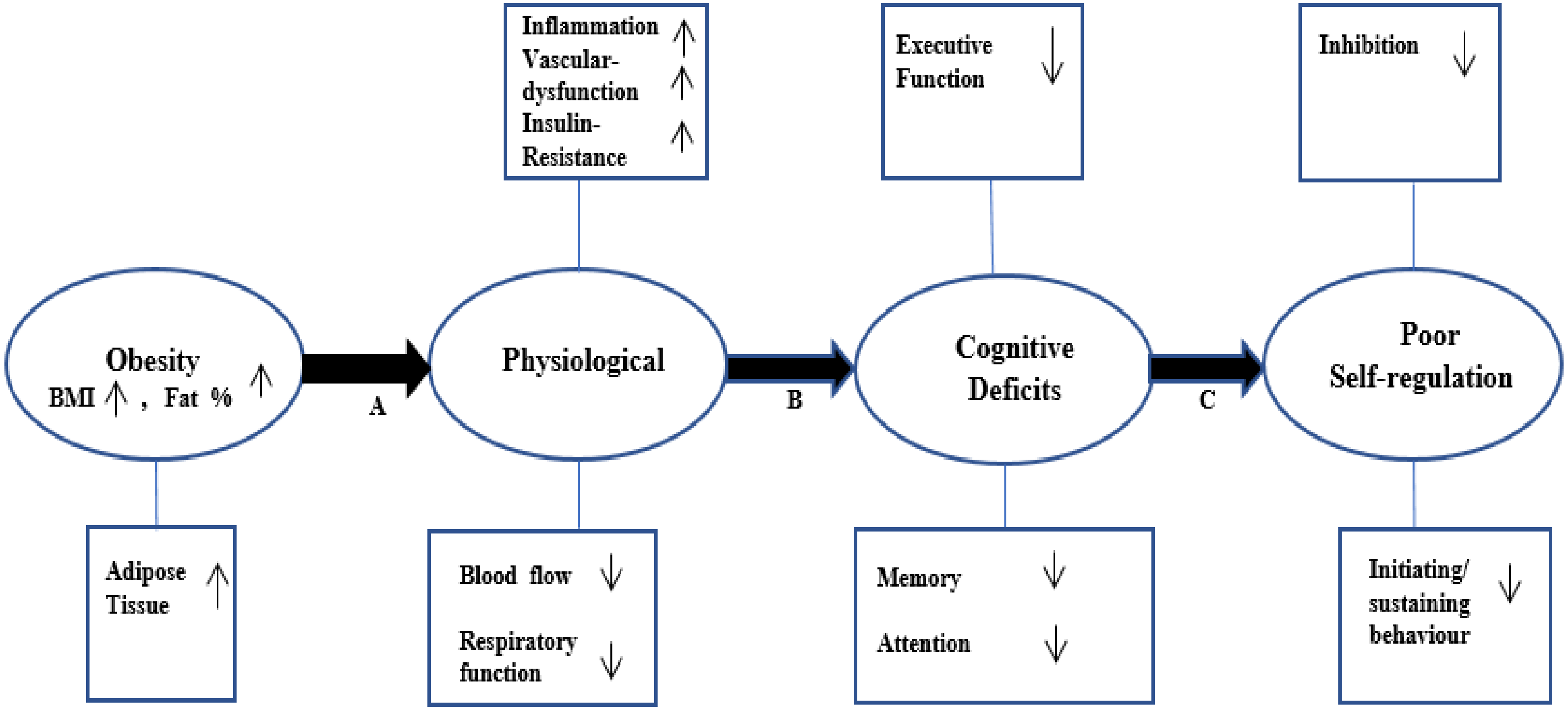

Figure 2. Redrawn cyclical model of obesity and cognitive function from Brownell and Walsh [67]

6.2 Strengths and weaknesses

One strength of the present study was that the setting in Kuwait meant that associations between obesity and cognitive processes could be tested relatively free of the problems of confounding by socioeconomic status. Studies in the western world which report poorer cognitive performance or poorer educational attainment in obese individuals find it hard to exclude the possibility that low socioeconomic status is responsible, because low socio-economic status is associated strongly with both obesity and poorer educational attainment in the western world. This study was conducted only on Kuwaiti studies on this ground, as well as the ground that work in Kuwait is novel.

A second strength of the present study was that body fatness was measured, not just BMI, though in practice the results were similar whether obesity was defined as a high BMI or a high body fatness. The use of the Stroop Colour Word Test as our measure of cognitive function was also a strength this is a reliable and valid measure of various cognitive processes(36). A further strength of the present study was novelty- there are few such studies in adolescents or in young adults, and much of the research effort on the impact of obesity on cognitive function has focused on the elderly with an emphasis on cognitive ageing(61). There are few studies of this kind from Arab states in general and the Gulf States in particular, and research of this kind may encourage greater effort at obesity prevention in the Gulf States in future.

The present study also had a number of weaknesses. There was some evidence that reaction time was faster in the obese group (defined by BMI) but there was no evidence that reaction time was faster in the group with high body fatness, so whether or not reaction time was affected in the present study was unclear. Faster reaction time can reduce accuracy in test performance, so might have been used as an explanation of the lower test accuracy in the obese individuals in the present study. There is some previous evidence of faster reaction time among obese individuals in the literature[51],and this could indicate either faster cognitive processing or more impulsive responding (greater impulsiveness could be a cause or an effect of obesity and which might reduce the percentage of correct answers in the SCWT). However, reaction times were probably relatively slow in both the obese and non-obese study participants in the present study as discussed below.

The present study focused only on the overall correct answers and overall reaction time, and not on the many other potential impacts of obesity on different cognitive processes[36,49,68]. In the current study only selective attention was measured and linked to cognitive inhibition. However, executive function includes other processes such as cognitive flexibility and memory performance; we were not able to measure those in this study This restriction was practical data collection for chapters 4-6 had to be carried out in a single visit to Kuwait in a short period of time in 2019 and there was a limit to what could be asked of study participants in the limited time available. Further research could be carried out in Kuwait on the impact on other cognitive processes and in other populations (e.g. in males, in children). Similarly, there was no possibility of increasing the sample size in the present study, but the sample size was larger, and the sample was more homogenous than in many previous studies of this kind[11,12,55,59].

While it is difficult to compare Stroop Test results between different studies because of enormous variation in how testing is performed and scored[36], and because there has been limited use of Stroop Testing (SCWT) in Arab populations as noted above, the % correct answers in the present study may have been somewhat lower than expected, and the reaction times may have been somewhat slower than expected. Unpublished data from use of the COMPASS software Stroop Colour Word Test using a laptop with a mouse (no data are available with use of a trackpad as was used in the present study) in young English adults [36] suggests that an expected mean or median % correct answer score should be at least 70% - the median for the entire sample was 70% in the present study which would be considered slightly low performance compared to, for example, a group of students in the UK. Typical (mean or median) reaction time from use of the COMPASS version of the Stroop Colour Word test in young English adults is around 991ms[69], faster than in the present study. The present study was the first to use an Arabic version of the Stroop Colour Word Test and this particular version of the test may need refinement in future. In addition, participants could have been given more familiarization or practice with the tests before the data were collected in the present study- greater familiarization might have either improved the % correct answers, or the reaction time, or both. Participants did not receive any practical training on how to use the laptop used to administer the test, and it may have taken them longer than expected to navigate the keyboard in order to click on the correct answer. This might have increased the reaction time – reaction times were relatively long (slow reactions) in the present study. Lack of familiarity with the testing set up might also have possibly reduced the test performance. Faster reaction times might also tend to reduce accuracy - when participants react quickly this can reduce accuracy. However, 19 students were used in a pilot study to see if the participants would be able to complete the SCWT tests. A previous study reported a similar issue[51]. It was the case that reaction time in the first of the 20 trials was consistently slower than in the subsequent 19 trials, and this might suggest that students needed to become more familiar with the test. (Please see Chapter 4 for further information). However, test conditions were the same for all study participants and this should make a comparison between obese and non-obese individuals appropriate. Unfortunately, because of the limitations summarized above, including a speed (reaction time)/accuracy trade off this means that the results are less certain than would have been desirable, and so the present study can only provide tentative evidence that high BMI and high body fatness impair performance on the cognitive test used. The time available to do the Stroop testing was due to the fact that there was a limited amount of time for each participant and before that each participant had to be weighed, body measurements taken and then for the tests to be performed.

Visual acuity of participants was not measured in the present study although we asked study participants to use their optical glasses, so we are not aware if this has any overlapping effect. The vision here may be having an effect and considered as an external factor which may interfere when the SCWT was conducted to measure the student performance. This interval effect may affect the data. Therefore, it was very important to adjust the effect of any external confounding factor and make sure that effect has been neutralized as possible. This issue has been addressed previously by few publications[17, 51]. Further investigation will be required to measure the effect of the vision on the SCWT data. However, in one published research excluded criteria included any vision issue such as having issue to see the colour, hyperopia, astigmatism[17] or were as other research requested the participants to wear the optical glasses if they aware they are having vision problems[51].

7. Conclusions

This study suggests that having obesity, whether defined by BMI or high body fatness, may impair some aspects of cognitive function in Kuwaiti female students. Further research will be needed to confirm these findings in this same population of adolescent females, to examine the generalisability of these findings to other populations, and to identify the underlying mechanisms of any effect of obesity on cognitive function.

8. References

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Table 1. Characteristics of participants in the study (mean and SD or median and range or median and IQR)

Variables	Mean or median	SD; Range; IQR
Age; mean and SD	18.0	0.6
BMI kg/m^2; median and range	27.5	15.1 to 50.2
Fat (%); median and range	32.0	5.1 to 54.0
Stroop Correct (%) answers; median and IQR	70	25th IQR = Q1 85-100 75th IQR = Q3 50-70 100thIQR= Q4 10-50
Response time (RT) milliseconds; mean and SD	2343	508

Table 2. Stroop Test performance quartiles by weight status & body fatness categories [2]

Exposure variables	Number of Correct Answer (Stroop Test) n= 400				Total (n)
	Q1	Q2	Q3	Q4	
Non-Obese	74	70	47	46	237
Obese	26	30	53	54	163
Non-High Fat	52	47	27	27	153
High Fat	48	53	73	73	247
Total (n)	100	100	100	100	400

(Q 1 = highest quartile; Q4 = lowest quartile)

[2] Stroop correct answer range for each quartile as follows: Q1 85-100 (median 90); Q2 70-85 (median 80); Q3 50-70 (median 60); Q4 10-50 (median 35).

Chapter 8: Thesis Discussion and Conclusion

1. Preface

This chapter will summarise the overall discussion for the four studies (manuscripts 1-4, thesis chapters 3, 5, 6, and 7). This chapter also serves as an overview of the thesis and the important findings, highlights the strengths and the limitations, provides recommendations for future research and policy, and makes conclusions.

2. Background

The present thesis aimed to assess the overall impact of child and adolescent obesity in Kuwait and four studies were conducted to address this aim. The introduction and literature review (Chapter 1) covered the BMI- for age based definitions of obesity, the diagnostic accuracy of BMI for excessive fatness, the prevalence of obesity in Kuwait and other Gulf countries(GCC), and obesity health consequences as well as other possible consequences (on educational attainment and cognitive function in children and adolescents). Chapter 1 highlighted the lack of recent evidence on the prevalence of obesity among school-age children and adolescents in Kuwait and the Gulf region (GCC), and therefore a systematic review-study 1 was conducted according to the methodology of the systematic review explained in detail in Chapter 2. The systematic review study 1 (Chapter 3) was published in BMC Obesity in January 2019.

Chapter 4 detailed the methodology for three studies 2, 3 and 4. These studies 2, 3 and 4 started out as feasibility studies for reasons given in Chapter 4 section 2. Briefly, data collection was feasible in the limited time for data collection in Kuwait and studies 2, 3 and 4 became possible and were more than feasibility studies at the end, and therefore feasibility outcomes were not emphasised in the final thesis. Study 2 (Chapter 5) aimed to assess the extent to which BMI might underestimate obesity (high body fatness) in Kuwaiti female late adolescents at university, and this study was published in Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy in April 2020. Study 3 (Chapter 6) aimed to test the association between obesity defined by BMI for age and body fat % and educational attainment in the same sample of Kuwaiti female adolescents, and this study was published in the Journal of Nutritional Science in July 2020. The final study (Chapter 7) aimed to test the association between BMI for age and body fat % defined obesity and inhibition among Kuwaiti female undergraduates.

3. Summary of the thesis findings

This thesis has resulted in a number of novel findings that contribute to the development of knowledge for better understanding of the current prevalence of obesity and the overall impact on children and adolescents in Kuwait and other Gulf Cooperation Council (GCC) countries. Firstly, the systematic review (study 1) was the first systematic review in the GCC countries targeting the prevalence of obesity only, rather than the prevalence of obesity and overweight combined as in other reviews (Nahhas *et al*., 2018). Obesity is not the same as overweight. For example, there is good evidence on the adverse health effects of obesity in children and adolescents, but it is much less clear whether there are adverse health effects of overweight in childhood and adolescence (Reilly *et al*., 2003; Reilly, 2005; Han *et al*., 2010; Kelishadi *et al*., 2015). Thesis study 1 is an advance on previous studies in the GCC countries in part because of the focus on child and adolescent obesity. In addition, the systematic review reviewed recent data to provide the current evidence on the prevalence of obesity, while previous reviews had included older evidence, e.g. the review by Nahhas *et al*., (2018) included studies from 2000 onwards. Since obesity prevalence may have increased very rapidly in the GCC countries in recent years it is important to identify the most recent evidence from the literature in order to understand the current situation, thesis study 1 aimed to do that and so improve on previous literature. The systematic review of this thesis found that the prevalence of obesity, mostly defined by BMI-for-age, was very high in the six GCC states and it increased with age. In addition, it showed that surveillance of BMI-defined obesity in the six GCC countries was very limited, especially outside Kuwait. Collectively, the results of the systematic review suggested that public health surveillance of obesity must improve substantially in the GCC countries. All the GCC states are high-income countries and so have the resources to do large, nationally representative, surveys of the prevalence of obesity in children and adolescents in their populations. As in other high income countries, these nationally representative surveys should be carried out periodically so that changes in population prevalence of obesity can be identified. Despite gaps in the evidence, it is clear that there is a very high prevalence of obesity in children, adolescents, and adults in the GCC states and the high prevalence makes it imperative that better surveillance takes place in future. Even with surveillance data on obesity as defined by BMI-for-age, the prevalence of obesity (high body fat) in Kuwait might be underestimated. Previous systematic review evidence shows that BMI-for-age underestimates the prevalence of high body fatness, and so while nationally representative surveys of BMI-for-age would be informative, they are still likely to underestimate the scale of the problem. An additional concern is that prior to the present thesis there was a lack of evidence on the classification accuracy of BMI in Arab populations.

The findings of study 2 confirmed that definitions of obesity based on BMI for age have moderate sensitivity. This was the first study of the accuracy of BMI-for-age to define the fattest individuals in any Arab population. Study 2 therefore suggests that the underestimation of body fatness prevalence by BMI-for-age and BMI found in non-Arab populations also applies to Arab populations. Study 2 makes it likely that the low-moderate sensitivity of BMI-for-age and BMI to identify the fattest individuals in the population applies to a range of human populations, and this was not clear prior to this thesis. Study 2 also suggests that all previous studies and surveys of obesity prevalence have underestimated Kuwait's actual situation regarding obesity prevalence, consistent with many previous studies in other populations (Reilly *et al*., 2010; Okorodudu *et al*., 2010; Javed *et al*., 2015; Diouf *et al*., 2018).

Assessing the associations between obesity and educational attainment in Kuwaiti female undergraduates, study 3 showed that obese female students had poorer academic performance (GPA) than non-obese female students and these results were broadly in line with systematic reviews of the evidence (Santana *et al*., 2017; Hill *et al*., 2018; Martin *et al*., 2016; Martin *et al*., 2017). Mechanisms by which obesity might impair educational attainment remain unclear (as described in chapter 1 and chapter 6), and the present thesis was not designed to identify or test mechanisms. Nonetheless, the present study adds to the body of evidence that individuals with obesity tend to do more poorly in education than individuals who do not have obesity, especially girls and women (Booth *et al.*,2014; Martin *et al*., 2016). One issue raised by the present thesis and similar studies is what the response to these findings should be. For example, should university students be made aware that obesity is likely to impair their educational attainment? Should universities use these findings to help improve educational attainment? These questions go beyond the scope of this thesis, but at the very least it seems that the impact of obesity on educational attainment should be better known among university students, academics, and university managers and leaders.

Study 4 showed that obese students had poorer inhibition than non-obese students. Poorer inhibition might harm academic achievement and also lead to unhealthier lifestyles in children and adolescents (Bryant *et al.*, 2008; Amundsen *et al* 2017; Esteban-Cornejo *et al.*, 2020). Less inhibited eating, for example, will tend to increase energy intake and so make obesity more likely for non-obese individuals, and help maintain obesity in individuals who are already obese.

In both studies 3 and 4, the associations with educational and cognitive outcomes were detected whether obesity was defined as BMI, or high body fatness. The initial concept in the thesis (as summarised in chapter 1) was that, associations between body fatness and educational/cognitive outcomes might be more detectable and/or stronger when body fatness was the exposure variable than when BMI was the exposure variable (Booth *et al* 2014.; Diouf *et al.*, 2018; Martin *et al.*, 2017). Thesis studies 3 and 4 found that there was little difference between results between use of BMI-for-age or body fatness as exposures. This might support the use of BMI-for-age in future studies, and that would be simpler (e.g. quicker and cheaper) than measuring body fatness. However, the use of a direct measure of body fatness can be simple so long as the right measurement method is chosen (e.g. impedance, as in thesis study 2). In addition, having measures of body fatness may add more confidence that any effects of obesity might lie in fatness related mechanisms (e.g. direct biological effects of body fatness on brain structure and function as summarised in chapter 1) rather than just high body weight (Booth *et al*., 2014; Martin *et al*., 2016; Martin *et al*., 2017). If future research can use simple but reasonably accurate methods of measuring body fatness such as BIA, then measuring body fatness is probably worthwhile/ likely to add more information than BMI alone (Diouf *et al*., 2018; Javed *et al*. 2015; Shah & Braverman, 2012; Reilly et *al*., 2010)

Importantly, the associations in studies 3 and 4 were found to be independent of socioeconomic status (SES), in contrast to studies conducted in western societies where there is a strong socioeconomic gradient (much higher prevalence of adolescent obesity in families with lower SES). Parental education, rather than income, was used as an indicator of SES since Kuwait is a very wealthy country with less socio-economic disparity than in many other countries (UNICEF, 2014). A recent Kuwaiti study found that adolescent obesity was unrelated to SES (Rey-Lopez *et al*., 2019). However, a more recent study found an association between obesity and SES in adult Kuwaiti women (Weiderpass *et al*., 2019). These contradictory results regarding the confounding effects of SES might be age-specific, and more studies addressing this issue in Kuwait are needed. More details about the potential confounding of obesity-educational attainment associations by SES are covered in Chapter 1 and Chapter 4. Observational epidemiological studies are always at risk of confounding, and even when potential confounders are included in the design and analysis it is not always certain that confounding has been dealt with adequately (Booth *et al.*, 2014, Santana *et al*., 2017 Rey-Lopez *et al*., 2019). Future studies with better study designs (which are relatively free of confounding) would be especially informative. For example, randomised controlled intervention trials which aim to reduce body fatness could be used to test whether educational/cognitive outcomes are improved as a result, and the randomised designs should minimise confounding (Booth *et al.,* 2014; Santana *et al.,* 2017; Walk *et al*., 2020).

Collectively, the overall impact of the high prevalence of obesity among children and adolescents in Kuwait and the GCC countries may go beyond the commonly studied health consequences of obesity to include educational and cognitive outcomes. Impacts of obesity are necessary to be considered at a younger age, so that earlier policies and interventions can be implemented. The policy implications are discussed briefly below in more detail.

4. Thesis strengths and limitations

4.1 Strengths

The thesis focused on exploring novel research areas and was intended to overcome the limitations identified from the previous studies that were undertaken in the field. With many studies having been conducted in western countries, this research provided an opportunity to focus on the under-researched population of Arab children and adolescents and in the under-researched setting of the GCC. As mentioned earlier, the systematic review was the first review collecting the recent evidence on the prevalence of obesity in school-age children and adolescents in the GCC region (Al Hammadi & Reilly, 2019). Study 2 was the first study to assess the classification accuracy of BMI for high fatness in Gulf population (Al Hammadi & Reilly, 2020). In addition, studies 3 and 4 were the first large studies addressing associations between obesity and educational attainment and/or inhibition in adolescent females not only in Kuwait, but also in the whole GCC region.

Moreover, the present thesis implemented strong methodology in each of the four studies and used reliable measures for both the exposures and outcomes. The systematic review (study 1) followed robust criteria as discussed in Chapter 3. The studies 3 (Chapter 6) and 4 (Chapter 7) included both BMI and high body fatness as exposure measures for assessing the associations between obesity and educational and cognitive outcomes. The cognitive outcome in study 4 was measured by the computerised "Stroop Colour Word Test" that was also modified for the first time to include Arabic language to make it easier for Arabic-speaking students. Additionally, considering the SES in the analyses for the associations between obesity and educational attainment/cognition provided important knowledge for understanding the potential confounding effects of SES in this context from a different setting than western societies.

Although the studies 2-4 were faced with the challenge of limited time for data collection (explained in Chapter 4), the sample size achieved was relatively high and significant associations were detected, though for Study 4 in particular conclusions are more tentative than for the other thesis studies for reasons discussed in chapter 8.

4.2 Limitations

The present thesis has a number of limitations that need to be highlighted. The systematic review was restricted to English language studies because of time and resource limitations. The number of eligible studies in the GCC countries was limited, with data from only 3 of the 6 GCC countries. In addition, the grey literature searching may not have been comprehensive. Therefore, meta-analysis was not included due to the limited evidence (limited number of studies). In addition, the studies showed heterogeneity in sample characteristics and definitions of obesity, and therefore the narrative analysis of the evidence was all that possible. Future systematic reviews, with more time and more resource, should aim to minimise these problems, and should follow good practice in systematic reviewing (Campbell, 2020).

As discussed in more detail in Chapter 4, the time for data collection for studies 2, 3 and 4 was limited by practical constraints as well as by the PhD timetable and visa restrictions, therefore the studies and the analyses were initially planned to be exploratory and power calculations were not done. Now that these thesis studies have been done, and mostly published, it will be easier to plan future studies, e.g. to develop well informed power calculations. In addition, ROC analysis was not done for the classification accuracy of BMI (study 2) due to insufficient sample size and the lack of a gold standard for measuring body fatness. However, the aim of study 2 was not to define optimal BMI cut-off points, but the aim was to estimate the extent to which BMI-for-age estimates of obesity prevalence from study 1 might be underestimating the true prevalence of obesity (i.e. high body fatness). Further, there is lack of evidence on the definition of high body fat %, and the cut-off 30% was a working definition used in these studies, which may not be an ideal definition for detecting adolescent females with high fatness. Future studies should aim to identify the optimal body fat percentage with which to define excessive fatness. For example, large epidemiological studies could test for associations between body fatness and cardio-metabolic outcomes (blood pressure, blood lipids, glucose metabolism, inflammatory markers) in adolescents, and use ROC analysis to identify the optimal point in the body fat percentage distribution where increased risk of cardio-metabolic outcomes occurs. Intervention studies, which change body fat percentage, could also be used to identify what change in body fatness is needed to produce improvements in cardio-metabolic outcomes.

Studies 2, 3 and 4 were based on cross-sectional design and therefore causality between obesity and educational attainment/inhibition could not be confirmed. In addition, studies 3 and 4 were not designed to investigate the mechanisms underlying such associations (these were detailed in Chapter 1). Longitudinal or intervention studies addressing these issues are warranted. Animal models have also been informative of effects of obesity on brain structure and function (summarised in chapter 1) and greater awareness of the animal model studies among researchers working on human studies would be helpful. For example, in the personal experience of the author and Ph.D. supervisor, some researchers assume automatically that obesity-educational outcome associations must be due to confounding by socio-economic status, and are not aware of the range of mechanisms identified by animal studies (and the more recent human studies, such as the brain imaging studies summarised in chapter 1). Obesity has a wide range of impacts on brain structure and function, and many of these are still emerging (see chapter 1) and so researchers should not automatically assume that obesity-educational attainment associations are not 'real' and only due to confounding. If existing research evidence on the effects of obesity on brain structure and function – summarised in chapter 1 – was better known, then there might be greater acceptance of the idea that associations between obesity and cognitive/educational outcomes are causal and not just due to confounding.

Overall, although the findings of these studies were consistent with previous research, the generalisability of thesis study findings may be limited due to the small evidence base in the systematic review (Al Hammadi & Reilly, 2019) - study 1, and the sample characteristics for studies 2, 3 and 4 had a limited age range and restricted to female students at Kuwait University.

5. Future research and recommendations

This thesis has identified some gaps in the evidence base for child and adolescent obesity, which is important to consider in future research.

At the national level, there is a need for more and better evidence on obesity prevalence across the GCC through regular surveillance as discussed in the next section. In addition, there is a need for more research in Kuwait and the GCC countries targeting obese children and adolescents. Larger studies with a wider age range and representative samples using a gold standard measurement of body fatness are necessary to test the classification accuracy of BMI for high fatness in the Arab population. Additionally, more research addressing cultural, social and economic factors in the context of obesity from the Gulf region (GCC) can be especially informative about the potential confounding of these factors (in contrast to western high income countries). For example, given the apparently contradictory findings of Rey-Lopez *et al*. (2019) and Weiderpass *et al*. (2019) in relation to whether or not obesity is related to SES in Kuwait, there is a need for future research on whether or not SES does influence obesity risk, and whether this applies to children, adolescents, and/or adults.

Moreover, the use of direct measures of high fatness, rather than proxy measures, should be considered in epidemiological studies where obesity is tested either as an exposure or an outcome for better understanding of the causes and consequences of obesity. Impedance offers a good option for future large epidemiological studies and even national surveys as in the USA (Chumlea & Guo, 2000) – it provides fairly highly accurate measurement of body fatness, while also being practical, e.g. cheap, quick, painless and portable (Talma *et al*.,2013; Barreira *et al*., 2013). Future studies in this area – and national surveys – which only depend on BMI are missing an important opportunity if they do not use impedance.

This thesis also suggests that there is a need for well-designed studies for obese children and adolescents which focus on educational attainment and cognitive function outcomes. Further research for investigating these associations in different populations (age, sex, and ethnicity) and targeting different educational and cognitive outcomes is recommended. Measuring academic performance using standardised tests for specific subjects would also add to the evidence base for obesity-educational attainment association. Moreover, addressing the core executive cognitive domains that are highly correlated with inhibition, such as working memory and cognitive flexibility, would help understand the potential effects of obesity on each domain of executive function as well as the total cognitive ability (Booth *et al.,* 2014, Santana *et al*., 2017

In addition, longitudinal and intervention studies are more convincing than cross sectional studies about conclusions of cause and effect associations between obesity and educational and cognitive outcomes. For example, intervention studies aiming at reducing body fatness and examining changes in educational attainment or cognition are recommended, along the lines of the study designs suggested above, and recommended in recent literature (Santana *et al.,* 2017; Martien *et al.,* 2017; Sweat *et al.,* 2017; Hill *et al.,* 2018). Such studies might also be needed to estimate dose-response type effects, i.e. what change in body fatness is needed to produce a certain change in educational attainment or some cognitive function. Furthermore, mechanistic studies are needed to explore the potential mechanisms of effect obesity which have been explained in detail in Chapter 1 – it is not certain that all of the mechanisms from animal models for example apply to humans.

The possible effects of obesity on educational attainment and cognitive ability among university students should be taken seriously by universities. Taking responsibility for raising health awareness among students and preparing them for being responsible future adults would help reduce the prevalence of obesity or at least the possible psychological effects associated with obesity. Obesity has a range of adverse effects which are often considered as quite separate from educational attainment and cognitive functions (e.g. poorer mental health, poorer physical health such as impacts on sleep, asthma, iron deficiency, vitamin D deficiency (Reilly, 2005); Sansone *et al.,* 2020), and help in preventing or treating obesity in university students might be considered by universities as ways of improving their physical and mental health (Cecil *et al.,* 2012; Musaiger *et al.,* 2016; AlMarri *et al.,* 2017). Such efforts might also improve educational attainment at the same time.

Engaging students in physical activities and providing separate sport facilities for males and females on campus might help them maintain healthy body fatness, and might help reduce body fatness in those with obesity (Musaiger *et al*., 2014; Weiderpass *et al*., 2019). Higher levels of physical activity would also improve mental health and wellbeing (Reilly *et al*., 2010; Martin *et al.*, 2016)

Finally, the present thesis also identified areas of research that may add more evidence for the importance of weight management among obese children and adolescents. Besides reducing health risk factors associated with obesity, weight management may also help improve educational attainment and cognitive functions among age-school children and adolescents.

6. Policy implications

The systematic review (study 1) showed that the GCC states have very limited public health surveillance of children and adolescents obesity despite the very high obesity prevalence (Al Hammadi & Reilly, 2019), so more extensive and higher quality surveillance is required. Regular national surveys should consider a more accurate simple measure of obesity, such as using the WHO overweight cut-off (Z score $\geq$1) to improve the sensitivity of BMI for detecting those with high fatness as discussed in chapter 1. As suggested above, national surveys in the GCC states could actually use impedance to measure body fatness, as in other high income countries with high obesity prevalence such as the USA (Chumlea&Guo, 2000). More uniformity of national surveys and obesity measures across the GCC countries would allow for comparisons between countries and trends could be identified. This sort of evidence would be useful for achieving more effective implementation of surveillance, prevention, control and treatment measures of obesity in the Gulf region. If surveillance is limited or absent it is not clear if obesity prevalence is getting better or worse, or if efforts being made to reduce obesity prevalence are working.

Several studies have shown the importance of the cooperation between different stakeholders for preventing obesity. Clarke *et al.*, (2013) conducted a meta-synthesis of 18 qualitative studies from western high income countries and concluded that schools play a major role in preventing child and adolescent obesity through promoting physical activity and healthy eating and that parents should take responsibility to support the schools policies. In addition, governments have to be involved to provide clear guidance and coordination to schools and universities, resources, and effective support to parents (Clarke *et al*., 2013). A study by Stott *et al*., (2013) found that the government agencies in the GCC countries did not have established links within community organisations to facilitate healthy lifestyles for children and adolescents to prevent child and adolescent obesity (Stott *et al*., 2013). In addition, a study investigated the perceived personal, environmental, and social barriers to healthy eating and physical activity among university students in Kuwait (Musaiger *et al*., 2014). Female students were more likely than males to report barriers to physical activity, particularly the hot climate. Both males and females reported lack of nutritional information and skills as major barriers to healthy eating (Musaiger *et al*., 2014). Therefore, the high prevalence of obesity in Kuwait and the GCC countries could be partly due to the lack of effective policies concerning obesity in schools, universities and the whole community, partly to lack of knowledge and skills, and partly due to not having measures available to be active during the hot summers.

This thesis provided updated evidence on the high prevalence of obesity that should lead to an outcome of obesity prevention and control being taken more seriously in Kuwait. Children and adolescents should arguably be a high priority for prevention and treatment efforts as they have a very high prevalence of obesity (study 1, chapter 3). These policies should also be taken more seriously if obesity impacts on educational and cognitive outcomes. The Kuwait National Programme for Healthy Living is an initiative developed with the aim of improving the health and well-being of Kuwaiti population by emulating the work achieved in several countries, especially in Singapore, with some modification to focus on obesity and its comorbidities (Behbehani, 2014). The plan included increasing physical activity and promoting healthy diet for creating a healthy school/university environment (Behbehani, 2014). The findings of this thesis may help promote these objectives. Raising awareness about the potential negative effects of obesity on educational attainment and cognition may help motivate students and families for involvement in intervention programmes, and adopting healthier behaviours. Moreover, improving knowledge of nutrition and preparation of healthy food among students as well as implementing more opportunities for physical education is recommended by the aforementioned initiative.

The present thesis also provided helpful insights to be used by the governments and associated stakeholders to improve policies in Kuwait. These policies should focus on early prevention of obesity and creating an environment that encourages healthy lifestyle. Increasing the availability and access to healthy food in the community, establishing separate facilities for males and females for practicing physical activity, and engaging families in activities and health promotion programmes. In addition, governmental funding of more school-based intervention programmes and research is needed to improve the understanding and resolutions of these challenges. All of these recommendations align with the WHO Global Action Plan on Physical Activity (WHO, 2018).

In summary, the findings of this thesis should be utilised to inform the national policy of Kuwait for more efforts towards obesity prevention and control. The literature review for this current study indicates that obesity in children and adolescents, both in schools and in higher education, is negatively associated with low performance in educational achievements and/or cognitive functioning. However, children and young adolescents who are more active and within recommended weight or body fatness limits are more likely to achieve higher levels of educational attainment and/or cognitive functioning.

The evidence from Kuwait could possibly be used to encourage other GCCs to update their own data on prevalence of obesity in children and adolescents (Al Hammadi & Reilly., 2019). Anecdotally, discussions with the students who participated in the research in Kuwait, and with staff who helped, suggested that active commuting –(by walking or cycling) was very rare; instead they are normally chauffeured whenever they travel. An almost total absence of active commuting is not likely to be helpful to obesity prevention or treatment, but this issue is beyond the scope of this thesis. An absence of active commuting can be explained by the cultural barriers that still exist for all Arabic women (Sharara *et al*., 2018). The literature attributes this to a perceived lack of safety and a lack of government support, exacerbated by the hot climate in the GCC during the summer as mentioned briefly above and in chapter 1 (Farrag, 1983; Musaiger, 1987).

Findings from the present thesis indicate that obesity in adolescent females is high in Kuwait University. The university might be persuaded to help students to recognise the problem of obesity and its consequences in future as a result of the thesis findings.

If we are able to highlight the effects of obesity on education achievement and/or cognitive function then this may well be a form of a “wake-up call” for the Kuwaiti government and will, hopefully, help them to reduce, and perhaps eventually reverse, the rise of an obesity epidemic in the coming decades. Most importantly, the government needs to be able to address the issue that obesity intervention must start at an early age, as children and young adolescents’ learned behaviours are shaped at an early age and, unfortunately, most unhealthy behaviours often persist into adulthood (Leme *et al*.,2020 ;Scaglioni *et al*.,2018;Alrashidi *et al*.,2015 Musaiger *et al*., 2014). Research has shown that children who are obese are more likely to be obese as they grow older and throughout adulthood (Reilly, 2010). Therefore, interventions for child and adolescents' obesity must be considered as primary health care interventions, similar to other primary health interventions, such as vaccinations (WHO 2017)

7. Conclusions

In conclusion, this PhD thesis found that the prevalence of obesity among school-age children and adolescents is very high in Kuwait and the Gulf region (GCC) and prevalence of obesity might be underestimated due to the wide use of BMI for age to define obesity. The research showed associations between obesity and poor academic attainment and inhibition in adolescent females. Further research is needed to investigate these associations in different populations or countries and address different education attainment and cognitive outcomes with larger sample size and longitudinal studies, and intervention studies where possible. The present thesis suggests implementing more regular national surveys for surveillance in the Gulf region (GCC), considering a direct measure of high fatness in addition to the proxy measures in epidemiological studies and surveys, and improving policies and interventions for obesity prevention. The recent establishment of the Dasman Diabetes Institute, which is a specialised research and treatment centre for diabetes and obesity (Dasman Diabetes Institute, 2021), further highlights the urgent need to tackle these public health issues in Kuwait. Future research studies may focus on filling the gaps identified by this thesis and providing a comprehensive approach to understanding and resolving the obesity epidemic in Kuwait and the Gulf region.

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Appendices

Appendix A: PROSPERO Registration of Review

PROSPERO International prospective register of systematic reviews

Prevalence of obesity among school-age children and adolescents in the Gulf Co-Operation Council States: a systematic review

John Reilly, Hanouf Hassan

Citation

John Reilly, Hanouf Hassan. Prevalence of obesity among school-age children and adolescents in the Gulf Co-
Operation Council States: a systematic review. PROSPERO 2017:CRD42017073692 Available from
http://www.crd.york.ac.uk/PROSPERO_REBRANDING/display_record.asp?ID=CRD42017073692

Review question(s)

What is the prevalence of obesity among school-age children and adolescents in the gulf states?
Does obesity prevalence vary by the following variables: age; gender; time of the survey or study; definition of obesity used; and nation?

Searches

Database searching in the following databases:
-MEDLINE
-PE Index
-Scopus
-WHO Databases
-Forward and backward citation searching
For articles published in English or Arabic.
Database searching as described above should identify at least some relevant grey literature. This search for grey literature will be supplemented with an extensive search for relevant data in each of the six GCC nations: the rationale here is that obesity prevalence estimates from national or regional surveys might be contained in national government or NGO reports rather than in academic publications. Grey literature searching will therefore also be carried out by searches in Google Scholar, plus by making contact with relevant individuals and organisations in each of the 6 GCC states. The contacts in each nation will include Academia, Government Health Ministries, Government Education

Ministries, and NGOs (e.g. UNICEF).

Types of study to be included

Inclusion: any study design where obesity prevalence data are included.

Exclusion: obesity prevalence data obtained after interventions intended to reduce obesity prevalence.

Condition or domain being studied

Obesity, derived from body mass index (BMI) for age and sex based on measured weight and height, and defined using one of the following standard/accepted methods: relative to national population reference data; relative to WHO (2007) reference data; or International Obesity Task Force.

Participants/ population

Inclusions: participants of school age (5.0-19.0 years as defined by WHO); from one of the 6 GCC countries (Kuwait, KSA, Qatar, UAE, Bahrain, Oman); if the participants are from apparently healthy/community samples; if data have

been collected within the last 10 years (since January 2007; since obesity prevalence has been increasing dramatically in the gulf states in recent years; the WHO recommended definition of obesity only became available in 2007 and so child and adolescent obesity prevalence as defined by WHO was not available until relatively recently).

Exclusions: participants outwith the school age as specified above, from nations other than the 6 GCC nations listed above, from clinical/non-community samples, and if data were collected prior to January 2007.

Intervention(s), exposure(s)

Obesity, defined using measured BMI for age.

Obesity based on self-reported BMI; prevalence of overweight as opposed to obesity (or overweight and obesity combined) will be excluded

Comparator(s)/ control

Not applicable.

Context

School and/or community settings included; data from clinical populations will be excluded.

Outcome(s)

Primary outcomes

Prevalence of obesity (for primary research question).

Secondary outcomes

Differences in obesity prevalence by subgroup (age, gender, time, and nation).

Data extraction, (selection and coding)

Two researchers will independently screen the titles, abstracts and potentially relevant full-text articles in duplicate. If the two researchers cannot agree a third researcher will be consulted to solve disagreement.
Data extraction will be guided by a pre-defined and piloted template. The following data will be extracted: Time of data collection; Definition of obesity used; Sample size, summary data on age and gender of sample, location, evidence as to whether samples were representative or not; and Prevalence of obesity. Data extraction will be performed by the one reviewer and double-checked by a second reviewer.

Risk of bias (quality) assessment

Two reviewers will independently appraise the quality of included studies using the (EPHPP) tool. Results will be compared and discussed to reach agreement. A sensitivity analysis will be performed for studies with high risk of selection and attrition bias.

Strategy for data synthesis

Should the data and level of heterogeneity between primary studies allow, similar outcomes will be combined by meta-analysis. Initial scoping of the literature suggests this is not likely to be possible due to marked differences between studies (in participant age, definition of obesity, and timing of the survey, all of which are known to influence obesity prevalence). Narrative synthesis will be carried out.

Analysis of subgroups or subsets

Gender differences in prevalence. Age differences in prevalence (WHO defined children, 5.0-9.9 years vs WHO defined adolescents, 10.0-19.0 years). Setting (national differences in prevalence). Timing of survey (to test for evidence of secular trends in prevalence).

Dissemination plans

Full peer-reviewed journal article to be submitted to a relevant journal & presented at relevant scientific meetings.
Inclusion of study report as a PhD thesis chapter, which will be available electronically.
Key messages to be disseminated to policy makers and key delivery groups in Kuwait and in the GCC, where possible.

Contact details for further information

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Review team

Professor John Reilly, University of Strathclyde

Mrs Hanouf Hassan, University of Strathclyde

Anticipated or actual start date

17 July 2017

Anticipated completion date

31 January 2018

Funding sources/sponsors

Hanouf Hassan is working on a PhD funded by the Kuwaiti government.

Conflicts of interest

None known

Language

English

Country

Scotland

Subject index terms status

Subject indexing assigned by CRD

Subject index terms

Adolescent; Child; Humans; Kuwait; Obesity; Prevalence

Stage of review

Ongoing

Date of registration in PROSPERO

10 September 2017

Date of publication of this revision

10 September 2017

Stage of review at time of this submission	Started	Completed
Preliminary searches	Yes	No
Piloting of the study selection process	Yes	No
Formal screening of search results against eligibility criteria	No	No
Data extraction	No	No
Risk of bias (quality) assessment	No	No
Data analysis	No	No

Appendix B: Letter for grey literature searching

Ms Hanouf Al -Hammadi

University of Strathclyde

Glasgow, UK

Physical Activity and Heath Department

Friday, 13 October 2017

Dear Prof xxxxxxx,

RE: Help identifying published studies and unpublished studies (grey literature) for a systematic review on the recent prevalence of child and adolescent obesity in GCC countries.

I hope this email find you well.

I am Hanouf Al Hammadi. PhD student at University of Strathclyde, Glasgow, UK. My study title is *systematic review of recent child and adolescent obesity prevalence in the GCC countries*. My study is under supervision Professor John Reilly, Department physical activity and health. We have been looking for evidence which meets the following inclusion criteria:

- Data collected on or after 2007
- Data collected from one or more of the GCC countries
- Data collected from school-age children/ adolescents
- Obesity prevalence defined using an accepted method (e.g BMI -for- age)

I am honored to contact you based on your expertise in Nutrition research and the problem of childhood obesity. I would request you kindly to help me to identify published/ unpublished studies for a systematic review on the recent prevalence of child and adolescent obesity in GCC countries.

Our search of the literature has identified 8 eligible studies from GCC countries. These are listed in the table below – would you mind doing the following within the next month:

a) Letting me know if you aware of any eligible studies other than those listed in the table?

b) Letting me know if you are aware of any unpublished evidence which might meet our inclusion criteria (e.q. national surveys/ grey literature).

Country	Year of data collection	source
Kuwait	2009	Shoroq et al. 2011
Kuwait	2009-2010	AlHaifi 2014
KSA, Kuwait ,Bahrain	2013-2014	Musaiger 2016
Kuwait	2012	Shaban etal 2017
Kuwait	2012-2013	N.ElKum etal, 2015
KSA	2009-2010	Al-Hazzaa et al 2014
UAE	2013-2014	Al_Balooshi et al 2016

Any information you provide will be much appreciated.

I look forward to hearing from you.

Yours Sincerely,

Hanouf Al Hammadi

Appendix C: JBI Critical Appraisal Checklist for Studies Reporting Prevalence Data

THE JOANNA BRIGGS INSTITUTE

JBI Critical Appraisal Checklist for Studies Reporting Prevalence Data

Reviewer_________________________________Date_________________________________

Author ______________________________________Year________Record Number____________

	Yes	No	Unclear	Not applicable
1. Was the sample frame appropriate to address the target population?	☐	☐	☐	☐
2. Were study participants sampled in an appropriate way?	☐	☐	☐	☐
3. Was the sample size adequate?	☐	☐	☐	☐
4. Were the study subjects and the setting described in detail?	☐	☐	☐	☐
5. Was the data analysis conducted with sufficient coverage of the identified sample?	☐	☐	☐	☐
6. Were valid methods used for the identification of the condition?	☐	☐	☐	☐
7. Was the condition measured in a standard, reliable way for all participants?	☐	☐	☐	☐
8. Was there appropriate statistical analysis?	☐	☐	☐	☐
9. Was the response rate adequate, and if not, was the low response rate managed appropriately?	☐	☐	☐	☐

Overall appraisal: Include ☐ Exclude ☐ Seek further info ☐

Comments (Including reason for exclusion)

Appendix D: Ethics

SCHOOL OF PSYCHOLOGICAL SCIENCES & HEALTH

University of Strathclyde
Humanities & Social Sciences

18th December 2018

Confirmation of ethics approval:
Associations between obesity and educational attainment and cognition in adolescent girls (17-19 year olds) in Kuwait, a feasibility study

I am pleased to confirm that the above proposal has been approved by the School of Psychological Sciences and Health Ethics Committee.

Dr Diane Dixon
Ethics Committee Chair, School of Psychological Sciences & Health,
Faculty of Humanities and Social Science, University of Strathclyde

Appendix E: Letter from the supervisor to Kuwait University

SCHOOL OF PSYCHOLOGICAL SCIENCES & HEALTH

University of Strathclyde Humanities & Social Sciences

P.O.Box 5969,Safat-,3060 Kuwait

Shwawikh Campus.

Kuwait University.

Permission request, Kuwait University: Associations between obesity and educational attainment and cognition in adolescent (17-19 year old) girls in Kuwait: a feasibility study.

To Faculty Deans,

We are writing to seek permission to gain access to Kuwait University in order to carry out the above study, which will form part of the PhD for Hanouf H. Al Hamadi at the University of Strathclyde, Glasgow, UK. The study has received ethical approval from the School of Psychological Sciences and Health at the University of Strathclyde.

This project has two aims. The primary aim is to test the feasibility of carrying out an epidemiological study of associations between adolescent obesity and (a) educational attainment and (b) cognitive function in Kuwaiti adolescents (Study 1). The secondary aim is to test the extent to which a simple standard proxy measure of obesity (BMI-for-age) underestimates the prevalence of obesity (i.e. excess body fatness) in Kuwaiti adolescents (Study 2, using data collected for Study 1).

In order to carry out the study we want Hanouf to be able to recruit 600-700 adolescent female students (17-19 year olds), during 2019 and 2020. We would be happy to meet with you or your colleagues to discuss the study in more detail. All data would be collected during short visits to the campus, and we would like to access GPA records for each of the girls who takes part. We would aim to recruit study participants using our study flyer, information sheet and consent forms (all enclosed).

Please contact us if you would like more information.

Yours sincerely

Prof John J Reilly Hanouf Al Hammadi

Appendix F: Letters of agreement for equipment delivery and data collection

The document shows that Kuwait Institute for Scientific Research (KISR) lent the statistical and research unit of College of Social Science, Kuwait University the following equipment:

- Body Composition Analyzer-Tanita (Qnt. 3)
- Stadiometer-seca (Qnt. 2)

The document shows also the agreement between Kuwait University and HA to do the research in the College of Social Science. Dr. Hamad Alaslawi kindly provided the place, his office, to collect the data.

جامعة الكويت | كلية العلوم الاجتماعية | مكتب العميد
Kuwait University | College of Social Sciences | Office of the Dean

التاريخ : ١٣/٢/١٩م
المرجع : ١٤٧

إلى : الدكتور / سمير الزنكي
مدير إدارة العلوم التكنولوجيا - مركز البيئة والعلوم الحياتية

من : الأستاذ الدكتور / حمود فهد القشعان
عميد كلية العلوم الاجتماعية

تحية طيبة وبعد،

ورد إلينا خطاب من الزميل الدكتور/ حمد العسلاوي يفيد بموافقته على الاشراف على تطبيق دراسة الباحثة / هنوف عبد الله الحمادي والتي تتطلب المعدات التالية:

1-Tanita : body composition analyser Qnt.3 .
2-Stadiometer Qnt.2

يرجى العلم بالموافقة على تطبيق الدراسة بالكلية على أن يتحمل الدكتور حمد العسلاوي، رئيس وحدة الاستشارات الإحصائية والبحثية في كلية العلوم الاجتماعية، مسؤولية عهدة واستلام المعدات في مقر الوحدة بغرفة مخصصة لحفظ المعدات من تاريخ 2019/3/15م إلى 2019/5/15م، وهي فترة جمع البيانات.

وتفضلوا بقبول وافر التقدير والاحترام ،،

فاكس 24841020 (965) | هاتف 24844956(965) / 24988808 (965) | ص.ب. 68168 كيفان 71962 الكويت
Fax (965) 24841020 | Tel (965) 24844956 / (965) 24988808 | P. O. Box 68168 Kaifan 71962 Kuwait
www.ku.edu.kw

Meeting for finalizing equipment delivery

March 25, 2019
1:00 pm

Attendants:
Mr. Hasan Alattar
Dr. Hamad Alaslawi

We have agreed upon the following:

- The Kuwait Institute for Scientific Research have agreed to lend the Statistical and Research Unit of College of Social Sciences, Kuwait University the following equipments:
    - Body composition analyser – The brand is Tanita- The quantity 3.
    - Stadiometer – The brand is Seca – The quantity 2.

- The equipments will be placed at room number G12-08 which is the office of the head of Statistical and Research Unit.
- Dr. Hamad Alaslawi will be receiving the equipment and signing a receival sheet.
- We have agreed that Mr. Hasan Alattar will be visiting the location of the study weekly to check up the process and the equipment status.
- There is only one key for the office and it will be held with Ms. Hanouf Al-Hammadi. Therefore, in case Mr. Hasan Alattar want to visit the facility he will contact Mohammed Albloshy to allow him enter the facility. His contact number: 99393518.
- The duration of collecting the data will be two months starting from the date of receiving the equipments.
- Mr. Hasan Alattar will provide a training workshop for Ms. Hanouf Al-Hammadi with her colleagues who will assist her in collecting the data.

25/3/2019

Dr. Hamad A. Alaslawi
Assistant Professor
Department of Sociology & Social Work, Kuwait University
د . حمد عادل العسلاوي
أستاذ مساعد
قسم الاجتماع والخدمة الاجتماعية
جامعة الكويت

KISR

Urgent

RECEIVED
KISR DG'S OFFICE
07 APR 2019
No: 385

مذكرة للاتصالات الداخلية

التاريخ : 2019/4/7

إلـــى : د. سميرة أحمد السيد عمر - المدير العام

بواسطة : د. عبد النبي الغضبان - المدير التنفيذي-مركز أبحاث البيئة والعلوم الحياتية

بواسطة : د. سمير الزنكي - مدير إدارة العلوم والتكنولوجيا-مركز أبحاث البيئة والعلوم الحياتية

بواسطة : د. عفاف الناصر - مدير إدارة العمليات-مركز أبحاث البيئة والعلوم الحياتية

بواسطة : السيد/ عدنان حسين - مدير برنامج الغذاء والتغذية

مـــن : حسن العطار - مشارك أبحاث

الموضوع : الموافقة على استعارة أجهزة من المعهد

بالإشارة إلى كتاب جامعة الكويت رقم (147)، والمؤرخ في 2019/3/13 (مرفق نسخة) بخصوص الموضوع أعلاه، وإستناداً إلى محضر الاجتماع المؤرخ في 2019/3/25 (مرفق نسخة)، وكذلك استناداً إلى مذكرة التفاهم بين المعهد وجامعة الكويت. يرجى منكم التكرم بالموافقة على إعارة الأجهزة المطلوبة إلى الباحثة/ هنوف عبد الله الحمادي- كلية العلوم الاجتماعية، لفترة لا تتجاوز شهرين من تاريخ استلام الأجهزة. علماً بأن هذه الأجهزة لا تستخدم في أي مشروع قائم حالياً، أو سيقام في المعهد. وتتمثل تلك الأجهزة في الجدول التالي:

	اسم الجهاز	رقم ملكية الجهاز
1	Body Composition Analyzer - Tanita	086270- 086268-086267
2	Stadiometer - seca	086444 - 086443

وشكراً،،،،

for DG-
Approved according to rules & regulation
6/4/2019

Appendix G: Consent in English and Arabic

Participant Information Sheet for Parents

Name of department: Physical activity for health
Title of the study: Associations between obesity and cognitive function and educational attainment in Kuwaiti adolescent girls: a feasibility study

Introduction

Dear parent or guardian

are invited to participate in a research project being conducted by Strathclyde University in United Kingdom. The Ministry t of Education has given approval for your school to take part in this research project. Please read this sheet carefully and be confident that you understand its contents before deciding whether or not to participate. Once you understand what the project is about and if you agree to take part, you will be asked to sign the Consent Form. By signing the Consent Form, you indicate that you understand the information and that you give your consent for you and your adolescents to participate in the research project. If you have any questions about the project, please do not hesitate to call one of the investigators.

Hanouf ALhammadi is a student at Strathclyde University at the UK. She is conducting this research as a part of a PhD degree programme in Physical activity for Health.

What is the purpose of this investigation?

There will be no immediate or direct benefit to your adolescents or to you; however, this study will benefit our current understanding of relationship to adolescent's obesity and education attainments and cognitive function effects , and the researcher hopes that it will provide a clear understanding of obesity among students

Do you have to take part?
Your participation is voluntary, and you are invited to participate in this study. You can withdraw from the study at any point, up until the data is anonymized. If you decide to withdraw from this study, your data will be deleted, and it will not be used. Withdrawal from the study after data is anonymized is not possible since we will no longer be able to identify your responses.

What will you do in the project?

Your adolescents will be asked for:

1. Anthropometric measurements (weight, Height, and Body mass Index BMI)

Which weight will be measured with subject bare footed and wearing a PE (school physical education uniform) for max 10 min. These height and weight measurements will be taken in a PRIVATE room to ensure privacy and confidentiality. The measurement results will NOT be shared with the child or with anyone else at the school. Children who take part will be asked to remove their shoes and coats and will be weighed in light indoor clothing.

Any cultural needs of the child will be respected. Children will not be forced to take part in these measurements if they do not wish to do so.

Body mass index is a number calculated by dividing the child's weight over the child's height squared. It is a way of checking to see if a child is at a healthy weight. Body mass index is a useful tool that enables health professionals to Identify individuals who are obese.

2. Cognitive functions. Inhibition testing paradigms, stroop test.

COMPASS is the computerised mental performance system a simple solution to complexities of cognitive testing

Each student will present with a laptop with a mouse to click, that required to match the four colours (colours of the square boxes) with the colour of the word presented, the student will require answering as quickly and as accurately as possible. Max 20min.

3. Educational attainment: Student's grads

4. Socio-demographic status: educational level of their parents (illiterate, can write and read primary, intermediate or high school pass or highly educated

Why have you been invited to take part?

Your adolescents have been invited to respond to test to assist in understanding the the relationship between obesity and the cognitive function/academic achievements in Kuwaiti adolescent girls aged between 16-19yrs old. . Please note that your participation is on a voluntary basis. You may contact the researcher by phone or email to seek further clarification regarding your participation.

There will be no immediate or direct benefit to your adolescents or to you; however, this study will benefit our current understanding of childhood obesity, and the researcher hopes that it will provide a clear understanding of obesity and would affect their academic or cognitive function in life time .

What are the potential risks to you in taking part?
No harm or risk is expected through participating in this study, and there are no preparatory requirements for taking this test.

What happens to the information in the project?
After the adolescents completed with the test, your data will be completely anonymised, and the questionnaire will be deposited on the University's servers by the investigators for up to 5 years after the completion of this study. Anonymised data will be published and presented in scientific meeting and literature.
This study will not use information where you can be identified.

The University of Strathclyde is registered with the Information Commissioner's Office who implements the Data Protection Act 1998. All personal data on participants will be processed in accordance with the provisions of the Data Protection Act 1998.
Thank you for reading this information – please ask any questions if you are unsure about what is written here.

What happens next?
If you are happy to be involved in the project, you will be invited to sign a consent form to confirm this.

If you decide you would rather not participate in this study, ignore this invitation and no further contact will be made.

Researcher contact details:

Hanouf Hasan ALHammadi Postgraduate student
Department: Physical activity for Health Group
Telephone: +44 (0) 747 986 0936
E-mail: hanouf-a-a-m-hasan@strath.ac.uk

Chief Investigator details:

Prof.John Reilly

Department: Physical activity for Health Group

Telephone: +44 (0)141 548 4706

E-mail: john.j.reilly@strath.ac.ukf.John Reilly

This investigation was granted ethical approval by the University of Strathclyde Ethics Committee.

If you have any questions/concerns, during or after the investigation, or wish to contact an independent person to whom any questions may be directed or further information may be sought from, please contact:

Secretary to the University Ethics Committee
Research & Knowledge Exchange Services
University of Strathclyde
Graham Hills Building

50 George Street
Glasgow
G1 1QE

Telephone: 0141 548 3707
Email: ethics@strath.ac.uk

Consent Form to be Completed by Parents of Study Participants under 18 yrs old and by students over 18 yrs old.

Name of department: Physical Activity for Health, School of Psychological Sciences and Health

Title of the study: Associations between obesity and cognitive function and educational attainment in Kuwaiti adolescent girls.

o I confirm that I have read and understood the information sheet for the above project and the researcher has answered any queries to my satisfaction.

o I understand that my participation is voluntary and that I am free to withdraw from the project at any time, without having to give a reason and without any consequences.

o I understand that I can withdraw my data from the study at any time without having to give a reason and without any consequences.

o I understand that any information recorded in the investigation will remain confidential and no information that identifies me will be made publicly available.

o I consent to being a participant in the project

(PRINT NAME) …………………………………………………………

PRINT DATE OF BIRTH ………………………………………………………...

I hereby agree to take part in the above project

Signature of Participant: ……………………………………………………….

Date: (/ /2019)

ورقة معلومات المشاركين لأولياء الأمور

اسم القسم: النشاط البدني للصحة

عنوان الدراسة: الارتباط بين السمنة والوظيفة المعرفية والتحصيل العلمي لدى المراهقات الكويتيات: دراسة جدوى

المقدمة

عزيزي الوالد أو الوصي

أنتم مدعوون للمشاركة في مشروع بحثي تجريه جامعة ستراثكلايد في المملكة المتحدة. أعطت وزارة التربية والتعليم موافقة للكلية على المشاركة في هذا المشروع البحثي. يرجى قراءة هذه الورقة بعناية وكن على ثقة من فهمك لمحتوياتها قبل اتخاذ قرار بالمشاركة أم لا. بمجرد أن تفهم ما هو المشروع، وإذا وافقت على المشاركة، سيُطلب منك التوقيع على نموذج الموافقة. من خلال التوقيع على نموذج الموافقة، فإنك تشير إلى أنك تفهم المعلومات وأنك تمنح موافقتك على مشاركتك في مشروع البحث. إذا كان لديك أي أسئلة حول المشروع، من فضلك لا تتردد في الاتصال بأحد المحققين

هنوف الحمادي طالبة في جامعة ستراثكلايد في المملكة المتحدة. تقوم بإجراء هذا البحث كجزء من برنامج درجة الدكتوراه في النشاط البدني من أجل الصحة.

ما هو الغرض من هذا التحقيق؟

لن تكون هناك فائدة فورية أو مباشرة للمراهقين أو لك؛ ومع ذلك، ستفيد هذه الدراسة في فهمنا الحالي للعلاقة مع السمنة لدى المراهقين والتحصيل التعليمي وتأثيرات الوظيفة المعرفية، ويأمل الباحث أن توفر

هذه الدراسة فهمًا واضحًا للسمنة بين الطلاب

هل عليك المشاركة؟

مشاركتك تطوعية، وأنت مدعو للمشاركة في هذه الدراسة. يمكنك الانسحاب من الدراسة في أي وقت. إذا قررت الانسحاب من هذه الدراسة، فسيتم حذف بياناتك ولن يتم استخدامها. لا يمكن الانسحاب من الدراسة بعد أن تكون البيانات مجهولة المصدر لأننا لن نتمكن بعد الآن من تحديد ردودك.

ماذا ستفعل في المشروع؟

سيُطلب من المراهقين:

1.القياسات الأنثروبومترية الوزن والطول ومؤشر كتلة الجسم (BMI)

ما هو الوزن الذي سيتم قياسه بالمريض حافي القدمين وارتداء PE (زي التربية البدنية المدرسية) لمدة 10 دقائق بحد أقصى. سيتم إجراء قياسات الطول والوزن هذه في غرفة خاصة لضمان الخصوصية والسرية. لن يتم مشاركة نتائج القياس مع المشاركين أو مع أي شخص آخر في المدرسة. سيُطلب من المشاركين خلع أحذيتهم ومعاطفهم وسيتم وزنهم بملابس داخلية خفيفة.

سيتم احترام القيم الثقافية والمجتمعية للمشارك. لن يُجبر المشارك على المشاركة في هذه القياسات إذا لم يرغبوا في ذلك.

مؤشر كتلة الجسم هو رقم يتم حسابه بقسمة وزن المشارك على مربع طول المشارك. إنها طريقة للتحقق لمعرفة ما إذا كان المشارك يتمتع بوزن صحي. مؤشر كتلة الجسم هو أداة مفيدة تمكن المهنيين الصحيين من التعرف على الأفراد الذين يعانون من السمنة.

2.الوظائف المعرفية. نماذج اختبار التثبيط، اختبار ستروب.

كومباس هو نظام أداء عقلي محوسب وهو حل بسيط لتعقيدات الاختبار المعرفي

سيقدم كل طالب جهاز كمبيوتر محمول به ماوس للنقر عليه، وهو المطلوب لمطابقة الألوان الأربعة (ألوان المربعات المربعة) مع لون الكلمة المقدمة، وسيتطلب الطالب الإجابة بأسرع ما يمكن ودقة قدر الإمكان. 20 دقيقة كحد أقصى.

3.التحصيل العلمي: خريجي الطالب

4.الحالة الاجتماعية والديموغرافية: المستوى التعليمي لوالديهم (أمي ، يستطيع كتابة وقراءة شهادة التعليم الابتدائي أو المتوسط أو الثانوي أو تعليم عالٍ

لماذا تمت دعوتك للمشاركة؟

تمت دعوة المراهقين للاستجابة للاختبار للمساعدة في فهم العلاقة بين السمنة والوظيفة المعرفية / الإنجازات الأكاديمية للمراهقات الكويتيات اللائي تتراوح أعمارهن بين 17 و19 عامًا. يرجى ملاحظة أن مشاركتك على أساس تطوعي. يمكنك الاتصال بالباحث عبر الهاتف أو البريد الإلكتروني للحصول على مزيد من التوضيح بشأن مشاركتك.

لن تكون هناك فائدة فورية أو مباشرة للمراهقين أو لك؛ ومع ذلك، ستفيد هذه الدراسة في فهمنا الحالي لسمنة المراهقين، ويأمل الباحث أن توفر فهمًا واضحًا للسمنة وتؤثر على وظيفتهم الأكاديمية أو المعرفية في حياتهم.

ما هي المخاطر المحتملة بالنسبة لك في المشاركة؟

لا يتوقع حدوث ضرر أو مخاطر من خلال المشاركة في هذه الدراسة، ولا توجد متطلبات تمهيدية لإجراء هذا الاختبار.

ماذا يحدث للمعلومات في المشروع؟

بعد انتهاء المراهقين من الاختبار، سيتم إخفاء هويتك تمامًا، وسيتم إيداع الاستبيان على خوادم الجامعة بواسطة المحققين لمدة تصل إلى 5 سنوات بعد الانتهاء من هذه الدراسة. سيتم نشر البيانات مجهولة المصدر وتقديمها في الاجتماعات العلمية والأدب.

لن تستخدم هذه الدراسة المعلومات التي يمكن تحديد هويتك فيها.

تم تسجيل جامعة ستراثكلايد لدى مكتب مفوض المعلومات الذي ينفذ قانون حماية البيانات لعام 1998. وستتم معالجة جميع البيانات الشخصية الخاصة بالمشاركين وفقًا لأحكام قانون حماية البيانات لعام 1998.

شكرًا لك على قراءة هذه المعلومات - يرجى طرح أي أسئلة إذا لم تكن متأكدًا مما هو مكتوب هنا.

ماذا حدث بعد ذلك؟

إذا كنت سعيدًا بالمشاركة في المشروع، فستتم دعوتك للتوقيع على نموذج موافقة لتأكيد ذلك.

إذا قررت أنك تفضل عدم المشاركة في هذه الدراسة، فتجاهل هذه الدعوة ولن يتم إجراء أي اتصال آخر.

تفاصيل الاتصال بالباحث:

هنوف حسن الحمادي طالبة دراسات عليا

القسم: النشاط البدني لمجموعة الصحة

هاتف: 0936 986 747(0) 44+

البريد الإلكتروني : **hanouf-a-a-m-hasan@strath.ac.uk**

تفاصيل رئيس المحققين:

البروفيسور جون رايلي

القسم: النشاط البدني لمجموعة الصحة

هاتف: 4706 548 141 (0) 44+

البريد الإلكتروني: **john.j.reilly@strath.ac.uk**

تم منح هذا التحقيق الموافقة الأخلاقية من قبل لجنة الأخلاقيات بجامعة ستراثكلايد

إذا كانت لديك أي أسئلة / مخاوف، أثناء التحقيق أو بعده، أو ترغب في الاتصال بشخص

مستقل يمكن توجيه أي أسئلة إليه أو الحصول على مزيد من المعلومات منه، فيرجى الاتصال بـ:

سكرتير لجنة الأخلاقيات بالجامعة

خدمات البحث وتبادل المعرفة

جامعة ستراثكلايد

مبنى جراهام هيلز

50 George Street

Glasgow

G1 1QE

Telephone: 0141 548 3707

Email: ethics@strath.ac.uk

نموذج الموافقة على أن يملأه أولياء أمور المشاركين في الدراسة

اسم القسم: النشاط البدني للصحة، كلية العلوم النفسية والصحة

عنوان الدراسة: - الارتباط بين السمنة والوظيفة المعرفية والتحصيل العلمي لدى المراهقات الكويتيات: دراسة جدوى

• أؤكد أنني قد قرأت وفهمت ورقة المعلومات الخاصة بالمشروع أعلاه وأن الباحث أجاب على أي استفسار يرضي.

• أفهم أن مشاركتي طوعية وأنني حر في الانسحاب من المشروع في أي وقت، دون الحاجة إلى إبداء الأسباب ودون أي عواقب.

• أفهم أنه يمكنني سحب بياناتي من الدراسة في أي وقت دون الحاجة إلى إبداء أسباب ودون أي عواقب. 278

• أفهم أن أي معلومات مسجلة في التحقيق ستبقى سرية ولن يتم إتاحة أي معلومات تحدد هويتي للجمهور.

• أوافق على أن أكون مشاركًا في المشروع. (اسم الطباعة)

طباعة اسم ....

طباعة تاريخ ميلاد ....

بموجب هذا توافق على المشاركة في المشروع أعلاه توقيع المشارك:

.... التاريخ: (/ / 2019)

Appendix H: Letter from the Vice Dean for Student Affairs

This appendix shows that the number of the students in the scientific departments of the College of Social Sciences in 2018/2019. This information is given by the dean of the office of the Vice Dean for Student Affairs. The chart shows the number of the students, their gender, their major, and their nationality (Kuwaiti or non-Kuwaiti). The number 3024 is the total number of the students in the college including males, females, Kuwaiti, and non-Kuwaiti. The number of Kuwaiti females is 2169.

جامعة الكويت
Kuwait University

كلية العلوم الاجتماعية
College of Social Sciences

قسم الاجتماع والخدمة الاجتماعية
Department of Sociology and Social work

التاريخ : ٢٠١٩/١٤/١٧
المرجع : ١٣٤

إلى : الفاضل الدكتور جاسم محمد العلي المحترم
العميد المساعد للشئون الطلابية

من : الدكتور يوسف غلوم علي
رئيس قسم الاجتماع والخدمة الاجتماعية

الموضوع : طلب الموافقة على تزويدنا بإحصائية بعدد الطلبة المقيدين بالكلية

تحية طيبة .. وبعد ،،،

يرجى التفضل بالموافقة واتخاذ ما ترونه نحو تزويدنا بإحصائية عن عدد الطلبة المقيدين بالأقسام العلمية بكلية العلوم الاجتماعية متضمنة : العدد ، الجنس (ذكور إناث) ، الجنسية (كويتي – غ كويتي).

وتفضلوا بقبول وافر التحية والتقدير ،،،

ص.ب : 68168 كيفان 71962 الكويت
P.O. Box 68168 Kaifan, Kuwait

هاتف 24840649 (965) / 24988868 (965)
Tel : (965) 24840649 / (965) 24988868

فاكس 24840634 (965)
Fax: (965) 24840634

www.ku.edu.kw

أعداد طلبة كلية العلوم الاجتماعية المقيدين حتى تاريخ ٢٠١٩/٠٤/٢٢

الكلية	التخصص	الجنس	الجنسية	عدد المقيدين
العلوم الإجتماعية	الجغرافيا ١٣٤١	انثى	غير كويتي	17
العلوم الإجتماعية	الجغرافيا ١٣٤١	انثى	كويتي	119
العلوم الإجتماعية	الجغرافيا ١٣٤١	ذكر	غير كويتي	8
العلوم الإجتماعية	الجغرافيا ١٣٤١	ذكر	كويتي	42
العلوم الإجتماعية	الجغرافيا البشرية ونظم المعلومات الجغرافية	انثى	غير كويتي	7
العلوم الإجتماعية	الجغرافيا البشرية ونظم المعلومات الجغرافية	انثى	كويتي	82
العلوم الإجتماعية	الجغرافيا البشرية ونظم المعلومات الجغرافية	ذكر	غير كويتي	4
العلوم الإجتماعية	الجغرافيا البشرية ونظم المعلومات الجغرافية	ذكر	كويتي	33
العلوم الإجتماعية	الجغرافيا الطبيعية ونظم المعلومات الجغرافية	انثى	غير كويتي	5
العلوم الإجتماعية	الجغرافيا الطبيعية ونظم المعلومات الجغرافية	انثى	كويتي	91
العلوم الإجتماعية	الجغرافيا الطبيعية ونظم المعلومات الجغرافية	ذكر	غير كويتي	1
العلوم الإجتماعية	الجغرافيا الطبيعية ونظم المعلومات الجغرافية	ذكر	كويتي	5
العلوم الإجتماعية	الخدمة الاجتماعية ١٣٧٢	انثى	غير كويتي	37
العلوم الإجتماعية	الخدمة الاجتماعية ١٣٧٢	انثى	كويتي	359
العلوم الإجتماعية	الخدمة الاجتماعية ١٣٧٢	ذكر	غير كويتي	10
العلوم الإجتماعية	الخدمة الاجتماعية ١٣٧٢	ذكر	كويتي	62
العلوم الإجتماعية	العلوم الاجتماعية	ذكر	غير كويتي	1
العلوم الإجتماعية	العلوم الاجتماعية	ذكر	كويتي	3
العلوم الإجتماعية	العلوم السياسية ١٣٦١	انثى	غير كويتي	20
العلوم الإجتماعية	العلوم السياسية ١٣٦١	انثى	كويتي	254
العلوم الإجتماعية	العلوم السياسية ١٣٦١	ذكر	غير كويتي	20
العلوم الإجتماعية	العلوم السياسية ١٣٦١	ذكر	كويتي	261
العلوم الإجتماعية	جغرافيا/الدراسات الطبيعية و البيئية	انثى	غير كويتي	7
العلوم الإجتماعية	جغرافيا/الدراسات الطبيعية و البيئية	انثى	كويتي	41
العلوم الإجتماعية	جغرافيا/الدراسات الطبيعية و البيئية	ذكر	غير كويتي	1
العلوم الإجتماعية	جغرافيا/الدراسات الطبيعية و البيئية	ذكر	كويتي	1
العلوم الإجتماعية	جغرافيا/تخطيط حضري /نظم معلومات	انثى	غير كويتي	2
العلوم الإجتماعية	جغرافيا/تخطيط حضري /نظم معلومات	انثى	كويتي	29
العلوم الإجتماعية	جغرافيا/تخطيط حضري /نظم معلومات	ذكر	غير كويتي	1
العلوم الإجتماعية	جغرافيا/تخطيط حضري /نظم معلومات	ذكر	كويتي	8
العلوم الإجتماعية	علم الاجتماع ١٣٧١	انثى	غير كويتي	24
العلوم الإجتماعية	علم الاجتماع ١٣٧١	انثى	كويتي	241
العلوم الإجتماعية	علم الاجتماع ١٣٧١	ذكر	غير كويتي	26
العلوم الإجتماعية	علم الاجتماع ١٣٧١	ذكر	كويتي	175
العلوم الإجتماعية	علم نفس	انثى	غير كويتي	94
العلوم الإجتماعية	علم نفس	انثى	كويتي	769
العلوم الإجتماعية	علم نفس	ذكر	غير كويتي	17
العلوم الإجتماعية	علم نفس	ذكر	كويتي	147
المجموع				3024

Appendix I: Advertised poster

Poster for the Kuwaiti female students at College of Social Sciences to participate in the study (Differences in educational attainment between obese and non-obese Kuwaiti female university student.

Appendix J: Data Collection Sheet

Data Collection Form

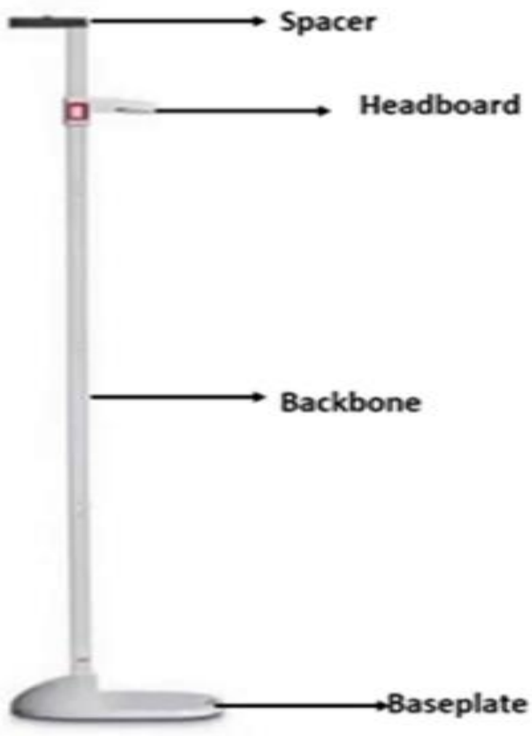
NO. of Data collection : ....

Name of Faculty: .... *Date : ....Time ....*

Student ID	**Student GPA** for the first semester2018 /2019	**Single /married**	**Time of measure**		**Fat %** to 0.1	**D.O.B** D/M/YYYY	**Height** (to 0.1 cm)		**Weight** (to 0.1kg Kg)		**Parents educational Level**(high (secondary school-university level)	***Stroop test % correct score***	***Stroop test Reaction time***	**Comments**
			am	**pm**			Meas (1)	Meas (2)	Meas (1)	Meas (2)				

Appendix K: S.O.Ps

Height measurement S.O.Ps



1. Call the student to Height measurement and inform them what you are going to do.

2. Ask the student to remove their footwear. The student should remove the head scarf or Kippah from their head, expect those who wear the hijab (religion purpose). If the student refuse to remove the scarf then write a note on the folder. Make sure when you take the measurement to gets in as close as possible.

3. Make note on the record if you notice any physical problem

4. Request the student to step onto stadiometer (SECA) and put their heels together and shoulders back, standing with heels near the rear of the baseplate.

5. Request the student to stand upright, arms hanging at the sides with his/her heels together.

6. Request the student to look at a point on the wall the back of their buttocks, shoulders and head must touching the backbone of the stadiometer (SECA).

7. The student should look ahead by the lower border of the bony orbit and the upper end of the external opening of the auditory canal in the same horizontal line.

8. Request the student to take a deep breath in and stretch up high while putting their heels on the floor.

9. The researcher places the headboard firmly down on the student's head, pressing down as much hair as possible.

10. The height measurement is taken from the highest part (top) of the head and entered in centimetres. Record the measure to the nearest 0.1 cm on data collection form.

11. Lift up the headboard and request the student to step aside from the stadiometer (SECA).

12. Repeat this procedure for the twice and record the data.

13. If the two measures vary by more than 0.5 cm, measure and record a third time using the same method.

TANITA (TBF-310) S.O.P'S

Setup the scale

1. Turn on the Power and wait for 60 sec the unit will beep to confirm the activation
2. Select the personal number and press the SET button; the unit will beep for confirmation.
3. Set up the student birthday (day/month/ year)

SOP for measuring weight

1. Socks should be removed and bare Feet must be clean. Make sure that student heels are correctly aligned on the measuring platform. Do not worry if the readings can still be obtained if your toes overhang the platform
2. Make sure the measurement or the reading was taken after 2 hours of student no eating or exercise
3. Press power button to start up the scale
4. Body composition analyzer mode should be selected.
5. The clothes weight should be taken and saved in separate sheet (data sheet) to be then entered in the analyzer.

6. Select Gender, the age, body type e.g. (standard-Athletics).cloths weight, Height will be taken before (recorded) and ask the student to step on to the scale. With no shoes or socks.

- Step on to the scale while is off, the scale will turn on automatically.
- Make sure the feet are in the correct spot on the scale and make sure that heels centered on electrodes.
- Students should remain on the scale until the reading has been taken.

And the paper sheet is printing the results.

- Weight (0.1kg), BMI and % fat mass will appear on the monitor. And printed.

7. Record the information on data sheet the % Body fat to round 0.1%, Body weight to round 0.1Kg and BMI.

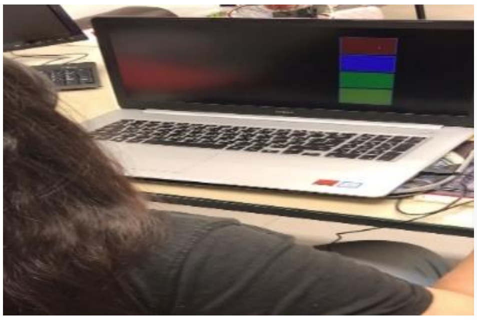
8. Clear the results and prepare the scale for the next student.

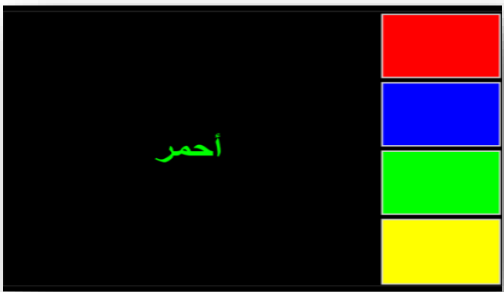
Stroop test instructions

The cognitive test will be assessed by: Hanouf H Al Hammadi PhD student from Strathclyde University:

Please flow the steps:

- Fasting for 2 hour before you start.
- The computerised test will take 1- 2 min max, you must read the instruction carefully for stroop test before you start.
- Time and speed of your answers are very important; this will be recorded and will take approximately 1-2min.
- You will be provided with a laptop and mouse to click. You must match the four colours (colours of the square boxes) with the colour of the word (in Arabic) presented.
- The colour names may have been written in a different colour from the name itself.



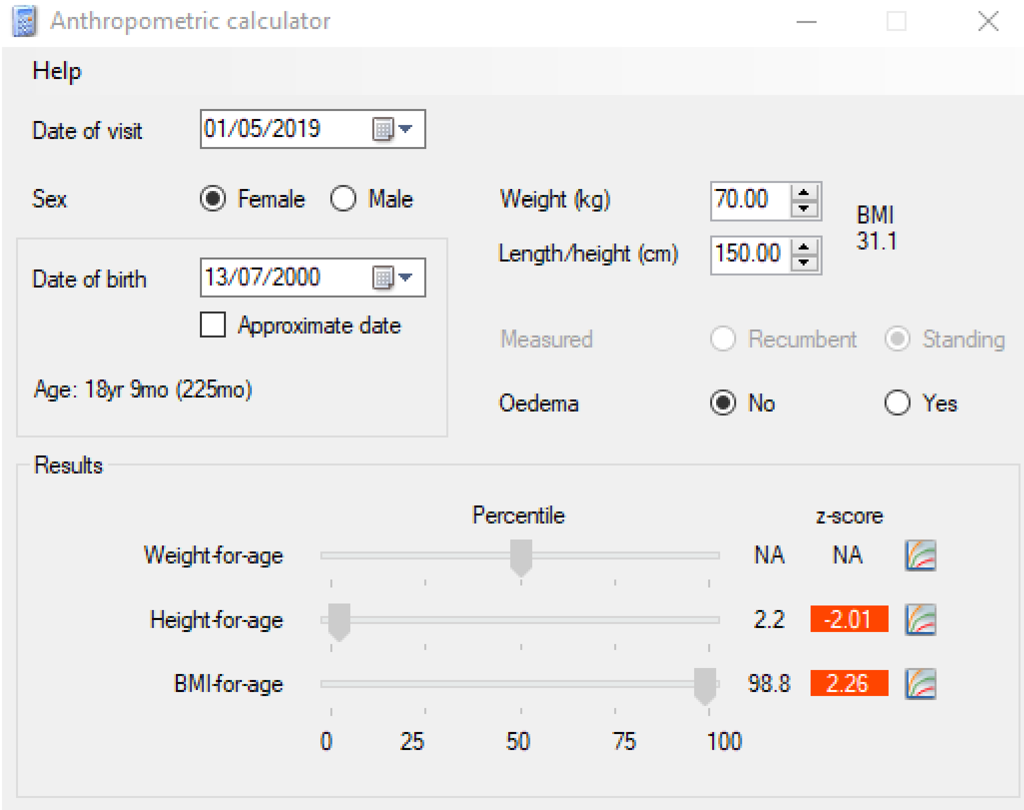


- e.g. BLUE, RED, YELLOW, GREEN

- You should click on the right-hand screen where the coloured boxes are to be found: the coloured box corresponded with the colour of the word written.
  - E.g. for **GREEN** one would click on 
- You should answer as quickly and as accurately as possible.
- As software was used, the score for this test will be calculated on the computer, and the overall correct percentage and reaction time will be recorded in milliseconds for each participant.
- There is an Arabic translated sheet.

Thank you for reading this information – please ask any questions if you are unsure about what is written here.

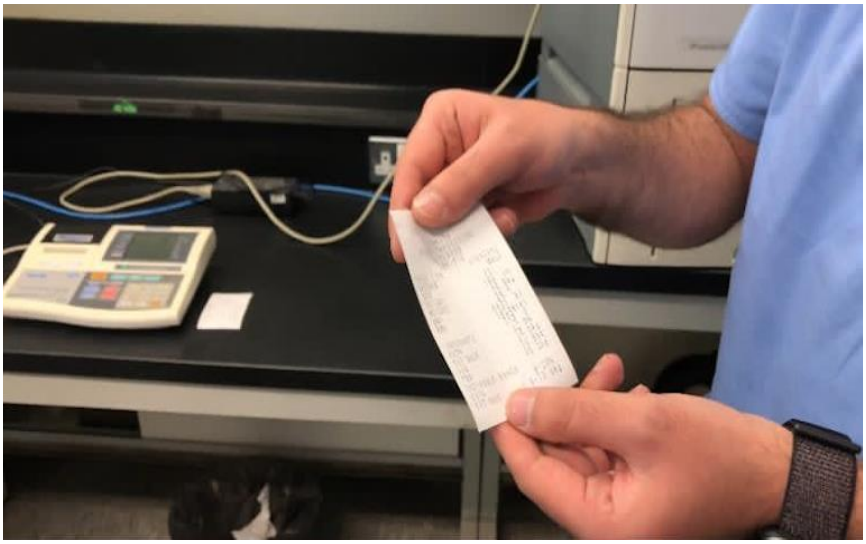
Appendix L: Anthroplus



Photos

Kuwait University, College of Social Science

Private room for participants



Adolescent girl aged 18 years old on the BIA, and in the second photo she is doing the Stroop test.