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An investigation on body composition, dietary intakes and physical activity in girls aged 8-11 years in Saudi Arabia

By

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Abstract

Introduction: Obesity has become a major world-wide health issue. Social-economic status, physical activity levels and dietary intake may influence the weight status in children. However, these issues have not been examined together in studies of young girls in Saudi Arabia.

Aim: This study aimed to investigate energy and nutrient intakes, physical activity and social economic status of girls aged 8-11 years in western Saudi Arabia according to their BMI.

Methods: This study was conducted in two phases, phase one was a pilot study where 32 girls were selected to assess the suitability of body composition, dietary intake (food diary, food frequency questionnaire) and physical activity measurement tools (pedometer, physical activity questionnaire). The findings of this phase were employed in phase 2; the diet diary and accelerometer were nominated as assessment tools.

In phase two, girls (n= 234) participated from different schools. Waist circumference, height and weight were measured and BMI was calculated. Girls were classified according to BMI centile charts (CDC). Dietary intake was measured via a 4-day food diary and accelerometers were used to assess the intensity and time spent in physical activity.

Results: A total of 30% of the sample were classified obese or overweight. There was a significant difference in the mean daily energy intake between the BMI groups with the obese group having the highest energy, fat, carbohydrate and protein intake (obese group: 2677 ± 804 kcal/d; healthy weight group: 1806 ± 403 kcal/d, $p < 0.001$), but the percentage contribution of the macronutrients to energy intake remained the same across the BMI groups. Carbohydrate intake was shown to be the main contributor to predict obesity levels.

There were no differences in number of steps taken per day or time spent in moderate/ vigorous intensity exercise according to BMI category. Most of the girls did not meet daily physical activity guidelines (5969 to 6773 steps per day and 18.5 - 22.5 mins per day of moderate- vigorous activity).

Intake of sweets and sugary drinks, and total energy intake were significantly higher in the high income group compared to the low income group. However, family income was not associated with BMI status.

Conclusion: The results of this study suggest that obesity in girls aged 8-11 years is linked to excessive energy intake from all macronutrients and the majority of girls in all weight categories are inactive. Research should be conducted to develop interventions to promote dietary change and activity that is culturally acceptable for girls in Saudi Arabia.

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List of abbreviations

ADP	Air-Displacement Plethysmography
AEE	Activity Energy Expenditure
ANOVA	Analysis of Variance
BDNF	Brain –Derived Neurotrophic Factors
BIA	Bioelectrical Impedance Analysis
BMI	Body Mass Index (kg/m^2)
BMR	Estimating Basal Metabolic Rate
Bwt	Body weight
CADET	Child and Diet Evaluation Tool
CDC	Centres for Disease Control and Prevention
CHO	Carbohydrates
cm	Centimetre
CPM	Counts Per Minute
DD	Diet Diary
DLW	Doubly Labelled Water
DIT	Diet-Induced Thermogenesis
DRV	Dietary Reference Values
DXA	Dual X-ray Absorptiometry
EE	Energy Expediture
EI	Energy Intake
EV	Evenson
FFM	Fat Free Mass
FFQ	Food-Frequency-Questionnaires
g	Gram
ht	Height
HW	Healthy weight

kcal	Kilocalories
Kg	Kilogram
KSA	Kingdom of Saudi Arabia
LPA	Light physical activity
M	Mean
m	Meter
MET	Metabolic Equivalent
ml	Millilitre
MONICA	Multinational Monitoring of Trends And Determinants In Cardiovascular Disease
MRI	Magnetic Resonance Imaging
MVPA	Moderate to Vigorous Physical Activities
NCMP	National Child Measurement Programme
NDNS	National Diet and Nutrition Survey
NHANES	National Health And Nutrition Examination Survey
NHS	National Health Service
NMES	Non-Milk Extrinsic Sugars
OB	Obese
OW	Overweight
p	Calculated Probability
PA	Physical Activity
PAL	Physical Activity Level
PAQ-C	Physical Activity Questionnaire for Children
PICOC	Participants, Interventions, Comparisons, Outcomes
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
r	Correlation
SES	Socioeconomic Status
SD	Standard Deviation
SFT	Skinfold Thickness

SHBG	Sex Hormone Binding Globulin
SLR	Systematic Literature Review
SPA	Sedentary Physical Activity
SPSS	Statistical Package for The Social Sciences
SR	Saudi Riyals
TEE	Total Energy Expenditure
TEE_A	Estimating Total Energy Expenditure by Ekelund Equation
TEE_M	Estimating Total Energy Expenditure by METs
T2D	Type 2 Diabetes
UK	United Kingdom
USA	United States of America
UW	Underweight
VO_2	Oxygen Consumption
WC	Waist Circumference
WHO	World Health Organisation
WHR	Waist-Hip Ratio
Wt	Weight

Appendices Headlines

Conferences and Workshops:

Conferences proceedings

- Nutrition Society Postgraduate conference: 9 and 10 September, 2013 King's College London. (Attendance).
- Alkutbe, R.B, Rees G.A, de Looy A. Body composition. Energy intake and number of steps of girls aged 8-11 years in Saudi Arabia. The 1st national conference on physical activity and health in Qatar in February 2014. (Poster presentation).
- The Fourth Arab Conference on Obesity and Physical Activity., Kuwait, 18 -20 February 2014 (Arabic, Attendance).
- Alkutbe, R.B, Rees G.A, de Looy A. Body composition. Energy intake and number of steps of girls aged 8-11 years in Saudi Arabia. PU PSMD Research Event, Plymouth University, 22nd October 2014. (Poster presentation).
- Alkutbe, R.B, Rees G.A, de Looy A. Energy and nutrient intake, and number of steps taken per day according to body mass index of girls aged 8-11 years in Saudi Arabia. The 8th Saudi Student Conference, London, 31st Jan-1st Feb 2015. (Poster presentation).
- Alkutbe, R., Rees, G., & De Looy, A. (2015). Energy and nutrient intake, and number of steps taken per day according to body mass index of girls aged 8–11 years in Saudi Arabia. *Proceedings of the Nutrition Society,74*(OCE5). doi:10.1017/S0029665115003912 Abstract published
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Workshops and seminars

- Seminar (Obesity: From stigma to research agenda) by Professor Jonathan Pinkney (Institute of Health Service Research, Peninsula College of Medicine and Dentistry). (Attendance) 2012.
- Course in Statistics for Nutrition Research: 12 September 2013: University of Westminster, London.
- Workshop in Dietary assessment methods: 27 September 2013: Nutrition Society, London.
- SPSS: Plymouth University 6 February 2013.
- Introduction to Endnote course: Plymouth University 2013.
- Physical activity objective measurement workshop 24th – 25th November 2015, Qatar

Publications

- Al-Kutbe, R., Payne, A., Looy, A. and Rees, G.A., 2017. A comparison of nutritional intake and daily physical activity of girls aged 8-11 years old in Makkah, Saudi Arabia according to weight status. *BMC public health*, *17*(1), p.592.
- Alkutbe .R, Khalaf .A. Book chapter: obesity and body image in the Middle East: determinants and health consequences for women in the region. Healthcare in the Arab World Book (December 2017) (*in preparation)*.
- Alkutbe, R.B, Payne, A., de Looy A, Rees G.A., The impact of socio-economic factors on diet and body compositions of girls aged 8-11 years in Saudi Arabia (*manuscript in preparation).*

Chapter 1: General introduction

1.1 Rationale and justification for this study

In recent decades Saudi Arabia has experienced enormous changes economically, and these transformations have affected the lifestyle of the population. It is likely that, as a result of these changes, the epidemic of obesity is rising among the Saudi population. It has been reported by the World Obesity Federation (2014), that Saudi Arabia has the highest rate of obesity among female adults in the Eastern Mediterranean region at 50.4%, followed by Kuwait (47.9%) and Qatar (45.3%). This high prevalence of obesity is not only an issue for adults in Saudi, but also for children. The prevalence of overweight and obesity in children in Saudi Arabia has been estimated at 23.1% and 11.3% respectively (El Mouzan et al., 2010b) . Tackling obesity in children is important as it might reduce the risk of adulthood obesity and may reduce risk factors for chronic disease at an earlier stage of life (Singh et al., 2008).

Several factors have been identified as contributing to the high incidence of obesity amongst Saudi children. As in many other countries worldwide, a general lack of physical activity, sedentary behaviour from prolonged use of computers and screen-based devices, and watching television while simultaneously eating energy-dense snacks have been found to be common (Khalid, 2008, Al-Hazzaa et al., 2012). A previous study has suggested that 60% of children and adolescents aged 5-17 years in Saudi Arabia do not participate in sufficient physical activity (Al-Hazzaa, 2002). Besides, cultural restrictions on girls and women limit their opportunity for physical activity as it is not acceptable to exercise publicly. Also, the climate may restrict outdoor activity. Moreover, socioeconomic status is also of relevance as family income, parents' education and other determinants could affect the health status of school children and development of early obesity (Al-Muammar et al., 2014).

Energy dense snacks and sugar-sweetened soft drinks are widely available for children and consumption is high in teenagers (French et al., 2003), but little is known about the consumption patterns of these and other foods and activity patterns of young girls of differing weight status. Previous studies have not undertaken anthropometric measurements and prospective assessment of activity and diet simultaneously in girls in the 8-11 years age group. This sample has been selected, firstly, because there have not been any specific studies of the levels of overweight and obesity and level of physical of activity combined with the dietary intake in this cohort in Saudi. The recent large-scale study by Al-Hazzaa et al. (2011) highlighted the problem amongst teenage students aged 14- 19 from several schools in different cities in Saudi Arabia, and the authors noted that by that age individuals are making their own life style choices about such daily matters as food as exercise. Therefore, it may be important to intervene while parents and teachers have influence over the child's behaviours. Also, some girls will be married from the age of 16 years.

Children are often considered the priority population for intervention strategies because weight loss in adulthood is more difficult and disease processes have already started (Singh et al., 2008). The 8-11 years age group has been selected also because, like many disease and conditions, early detection of obesity can lead to prompt action to prevent the development of the disease. Finally, the selected age is considered as pre-puberty and the measurements are more difficult for children during the years of puberty because their bodies undergo a number of physiological changes.

Shedding light on the nature of the factors that play a role on overweight/obesity and the link between them could be beneficial in implementing obesity prevention strategies and treatments of several obesity-related diseases in early childhood. Therefore, with particular attention to robust methods of measurement, this study sought to determine how nutritional intake, physical activity, and socioeconomic status differ according to weight status in primary-school girls aged 8-11 years old in the city of Makkah in western Saudi Arabia.

1.2 Summary of the chapters

1.2.1 Chapter 2: Review of the literature

This chapter is an appraisal of the literature focusing on obesity. Firstly, the definition of obesity is reviewed, followed by causations and main factors that contribute to obesity. Then, a review of studies was conducted in Saudi Arabia examining the prevalence of obesity in children. Finally, different methods for measuring body composition, physical activity, and dietary intake in children are summarized.

1.2.2 Chapter 3: Determination of methodology

This chapter assesses the suitability of various body composition methods and justifies the ones that will be used in this study. Different methods for measuring dietary intake and physical activity were reviewed using a systematic approach to determine which methods would be most suitable for use with the sample population. A pilot study was then designed to test the selected methods. A food frequency questionnaire and a 4 day food diary were chosen for piloting as well as an activity questionnaire and pedometer for measuring physical activity.

1.2.3 Chapter 4: Phase one - pilot

This chapter reports the pilot experimental phase, which determined the final methods for use in phase 2.

1.2.3.1 Aims

The purpose of this study was to develop reliable and acceptable methods for measuring body composition, dietary intake, and exercise habits in schoolgirls aged 8-11 years in Saudi Arabia.

1.2.3.2 Objectives

The research objectives of the pilot study were as follows:

1 To assess which body composition method can be used quickly, are cheap and portable, and are valid, accurate and reliable.

2 To assess which of these methods has the minimum disruption to the children and is acceptable for the girls, teachers, parents, and the school policy.

3 To pilot the use of the Arab food composition food tables and data analysis package.

4 To test two different methods of measuring dietary intake

5 To investigate what methods are suitable for measuring the type, intensity, and duration of physical activity of this cohort, and the validity and reliability of those methods.

1.2.4 Chapter 5: Phase two: main study

This chapter presents the main study: 266 participants were recruited to investigate the relationship between obesity and energy intake, physical activity and socioeconomic status.

1.2.4.1 Aims

The aim of this phase was to investigate body composition, diet and exercise patterns in schoolgirls aged 8 to 11 years living in Makkah, Saudi Arabia, and to draw comparisons between those who were overweight or obese and those who were of a healthy weight.

1.2.4.2 Objectives

This study was designed to address the following questions:

1. How do anthropometric measurements vary between BMI groups?
2. How do energy and macronutrient intake vary between in overweight and obese girls compared to healthy weight?
3. Which snacks and selected food types contribute to energy intake in obese/ overweight girls compared to girls of a healthy weight?
4. What is the level of activity in the girls and does activity (level and intensity) differ between overweight/obese and normal weight girls?
5. To what degree are 8-11 year old girls of different economic status overweight or obese in schools in the western region in Saudi Arabia?

1.2.5 Chapter 6: General discussion

The results of this study will contribute to knowledge to address the issue of obesity in girls in Saudi Arabia. The findings could play a critical role in promoting good nutrition in children in Saudi Arabia. Also it is envisaged that the findings will shed light on the causations of obesity, these might facilitate diet and activity interventions or nationwide programs and guidelines for school-age-girls.

Chapter 2: Review of the literature

2.1 Introduction

Obesity has become a serious and widespread health concern in most developed nations (Casterson et al 2002; WHO Report 2009). It is well established that while some genetic and physiological factors may contribute to overweight and obesity in some individuals, in general it is due to excessive energy intake and insufficient expenditure of energy in the form of vigorous physical activity (Loos and Bouchard, 2008, Farooqi and O'Rahilly, 2006, Walley et al., 2009). Obesity in children is proving to be of especial concern because, when carried into adulthood, it is a major contributor to ill-health (Lobstein et al., 2004).

Obesity and overweight are linked with serious health problems in adults such as cardiovascular and cerebrovascular diseases, diabetes, hypertension, atherosclerosis, dyslipidaemia, musculoskeletal disorders and some cancers. It is associated with long-term risk of developing insulin resistance, impaired glucose tolerance and progression to type2 diabetes, which is a condition that was almost exclusive in adults for some years, but is now becoming more common at younger ages, especially in children with obesity (Al-Almaie, 2005).

If this situation is of concern in adults, it is even more so in children and adolescents. Childhood obesity is now a major public health problem, and from the sources of information available, it continues to rise worldwide (Amin et al., 2008). Childhood obesity in Saudi Arabia has increased over the past 20 years, and it is a problem that is reported almost all over the country (Al Shehri et al., 2013). Al-Nuaim et al. (1996) found that eating habits that included foods such as pizza, sweets, and sugary drinks were correlated with the prevalence of obesity in Saudi children. Also sedentary behaviour among school age boys in Saudi was associated with obesity (Al-Hazzaa (2007) Moreover, there are significant studies that showed that obesity in childhood leads to obesity in adulthood (Singh et al., 2008).

2.2 The definition of obesity

The simple definition of obesity and overweight is excess fat in body. It is essential to note that in large-scale population studies the World Health Organization (WHO) defined obesity by cut offs according to body mass index (BMI): weight/height squared (kg/m^2) (Table 1). Adults are classified as overweight if BMI is over 25 kg/m^2, while considered as obese if the BMI exceeds the value of 30 kg/m^2 (WHO 2016). However, it is important to note that the relationship between body fat percentage and BMI varies between different ethnic groups, therefore, cut-off values for overweight and obesity constructed based on BMI must be ethnic-specific. This means that the cut-off points for some ethnic groups could be lower or higher than the figures recommended by the WHO or other international agencies (Panel, 1998). Identifying appropriate cut-off point values will have important consequences for the data in some countries as the reported prevalence of obesity will markedly increase or decrease.

Table 2.1: BMI classifications for European adults

BMI Range kg/m^2	**Classification**
<18.5	Underweight
18.5-24.9	Healthy weight
25-29.9	Overweight
30-34.9	Obesity 1
35-39.9	Obesity 2
>40	Obesity 3

Obesity can be measured in several ways, some entailing the use of costly and complex hospital-based imaging equipment, others requiring basic tools and uncomplicated measurements. In some regions where clinical facilities are unavailable it is possible to achieve reasonable results with anthropometric measurements such as weight and height, relative weight, body mass index, skinfold thickness, waist, and waist-hip circumference ratio. The appropriateness and accurateness of these procedures is discussed below. The BMI system using height and weight measurements is still widely used, and while it has shortcomings it has the advantage of readily available international reference data for BMI.

It should be noted here that it is difficult to quantify obesity in children and adolescents and until the recent years there has been little agreement on a common definition and a systematic classification of obesity in young people (Flamenbaum, 2006). This is primarily because of the different rates of growth in young boys and girls, the variations in increase in weight-for-height, the effects of sexual maturation, and the changing body composition evident in child growth. Numerous approaches and techniques have been employed to measure adiposity in children such as absolute weight, weight for height percentiles, percent of ideal body weight, body mass index, and skinfold (section 2.6).

2.3 Prevalence of obesity

2.3.1 Prevalence of obesity worldwide

At this point it is pertinent to place the Saudi experience within a global context. Studies and reports from most countries (except those nations in central and west Africa) comment on the continuing problem of overweight and obesity; indeed, it is often referred to not just as a health problem but as an epidemic and a crisis (Kelly et al., 2008). Until the 1980s relatively few (less than 10 percent) of people in the more developed countries were overweight or obese, but since then there has been a steady increase. In a WHO (2016) report for 2014 it was stated that overall about 39 percent of the world's adult population aged 18 years and over (38 % of males and 40 % of females) were overweight, and about 13 percent of (11 % of males and 15 % of females) were obese. The highest rates are in Pacific Islands; in those countries the inhabitants have little access to fresh food, relying mainly on imported processed foods high in salts and sugars (OECD/EU, 2016). At least 1 out of 3 New Zealanders, Mexicans and Americans and more than 1 out of 4 Australians, Canadians, Chileans, and Hungarians are considered obese. The Gulf States and Middle Eastern countries (Kuwait, Qatar, Saudi Arabia, and Egypt) also now record levels similar to other developed nations. Similar statistics have been provided by a recent WHO (2016) report which added another relevant point that majority of the world's people live in countries where obesity has higher mortality rate in comparison to underweight.

The period since 2000 has also seen a marked increase in body mass among children worldwide (Kelly et al., 2008). Currently, in developed nations about 24 % of boys and 23 % of girls are overweight or obese. Similarly, in developing countries the rates have risen to about 13 % for boys and 14 % for girls. A noteworthy feature of the various global statistics on this issue is that, considered overall, female rates are about the same, or higher, than the rates for males; and in the Middle East the rates for females are markedly higher because of the social restrictions on female activities - including outdoor games and sports (Kelly et al., 2008, WHO, 2016). So far relatively little research has been conducted in Saudi Arabia, and it is difficult to obtain current figures for each region (Al-Nozha et al., 2005). Nevertheless, in the light of global patterns it can be seen that the situation in Saudi Arabia is serious, and that in some respects it is more urgent than in many other regions and nations.

2.3.2 Prevalence of obesity in Saudi Arabia

2.3.2.1 Obesity in adults

Saudi Arabia has changed very rapidly since the 1960s. The Kingdom has developed economically, and with it has come profound social and lifestyle changes. For example, people now have greater leisure time, and nowadays there is a greater range of energy-dense soft drinks, and restaurant-prepared fast-foods available which contain high levels of fat, sugar, and salt. Indeed, in most respects the lifestyles and food options available to Saudi citizens are the same as in other developed nations (Al-Hazzaa et al., 2012, Al-Nuaim et al., 1997). According to the World Obesity Federation (2014), female adults in Saudi Arabia has the highest rate of obesity in the Eastern Mediterranean region at 50.4%, followed by Kuwait (47.9%) and Qatar (45.3%). This is higher than female obesity rates in England (27%) and the USA (35.8%).

A few epidemiological studies have examined obesity levels in several Saudi cities (Al Othaimeen et al., 2007), though the studies have tended to be localised (Khalid, 2008, Al-Nozha et al., 2005, Al-Almaie, 2005). Also, most studies have been of males and proportionally fewer studies have been conducted into obesity in young females (Amin et al., 2008, Al-Saeed et al., 2007). Nevertheless, the findings of all the enquiries have revealed that the problem is as severe (or even more severe) as in Western countries.

Table 2.2: studies examining overweight and obesity in children in Saudi Arabia

Author and year	City	n	Gender	Age	Overweight %	Obese %	measurements	Factors examined	Results
Al-Nuaim et al. (1996)	Riyadh	9061	Males	6-18 years	11.7 %	15.8 %	* BMI Growth chart *(NHANES)	Structured questionnaire (location of school, socio-demographic characteristics)	A high prevalence of childhood obesity when compared with the NCHS/CDC
El-Hazmi and Warsy (2002)	Different regions	12701	Both gender	1-18 years	F 12.7 % M 10.68 %	F 6.74% M 5.98%	BMI	Prevalence of obesity according to gender, age, and province	Obesity higher in girls than boys
Al-Saeed et al. (2007)	Al Khobar	2239	Female	6-17 years	20 %	10 %	BMI	Questionnaire socio-demographic	Prevalence high with educated mother Obesity and overweight are high in female
Amin et al. (2008)	Al Hassa	1139	Males	10-14 Years	14.2 %	9.7 %	BMI	Questionnaire collecting socio-demographic statues FFQ food habits and dietary intake	Obese children consumed more sugary drinks and sweet
El habib Khalid (2008)	Southern region	1884	Both gender	6-15 Years	Overall 10%		BMI (WHO)	questionnaire to measuring parents' socioeconomic status	high income was a significant predictor of childhood obesity
Mahfouz et al. (2008)	Abha city	2696	Male	11-19 years	11 %	5 %	BMI (WHO)	Questionnaire collecting socio-demographic statues, food choices and physical activity	Lack of Physical Activity 54% consumed sugary drinks
Collison et al. (2010)	Riyadh	Boys 5033 Girls 4400	Both Gender	10-19 years	12.2 %	27 %	Waist circumference (WC) BMI (CDC)	(FFQ) Dietary habits, exercise and sleep patterns	WC and BMI correlated with sugar-sweetened carbonated beverage. WC and BMI correlated negatively with the lowest frequency of the exercise
El Mouzan et al. (2012)	Different regions	3525	Both gender	2-17 years	Central 21 % Southwestern 13.4% Northern 20.1%	9.3 % 6 % 9.1 %	BMI (CDC)	Survey questionnaire, clinical examination and body measurements	Southwestern lower prevalence than other regions

Al-Ghamdi (2013)	Riyadh	397	Both gender	9-14 years		50.6 %	BMI (IOTF)	Questionnaire collecting Time watching TV, frequent meals and Physical Activity.	Watching TV correlated with obesity
Al Alwan et al. (2013)	Riyadh	1243	Both gender	6-16 years	21.1 %	12.7 %		Questionnaire collecting Social and demographic variables	Male are more overweight and obese. The prevalence in high income family more than the low income
Al-Enazy et al. (2014)	Tabuk	331	Both gender	6-13 years	9.7%	19.0%	BMI (WHO)	Pre-designed self-administered Questionnaire collecting socio-demographic and lifestyle factors	Prevalence of obesity and socio-demographic Obesity higher in educated parents and working mothers
Al-Asiri and Shaheen (2015)	Riyadh	304	Female	8-15 years	21.12 %	14.19 %	BMI and HRPF* (SFT)	HRPF measured by (body fat composition, strength and endurance, flexibility and cardio-respiratory fitness)	BMI affects HRPF

*(BMI) Kg/m^2

*(WHR) Waist to Hip Ratio,

*(WC) Waist Circumference,

*(SFT) Skin Fold Thickness,

*(NHANES) American National Health and Nutrition Examine Survey,

*(IOTF) International Obesity Task Force,

*(HRPF) Health related physical fitness

2.3.2.2 Obesity in children and young people in the Middle East

Writing in the Saudi Medical Journal, Al-Almaie (2005) reported a study of 1766 secondary school students in the Al Khobar district of eastern Saudi Arabia. Using growth charts developed for the American Nutritional Health and Nutrition Examination (NHANES) to calculate the body mass index the researchers found 29.5 % of boys and 29 % of girls were overweight/obese .

Despite these findings little has been done to address the issue, yet it is a health problem that requires a co-ordinated national approach. To date there has been no national policy or plan for tackling the problem, and it receives only passing mention in national policy statements. In order to provide a context for this proposal it is appropriate briefly to mention several studies that have been conducted in Saudi Arabia over the past decade or so. None has focused specifically on the issues of obesity in girls (Al-Saeed et al., 2007).

A larger-scale survey was conducted by Moshen El-Hazmi and Warsy (2002) . The authors sought to identify any regional differences, and on this occasion they studied 12 701 children (6281 boys and 6420 girls) between the ages of one and eighteen years. Using BMI parameters recommended by the World Health Organisation (WHO) their study sought to consider other variables such as background social factors. Their results showed markedly high rates of overweight and obesity in the oil-field eastern provinces and lower rates in the mountainous south-west of Saudi Arabia where diets are slightly healthier and children more active. Overall, girls had higher rates of obesity and overweight than the boys: 12.7% of girls were overweight and 6.74% were obese (Table 2.2).

Amin et al. (2008) examined 1138 primary-school boys in one city using a variety of anthropometric measurements. This comprehensive survey detailed the socio-economic status of the families, and used a range of questionnaires to ascertain diets and levels of activity. The result was that 14.2 percent were found to be overweight and a further 9.7% were obese. El-Habib Khalid (2008) surveyed 1900 children in the mountainous south-west. He also noted that about 10 percent of the children were overweight; finding that living at higher altitude was a particular risk factor.

The excessive weight has become a major worldwide health issue. The factors relating to the issue are now well-documented, however there are subtle and important differences between ethnic categories and between countries as a result of differing regional diets, lifestyles, and cultures, and these require closer scrutiny so that appropriate interventions can be developed.

A particular justification for this investigation is that relatively little research has been conducted into the levels of obesity in girls in Saudi Arabia, and those that have been undertaken have shown that, in general, girls (and indeed all females) have rates of obesity that are as high (or even higher) than for males. Moreover, the proportion of overweight young people (both children and adolescents) has been rising steadily in recent decades. A meta-analysis by Al Shehri et al. (2013) has provided evidence of a continuing country-wide rise in obesity, recent national data showing that the levels of overweight and obesity among all school-age children have reached 23 percent and 9.3 percent respectively. This was a marked increase since El-Hazmi and Warsy (2002) reported a large-scale national survey that they had undertaken between 1994 and 1998. At that time 10.68 percent of boys were overweight and 5.9 percent obese; for girls the figures were 12.7 percent and 6.7percent. The overall figures for all those surveyed were an average of 11.69 percent overweight and 6.3 percent obese. Within seven years of that initial survey a comparable later study by El-Mouzan et al. (2007) found that the levels had almost doubled to 23.1

percent and 9.3 percent. Other work, by Abalkhail (2002) and Alsaeed (2006), reported similar trends.

It was noted by Al Shehri et al (2013) that there have been some slight statistical variations between the findings of different researchers and so while it is not possible to make definitive statements nevertheless they comment that "the trend of increasing rates of overweight and obesity over time was clear from the national studies that were reviewed, as well as the studies in local regions" (Al Shehri et al., 2013). A recent survey of the health of children was a cross-sectional study of students from four primary schools in the north-western city of Tabuk where the researchers found that the proportions of overweight and obese girls were somewhat reversed, the figures being 12.4 percent and 20.9 percent respectively (Al-Enazy et al., 2014). Taking note of sociological influences, the authors also reported that overweight and obesity were more predominant among children living with both parents, with highly educated parents, with history of maternal obesity, with working mothers, and with smaller family size, though the links between these various factors were not explained.

One consistent geographical variation over time is that the eastern provinces have recorded the highest levels of overweight and obesity while the south-western region (which is mountainous and marginally less prosperous) have the lowest rates. Writing in 2012, El-Hazmi et al found that overall national levels of overweight and obesity had doubled in the decade since 2002 (El-Hazmi and Warsy, 2002), and they also noted much lower levels for the south-western district. For example, of girls aged 6 to 13 years in the central province of the country 21 percent were overweight and 9.1 percent obese, a rate twice as high as for girls of the same age in the south-western corner where only 10.8 were overweight and 4.7 obese (El Mouzan et al., 2012).

Only two recent surveys have given attention to the western region and to the cities of Jeddah and Makkah (Mecca), the site of this project. Abalkhail (2002) and Washi and Ageib (2010) showed that those cities, too, have trends similar to the rest of the country, and Al Shehri et al. (2013) concluded that at present the rates for both genders are about 17.8 percent for overweight and about 13.5 for obesity. Moreover, it was noted that obesity at a young age accelerated adulthood obesity and overweight (Daniels, 2006). This point was also stressed by Al Dossary et al. (2010) who reported that after about age five children were becoming overweight, and in their study they found that by age nine 21 percent of Saudi children were overweight and 21 percent obese - and their weight continued to rise into the adolescent years. These researchers also noted that the peak of obesity occurred at ages 10-13 years and that 80 percent of obese adolescents become obese adults. These writers concluded that this is the critical period for the development of adult obesity; "intervention before this age is vital both for future health and for the ability to maintain long-term weight control" (Al Dossary et al., 2010). This finding was later confirmed by Al-Hazzaa et al. (2014) who conducted a large-scale study (n=2908) of adolescents in the eastern, central, and western regions of KSA. Using a stratified cluster-sampling technique, the researchers measured weight, height, and waist-circumference, reporting that 19.5 % of males and 20.8 % of females were overweight while 24.1 percent of males and 14 percent of females were obese. They also commented that a higher predominance of obesity was observed among privately schooled students, a result mentioned by some other writers (Al-Hazzaa et al., 2014).

It is relevant to consider the levels in Saudi Arabia within the context of the surrounding Arabic-speaking countries, and a recent survey of 18 nations in the Middle East and North Africa shows that the oil-rich Gulf States have particularly high rates of obesity (Badran and

Laher, 2011). The authors explain that it is not possible to be too definitive when analysing or comparing statistics from the region because there are differences between nations in regard to both methodologies and reliability. Nevertheless, they report that across all those countries proportionally more females than males are overweight or obese. For adult females, Kuwait recorded the highest proportion of 55 percent of obese and overweight while for Saudi Arabia the figure was 36 percent (Badran and Laher, 2011). Charting changes in obesity over several decades, the researchers (Badran and Laher, 2011) stated that obese children more likely to be obese during the adulthood, one-third (26, 41% male and female, respectively) of the children at preschool in Arab speaking country tend to be obese in their adulthood while half (42, 63 % male and female, respectively) of the children at the school age tend to be obese in their adulthood. It has been suggested that further screening for obesity to prevent and control it at early age.

It is not possible here to detail all the findings, but it is pertinent to note three other projects on this subject. Al Herbish et al. (1999) recorded the conditions of children admitted to a clinic in Riyadh, concluding that the levels of overweight were similar to those described above, but they also found that a proportion (about 10 percent of those overweight) suffered from conditions such as Prader-Willi Syndrome. Other Gulf States have conducted surveys with similar results. For example, in 1998, a project conducted by the WHO for monitoring of cardiovascular diseases (MONICA) stated that Iran is considered one of the seven nations with the highest predominance of childhood obesity (Dehghan et al., 2005). A particularly detailed enquiry was by a PhD candidate in Kuwait. Al Shamari (2007) examined 1536 children aged 6-13. He recorded both BMI and socio-economic factors, and he also noted that about 15% were at risk of metabolic syndrome because of obesity. This is reportedly due to the relatively homogeneous composition of the predominantly Arab population. More recently Al-Hazzaa et al. (2012) surveyed a random sample of teenagers in three Saudi cities, reporting that about one-third of both males and females had BMI levels above 25.

2.4 Associated disease in adult- children

The urgency arising from this issue is that excessive weight acquired in early life can be very difficult to reduce (Singh et al., 2008); consequently, overweight children tend to become overweight adults. In addition, as has been documented in so many studies, excessive weight in adults is a major risk factor for numerous chronic illnesses (Jensen et al., 2014, Kearns et al., 2014). While BMI calculations are useful for determining overall levels of overweight and obesity in populations, and while they can be useful for identifying changes in patterns, they do not necessarily reflect the health of individuals. Instead, for adults the anthropometric systems of measuring both waist circumference and waist/hip circumference ratio are preferred as measures of intra-abdominal fat. These measures are frequently performed to predict the health effects of obesity in adults, as alterations in these measurements tend to reflect alterations in cardiovascular diseases risk factors and other chronic illnesses (WHO, 2008).

Moreover, obesity leads to many problems with daily activities that can be precursors of complications and subsequent serious health issues. According to the British NHS (2014), numerous daily problems can be caused by obesity, these problems being manifest by such symptoms as breathlessness, excessive sweating, snoring, difficulty conducting physical activity, general fatigue, joints and back pain, low confidence and self-esteem, and feeling isolated. These are day-to-day problems which are often caused by obesity, but other serious conditions include type 2 diabetes, hypertension, hypercholesterolemia, and atherosclerosis, which can result in coronary heart disease and strokes, asthma, metabolic syndrome, numerous cancer types (including bowel cancer, breast cancer and uterine cancer), low fertility, liver and kidney diseases. Added to this list are the effects on pregnancy, such as gestational diabetes or pre-eclampsia.

2.4.1 Cardiovascular diseases

Obesity is a key contributor to cardiovascular diseases in adults, numerous studies having drawn attention to the link, and two recent reports further highlight the extent of the problem. Firstly, a large scale longitudinal project followed the health of 2.3 million Israeli adolescents from initial BMI measurements taken in 1967 until their later adult years in 2010 (Twig et al., 2016). This was a very thorough and detailed survey which took account of many medical and lifestyle factors. Using a methodology of the U.S. Centres for Disease Control and Prevention, it found that hazard ratios for death from cardiovascular causes rose slightly but steadily during the participants' first ten years, but then rose markedly after 30-40 years. Their report reached a conclusion that a BMI kg/m^2 in the 75^{th} to 84^{th} percentiles during adolescence linked with increased cardiovascular and all-cause mortality during 40 years of follow-up. The results from that enquiry were very strong indeed, the writers stating that overweight and obesity were closely associated with elevated cardiovascular mortality in adulthood (Twig et al., 2016).

Similar findings were reported from an Australian Health Survey in 2011-2012 which noted that over six percent of all Australian adults had current and long-term heart or vascular diseases, much of it stemming from excessive weight (ABS, 2013). Most commonly, these conditions are grouped under the wider term of 'heart disease' or 'cardiovascular disease'. The reports detailed how ischaemic heart disease [which includes angina, blocked arteries of the heart, and heart attacks] was the prominent cause of mortality for all Australians; that is, over 14 percent of all mortalities registered in 2011. Furthermore, at that time obese persons were approximately five times more susceptible to those who were of normal weight to have hypertriglyceridemia (25.3 percent) or underweight (5.3 percent). Additionally, obese individuals were twice as likely to have lower than normal levels of HDL 'good' cholesterol; of people of normal weight 36.2 percent were likely to have low HDL compared with only 14.1 percent who were underweight (ABS, 2013).

2.4.2 Diabetes

Obesity is a well-known risk factor for diabetes because excess body weight can affect the production of insulin and could lead to insulin resistance. Much has been written on this subject, and the link has been confirmed in many reports (Zeitler et al., 2014, Garber, 2012, Verbeeten et al., 2011). It is not possible here to review all aspects of the issue except to note that numerous research papers continue to be published, and a number of specialist journals have emerged to explore the topic further (e.g. Diabetes, Obesity and Metabolism).

The issue of relevance to this study is that excessive weight that is accumulated in early years will very probably contribute to diabetes in later years; and not just in older adults, young overweight adults, and some adolescents, also being likely to develop some form of insulin resistance (Liu et al., 2010). However, as Zeitler et al. (2014) pointed out, relatively few pre-pubescent children develop type 2 diabetes, though for those that do there is a close association with weight. Moreover, in younger people, especially adolescents, there is a stronger inherited tendency to developing type 2 diabetes in comparison to type 1, the latter being an autoimmune condition. However, type 2 diabetes in young population is largely linked to obesity, lifestyle habits, or insulin resistance, some overweight children could develop type 2 diabetes as young as ages nine or ten (Verbeeten et al., 2011, Liu et al., 2010). Verbeeten et al. (2011) conducted a meta-analysis and systematic survey of the links between obesity and diabetes, noting that most studies identified the dangers associated with childhood obesity. An Australian health survey (ABS, 2013) also showed that children with obesity are at markedly higher risk suffering from chronic health conditions such as type 2 diabetes that impact physical health in the future. Excessive weight in childhood and adolescence is commonly carried into adulthood (Garber, 2012, Verbeeten et al., 2011), and the Australian project recorded a high correlation level for adult diabetes, stating that obese adults were at risk to have diabetes seven times more than normal weight or underweight (ABS, 2013).

In developed countries weight-related diabetes is becoming more prevalent in adolescents and young adults (OECD/EU, 2016), but similar patterns are emerging in developing nations too. Work by Hossain et al. (2007) examined numerous nations, finding that diabetes (and cardiovascular diseases) is mainly high in the middle-income countries of Latin America, Eastern Europe, and Asia, where obesity is an emerging causation of the disease. They explain that the marked risk of both diabetes mellitus and cardiovascular illness are linked to obesity in Asian population might be as a result of a tendency to abdominal obesity, leading to the metabolic syndrome and impaired glucose tolerance. They reported, too, that similar patterns of change are particularly pronounced in Arab, migrant Indian, Chinese, and U.S. Hispanic communities, the reason being that they have swiftly moved away from rural traditions and foods, instead adopting highly-processed cuisines and urban lifestyles. In these populations such as Australia the levels of overweight are rising rapidly 2-3 % in past 5 years and as a consequence the prevalence of diabetes in all those nations now ranges from 14 to 20 percent (OECD/EU, 2014).

2.4.3 Some cancers

There is strong and consistent evidence that excessive body fat is linked with increased risk of a number of cancers (Lauby-Secretan et al., 2016). However, it is not possible to make definitive claims or meaningful generalizations about the extent of the links because there are so many types of cancer and because of the variety of confounding factors involved (Deutsch et al., 2003). For example, in the US a recent population-based survey by Arnold et al. (2015) estimated that in that country approximately 28,000 new cases of cancer in males (3.5 percent) and 72,000 in females (9.5 percent) were due to excessive body fat.

There is a high variation in the percentage of attribution of excessive weight to different cancers types; more than 50 percent of gallbladder cancer in females were attributed to excessive weight. However, the complexity of this subject is such that we cannot review all aspects, though a brief summary of some of the links for some cancers (especially those that affect females) helps put this issue in context.

2.4.3.1 Endometrial cancer

Work by (Setiawan et al., 2013) shows that overweight females are approximately 2-4 times at higher risk than normal-weight females to develop endometrial cancer (cancer of the lining of the uterus). For highly obese females, the risk is approximately seven times higher.

2.4.3.2 Breast cancer

In premenopausal females overweight and obesity have been found to be linked with a 20 percent decreased risk of breast tumours (Cancer, 2012). However, for post-menopausal the situation is the contrary: females with a BMI in the ‘overweight’ range are associated with a modest increase in risk of breast cancer, Renehan et al. (2008) reporting that an increase of five points in BMI is associated with a 12 percent increase in risk. In regard to highly obese post-menopausal women the researchers noted a 20-40 percent raise in risk of developing breast cancer in comparison to normal-weight females.

2.4.3.3 Ovarian cancer

Higher BMI is connected with a slight rise in the risk of ovarian cancer, mainly in females who had no menopausal hormone therapy (Cancer, 2012). For instance, a rise of approximately five BMI points is linked with a ten percent increase in ovarian cancer risk.

2.4.3.4 Esophageal adenocarcinoma

overweight or obese population are approximately twice as likely as people of normal weight to develop a type of esophageal cancer called esophageal adenocarcinoma, the risk increase to more than four times in extremely obese population (Hoyo et al., 2012).

2.4.3.5 Gallbladder cancer

Overweight population have approximately 20 percent increase in risk of gallbladder cancer as compared with people of normal weight (Li et al., 2016). Obesity significantly elevates the likelihood for all people, though the risk increase is markedly higher for women, and obese women have more than a 50 percent chance of developing cancer of the gallbladder.

2.4.3.6 Other cancers

Other cancers, too, have some degree of association with excessive weight. For example, individuals with a high BMI are nearby 1.5 times as likely to develop pancreatic cancer as people of normal-weight (Genkinger et al., 2011); almost 30 percent more likely to develop colorectal cancer (Ma et al., 2013), and the risk of thyroid cancer increases by about ten percent (Kitahara et al., 2016).

2.4.4 Pregnancy complications

Obesity is considered one of the most common medical condition in females of reproductive age (Catalano and Shankar, 2017). Excessive body mass has been shown to have many adverse consequences for all phases and aspects of reproduction. To various degrees it elevates the chances of infertility, it reduces the success rate of in-vitro fertilization, it can negatively affect the mother's health during pregnancy, it can seriously affect the development of the foetus, it can cause complications for the birth, and postpartum it may harm the health and later development of the child. This issue has been closely researched, and some of the key findings are summarised below.

Overweight and obesity prior to, and during, pregnancy increase the risk of various maternal and neonatal complications (Scott-Pillai et al., 2013, Kulie et al., 2011, Johansson et al., 2014). For the mother the risks include:

1. *Gestational diabetes:* obese females are more likely to develop diabetes during pregnancy.
2. *Infection:* women who are obese during pregnancy are at increased risk of various infections, most commonly urinary tract infections and postpartum infections.
3. *Pre-eclampsia:* overweight or obese females are at heightened risk of developing complications such as hypertension and damage to organs such as the kidneys.
4. *Late delivery and labour problems*: excessive body mass elevates the prospect that pregnancy will continue beyond the due date. Also, labour induction is more common in obese females. Obesity can even interfere with analgesic medication such as an epidural block.

5. *C-section:* obesity before and during pregnancy increases the probability of elective and emergency C-sections. Additionally, it raises the risk of C-section complications such as infections.

This summary of some of the main weight-related risks and complications has been confirmed by a large study (n=64,000 births) by MARSHALL et al. (2010). Focusing on three categories of obese women (BMI (kg/m^2) = 30-40; BMI 40-50; and BMI >50), the writers clearly confirmed that increasing BMI is strongly correlated with the chances of perinatal complications such as those listed above.

For the baby the risks include:

1- Birth defects: excessive maternal body mass during pregnancy may contribute a slight increase in risk that the baby may be born with a birth defect.

2- Macrosomia: overweight women are at higher risk of delivering a child who is significantly larger than average. The baby is also likely to have more body fat than normal, and as the birth weight of the child increases this may contribute to later childhood obesity.

3- Chronic conditions: excessive maternal weight can also contribute to an elevated risk of the child developing heart disease or diabetes as an adult.

4- Child Mortality: Some recent research has further highlighted the links between maternal excessive body mass and increased risks of infant death due to increased mortality risk in term of births and an increased prevalence of preterm births. A large scale (n=1,857, 822 live single births) longitudinal project (1992 to 2010) by (Johansson et al., 2014) found that risks of infant, neonatal, and post-neonatal mortality rose steadily according to the level of obesity of the mother. In general terms, the higher the maternal BMI the higher the likelihood of infant, neonatal, and post-neonatal mortality. Their study also confirms the associations between maternal obesity and the reduced health outcomes of infants.

Related to these findings is the recent investigation by Catalano and Shankar (2017). Their large and detailed study found very high levels of association between obesity and still-births, and they summarized the situation by asserting that in high income countries, overweight, obesity, cigarette smoking, and advancing maternal age are the chief causes of stillbirths. Another study, this time by Scott-Pillai et al. (2013) made very similar conclusions. In that case the team examined 30,298 singleton pregnancies over an eight-year period from 2004 to 2011. They, too, found that, in general terms, the higher the maternal BMI the higher the chances of hypertensive disorders, diabetes, postpartum haemorrhage, macrosomia, and stillbirths.

Finally, it is pertinent to mention the cost implications of maternal obesity. For example, two surveys (Galtier-Dereure et al., 2000, Morgan et al., 2015) show that in-vitro fertilization (as a consequence of obesity) is a heavy impost on health services. At all stages in the reproductive cycle (pregravid, gravid, and post-partum) overweight women require above-average amounts of medical and nursing intervention. Similarly, infants born to mothers with high BMIs require additional health resources in the first year of life, the authors making the comment that reducing body mass prior to pregnancy would be very cost-effective.

2.4.5 Another complication resulting from excessive body mass

As discussed above, excess body weight is associated with Type 2 Diabetes and with general ill-health later in life. But for children it can have a number of immediate psychological, social, and physiological implications. An instance was highlighted recently by Pinkney et al. (2014) who drew attention to the consequences of adiposity for girls and at puberty. Using both BMI and waist circumferences measurements, the researchers sought to examine the effects of adiposity on sex hormone binding globulin (SHBG) which is important in childhood development and in the transition to adulthood. This longitudinal investigation initially comprised 347 plymouth children aged five, the participants being measured for both adiposity and hormone levels each year for ten years. The research team took account of many inter-related variables; SHBG and endocrine markers such as insulin, leptin, androgens, and adiponectin. The principal findings were that increasing adiposity and inflammation were linked with low levels of SHBG between the ages 5-15 years, and low levels of SHBG anticipated earlier puberty. In particular, excess body fat contributes to altered levels of sex hormones, and this, in turn, seems to be a major contributor to the earlier onset of puberty, especially in girls. Therefore, preventing obesity in pre-adolescents will benefit the child’s health now and in the future (Todd et al., 2015).

2.5 Factors associated with overweight and obesity

Much has already been written on the multiple inter-related factors that contribute to excessive body mass. Indeed, obesity is not a single disease; instead it can be described as a condition or syndrome with multifactorial aetiology, and contributing factors include genetic, environmental, metabolic, cultural and social influences. While these various factors are quite well understood, and while public awareness and healthy-lifestyle programs have long been used to highlight the situation, it is still proving to be difficult to contain the rise in levels of overweight or to permanently reverse the condition once it has been established in individuals. Although unhealthy diets and low amounts of physical exercise represent major risk factors for overweight in children and adults, numerous cultural and social norms for diet and body image also play key roles as risk factors; these risk factors differ according to different societies (Al Shehri et al., 2013).

The many related causes of overweight and obesity are essentially the same everywhere, and in the Arab world rapid economic development since the 1970s has brought significant prosperity and easier lifestyles – or what has been described as an 'obesogenic environment'. People in Saudi Arabia, the Gulf States, and nearby oil-producing countries gained easy access to fast food, their own cars, cheap migrant labour for domestic and industrial work, seemingly unlimited television programs, computers and screen-based entertainments, and other opportunities for sedentary lifestyles. Many researchers into this issue have highlighted the key influences as altering food consumption, socioeconomic and demographic factors, and physical inactivity (Washi and Ageib, 2010, Al-Hazzaa et al., 2014, El Mouzan et al., 2010a, Al Shehri et al., 2013) also comment that, until recently, another consideration was a poor knowledge of food choices; that is, a lack of understanding of the contents of different food types, and especially high-energy processed food.

2.5.1 Socioeconomic factors

The links between socio-economic status and obesity are somewhat ambiguous, and the many studies of this subject show shifting patterns over time as well as differences between countries and ethnic groups. Early reports from the US and Europe indicated a strongly inverse relationship, obesity levels being highest among people of low economic status (Stunkard and Sorensen, 1993), but it was unclear whether obese men and women tended to accept partners of lower status or whether low incomes led to obesity. The complexity and seeming ambiguity between research findings were later highlighted by writers such as Wang and Zhang (2006) whose large-scale, long-term study noted fluctuations over time between obesity levels and socio-economic status of black and white males and females in the US. They found that a reverse association existed only for white females (that is, low socio-economic females tended to have higher rates of obesity) but African-Americans across all socio-economic groups tended to be heavier than other racial groups. They concluded, “Efforts solely targeting reductions in income disparities probably cannot effectively reduce racial disparities in obesity.” This conclusion was similar to the of McLaren (2007) whose meta-analysis recorded increasing proportions of positive associations and a decreasing proportion of negative associations as one relocated from high levels of socioeconomic development countries to countries with medium and low levels of development. He commented that obesity levels varied according to socio-economic indicators; that is, negative associations (lower SES status was correlated with larger body size) for females in developed countries were most common with education and occupation, however the association was positive for females in less developed countries and was commonly linked with income and material possessions.

It is not possible here to consider the very numerous and varied reports on the topic of obesity and socio-economic status, and this issue has not been examined in studies in Saudi Arabia. However, it is pertinent to note a finding of Al-Hazzaa et al. (2014) who recorded a higher predominance of overweight and obesity in adolescents attending Saudi private schools in comparison to those enrolled in public schools. The writers suggested that such findings could be as a result of the fact that adolescents in private schools usually came from high socioeconomic status families (higher income and educational level). It could also be that private schools have less restriction on food and snack options in comparison to public schools.

2.5.2 Physical activity levels of females in Arab countries

Another possible factor leading to overweight and obesity is the restrictions placed on females of all ages regarding physical activities; that is, while segregated facilities such as gymnasiums are acceptable, the opportunities for vigorous outdoor games, sports, or other activities (such as cycling, rowing, and long-distance running) are limited.

The influences on each individual may vary slightly according to circumstances; nevertheless the underlying cause of obesity is excessive food intake and insufficient expenditure of energy by way of physical activity. Home, school, work, leisure, travel, peer influence – these and many other cultural and environmental forces can shape the health and physical conditions of individuals. The home environment and family lifestyle are often linked to the development of childhood obesity (Washi and Ageib, 2010, Daniels, 2006). For example, several surveys have confirmed the association between childhood obesity and the domestic environment characterised by sedentary lifestyle (physical inactivity and the consumption of energy-dense food) (Biddle et al., 1998, Al-Enazy et al., 2014). As commented by Al Dossary et al (2010), Saudi children rarely walk to school, and compared with children of the same age in Western countries, they have low levels of participation in sporting activities (Mahfouz et al., 2008, Al Dossary et al., 2010).

2.5.3 Dietary intake

Very many articles, reports, studies, reviews, meta-analyses, systematic surveys, regional projects, and national publications have examined the factors contributing to overweight and obesity (Dooyema et al., 2013, Foltz et al., 2015). So, too, global organizations such as the WHO have considered this problem (James, 2008). It is an extensively-documented issue and cannot be re-examined in any detail here except to note that the central ‘formula’ remains true: that is, for most people excessive body mass accumulates as the result of an energy imbalance between consumed and expended calories (Prieto and Kales, 2016, Ebbeling et al., 2012). This explanation applies equally to children and adults, but as mentioned numerous times before, it is in many respects more serious for children because excess fat is so very difficult to remove (Dehghan et al., 2005), and children with high BMIs are most likely to become lifelong overweight adults who experience some of the health complications listed above (Dehghan et al., 2005).

However, many highly specialized research projects have drawn attention to the various biochemical, metabolic, hormonal, physiological, socio-economic, and psychological variables that contribute to the problem e.g. (Ebbeling et al., 2012). The chemistry of metabolism and the biochemical aspects of weight-gain have received considerable attention; just how the body reacts to excessive food is a complex subject, and it is confounded by so many variables relating to age, gender, health, environment, individual metabolism, and genetics e.g. (Melanson et al., 2009, Thompson et al., 2011). In simplified terms, many research projects have focused on food intake and physical exercise, numerous publications drawing attention to such specific matters as food types: that is, processed versus fresh; proteins, fats, carbohydrates; snacks; and national cuisines. For instance, a recent longitudinal project by Ogden et al. (2016) observed that different foods may be of equal calorific value, nevertheless they may be associated with different levels of energy expenditure, the authors making the comment that "a calorie may not just be a calorie". That study highlights the complexity of the subject and the many factors that contribute to body composition.

Meal portions, timing of meals, and settings (e.g. communal shared meals, and individualized servings) have all been analysed (Garaulet et al., 2013). However, the fact remains that too much energy-dense food and insufficient physical activity lead to an imbalance.

One aspect of this problem that is currently receiving close attention both by researchers and national leaders is the contribution which sweetened soft drinks make to weight gain, especially in children (Ogden et al., 2011, Poti and Popkin, 2011, Vartanian et al., 2007). The UK and Mexico governments announced in 2016 that sugar-sweetened soft drinks would be taxed by about 20 percent, the purpose being to discourage consumption by children by making the drinks less affordable. The primary reason drinks are being targeted (or more specifically the sugar in the drinks) is that many/most children consume them each day; that is, they are not ‘treats’ but routine, and instead of drinking water children regard them as the main way of satisfying thirst (Ogden et al., 2011, Poti and Popkin, 2011). People who drink them tend to have them every day, and over the past four decades or so drinks have been provided in ever-larger containers. The other reason is that some of the drinks have very high sugar content. A typical can contains 35gm of sugar - about nine teaspoons – which is over the recommended daily sugar intake (Lasater et al., 2011), some writers describing them as ‘empty calories’ because they provide energy but have no nutritional benefit.

2.5.4 Other factors

Researchers have drawn attention to factors that are particularly influential as regards obesity in females in Middle Eastern countries (Al-Hazzaa et al., 2014, Abalkhail, 2002, Al-Saeed et al., 2007, Al Dossary et al., 2010). One factor is the multiple pregnancies experienced by many women; with perhaps six or more births over a decade or so there is little opportunity for women to exercise or to restore their former weight. Another explanation is provided by Al Dossary et al. (2010) who make the point that adolescent males may, in many instances, have higher rates of obesity than adolescent females because females of that age are self-conscious about their weight and appearance and so avoid progressing to obesity. Also, unlike females, young males have the right to drive and are able to gather at fast-food venues where they can consume more high-fat, high-sugar meals.

Body weight is affected mostly by exercise and the nutritional habits of the individual, though biological or genetic predispositions are also determinants. The exercise and nutritional habits of individuals and populations are strongly influenced by their environment and social particularities (Khalid, 2008). In Saudi Arabia, as in the other Gulf States, increasing modernization, food-choices, and exercise habits have changed much: the widespread decrease in physical inactivity is largely the result of prolonged TV watching and computer games, as well as increasing use of vehicles instead of walking (Al Herbish et al., 2009). For many children and their families, their nutrition and dietary behaviour have changed because now there is a virtually unlimited supply of energy-dense foods that are available as finished products, and their composition cannot be controlled (Al Herbish et al., 1999). The food industry and the media encourage this behaviour through an increase in advertising targeted at children. As Al-Saeed et al. (2007) explained that, it is unlikely that the significant increase in the prevalence of obesity and overweight in the last 20 years is due to changes in the human genome in such a short time.

In summary, these and other studies clearly demonstrate that overweight and obesity are serious health problem in Saudi Arabia. The rates of obesity might vary slightly between regions and nations, but the many reports cited above conclude that excessive weight is a major concern. However, it is particularly important to point out that for many countries (such as those in the Middle East) there is less information about girls. Published studies usually include surveys of girls together with boys, or boys only. The purpose of this proposed research is to redress this situation.

2.6 Measurements of body composition

There are several methods for determining overweight and obesity. There is no single method that suits all research requirements, all having their advantages and limitations. Power et al. (1997) defined the ideal measure of body fat as “accurate in its estimate of body fat; precise, with small measurement error; accessible, in terms of simplicity, cost and ease-of-use; acceptable to the subject; and well-documented, with published reference values”. They add, however, that “no existing measure satisfies all these criteria”.

Various body-scanning techniques have been shown to be very precise for measuring body-fat mass, but so far they are too complex and expensive for use in regular public health practice or for large-scale screening. Anthropometric measures are slower to conduct and not quite so accurate, however, they are useful for assessing the general condition of individuals and for providing information about the overall condition of a population. Among the anthropometric measures of relative adiposity, or fatness, are waist, hip and other girth measurements; skinfold thickness; and indices derived from measured height and weight, such as BMI (Deurenberg et al., 1999, WHO, 2008, Panel, 1998). The accuracy of anthropometric measurements depends on the care and skill of the measurer and the precision of the measuring equipment. Moreover, accuracy must be validated against a ‘gold standard’, or reference measure of adiposity.

2.6.1 Anthropometric Measures

There are several commonly used techniques that entail the taking of measurements of various parts of the body. The main anthropometric techniques are skinfold thickness

(SFT), body mass index BMI (kg/m^2), waist circumference (WC), and waist-hip ratio (WHR). For each of these methods researchers have developed equations by which the respective measurements can be used to identify body composition without complex and costly techniques. However, it has long been evident that the predictive equations and reference charts for these techniques apply only to particular populations: that is, they may be inappropriate for persons with other genotypic and phenotypic characteristics. Consequently, appropriate charts need to be developed for each racial and cultural group within each setting.

2.6.2 Skinfold Thickness (SFT)

This refers to the measurement of subcutaneous fat deposits by means of pinching a fold of tissue at various anatomical sites on the body and measuring the thickness with a calliper (Wells and Fewtrell, 2006). In many former studies skinfold thickness measurements were used to rank individuals in terms of relative ‘fatness’ or to assess the size of localised subcutaneous fat depots. Skinfold thickness data have, in previous surveys, provided raw values which act as indices of regional fatness, and these values can be converted into a format of standard deviation score longitudinal studies. This method has a number of advantages: measurements can be made quickly and are simple to obtain in most age groups: in general, intra-observer and inter-observer errors are low compared to between-subject variability: they are accurate, repeatable, and dependable (when conducted by a person skilled at measuring), although a limitation is that different results can be achieved if measurements are not taken from the exact spot on each participant each time, and if the use of the callipers is not standardised. A disadvantage (which contributed to this technique being rejected from this study) is that it is perceived to be intrusive and entails personal body measurements.

2.6.3 Body Mass Index (BMI)

Body mass index calculated by means of the formula BMI = Weight (kg)/Height (m) ^{2}. It is the most commonly used technique for ascertaining overweight and obesity and of assessing the risk of cardiovascular disease and diabetes (Pasco et al., 2014, Nuttall, 2015). It has long been used as a quick and efficient estimation of an individual's level of 'fatness' and hence his/her likelihood of developing other forms of ill-health. Weight alone is not a reliable guide to health and fitness, and the value of BMI is that the confounding effects of individuals being of different heights is taken into account by expressing body weight relative to the square of the height. The simplicity and ease of measurement have popularised the use of BMI as a marker of adiposity in both epidemiological work as well as in clinical practice. A recent large-scale systematic review of methods used for measuring obesity and overweight in children found that most studies (78%) used BMI, and many combined anthropometric techniques (especially BMI) with electromagnetic measurements or digital devices (Jensen et al., 2016). BMI has been broadly accepted as a general guide to fatness, but it is only a guide, several studies noting that, considered in isolation, it fails to take account of a number of other factors. For example, exercise can lead to a reduction in body fat as a proportion of total mass, but that reduction in fat may be supplanted by lean muscle of equivalent weight. Furthermore, as Pasco et al. (2014) note, build-up of body fat in healthy bodies is usually accompanied by a compensatory response from the musculoskeletal system, acting through muscle and bone, as it adapts to better cope with the increasing mechanical load: that is, an increase in proportion of body fat may not lead to a decline in fitness.

It is not possible here to consider all aspects of this approach except to note that, like all methods, it is not appropriate for all studies and it has its disadvantages. While BMI is often adopted for use in epidemiological surveys, one limitation is that the relative cut-off levels for defining over-weight and obesity need to be determined for each population group in each specific setting. This technique has general application. Duren et al. (2008) and as Jensen et al. (2016) found there has been widespread positive correlation between the BMI and the various other anthropometric methodologies. However, when compared with other forms of laboratory-based and technology-based measurements there is not always a close correlation. For example, Pasco et al. (2014) reported a study in which the prevalence of obesity using a particular BMI threshold apparently underestimated the true extent of obesity among young and elderly men. The writers have commented that sex-and-age-specific thresholds need to be established and verified for defining underweight and obesity in terms of body fat.

2.6.4 Waist Circumference (WC)

WC is a simple process and entails measuring the abdomen without clothes at the level of the umbilicus. In order to provide standardised methods the WHO has provided instructions and definitions about the posture of the subjects and about the placement and tightness of the measuring tapes, and it seems that these have been adopted in many countries (WHO, 2008). This technique provides a general indication of abdominal fat and is a useful guide associated with specific health risks (Chan et al., 2003). A number of reference charts and waist-circumference cut-offs have been suggested to help describe people according to health risk categories (Brambilla et al., 2013). In Western countries the most common categories are 80cm for women and 94cm; figures above these indicate an increased risk. Those regarded as being of high risk have WCs of above 88cm for women and 102cm for men. Jensen et al. (2016) reported that many studies recorded high correlations between WC and other anthropometric techniques. However, abdominal circumference does not accurately indicate levels of intra-abdominal adipose tissue because it also includes subcutaneous fat deposition. WC has the advantage in epidemiological studies of child populations of being easy and safe, and well accepted by the children. But in some cultures this method is unacceptable, especially for use with girls and women because it is perceived to be intrusive and involves intimate contact.

2.6.5 Waist-Hip Ratio (WHR)

WHR refers to the relationship between the measurement of waist circumference and that of the hip. As explained above, the waist is measured at the umbilicus and the hip circumference at the widest point of the buttocks; subjects must be standing and upright (WHO, 2008). [Some studies measure the waist at the minimum point]. The value of WHR is that it indicates the distribution of subcutaneous fat, and studies have confirmed that this methodology yields strong correlations with various cardio-vascular conditions as well as showing predictions of morbidities (Welborn et al., 2003, Chan et al., 2003). This approach has been used in several studies of adults, but has been little used for assessing the health of children, partly because after puberty there is a tendency for individuals, and especially girls, to experience changes in body morphology. Also, as noted, in the context of Saudi Arabia it is perceived to be unacceptably intrusive.

2.6.6 Medical and laboratory methods for measuring body composition

In recent decades a dozen or more techniques have been developed which use forms of body imaging, digital technologies, and electromagnetic systems. It is not appropriate to consider them all here, but it is useful briefly to review their main applications, their advantages and disadvantages. In most instances they have been excluded from this research because of the practical difficulties associated with measuring a large number of individuals in laboratory conditions, because of the time and complexity required in using some of the instruments, because many such devices and techniques are available only in hospitals and research institutes, because some would be intrusive and intimidating for children, and because of very high costs.

2.6.6.1 Bioelectrical impedance analysis

BIA is a method by which body fat is estimated by passing a very small, safe current through the body – usually from one hand to the other, or by hand to foot. This process identifies differences in impedance resulting from the fact that fat and lean tissues have different degrees of electrical conductivity (Dehghan and Merchant, 2008). Impedance is low in lean tissue, where cellular fluids and electrolytes are primarily contained, but resistance if higher in fat. Thus, impedance is proportional to total body water. As with other methods of measuring fat, adjustments must be made to the raw data in order to take account of the age and height of the subjects as well as other characteristics and local factors. Published BIA equations are population specific.

Since the 1980s many electronic and digital BIA devices have been produced, and they have steadily been refined and improved so that now they offer a range of effective techniques for use by clinicians and researchers. Most are held in the hand or floor based, like bathroom scales. They offer a number of advantages; they are generally inexpensive, quite reliable (when correctly adjusted), and safe. They are also particularly useful for studies such as this: they can be used quickly in large epidemiological surveys, they are safe for children, and they are unobtrusive. As detailed elsewhere, these are the reasons one model was selected for use here (chapter 3).

2.6.6.2 Magnetic resonance imaging (MRI)

Magnetic resonance imaging (MRI) is an imaging technique used to obtain pictures of the anatomy by means of strong magnetic fields and radio waves; it is different from the use of X-rays, considered much safer and, in many cases, more useful as a diagnostic tool (Wells and Fewtrell, 2006). In regard to its use for estimating body fat, it measures the volume of adipose tissue rather than the mass since mass density can differ between people and within individuals. Although MRI provide high imaging quality, it is difficult to compare results with those obtained using other techniques (Duren et al., 2008). A major advantage of using MRI imaging over other techniques is its capability for estimation of regional body composition, and it is presently the only precise and viable approach for the estimation of intra-abdominal adipose tissue. Despite its usefulness and advantages, MRI would be quite inappropriate for a study such as described here: it is relatively costly, too slow for use with large population surveys, available only in major hospitals, very noisy, and unsuitable for researching young children.

2.6.6.3 Dual X-ray absorptiometry

DXA uses a very small dose of radiation to produce images of the inside of the body. Initially it was a procedure used for estimating bone density and bone mass, but over the past two decades it has been applied more broadly for surveying body composition; indeed, it is regarded as very effective for estimating body fat (Kakinami et al., 2014). It functions on the principle that X-rays passing through various body tissues decrease at different rates and therefore tissues of different densities can be distinguished. Moreover, by using X-rays at two different energy levels, better tissue-differentiation is possible compared with single energy systems. DXA has many uses as a diagnostic tool, but it would be quite inappropriate for this study: it is expensive, available only in major facilities, and any unnecessary use of X-rays (even in small doses) for researching young children would be unacceptable.

2.6.6.4 Hydro-densitometry

Hydrostatic weighing is a method for determining body composition by means of immersion in water. It is based on Archimedes Principle where the density of the body can be calculated using weight and volume (Density = Mass /Volume), and it is regarded as an accurate approach for estimating body composition (Duren et al., 2008, Demerath et al., 2002). Hydro-densitometry entails weighing the participant prior to immersion in water, during immersion, and by measuring the volume of water displaced. A high proportion of body fat makes an individual more buoyant because fat is less dense; lean mass is more dense than water and makes the person sink, thus individuals with high proportions of fat experience a greater weight difference when submerged. While this is regarded as an accurate approach it has some serious disadvantages which make it unsuitable for this project: it is a slow procedure, entails unclothed individuals being fully submerged, and requires access to immersion and measuring equipment which is not portable. Moreover, it is inappropriate for medium or large population-surveys.

2.6.6.5 Air-displacement plethysmography (ADP)

ADP is a method which is akin to hydro-densitometry insofar as it determines body composition by way of displacement – in this case displacement of air rather than water (Wells and Fewtrell, 2006, Demerath et al., 2002). In ADP the volume of the body can be measured indirectly by calculating the volume of air a person displaces when inside an enclosed chamber (plethysmograph). That is, the volume of the human body is measured from the displacement of the volume of air equivalent to their body volume. Body volume is simply measured by calculating the difference between volume of air remaining inside the chamber when the individual is inside from the volume of air in the chamber when it is empty. Since lean tissue is denser than fat, it is feasible to determine the lean-to-fat ratio from an individual's density, and in order to calculate density it is essential to identify both weight and volume.

This approach is regarded a reliable research methodology, but in a population survey it would entail a considerable number of mathematical calculations. It has the advantages of being quick, comfortable, automated, non-invasive, and safe. However these tend to be outweighed by the disadvantages that it takes time, is costly, and non-transportable – most commercially-produced air-chamber 'pods' being located in research institutions.

2.6.6.6 Other methods of body measurement

There are several other techniques for ascertaining body composition, but most are unsuitable for a medium-sized population survey such as this: in general they are expensive or laboratory-based and located in major hospitals or research facilities. Furthermore, some entail the use of radio-active materials and some are invasive - thus being unsuitable for use with young children. They cannot all be described here, except to note that they include such research techniques as computerized axial tomography, measurement of total body water by isotope dilution, spectroscopy total-body potassium counting, in vivo neutron activation analysis, and total body electrical conductivity.

2.7 Diet intake measurements

The measurement of the energy value of particular food items and of individuals' daily food intakes is complex; it challenges the researcher especially in regard to surveys at a group and population level. The method of measurement will depend on the types of information required and the objectives of the survey. For example, medical studies may require the precise energy values of food being ingested, regional health services may be seeking to identify the specific needs of a population sub-group, or healthcare agencies may seek data to evaluate the behavioural responses to a campaign to encourage healthy eating.

Several methods have been developed for measuring and recording the type, quantity, frequency, and energy-content of food being ingested by research participants. Usually the surveys have entailed regular (daily or weekly) records provided by participants, the most commonly used approaches being food-frequency-questionnaires (FFQs) and food diaries. However, other more precise biochemical techniques known as biomarkers have been developed. Each of these methods has advantages and disadvantages, but, as noted, the selection of a suitable method depends on the purpose of the research, the nutritional information being sought, and the resources (people and funds) available for the work. In some studies data are sought in regard to specific food items or food types (such as quantity and type of fats or proteins), in other projects the purpose might be to test for associations between foods and particular diseases.

2.7.1 Biomarkers

Biomarkers were not used in this project (primarily because of cost and inability to access appropriately-equipped testing laboratories) but it is pertinent briefly to consider their functions and benefits in regard to obesity research. In medicine and healthcare research, biomarkers are usually compounds isolated from blood plasma, serum, saliva, urine, or other fluids that can be used as an indicator of the presence or severity of a particular condition. Biomarkers have been used to estimate the intake of nutrients and to validate dietary records. For example, nitrogen excretion measured in urine is a biomarker for nitrogen intake and from this protein intake can be calculated. Also, biomarkers are proving to be an effective avenue of research into the links between metabolism and obesity. For example, a review by Rauschert et al. (2014) identified specific metabolomic biomarkers that were related to obesity including branched-chain amino acids (BCAA), organic acids, and phospholipids. Fung et al. (2001) examined 2 major dietary patterns: 'prudent', which was characterised by high consumption of fruit, wholegrain and poultry and this pattern correlated with plasma folate and negatively correlated with insulin. The second pattern was 'western', which was characterised by red meats and high fat products, and this pattern was correlated with insulin, leptin and negatively correlated with folate. Therefore, dietary patterns were related to biomarkers associated with obesity and CVD risk. Markers are also being used in the close examination of metabolic processes, the term 'metabolomics' now describing the methods for analysing metabolites in biological samples. Metabolomics is an analytical technique that aims to identify and quantify small metabolites. Biomarkers do not entail subjective judgements and are, by definition, objective, quantifiable characteristics of biological processes (Hedrick et al., 2012).

2.7.2 Food-frequency questionnaire (FFQ)

A food-frequency questionnaire (FFQ) is a tool which retrospectively records food consumption over a period of time, in order to estimate energy and nutrient intake. In general FFQs consist of list of commonly eaten foods quantified by portion size. The participant then chooses the most appropriate frequency to match their consumption of each food item. In the context of public health nutrition, instead of the use of expensive clinically-based analysis by biomarkers, self-report methods are commonly used to collect food intake data because they require fewer resources, they are cheaper and relatively easy to develop and manage. These can take several forms, but in general they entail survey participants recording in some way the content, quantity, and frequency of their food consumption.

The two most commonly-used approaches are food diaries and food-frequency-questionnaires (FFQs). The UK National Obesity Observatory lists eleven different survey methods which have been used in recent years (Roberts and Flaherty, 2010). However, personal assessment of food intake can be subject to random, unintentional, and systematic error because they rely largely on personal recollections and judgements. The particular criticism of these methods is that the psychological characteristics of individuals and the ability to accurately and honestly recall can influence dietary reporting (Roberts and Flaherty, 2010). As with other dietary assessment methods the FFQ has some advantages and disadvantages and these are detailed in chapter 3.

2.7.3 Food Diaries

Another form of data collection is food diaries (Roberts, 2010). These are written records of actual intake of foods and drinks at the time of consumption, the diary entries being kept for a specified period (usually several days). In some studies the quantities of food are weighed with accuracy prior to consumption, but in others the measurements are less precise, commonly being measured using approximate weights or estimated by using household measures (such as cups and tablespoons). They also use food models and pictures, which can help the participants to determine how much they consumed. Diaries may also be on the basis of 24-hour recall whereby the participant notes food intake for the proceeding 24 hours.

Diaries have proven to be useful when researchers seek to estimate group means (Wilson and Lewis, 2004), and in such cases a single record may be sufficient. However, it is important that the food consumed during the full week should be represented equally because of different patterns of eating on weekdays and weekends. If the reporting is to be for more than about ten days it may be necessary to randomise the pattern of days when diaries are used to ensure a representative food intake. Also, the recording period should not be too long otherwise participants can lose motivation and interest. When the research aim is to determine an individual’s intake or the distribution of individual intakes within a group then multiple records are required (Wilson and Lewis, 2004). How many depends will depend on the day-to-day variation of intake and the level of precision desired. If the aim is to identify the intake of energy and macronutrients then 4 to 10 days is considered adequate, but to examine long-term intake 3 to 4 days in each of the four seasons of the year would be required (Herrera Cuenca, 2015). More justifications on the dietary methods will be discussed more in chapter 3.

2.8 Physical activity measurements

2.8.1 Subjective methods for determining physical activity: questionnaires

Despite the steady development of new technologies and the increasing use of electronic assessment devices to measure PA, questionnaires provide a practical approach suitable for large observational studies (Helmerhorst et al., 2012). Physical Activity Questionnaires (PAQs) are an effective survey method because of their low cost and convenience. Most are designed to measure all, or most, aspects of daily events. They provide estimates of duration of activities of various levels of intensity, and are useful for surveillance of populations and for examining aetiology of disease in large observational studies (Helmerhorst et al., 2012).

Most PAQs are intended to measure several dimensions of PA, in particular, location, context, and domain of the activity. Similarly they provide estimated records of duration and intensity. However, it must be noted that there are limitations to the generalisability of the results for PAQs used to assess one population may not be extrapolated to other populations. Writers such as Telford et al. (2004), Helmerhorst et al. (2012) have surveyed the PAQs recently available, pointing out that they have been used for several decades; in that time they have been improved and refined so that now many are considered to be moderately reliable (r values 0.62-0.76) when compared to reference methods. Validity however was considered weak to moderate (r values 0.25 - 0.41) between the self-report and criterion method (Helmerhorst et al. 2012). However, the validty and reliability depends on the age of the child and if applied in the manner recommended by the developers (Telford et al. (2004). One of the main concerns about self-report and recall questionnaires is that, being subjective, they can be prone to error and bias due to misreporting, either deliberate (with a tendency to answer in ways that the participants think they should answer) or because of cognitive limitations related to recall or comprehension. The cognitive immaturity of children can lead to under- or over-estimating the duration and intensity of PAs, or they do not accurately remember details, and for that reason it is recommended that proxy reports are used (Dyrstad et al., 2014, Trost, 2007). That is, to ensure accuracy the children's reports are overseen by an adult or otherwise assisted by an adult (parent or teacher) who has been presented. More details will be discussed on methods in chapter 3.

2.8.2 Objective measurement of physical activity

In contrast to subjective means of measuring PA, which require the participants to comprehend the concepts of physical intensity and to accurately and reliably recall all activities of the day, objective techniques depend on mechanical equipment. Objective, or direct, means of determining PA include motion sensors such a pedometers and accelerometers, doubly-labelled water, calorimetry, and physiological estimates (such as respiratory rate and heart rate). Some of these require access to suitable laboratory equipment while others are intrusive on the individual, but all are considered ways of objectively increasing the accuracy of measuring PA for validating self-report techniques, and of removing the bias that may come from recall and response to questionnaires and diaries. However, the use of such equipment has limitations; in particular some can be expensive and time-consuming (Trost, 2007, Loprinzi and Cardinal, 2011). They also require mathematical calculations for converting raw data (time and intensity of PA) into meaningful statistical statements of energy expenditure, this proving to be a complex matter which has taken some time to resolve (Jensen et al., 2014, Basterfield et al., 2008, Crouter et al., 2012).

2.8.2.1 Doubly-labelled water

Doubly-labelled water contains non-radioactive isotopes which can be used to measure carbon dioxide production (from urine, saliva or blood samples) which, in turn, provides a measure of energy expenditure (Ekelund et al., 2001, Hill and Davies, 2001). While regarded as an accurate means of determining EE, it does not indicate PA. Besides, it is expensive and suitable only for small-scale studies. Although it is safe and considered as a gold standard measurement for EE (Burrows et al., 2010), it may not always be considered acceptable by some for use with young children because it entails consumption of a particular liquid and the collection of urine or saliva samples.

2.8.2.2 Heart-rate

Heart-rate is another measure of PA, considered reliable because of its linear relationship with steady-state exercise. However, it is limited in its application because it is highly influenced by such factors as body-size, age, and levels of emotional state. Moreover, there continues to be some disagreement about the extent to which it measures PA in children. A study by Livingstone et al. (2003) was conducted on 36 free-living children aged 7-15 years to compare heart rate monitors with DLW in the measurement of energy expenditure. For children aged 9 years they found a mean difference of -9.2 % with heart rate monitors under-estimating TEE, however there was closer agreement in children aged 12 years with a difference of -1.5%.

2.8.2.3 Pedometers

Pedometers are inexpensive, easy to use, and well-suited to large-scale surveys. They have been available for decades and in that time they have been refined and developed to a high degree of reliability and accuracy. As Tudor-Locke and Lutes (2009) explain, these small devices are usually attached to the waist and contain horizontal spring-supported arms which move up and down in response to vertical movements of the hip. The old-style spring mechanisms required a pedometer to be worn in a perfectly vertical position to count accurately. Depending on body shape, early models of waistband pedometers might be tilted and not able to count steps accurately. But modern 2-axis and 3-axis mechanisms can count steps accurately when tilted. Today they can provide data about time spent on PA, number of steps, and distance covered (Troiano et al., 2008, Pedišić and Bauman, 2014), some also indicating EE in the form of calories used (More details in chapter 3).

2.8.2.4 Accelerometers

Accelerometers have been used for decades and in that time they have been steadily improved so that now they measure not just up-down movements but also they contain sensors that detect movements on two axes and three axes (that is, sideways and forwards-backwards) (Troiano, 2005). Containing clocks and motion-sensors, they are small and easily attached to the body or clothing, and record time and duration of activity. Work by Biddle et al. (2010) and others have confirmed that these instruments are reliable for recording PA over a range of levels from sedentary to vigorous. The electronic sensors record accelerations and convert the signals to numbers referred to as ‘raw counts’. These counts and dimensionless units, and different brands of equipment have their own units of measurement. As detailed in methodology chapter, semi systematic review and pilot study will be examined the acceptability of the methods in children.

Chapter 3: Methodology

3.1 Introduction

This chapter provides the justification for the choice of the research tools which measure body composition, dietary intake, and physical activity in children.

3.2 Justification of methods for measuring body composition

At this point it is pertinent briefly to review the various techniques, which have been developed for measuring fat in the body. Several aspects of body composition have been found to be important for the health (and the future well-being) of children and in particular the amount, proportion, and distribution of body fat. In the past five decades or so various approaches have been developed; over time they have been improved and refined so that now there is a range of options available to researchers and clinicians. Moreover, many methods have been validated in different settings for use with different populations, reference tables have been confirmed, and many of the technology-based devices have made more reliable, affordable, and user-friendly for epidemiological studies (Duren et al., 2008).

3.2.1 Body mass index (BMI)

Body Mass Index (BMI) is one of the most common methods used to measure obesity. BMI is measured by dividing body weight in kilograms by height in meters squared. An adult with BMI of 25-29.9 kg/m^2 is considered overweight and above that is classified as obese.

BMI is widely used in the UK and many other countries, but it is essential to note that it is not a direct measure of body fat mass or distribution, and BMI measures may be skewed by very high muscle mass. Also, as noted above, the relationship between BMI and health also varies with ethnicity. In children and adolescents BMI varies with age and sex, for this reason a growth reference must be used (Flamenbaum, 2006). In England, the current

British growth reference charts are applied to categorise the weight status of children based on their age and sex for the National Child Measurement Programme and Health Survey for England (Dinsdale, 2012) The use of this technique has a number of advantages: it is easy to measure and compute, inexpensive and strongly correlates with body fat levels (as measured by the most accurate methods) (Ranasinghe et al., 2013), numerous studies have shown that a high BMI is effective as a predictor of higher risk of chronic disease and early death (Must et al., 1999). Moreover, after many years of use it has the benefit of well-established standardized cut-off points for overweight and obesity, as listed above in chapter 2. The limitations of this method are that it is an indirect measurement and does not differentiate between body fat and lean body mass, and is not as precise predictor of body fat in the elderly as it is in younger and middle-aged adults. Also, females have, on average, more body fat than men, and the proportions of body fat in 'healthy' people vary between the races (Hu et al., 2007a). Although more reliably quantifiable than skinfold thickness (discussed below), BMI measurements may be affected by variability in body frame size, and factors such as growth and development may complicate the use of BMI. In healthy children, BMI increases slightly with age, thus BMI percentiles, which are age- specific, must be used to define risk categories. In the UK, the National Obesity Observatory publish national trends in obesity for children (Dinsdale et al., 2011, NOO, 2012).

3.2.2 BMI Growth Charts

It is proposed that in this project reference will be made to the growth charts developed by the US Centre for Disease Control (CDC data). Other similar reference charts have been developed in other countries such as those by the International Obesity Force Task (IOTF). IOTF have formulated BMI centiles charts for children with specific centiles designated to classify obesity, overweight and thinness (Cole et al., 2000). These charts have been widely used, but they might not be suitable for use with this study population because even though they were derived from 6 countries, they were based mostly on western populations (Caroli et al., 2007). Also, in order to compare this study's results with other studies in Saudi Arabia, the CDC charts were chosen. CDC charts have been used more commonly in Saudi Arabia.

The CDC charts have been used, developed and refined for over 40 years and (although they are mainly intended for use in the US) they enable some comparisons between countries and between different research projects. The growth charts comprise of a series of percentile curves that illustrate the distribution of selected body measurements in children. The charts are not intended to be used as a sole diagnostic instrument; rather they are statistical tools that adjust raw weight and height measurements to take account of the body changes that occur with age, and they contribute to forming an overall clinical impression for the child being measured.

Because of the different rates of growth for boys and girls specific charts have been developed for each. They consist of two separate reference lists; one chart showing stature-for-age and weight-for-age, the other referencing BMI-for-age. They show the 3rd, 10th, 25th, 50th, 75th, 90th, and 97th smoothed percentile lines for all charts and the 85th percentile for BMI-for-age and weight-for-stature. Percentiles are commonly used statistical indicators to assess the relative size and children's growth patterns. An individual's measurements are plotted and ranked by percentiles, thus indicating where the individual lies in relation to the population of the same age and sex.

Z scores can also be used to evaluate and monitor a child's growth. A Z-score is principally calculated from the distribution of the reference population. It is "the deviation of the value for an individual from the mean value of the reference population divided by the standard deviation for the reference population" (CDC, 2009). Z-scores have a direct relationship with percentiles and so there is a Z-score corresponding to each percentile (Table 3.1). Z scores form a continuous scale including negative values (those below the median) and positive values (those above the median). For example, a Z score of 1 corresponds to the 84th percentile, and -1 to the 16th percentile. An advantage of using Z scores is that they can be used as a continuous variable in analysis and can better quantify growth at the extremes of the distribution (Wang and Chen, 2012).

Table 3.1: List of percentile z-score conversions values.

Percentiles	z-scores
0.2nd	–3
2.3rd	–2
2.5th	–1.96
5th	–1.64
15th	–1.04
16th	–1
50th	(median) 0
84th	+1
85th	+1.04
95th	+1.64
97.5th	+1.96
97.7th	+2
99.8th	+3

(Wang and Chen, 2012)

A research project which endorsed BMI as a measure of physical change was conducted by Cole et al. (2005). The researchers sought to identify the optimal method of measuring adipose change in growing children across the spectrum of adiposity. Their main focus was on the various methods of applying height/weight ratios and they assessed four versions of calculating BMI: that is, BMI, BMI %, BMI z-score, and BMI centile. Using these different computations the authors tracked the weight and height changes of 135 children for a period of nine months. They reported that even though the BMI z-score was optimal for assessing adiposity on a single occasion, it was not necessarily the best scale for measuring change in adiposity for individuals over time because the variability depended on the child's level of adiposity. Their conclusion was that better alternatives are BMI itself or BMI%.

Despite its general acceptance and widespread application BMI is not a useful measure in all situations, critics pointing out that it does not account for extremes of muscle mass, for some rare genetic disorders, the very young, and some individual variations. For instance, an adult with a BMI of less than 25 may still have excess body fat, and others may have a BMI that is above 25 though without much body fat. Moreover, being overweight is not automatically an indicator of ill-health or of health risks. Some of the non-anthropometric methods for determining body fat may be more accurate for individual cases but they come with added complexity.

Another criticism of BMI concerns its inability to reflect the changing health of an individual as a result of change in physical condition or lifestyle. For example Ross and Janiszewski (2008) point out that an individual may adopt a physically active lifestyle, along with a balanced diet so that body fat might be reduced and muscle increased. But as a consequence BMI may appear little changed and this may be interpreted as a failure, resulting in the disappointed individual resuming an inactive lifestyle and unhealthy eating patterns. They argue that weight loss or changes in BMI are not absolutely necessary to observe substantial health benefit from a healthy lifestyle, it being well-established that increased physical activity and associated improvement in cardiorespiratory fitness are associated with marked reductions in coronary heart disease and related mortality independent of weight or BMI.

In support of their comments on the limitations of BMI, Ross and Janiszewski (2008) also stress that exercise is linked with substantial reduction in cardiometabolic risk factors (such as 20 % improvement in insulin resistance after 1 hour of exercise, 10- 25 % reduction in triglycerides, and increasing about 7-15 % in high-density lipoprotein (HDL)), although it was not accompanied with any change in body weight. Authors also noted that abdominal fat and waist circumferences can be significantly reduced after regular exercise with minimal weight loss. Fat mass reduction often takes place simultaneously with equivalent increase in muscle mass in response to daily exercise for at least 8–16 weeks (Josse et al., 2011). Equal but opposite changes which are not detected by alterations in body weight, and thus BMI remains unchanged.

3.2.3 Waist Circumference

Another anthropometric method is the measurement of waist circumference (Magalhães et al., 2014). This is the easiest and most common used method to measure abdominal obesity, which is considered an important factor in health, studies showing that waist circumference can be a predictor of the development of disease and death.

The circumference of the abdomen is measured at the natural waist located between the lowest rib and the top of the hip bone, at the umbilicus, or at the narrowest point of the midsection (Al-Sindi, 2000, Hu et al., 2007b). One advantage of this measurement is that it is inexpensive and easy to use. In addition, there is strong correlation with body fat in adults as established by precise body scanning methods (Deurenberg et al., 1999, Panel, 1998, Hu et al., 2007b).

A very large-scale project, titled The EPIC- InterAct Case Cohort Study (Swerdlow et al., 2015), used waist circumference (WC) measurements for assessing the risk of Type 2 Diabetes. With 340,000 participants in eight European countries, the study used waist circumference and BMI as indicators to predict Type 2 Diabetes. Although working only with adults, the project was important because of its breadth and scope, following participants and those who developed diabetes for a period of ten years. The researchers reported that waist circumference proved to be a reliable and simple means of measuring excess abdominal fat and a strong predictor of T2D; in particular, they recorded strong correlations between waist circumference in women and the later onset of diabetes.

A study was conducted by McCarthy et al. (2005) on British children to investigate the trends in waist circumferences of 1821 children aged between 2 and 5 years. Their findings showed an increase in central adiposity over the period of 1987-1997. Moreover, McCarthy and Ashwell (2006) examined waist to height ratios in British children aged 5-16 years, and reported that there was a notable increase in central fatness between 1977 and 1997, and this ratio more closely predicted morbidity than BMI. Thus, these studies emphasise that measuring BMI itself provides no information on body fat distribution and problems related to obesity in children.

The main limitations of this technique are that measurement procedures have not been standardized; it can be difficult to measure and less accurate in individuals with a BMI greater than 35 kg/m^2 (McCarthy et al., 2014). Males and females have slightly different distributions of adipose, males developing tissue around the waist while females tend to develop more at the hips and buttocks.

There continue to be professional and academic differences of opinion regarding acceptable methods for measuring body composition, but it is evident that there is yet no ‘gold standard’. Indeed many researchers prefer to use mixed methods, though BMI and waist circumference continue to be regarded as acceptable approaches. However, a recent survey by Verweij et al. (2013) argued that while waist circumference may be acceptable for research projects it is not sufficiently accurate for clinical diagnosis. That is, even small errors in measurement of individuals may mean that subtle, clinically relevant changes in body mass may not be identified by healthcare practitioners. In response they argue for tightly-defined measurement protocols.

3.2.4 Bioelectrical impedance analysis (BIA)

Another method to be employed in this study is bioelectrical impedance analysis (BIA). This entails a small, safe, electrical current being passed through the body to measure its electrical resistance (Kyle et al., 2004). This system is based on the fact that fat and lean tissues have differing degrees of electrical conductivity, the current facing more resistance when passing through fat than it does passing through lean body mass and water. This technique is a predictive measure estimating body fat percentage in relation to muscle mass (Kushner and Roxe, 2002). Formerly, it could be performed only in clinical or research laboratories using specialized equipment, but today portable, inexpensive machines are readily available and require minimal training. In spite of the enhanced easiness of this process over the years, however, there are a number of factors which can affect the results, including hydration and body temperature, so it still requires some care when taking the test to ensure that the results are precise (Hu, 2008: Al Sindi, 2000). The advantages of using this equipment are that it is convenient, safe, relatively inexpensive, portable, quick and easy. The limitations are that the machines can be difficult to calibrate, accuracy can be compromised by the ratio of body water to fat being changed during illness, dehydration or weight loss, and with prolonged use the machines may decrease in accuracy.

Kyle et al. (2004) conducted a meta-analysis of the 1600 or more research papers (up to that time) which had reported the use of BIA. They reported that, overall, results showed very strong support for this method with correlations coefficients between $r^2 = 0.93$ and 0.55

when BIA was compared with DEXA or denistometry. Citing many of the prior studies they concluded that BIA works well in healthy subjects with stable water and electrolyte balance, though it was clear that the data had to be adjusted and validated with a BIA equation that is appropriate to the age and sex of the participants. They note, also, that the use of BIA in adult subjects at extremes of BMI ranges (that is, with a BMI less than 16 or greater than 34) or with abnormal hydration cannot be recommended for routine assessment until additional validation has been proven for BIA algorithm to be precise in such conditions. The authors define a number of procedural conditions, which must be met if this method is to be reliable (Kyle et al., 2004). That is, standardised conditions must be used for all participants: they should be standing, and if possible they should have fasted for about 8-10 hours because food can impede electrical flow and hence skew the readings. Also, if possible, measurements should be taken under the same conditions on two consecutive days.

Another approach to the measurement of body fat was developed by the Tanita Corporation (www.tanita.com). Like other bioelectrical impedance devices its body-fat analyser uses a variety of small electrical currents to determine body composition, but unlike others (which usually only identify only two aspects of body composition – fat and non-fat components) this machine converting the readings into four measurements of fat, muscle, body water, and overall body density. The machine has the advantage of ease-of-use and is well-suited to large scale studies; it is also being marketed for domestic use. Unlike other bioelectrical devices which use a hand-to-foot current pathway, the Tanita device measures the voltage drop as the current passes from one foot to the other from metal foot plates. Jebb et al. (2000) assessed this machine and compared it with other devices and with such methods as skinfold thickness and with BMI measurements. The testing team also developed a predictive algorithm for use when interpreting the information in this device, concluding that while it has particular advantages and proved to be more accurate than established height/weight formulas, it was not more accurate or reliable than other impedance equipment. However, a shortcoming which made this device unsuitable for this project was that it had not been calibrated for use with children, and neither has child-specific reference charts been developed.

The report by Jebb et al. (2000) was reinforced by a later meta-analysis by Dehghan and Merchant (2008) who examined many bioelectrical impedance devices and many studies which had made use of such devices. They reviewed the use of these machines for large epidemiological surveys, taking account of such factors as ethnicity, environment, and medical conditions of participants. For example, they point out that factors that may affect machine readings include recent food consumption and physical exercise of participants, medical conditions that affect fluid and electrolyte balance, individual characteristics, and ethnicity and associated variations in limb length. They noted that bioelectrical impedance can accurately measure body fat in populations where the machines have been validated for specific ethnic groups and conditions, but they are unreliable for large studies with diverse populations. Moreover, BIA was used on 1958 Caucasian children aged 5 -18 to measure their fat percentage in order to publish new charts for Child Growth Foundation in Southern England (McCarthy et al., 2006).

While many studies consider excess body fat in the context of overall body composition, some studies have focussed on specific aspects of fat distribution. One recent investigation considered skeletal muscle mass because the muscle-to-fat ratio has the potential as an enhanced measure of metabolic risk (McCarthy et al., 2014). Since skeletal muscle is key to motor development and represents a major metabolic influence that helps glycaemic regulation, it is important when considering the development of diabetes. That is, low muscle mass and fitness are linked with metabolic risk, while muscular strength is positively associated to higher insulin sensitivity in children and adolescents. Focusing not on waistline measurements or adipose distribution, but on the muscle-to-fat ratio, McCarthy et al. (2014) surveyed 1985 Caucasian children aged 5–18 years. Using a bioelectrical impedance device the researchers obtained skeletal muscle mass data from the four limbs, the data being employed to derive smoothed centile curves and the muscle-to-fat ratio.

The results of the study were that there was a very wide range of muscle-to-fat ratios for both boys and girls, but more importantly, the writers asserted that this approach to measuring body composition offers a more reliable indicator for predicting diabetes. Given that excess fat and muscle usually have opposite influences on glucose sensitivity they argue that the ratio of muscle-to-fat would be a better predictor of metabolic health than BMI; they cite as an example a child with a muscle-to-fat ratio of just 0.75 would have greater difficulty in sustaining glucose homeostasis than a child with a ratio of 3.0. Furthermore, they suggest that if this approach is confirmed as a good index of metabolic health it could lead to more precise classification of overweight and obese children into 'high-' and 'low-risk' based on their muscle-to-fat ratio.

The methods to be used in this research are all indirect insofar as they measure physical parameters (weight, height etc) in order to identify the condition of the individual. While they will not be used in this enquiry it is relevant briefly to note some of the other methods which can be used to measure overweight and obesity. There are a number of direct measures of body composition in which fat mass and various components of fat-free mass can be estimated. The direct techniques (chapter 2) can measure specific fat depots but are not usually employed to assess total body fat. These direct measures can identify with great accuracy the location and distribution of fat tissue but because of cost, time, and location they cannot be used in large-scale population surveys such as proposed here. Therefore, in this study the three measurements, BMI, waist circumference and bioelectrical impedance, will be tested to examine their acceptability in this age group.

3.3 Justification of dietary intake methods: Semi-systematic review of methodology to measure dietary intake in children

3.3.1 Introduction

In recent decades a number of methodologies have been devised for recording and assessing the diets of adults, and they include food frequency questionnaires (FFQs), diet histories, weighed records, and dietary recalls. Many of these have been modified for use with children and adolescents, and the choice of technique is usually determined by the research question, the nature and type of the enquiry, the number of subjects available and research budgets.

In this investigation, it was essential to ensure that the research methods were reliable and suited to answering the study questions. One of the strands of this enquiry involved recording and measuring the food intake of the subjects, however it is difficult to measure the food intake because children can be unreliable about recording the time when they ate, and they may become confused about details such as portion sizes and meal composition (Olukotun and Seal, 2015, Livingstone and Robson, 2000). Particular attention has been given by previous researchers to the issue of devising and validating techniques for recording food intake, and while as yet no agreed ‘gold standard’ has been developed, several approaches have been refined and improved to the point where they are considered to be highly reliable.

The aim of this literature review was to identify methods suitable for recording food intake of children aged 8-11 years.

A semi systematic approach was carried out as this review did not meet some of the criteria for a systematic literature review (SLR) (Cook 2012). Although the SLR criteria that conducted following PRISMA checklist (Moher et al., 2009) and fulfilled in formulating the research question, usage of the databases, selecting search terms related to each component of PICO, which stand for participants, interventions, comparisons, outcomes and study design, and definition of inclusion/exclusion criteria. One of the SLR criteria that could not be achieved is having multiple authors to assess the paper selections and evaluating the quality of data extraction. Therefore a semi-systematic approach was the most appropriate approach for this review.

3.3.2 Methodology

3.3.2.1 Search strategy

The search engines used were MEDLINE, AMED, and Child Development & Adolescent Studies. Search terms and keywords relating to dietary intake in children were used with Boolean Operators to combine or exclude the keywords (table 3.2). The time-period selected for reviewing published reports was from 1990 to 2013 (the date when the pilot study was conducted). Initially, abstracts and titles were assessed to meet the search aim.

Table 3.2: Search-strategy terms

Population	**Dietary intake**	**Assessments**
Children	diet*	Measure*
Child*OR Girls*OR Boys*	food*	tools, test*,
	nutrition*	assessment, evaluate*,
	consumption* OR intake*	valid*

Publications that met the inclusion criteria in table 3.3 were included in this review, whereas others were excluded if they were not relevant to the study population or aims of the review (Table 3.3).

Table 3.3: Inclusion and exclusion criteria for searching procedure

Inclusion criteria	Exclusion criteria
Healthy children	Breastfeeding
Population aged 5-18 years	Food challenge
Objectively measured for BMI	Adult – infants
English and Arabic papers	Grey literature, Conference, abstracts
Female	unpublished articles, dissertations
	Non-human studies
	Nutritional deficiency
	Food supplement
	Alcohol

3.3.2.1 Data extractions

The studies deemed to be eligible have been included in this review. They met the inclusion and exclusion criteria and have been evaluated by the researcher.

3.3.3 Results

3.3.3.1 Overall results

From a total of 828 articles originally identified, only 13 studies were included in this review as shown in Figure 3.1.

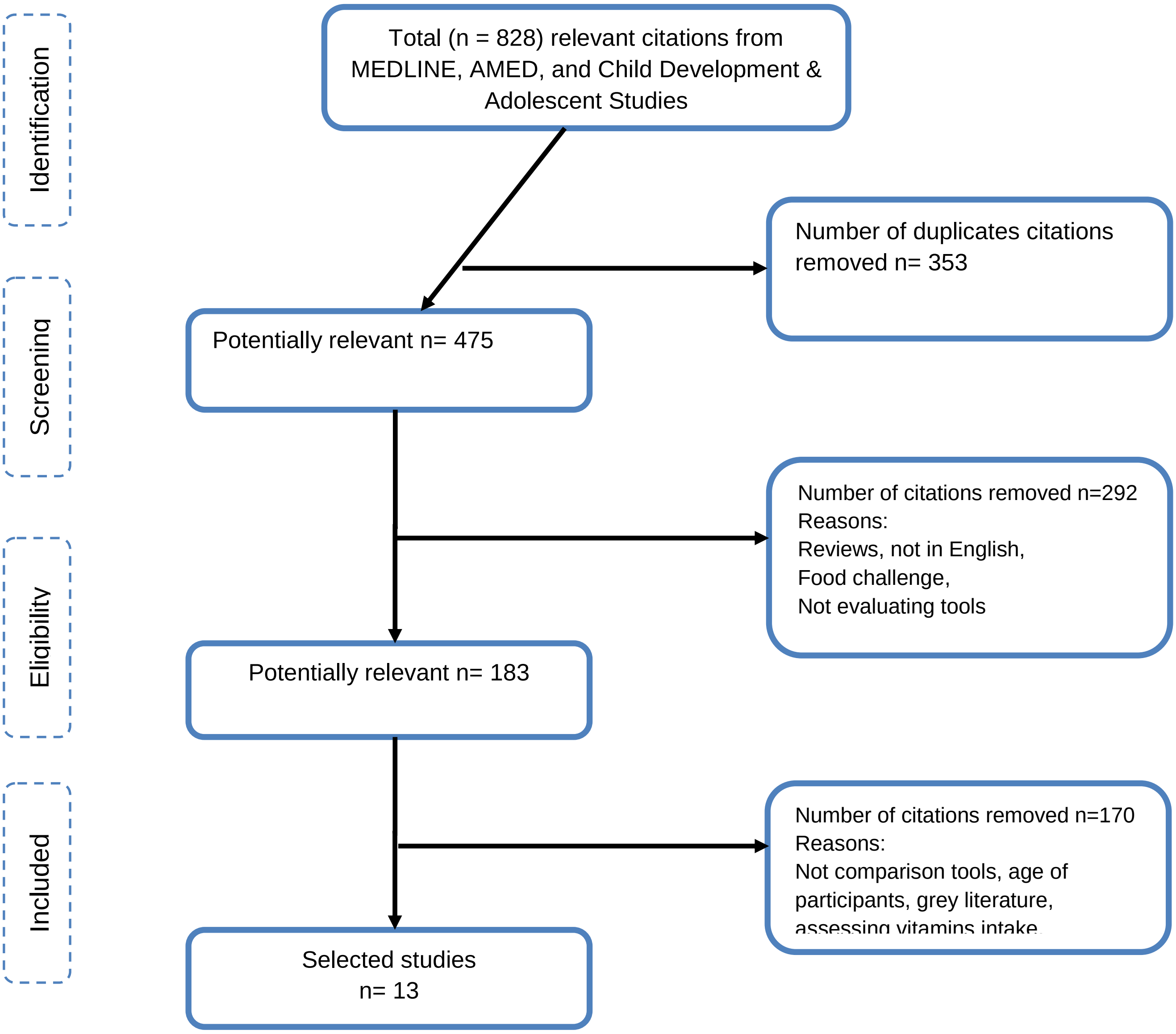


Figure 3.1: Flowchart of articles included in the systematic review of dietary intake methods for children (based on PRISMA (Moher et al., 2009).

To assess selected studies in more details they were divided into three categories: Food Frequency Questionnaires, food records and taped food record. A total of six articles examined the validity of FFQ, equally six of them examined the validity of food records, and only one examined the validity of a taped food record in children. The summary of these studies is represented in Table3.4.

Table 3.4: Summary of studies assessing the validity of Food frequency questionnaire (FFQ) in children

Author (years)	sample	Aim	Comparison	Measurements tools	Methods	Results
Burrows et al. (2013)	8-11 yrs n=9 Girls = 6 Boys = 3	Assessing the validation FFQ and WFR recording EI	Compare energy intake and total energy expenditure.	- (FFQ) - (WFR)	(FFQ) completed independently by the mother, father and child then compared EI from both methods with TEE measured by doubly labelled water For 4 days	- Both methods were equal in estimating EI - Not significant correlation in measuring EI using both methods (r=0.30, p=0.44)
Del Pino and Friedman (2011)	6-10 yrs n=103 Girls = 47 Boys= 44	Validate FFQ in estimating EI and adjusted nutrients	Compare energy and nutrients intakes	- (FFQ) - Three 24 h dietary recalls	By interviewing the parents For 3 days	- FFQ not valid with children - weak correlation 0.050 - Needs more research to address the source of errors
Cullen et al. (2008)	10-17 yrs n= 83 Boys and girls	To assess the validity and reliability estimating EI	Energy and nutrient intake	- (FFQ) - 24-hour dietary recalls	Completed by telephone For 7 days	- FFQ has validity on some nutrients not most food groups. -Significant $P<0.01$ between both methods in recording EI in ≤ 12y - More valid in adolescents
Wilson and Lewis (2004)	4-11 yrs Girls = 61	To assess the agreement between	Energy, protein, carbohydrate, and	- Block 98 (FFQ) - 3-day diet records	Completed by interviewing	- Weak agreement between both of them

		both methods estimating EI	fat intakes		caregiver, with help from the child if she was mature enough For 3 days	- Moderate correlation *r*= 0.40 to 0.55. -FFQ should be developed to reflects accurate energy and macronutrients intake
Kobayashi et al. (2011)	3-11 yrs 12-16 yrs n= 89 Boys and Girls	To assess the validity of the FFQ	Total energy, nutrients and fatty acids	- Children (FFQ) - Weighted dietary records (WDRs)	Completed by the subjects' mothers For 1 month (WDRs) once a week	- FFQ was a useful tool for habitual dietary intake - Moderate correlation (r= 0.21-0.58).
Yaroch et al. (2000)	11-17 yrs Girl =22	To assess validity of picture-sort FFQ	Energy and nutrient intakes	- (FFQ) - Three 24 h dietary recalls	Completed by participants For 3 days	- Larger sample needed - FFQ appeared to be promising and need further research -significant correlation between both methods measuring fat, CHO, S-fat, EI ($r \geq 0.48$, $p<0.05$)

***** WFR = Weighed food record

Table 3.5: Summary of studies assessing the validity of Food records (diet diaries- food recalls)

Author (years)	sample	Aim	Comparison	Measurements tools	Methods	Results
Garcia-Dominic et al. (2010)	9 yrs n= 614 Girls= 306 Boys= 308	To assess the accuracy of reported EI	Compare ERs with the predicted EI from dietary recall	- Three 24 h dietary recalls - Energy requirement	Dietary recalls were performed face-to-face by trained staff For 3 days	- Accurate measurements are needed
Lillegaard and Andersen (2005)	9 yrs Girls=167	Assessing EI from pre-coded food diary	EI compared with EE	- Pre-coded food diary (PFD)	Reported by participants and compared with EE from ActiReg For 4 days	- PFD method underestimating the average EI in boys more than Girls. - Variability in accuracy of EI at individual level. - Weak correlation (0.28 p=0.05).
Weber et al. (2004)	8-10 yrs n= 80 Boys and girls	To validate the modified diet record	Total energy, and nutrients	- Modified Diet records - 24-hours recalls	Self-recording by children Interviewing the children for 24 hours compared with the observed children's intakes during school time	- Modified Diet records showed accuracy in reporting total energy intake

Bandini et al. (1997)	8-12 yrs Girls=109	Validity of food records in estimating EI	EI compared with TEE	- 7-d dietary record	participants recorded their intake and EE measured by DLW For 2 weeks	- The foods records appeared to be accurate method For EI estimation. - paired test between EI and EE (*t*= 6.07, *p*< 0.0001).
Crawford et al. (1994)	9-10 yrs Girls= 58	Validate 3 dietary methods	Energy and nutrient intakes	3-day food records 24 hours recall 5-day food frequency	Observers recorded types and amounts of foods eaten during lunch For 3 days	- 3- days food records were accurate - 65% agreement in 9-10 years
Livingstone et al. (1992)	7-18 yrs n= 58	Validity of WDRs and DHs in estimating EI	EI compared with TEE	Weighed dietary records (WDRs) Record diet history (DHs)	By parents from 7-9 years and by participants over 10 years TEE measured by DLW For 7 days	- DHs were more characteristic of habitual intake -Sig lower in EI in WDRs p<0.01.

Table 3.6: Studies assessing Tape-recorded food

Author (years)	sample	Aim	Comparison	Measurements tools	Methods	Results
Lindquist et al. (2000)	6.5 – 11.6 yrs 30 girls and boys	Validate the Tape-Recorded food records for estimating EI	EI compared with TEE	Self-report by tape recorders interviewer-guided recall	Food intake was tape recorded by participants and compared it with TEE measured by DLW For 3 days	- This method did not show the assessment to be accurate - Not Sig in TEE ($r=0.32$, $p=0.08$)

3.3.3.2 Results assessing FFQ

A total of six studies were found that assessed the validity of FFQ in children. One such a typical study was undertaken by Yaroch et al (2000). The subjects were overweight girls aged 11 to 17 years from low income districts of Georgia (USA), this cohort being selected because few prior studies had been undertaken into that age group. The aim was to ascertain the reliability and validity of using pictures in diet surveys. The study used representative illustrations of 110 commonly consumed food items from that state, pictures of typical servings being provided. Also, pictures of typical mid-size bowls, saucepans, and typical-size fruit (such as oranges) were shown.

This methodology was found to be relatively reliable (Table 3.4), although, like so many other surveys, under-reporting was an issue. It was suggested that this stemmed from the fact that the girls were generally over-weight and that they sometimes ignored food items for which there was no illustration. Another shortcoming is that, for adolescent girls at least, the survey has an 'intervention effect' (Jensen et al., 2015). That is, the children may modify their eating for the duration of the study because they do not want to be identified as an over-eater. But despite these shortcomings it was concluded that the use of pictures markedly elevated the validity of the approach, (correlation of EI between FFQ and dietary recall method was significant: $r \geq 0.48$, $p<0.05$).

To explore the validity of the surveys which blend these data sources Burrows et al. (2013) conducted a comparative study of the reporting reliability of children, mothers, and fathers in Australia. The purpose of that research was to compare the accuracy of reporting of a child's energy intake by the child and by the mother and father – all working independently. The comparison was made by comparing the total energy intake (as recorded in a food frequency questionnaire completed by the child and each parent) with the total energy expenditure using DLW. The secondary aim was to compare the accuracy of the weighed food record with the DLW.

The participants in each family (that is, the child and two carers) independently completed a 4-day weighed food record assessment (validated for Australia) under supervised conditions to estimate the child's usual intake. The questionnaire was semi-quantitative and consisted of questions about intake frequency of 120 food items over the previous six months. It was developed and initially validated for use with Australian children in order to derive estimated total energy intake. The questionnaire contained items typically consumed by Australian children, the illustrations of portion sizes for individual food items being derived from the Australian Bureau of Statistics and the 1995 Australian National Nutrition Survey, which defined the typical serving size for common items such as a slice of bread. The child's completion of the FFQ provided a similar result to the 4 day weighed intake, and there was a significant correlation in EI from the FFQ completed by the father and TEE measured by DLW .

Two studies which modified then tested and validated food frequency questionnaires were conducted by Kobayashi et al (2011) in Japan and Del Pino and Friedman (2011) in Brazil. The former adopted the unusual approach of compiling two questionnaires; one for young children (3-7 years), a second for adolescents (12-16). Even though neither closely matched the cohort used in this thesis, nevertheless the process is illustrative of the difficulties of devising and adapting survey methods that achieve validity. The aim was to examine the reproducibility and validity of the survey method to assess dietary intake within the two groups – children and adolescents. Until that time (2011) questionnaires for adults had been used for children, but it had been evident that they had been unsuitable because the results overestimated the real intakes. Consequently the questionnaires were modified by adjusting portion sizes and by including items that young people would have been more likely to consume. The team developed two 75-item food questionnaires, which contained questions about both individual food items and mixed dishes based upon the typical eating habits of normal Japanese children or adults. The questionnaires for the young children were completed by their mothers. The questionnaires were applied twice, one month apart, and for the purpose of calculating food values four weighted dietary records were conducted each week for one month. Correlation coefficients between the first and second questionnaires were calculated to test the reproducibility of each. The subjects also detailed their food intake on weighed records; that is, on one day each week the ingredients of all their meals was weighed prior to cooking or to consumption, and the weight records were collected each week for four weeks. The day on which the weighing occurred was selected by the parents of the young children and by the adolescents themselves.

After the data from the questionnaires and the 4-day diaries had been collected, dieticians confirmed the content of the diaries and calculated the nutrient intake for each child using the Standard Tables of Food Composition in Japan. There was acceptable correlation between the information in the children's questionnaire and the weekly weighed records, and they concluded that the use of that method was appropriate for surveying younger children. However, there was low correlation between the data from the questionnaire and the weighed records of the adolescents. The researchers surmised that the adolescents were free to roam and to share and consume small snacks that might have been ignored or forgotten when the records were compiled. Another explanation for the relative accuracy of the children's survey was that the diaries were written by mothers who would have been aware of the details of the children's meals at home and at school.

Considerable discrepancy between the questionnaire and the information from the 24-hour recalls was found and their conclusion being that the questionnaire lacked validity and thus was not useful as a tool for epidemiological studies. It was commented that the task of adapting an existing questionnaire was laborious and prone to bias. The team did not dismiss all questionnaires, but they expressed the view that their particular model was not reliable. They did not explain how it could be improved, and neither did they comment on the accuracy of a diet survey which required subjects to describe typical food intake over such a long period as six months. This study could be useful insofar as it indicated some of the shortcomings of modified questionnaires. It also confirmed some of the pitfalls that can occur when including so many variables in a complex survey.

3.3.3.3 Results assessing food records

Six studies were found in assessing dietary intake using food records. The survey instrument often used in studies of children is the diet diary or diet record that can be completed (under guidance) by the child or administered by the parent. Investigations in the 1980s highlighted some of the basic problems encountered when studying children, the most common being notions of portion sizes, identifying and describing their meals, and forgetting snack or ‘non-meal’ foods. Many such studies identified under-reporting as an issue, particularly in girls, in adolescent girls, and in overweight, self-conscious, participants. An early study in California and Ohio by Crawford et al. (1994) assessed the validity of three types of food-intake recording systems. Using a comparative approach consisting of direct observations (by the team) and food records by the subjects, the writers tested a small cohort of girls aged nine and ten. Both qualitative and quantitative measures were applied, the purpose being to identify the most reliable and accurate technique that could be used for future epidemiological research.

The researchers used 3-day records, 24-hour recall, and 5-day recall approaches, all of which required the girls to remember and describe the quantities and types of food eaten previously. The result of this investigation was that the 3-day record was found to be most accurate, since the recordings being made soon after eating. It was found, too, that delays in recording led to errors in food quantification, to recordings of 'phantom' foods, and especially to missing foods. It was even noted that some girls seemed to forget the meal they had eaten the previous day and described an imaginary meal because they felt compelled to give the researchers some information. The conclusion to that study was that the 3-day record was most accurate (with fewest missing items) though it had the disadvantage of being rather time consuming for the children.

A similar project was undertaken in Minnesota by Weber et al. (2004) who aimed to assess the validity of self-reported food intake by 80 indigenous children aged 8 to 10 years. The children were first taught how to identify and record their daily food using diet records, and then they were later asked to recall their 24-hour food intake during interviews by trained staff. Prior to the commencement the children received training in portion size estimation and they were also taught about food types. For the purpose of comparison, and in order to validate the accuracy of their self-reported records, the researchers directly observed the children's intakes during school meals.

The results were quite definite; there were no significant differences between the children's diet records and the food (and energy intakes), which the children were observed to be eating during school meals. The children were able to correctly record and recall 75 percent of the foods they were observed consuming, and they correctly described and reported 83 percent of their food-by-food group. Agreement between recalled and observed food items was 75 percent, the participants correctly recording 57 percent of food quantities within 10 percent of observed quantities. The researchers later calculated that the percentages of energy intake from protein, fat, and carbohydrate from the children's records were not significantly different from the energy intakes from the observations for the combined school meals.

A key conclusion from that project was that the children were able to accurately report the macronutrient proportions of their total energy intake. Non-overweight participants were able to report their intake of total energy and macronutrients with reasonable accuracy. As in other studies e.g. (Crawford et al., 1994, Bandini et al., 1997) some overweight children tended to under-report their food; that is, they failed to include all their food, they under-estimated the portion sizes, and they failed to include all items.

Doubly-labelled water (DLW) has been adopted in a number of studies because it is a technique which yields accurate information on total energy expenditure (TEE). It entails biochemical measurement of metabolic rate by which the average metabolic rate of the body is calculated over a period of time. The use of DLW enables researchers to compare forms of diet records (such as self-reporting) with TEE so that the accuracy of self-reports and observations can be verified. In a person with stable weight, energy intake will be equal to energy expenditure, and so if energy expenditure (as measured by DLW) and energy intake (as measured by the calorific value of food items) are unequal then weight change will result. The use of DLW has the advantage of objective clinical accuracy, but it has a number of disadvantages; it is expensive, it requires access to clinical laboratory facilities, and it can be considered by some to be invasive insofar as it requires pre-and post-test samples of either blood, urine, or saliva (Speakman, 1997).

An early study examined the accuracy of dietary records by comparing them with DLW calculations was undertaken in Ireland by Livingstone et al (1992). With 78 participants aged three to 18 years, the aim of the project was to assess the validity of 7-day weighed dietary records and of diet histories by comparing them with the measurements derived from DLW analysis. The DLW analysis made use of urine samples collected daily over 10 or 14 days. For the written records the subjects were provided with dietary scales, a logbook for food consumed at home, a pocket notebook for food eaten elsewhere, and written samples and instructions on how to record their daily intake. Parents of the younger children (under age seven) were asked to oversee their child's daily records, the older children keeping their own diaries.

Similarly, a study conducted by Bandini et al. (1997) in Massachusetts compared diaries with metabolic analysis using DLW. With 109 girls aged 8 to 12 years that work was of two-week duration and involved the children using food diaries to record their daily intake. The girls were taught by a dietician to how to record their food in a diary, and food models and measuring cups and spoons were used to indicate portion sizes. To determine whether age or social factors might have influenced the diary records the team used multivariate regression analysis to take account of such matters as age, weight, total daily energy expenditure, body fat, ethnicity, and family income. The use of DLW extended over two weeks, several urine samples being collected for analysis. A shortcoming of that survey was the large number of variables which were tested, and thus the validity of the research method was somewhat complicated by the various ethnographic factors that were included.

Some of the lessons from Bandini's (1997) survey proved to be beneficial to this work too; his team found that the DLW analysis confirmed that food diaries were relatively accurate, commenting that one advantage of that methodology is that it represents current diets. However, they noted a positive correlation between accuracy and total daily energy expenditure, which indicates that subjects who ate more tended to report their food less accurately. They did not find any correlations with ethnicity or family income, but it was evident that older girls were more likely to under-report their food intake. It was surmised that the older girls might have been more aware of expectations of body shape, and that older girls spend more time away from home and so may forget or ignore outside sources of food. Another possible explanation was that younger children are more likely to receive closer parental scrutiny when completing their diaries.

One such study was completed by Garcia-Dominic and Wray (2010) who used three 24-hour dietary recalls to assess the validity of self-reported diet information by 614 nine-year-old boys and girls in Texas. Recognizing that self-reported food intakes in dietary surveys tend to underestimate actual energy intake, the researchers took the unusual step of using a new prediction equation for identifying inaccurate reports of dietary energy intake. That is, instead of seeking to quantify the accuracy of diet reports they aimed to use a reverse approach of identifying the inaccuracies – in particular the levels of under-reporting.

Garcia Dominic study performed three 24-hour dietary recalls. The recalls were face-to-face by trained staff that focused on interviewing and quantifying the food intakes described by the children. The multiple-pass interviewing methodology contained a scripted dialogue, food probing guides, and written recording methods. Food models and measuring utensils were used to assist the subjects to accurately estimate portion sizes. Parents were generally not present at the dietary interviews, though they were invited to participate in the interviewers when further clarification of the child's food intake recall was necessary. Using the prediction equations the study found that almost half of the children under-reported their energy intake. They found that the three 24-hour recalls were effective although they also found that in this group of children there were statistically significant differences in reporting by ethnicity ($p = 0.004$). As shown in other works Cullen et al. (2008), Lillegaard and

Andersen (2005), weight status is an important consideration in understanding the degree of under-reporting of energy intake, and so it was here where there were statistically significant differences in reporting by mean BMI. That is, children with the highest BMI reported consuming the fewest calories, and vice versa.

Finally, in this review it is useful to consider a work which is found to be particularly pertinent to this study. It was undertaken by Lillegaard and Anderson (2005) who compared the energy intake, as calculated from a pre-coded food diary, with energy expenditure as measured by an ActiReg device (a Norwegian position, motion and heart-rate monitor for calculating energy expenditure). Using 51 Norwegian boys and girls aged nine, they examined whether and how under-reporters (identified with an accelerometer) differed from acceptable reporters who were identified by means of food intake and BMI. The pre-coded food diary used household measures (eg. spoons, cups familiar to the children) and photographs to illustrate portion size estimation – which had been validated in previous work among Norwegian children and adolescents. The diary was comprehensive, comprising lists of 277 food items grouped according to typical Norwegian meal patterns. The diary was designed in the form of a cross-table with food listed on the left and time span across the top. The study was conducted over four consecutive days, and in that time the children also wore a waist-mounted ActiReg device which had sensors attached to chest and thigh.

The pre-coded food diary proved to be less time-consuming for participants compared with other methods, though it still captured much of the variability in food intake through the extensive food lists and an open-ended approach. Moreover, although it was the children who filled-in the diaries, parents reported that it was easy for the children to do in approximately 10 minutes.

3.3.3.3 Results assessing Tape-recorded food

Only one study was found regarding using this method in children. A rather different investigation method was undertaken by Lindquist et al (2000) who surveyed 30 children aged 6 to 12 in Alabama. On that occasion the objective was to ascertain the validity of using tape recorders (that is, recorded verbal reports rather than written records of food intake) and comparing those recordings with energy expenditure as measured by doubly labelled water. For the purpose of comparison the children were surveyed by way of three 24-hour dietary recalls and three 24-hour tape-recorded food records within two weeks of being dosed with the DLW. The children were considered to be representative of a range of body sizes and activity levels. Baseline data were collected on anthropometrics and various sociodemographic, dietary and physical activity factors. Also, baseline urine samples were collected prior to the subjects receiving doubly labelled water.

The use of telephone surveys is quite common, though that too has disadvantages, but audio-recording children's accounts of their food intake was innovative. The results showed low validity for the tape recorder method, with poor within-subject agreement and a weak correlation with energy expenditure as measured by the DLW (Figure 3.5). It was noted that inaccuracies in reporting were not random, with underreporting tending to occur at higher levels of energy intake and expenditure. Moreover the analyses showed that older children and children with higher adiposity were more likely to misreport using the tape recorders. The tape recorder method achieved greater accuracy among younger and leaner children and so it might be of use for those subgroups.

This under-reporting of intake in the tape recordings was unexpected for the researchers who anticipated more accuracy. That is, in the absence of personal contact there was expected to be less of a social desirability bias (that is, participants might be less ashamed to admit what they ate) because of the anonymity provided with the audio recordings. Indeed, anonymity was one of the advantages that the tape recorder method over interviewer-based techniques. However, the conclusion from that study was that there was poor validity from the tape recorder method and that it was not suited to dietary assessment among children.

3.3.4 Discussion

FFQs are often used in large epidemiologic studies, though diet records are often the instrument of choice for smaller studies (Garcia-Dominic et al 2010: Kobayashi et al 2011). This is so because large-scale studies can be conducted efficiently by means of computer-aided quantitative questionnaires whereas diet dairies require each record and each entry to be individually examined by the researcher.

FFQs ask participants to keep a record of the frequency of consumption of a defined list of foods (Martin & Worth, 2012: Roberts & Flaherty, 2010). The list might include information on portion size in order to estimate the overall intake, or the intake of specific nutrients. Usually a FFQ has a reporting period greater than 24 hours; that is, it may extend over several days, weeks, or month. Numerous writers have found that the validity of an FFQ improves if a more detailed food list is provided, though the list must not be so long as to weary the respondent (Wrieden et al, 2003: Roberts 2010). Also, it is important that the list is appropriate to the population.

A FFQ does not provide a precise figure for absolute nutrient intake; rather it classifies subjects on their positions relative to others by assigning quantile ranks (Martin & Worth, 2012). To comprehend the FFQ children usually have to be older than 12 years (Cullen et al., 2008), and for younger children it is necessary for an adult to help the child identify the appropriate items and to record the quantities. Compared with other approaches, such as food diaries and 24-hour recalls, FFQs are designed to record usual dietary intake. Moreover, they generally collect fewer details about such matters as cooking methods, and so the quantification of intake is not considered as accurate.

FFQs have the advantages of being quick and easy for participants to complete, they are relatively inexpensive, are suitable for both large and small surveys, and can be self-administered in any locations (Martin and Worth, 2012: Roberts 2010). However, they have a number of limitations too, in particular biases caused by errors in memory, and false (or unrealistic or mistaken) perceptions of food portion sizes. Additionally, daily variations in diet tend to be overlooked. To estimate nutrient intake the researcher must refer to food composition tables which must be appropriate to the types of food likely to be consumed by respondents, and the nutrient value of the food items need to be validated in relation to reference measures. There is uncertainty, too, as to whether the FFQ has sufficient precision to allow detection of important diet–disease associations. Schatzkin et al, (2003) and Fung et al (2001), among others, conclude that FFQs are not sufficiently comprehensive in regard to detailed data and so are not adequate as instruments for evaluating relations between absolute intake of energy or protein and disease.

Certainly the greatest concern with FFQs, and indeed with all methods of self-reporting, is reliability of the data supplied by participants. There are differences of opinion, and different experiences, mentioned by researchers. For instance, Price et al (1997, p 833) stated, “There is an increasing awareness that under-reporting of food intake may occur to a significant extent in dietary surveys, no matter how much care is taken to coax full and accurate information from the subjects”. The same authors likewise wrote; “There is considerable evidence that those prone to overweight tend to under-record their food intake, however low-energy reporting is not confined to the obese" (Price et al, 1997, p834). A cross-sectional study (n=118, mean age=10) balanced by race and gender was undertaken by Champagne et al (1998, p 426), concluding that under-reporting increased with age, and the "mean daily energy intake was underreported by 17 percent to 33 percent of energy expenditure". Under-reporting seems to be a common experience of many researchers, but others such as Martin and Worth (2012, p34) argue the opposite, that higher values of dietary intakes usually occur with first administration; that is, FFQ's generally overestimate habitual energy intake and greater frequencies of consumption at the completion of the first questionnaire, figures usually being lower if the questionnaire is administered again. Many investigations have used some form of FFQ, and according to Willett (2001) the validity of this approach has been confirmed by comparisons with other more detailed methods. However, all methods of dietary assessment have shortcomings, and the quantification of possible measurement errors is desirable for epidemiological studies.

However, measuring food intake in children is more difficult. When surveyed, children under about ten years old require close guidance and supervision because of their lack of understanding of such details as food types, portion sizes, frequency of meals, food ingredients, reduced ability to record mixed dishes, and lack of attention (Yaroch et al 2000). Indeed, techniques that require young children to record their own intake are vulnerable to considerable error, usually because of difficulty with recall, but also for sub-conscious desires to avoid being known to overeat, or to eat unhealthy food. The time between eating and recording, and the concept of time, can be problems when working with children. Similarly, children do not always reliably remember quantities or even types and contents of the food they eat – commonly ignoring snacks and other incidental items (Livingstone and Robson, 2000, Del Pino and Friedman, 2011).

Despite their small study sample, the results from survey by Crawford et al (1994) provided relevant comparisons between the different approaches, confirming the validity of short-duration diaries (that is, about three or four days) with 65% agreement between methods. Another positive feature of their work is that the team described the many research pitfalls that emerge when working with children, and it highlighted the need to use a technique which reduces the likelihood of participants forgetting their meals or confusing food types.

The survey by Weber et al. (2004) proved to be a very useful model for this thesis because it illustrated the importance of preparation and pre-survey training of the children. Their work gave great attention to teaching the children about food types and notions of portion sizes, the result being close agreement (correlations between 0.52 and 0.86) between the observed consumption of food types and quantities and the dietary reports provided by the children; that is, the children were found to be reliable reporters of what they had eaten.

Weighed dietary records were found to be rather unreliable, though the diet histories were more acceptable in the light of the measurements from the DLW. Although they were still relatively inaccurate, the diet histories were found to be more reliable for all age groups. In particular, it was noted that in the dietary records the adolescents tended to under-report their intakes, but, considered overall, the diet diaries tended to slightly over-estimate the intake. As in some other studies (Yaroch et al., 2000, Cullen et al., 2008), adolescents were less accurate than younger children in their records, possibly because of social pressures or their self-image. The team concluded that the use of DLW provided an accurate point of reference for all self-reporting systems, and they considered that motivation and compliance are key factors in achieving valid dietary studies.

Livingstone's (1992) work was only indirectly relevant to this study insofar as it required the use of DLW, but nevertheless this project considered a useful guide because it illustrated the various issues that can arise when children use diaries. Moreover, it showed that subtle differences in survey methodology can affect the outcome. For instance, a 7-day diary can be tiresome for younger children, and also children of widely differing ages treat the food records in rather different ways. That is, younger children generally tend to record what they did eat whereas adolescents can be selective, recording what they think they should have eaten.

In all dietary surveys an inherent problem concerns the ability of subjects to accurately identify and describe their food (especially cooked meals which contain mixed ingredients). Likewise, it is a challenge for subjects to accurately estimate the quantity of food they eat; that is, the size of portions. These obstacles are even more pronounced when surveying children who may have little understanding of weights, sizes, or food types. One approach that has become more common is to provide participants with pictures of different food that illustrates what is meant by portions. This technique can be modified to local circumstances and local cuisine; also it is inexpensive, easy to teach to children, and can provide fairly accurate representations of the meals and snacks which are likely to be consumed.

The use of diaries entails a number of considerations. Firstly, for young children it is essential that the diary entries be under the guidance of an adult because children may have limited language skills to adequately complete a diary, and they may be unable to identify the food types or to correctly estimate food portions. In such instances pictures and samples/models should be provided. To ensure accuracy, records of food consumption should be made promptly; in some studies use has been made of recording devices, while in others written descriptions have applied (Herrera Cuenca, 2015: ACAORA 2015). Secondly, it is important to take account of ethnic differences in the survey population because different ethnic groups commonly eat different types of food under different conditions (ACAORA 2015: Wilson 2011).

Advantages of diet diaries are that they record current food ingestion, and the duration of survey can be adjusted according to the requirements for precision of estimates of food consumption. They can be open-ended, enable accurate listing of portion sizes, and (if done immediately) do not rely on the children's memory (Wilson 2011: Roberts & Flaherty 2010). However, diaries have some limitations; they can be relatively expensive and labour-intensive for the researchers, they require reasonable levels of literacy and numeracy, and they call-on the goodwill and motivation of the participants. Moreover, descriptions of food types (which can include many blended ingredients) can be difficult so that coding and data entries can contain errors.

As Yaroch et al (2000) found that the use of pictures significantly strengthened the reliability of the study. It did not entirely eliminate the problems of under-reporting or over-reporting, but it did enable the team to confirm the benefits of pictures – especially for young people who may have limited literacy or little comprehension of food types. Compared with other such investigations the validity coefficients were significantly higher, the writers suggesting that this was due to the method of administration and the format. It was noticed that the use of pictures engaged the children more than the usual written formats (which some children find uninteresting). Moreover, it had the appearance of a game in which the subjects had to sort through the picture cards and select the correct pictures and portions. Another benefit of the pictures was that blended cooked foods were disaggregated – that is, the ingredients were illustrated separately (Yaroch et al., 2000).

Despite the fact that Yaroch el al's (2000) survey sample comprised adolescents rather than young children, their methodology provides an important lesson for researchers.

Certainly it was a useful model although there was considerable preliminary work in preparing the survey-information guides; nevertheless it proved to be important for ensuring validity. It demonstrated that greater preparation can yield better results, so the effort which gives to preparing and informing the participants (about the details of food types and food portions) helped yield data which were more reliable, thus ensuring the overall validity of this study.

While it has been noted that the undertaking of Lindquist et al (2000) was innovative and worth testing but it was ultimately shown to be a rather unreliable research tool and not suitable for this study. In the light of their findings it seemed evident that tape recorders and phone interviews would be inappropriate for this project. As some of participants were too young to confidently describe their daily food intake via tape recorder or phone, and to ensure the accuracy of their responses it needed to be present and to be able to refer to food pictures and measuring implements.

Similar to written diet diaries, diet recalls are a methodology which involve participants being interviewed about their food intake; these recalls typically entail participants describing the food they had eaten in the previous 24 hours, though in some studies the recalls are several days later. Some recalls are conducted face-to-face; others may require subjects to complete a questionnaire in which they indicate the food items, quantity, and time, food pictures often being used to help achieve accuracy. Food recalls and questionnaires have been applied in a number of studies, both techniques having advantages and disadvantages.

Despite the limitations of the 24-hour dietary recall, it is widely used in studies of both adults and children because it has the advantages of being inexpensive and easy to administer in many settings. Statistical methods have been devised to identify and screen implausible reports of energy intake, some of these methods for predicting energy expenditure being used instead of direct measures of energy expenditure. That approach involves comparing reported energy intake with predicted energy expenditure, which is calculated from age, weight, height, and sex.

The work by Garcia-Dominic and Wray (2010) made an important contribution to the study of childhood obesity, but the techniques were not quite appropriate for use in the current investigation. It was apparent that the multiple recalls would place an additional burden on the participating children. Moreover, it would have been difficult to have applied a statistical prediction equation because of the absence of suitable baseline data relevant to the Saudi context.

The selection of a research method for surveying diets in children is strongly influenced by determining who should provide the research data; that is, who would be most reliable and accurate in recording the dietary information - the child, parents, observer, or interviewer. As noted, various studies have found that young children (under about 8 years) do not have an adequate understanding of food names, ingredients, or portions, and thus are unreliable (eg. Livingstone and Robson, 2000: Garcia-Dominic et al, 2010). Children over 12 are considered to be capable of fairly reliably completing a food frequency questionnaire (Burrows et al., 2013), but for children between these ages (that is, 8 to 12) studies have usually obtained data from the child together with proxies such as parents.

The study by Burrows et al. (2013) arrived at the interesting finding that the energy data derived from the dietary information recorded by the children were closest to the total energy expenditure as measured by the DLW. That is, the children were the most accurate reporters, followed by fathers, with mothers the least accurate. The children’s 4-day weighed food record of total energy intake was also compared with the DLW; there was only a slight discrepancy between the two measures, indicating very good accuracy. It was noted that the weighed food record slightly under-reported the children's energy intake whereas the children's questionnaires slightly over-reported food intake.

In that study fathers were seen to be more precise reporters of their child's intake in comparison to mothers. This result was not expected as mothers are assumed to be more involved in meal preparation, that they oversee their child's eating behaviour and so are better informed of the child's intake. It is possible that mothers are prone to the social desirability of reporting what they believe the researchers want to hear, or possibly they may be influenced by the foods they serve their children rather than that actually consumed. These results also suggest that fathers are just as aware, if not more so, than mothers of their children's food and beverage intakes. The researchers did not recommend that children's dietary records should be fully trusted on all occasions, but their findings did indicate that children of ages 9 to 12 can, if supervised and guided, provide reliable information.

The work by Burrows et al (2013) was detailed and thorough, and had the advantage of baseline data from a previous Australian statistical survey. Although it was not immediately applicable as a model for this research because of its use of DLW, it was helpful because it made very good use of pre-test guidance notes for the participants and it confirmed the value of using weighed food records. Equally important, it showed that children can, if carefully prepared, make quite accurate recordings of their food intake.

The study by Kobayashi et al. (2011)was not a model that could readily be applied for this situation which was constrained by time, resources, and the limitations of approvals. Moreover, their project was complicated by the development of two questionnaires and by the use of a greater age-range among participants. Nevertheless it shed light on the relative advantages and disadvantages of questionnaires, and it confirmed that parental involvement in children's survey, while sometimes helpful, can give rise to other uncertainties.

The work in Brazil by Del Pino and Friedman (2011) found that energy intake was under-reported when compared with the energy expenditure. The boys had higher levels of under-reporting than did the girls; also, among the individuals there was considerable variability in the accuracy of the diary records. However, the writers considered that the proportion of under-reporting (18%) was acceptable, being within the range of previous studies by researchers such as Livingstone et al (1992) and Bandini et al. (1997). The team suggested that, as in other works, there were reasons for the under-reporting. For instance, they speculated that the parents shared the diary-writing with the children, but the children's reporting of eating events outside the home (in after-school care or other houses) may have gone un-noticed. In that study the girls showed a smaller discrepancy between energy expenditure and energy intake, possibly because the girls wanted to show how well they could follow instructions and fill in the diary.

Despite the under-reporting of energy intake, the authors concluded that this was an acceptable and reliable methodology which combined several measuring and reporting techniques. Moreover, their analysis did not show any systematic misreporting relating to macronutrients, unhealthy food, or BMI. This latter study was a useful model consisting of elements that could be adapted to this work. In particular, its application of a comprehensive diary that contained grouped lists of food items that closely reflected both local cuisine and portions typical to the meals of the local community. Moreover, it might be a suitable model because it made effective use of body-movement sensors to record energy expenditure.

Dietary studies have used various methodologies, but there is no standard system that can be applied in all situations. Consequently, research methods have to be adapted to suit local conditions.

A recent systematic review by Olukotun and Seal (2015) examined the various options for paediatric dietary research and listed the advantages and shortcomings, the biases and inaccuracies, the writers highlighting that results depend on the cooperation and honesty of the participants. In epidemiological studies, for reasons of time, cost, and efficiency food frequency questionnaires and short-term measurements such as 24-hour dietary recalls or food diaries are often used. But despite good intentions, both children and parents can misreport their food intake (usually unintentionally). Food frequency questionnaires are limited to a finite food list and are hindered by the failure of individuals to precisely recall and report their long-term consumption frequencies/ amounts.

Considering the results of this review, questionnaires and dietary records (unweighted diet diaries) can be valid methods to assess dietary intake in children. A variety of tools for both methods have been validated in children but it is still unclear which would be the best tool for a population of girls aged 8-11 years in Saudi Arabia. Therefore it was decided to test two different methods in a preliminary pilot study: a questionnaire and a diet diary.

The CADET (children and diet evaluation tool) is a questionnaire method and one of the more practical ways in measuring dietary intake in children. It was validated in UK children and used in large studies such as the National School Fruit and Vegetable Scheme, however; it has been used in children aged 3-7 years old (Roberts and Flaherty, 2010). According to a review conducted by National Obesity Observatory (NOO 2010) of dietary assessment methods in public health; , this tool is most likely applicable for older children.

The other tool that has been chosen to pilot is a four-day diary developed by the WAKEUP study group (Peninsula Medical School Primary Care) (WAKEUP, 2005). This required the participating children to record their own daily food intakes according to instructions and guideline samples (that is, sample portions/sizes) provided by the researcher. It was decided that these tools seem to be appropriate for this investigation and both of them will be piloted in our study population as none have been validated in Saudi children.

3.3.5 Conclusion

In summary, this review has shown that there is no single 'best' methodology for conducting dietary research among children. Although it was not possible to directly adopt a pre-validated methodology, nevertheless this overview of previous studies indicated the many and varied approaches (some proving to be valid and reliable, others less so) that can be applied in a survey such as this study.

Therefore, in the light of the studies cited above, the diet diary was selected as a methodology which has proved to be statistically acceptable and reliable in previous research. The food diary will be compared with a food questionnaire (CADET) in an initial pilot to assess the acceptability and reliability of these two methods in a sample of girls aged 8-11 years old in Saudi Arabia.

3.4 Justification of physical activity methods: Semi-systematic review of methodology to measure physical activity in children

3.4.1 Introduction

An important component of this research project has been the measurement of the physical activity (PA) of the participants. However, the measurement of PA has many challenges and so over the years researchers have applied and tested numerous approaches.

Moreover, the methods used to measure PA in adults are not necessarily appropriate for use with children. Children's PA can be different in nature and intensity to that of adults, and children's ability to comprehend or apply a subjective record of PA (such as a diary) can be unreliable and inconsistent. For instance, children typically have very sporadic activity patterns, more torsional movements than adults, and markedly fluctuating periods of intense play, situations which can lead to underestimations of activity (Bammann et al., 2011).

No single approach can adequately encompass the many variables that occur in PA and so most investigations now apply several measurement tools. In general, there are two broad categories of physical activity instruments objective and subjective (Sirard and Pate, 2001: Maduro 2009). Objective measures are those which do not entail personal, subjective judgements, instead relying on equipment such as heart-rate monitors, motion sensors (pedometers, accelerometers), doubly-labelled water, and calorimetry. Subjective techniques, on the other hand, include survey methods such as questionnaires and diaries. However, these latter should not be dismissed because they can be useful complements to objective measures, even though they are not always suitable for use with children. They are considered relatively undependable because they rely on personal perceptions of events, and those perceptions can vary between individuals and over time (Lubans et al., 2015).

Most research into free-living estimations uses two or more methods of evaluation, one is objective the other is subjective. In conjunction with the use of the various monitoring devices, it is common for some sort of complementary survey instrument to be applied, most commonly questionnaires and diaries. Like all survey methods, subjective techniques have limitations, but in recent decades a number of validation studies have been conducted using accelerometers and questionnaires, most reporting a fair degree of validity in these instruments. Many self-report questionnaires have been developed for assessing PA, however, they vary according to the purpose of the research and they differ in regard to the types of activities assessed and whether intensity and/or duration of activity are required. To be a valid research tool a physical activity questionnaire, like a measuring device, must be non-reactive (that is, it must not cause participants to alter their behaviour), it must be practicable, easy to use, and if it is accurate it may be regarded as reliable and valid (Hoelscher et al., 2009).

In this project steps were taken to ensure that the various methodologies were accurate, reliable, and appropriate for obtaining answers to the research questions. The following is an outline of the steps taken to review previous studies to justify the research techniques used here. As explained before, this review is described as a semi-systematic review as it fails to follow all the systematic literature review criteria (see section 3.3.1). The aim of this literature review was to identify methods suitable for measuring physical activity in children aged 8-11 years.

3.4.2 Methodology

3.4.2.1 Search strategy

The time-period selected for reviewing published reports was from 1990 to 2013 (the date when the pilot study was conducted). The search was conducted with MEDLINE, AMED, and Child Development & Adolescent Studies using the search terms and keywords relating to physical activity in children with Boolean Operators to combine or exclude the keywords. Table 3.7 outlines the steps in this search.

Table 3.7: Search strategy Terms

Population	Physical activity	Direct measurement terms	indirect measurement terms	General measurement terms
Child*OR Girls*	Sports* OR exercise* intensity* physical activity* PA	Accelerometer* Actigraph* monitors* questionnaire* Step* direct, objective, doubly labelled water, indirect/direct calorimetry, pedometer*, heart rate monitoring, GPS, direct observation	indirect, subjective, self-report, diaries, logs, questionnaires, surveys, interviews	Measure* tools, test*, assessment, evaluate*, valid*

All publications that have met the inclusion criteria as stated in Table 3.8 were included in this review, and if they met the exclusion criteria according to table 3.8 they were dismissed from this review. The numbers of studies retrieved, excluded and included are shown in Figure 3.2.

Table 3.8: inclusion and exclusion criteria for searching procedure

Inclusion criteria	Exclusion criteria
Healthy children	Did not compare at least two measures of PA
Population aged 5-18	Adults and infants
English and Arabic papers	Grey literature (eg. conference abstracts,
Female	unpublished articles, dissertations)
Direct and indirect measuring	Non-human studies
examining the agreement between at least two	
measures	

3.4.2.2 Data extractions

The studies deemed to be eligible have been included in this review. They met the inclusion and exclusion criteria and had been evaluated by the researcher.

3.4.3 Results

3.4.3.1 Overall Results

As shown below, 25 scholarly articles from refereed journals were identified for close analysis and a summary of these results are shown in Tables (3.9, 3.10, and 3.11)

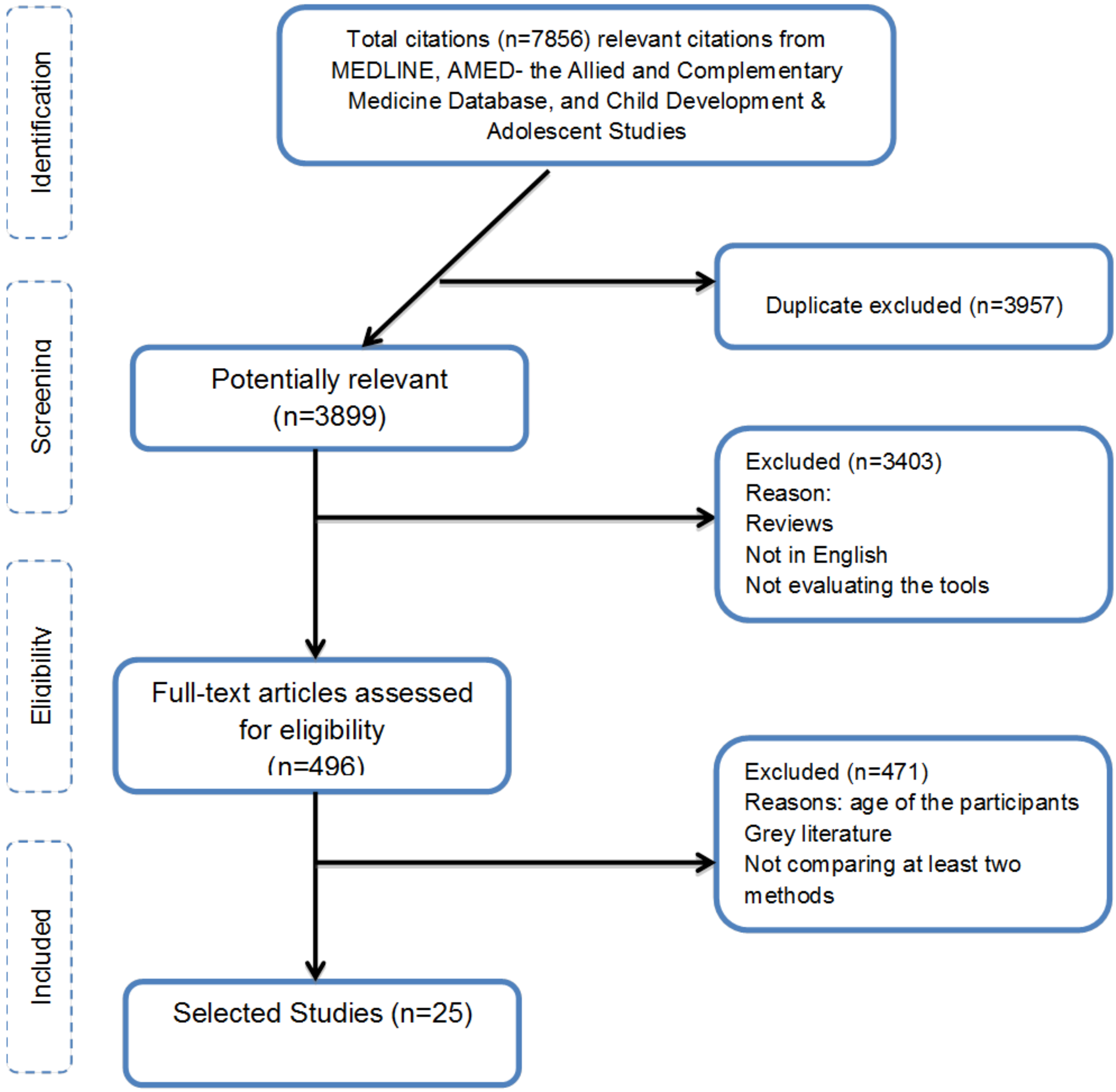


Figure 3.2: Flowchart of articles included in the systematic review of physical activity methods for children (based on PRISMA (Moher et al., 2009).

Table 3.9: Summary of studies assessing the accelerometer monitors (direct vs direct)

Author (year)	Sample	Method tools	Measurements	Duration	Results
Janz (1994)	7-15 years n=31 Girls=15, boys=16	Accelerometer (CSA) Heart rate monitor	Physical activity levels	3 days	- Accelerometer is a valid tool to measure PA levels in field. - Correlation r=0.67.
Janz et al. (1995)	7-15 years n=30 Girls= 15 Boys= 15	Accelerometer (CSA) Self-report	PA intensities	6 days	- Accelerometer is a valid to assess the intensity of children PA - Reliability achieved by 4 days or more of data collection - Questionnaires failed to assess PA with poor correlation (r= -0.03-0.51)
Trost et al. (1998)	10-14 years n=30 Girls=11 Boys=19	Uniaxial Accelerometer (CSA) VO2 by an automated system	EE	experiment sessions on Treadmill walking and running	- CAS showed validity and reliability in measuring the quantity of walking and running in children -Correlation in (EE r= 0.88, p<0.001)
Puyau et al. (2004)	7-18 years 32 n=32 Girls=18 Boys=14	Respiratory room calorimeters Accelerometer- Actiwatch (AW) Accelerometer- Actical (AC)	EE	1-h in an exercise laboratory 4-h in respiratory room calorimeters	- Both tools are valid in measuring AEE and PAR - Significant correlation was found between both tools and EE (r=0.79, 0.83) and between them and AEE (r=0.82, 0.85).
McDonald et al. (2005)	6-20 years n=97 Girls=56 Boys=41	StepWatch Activity Monitor (SAM) Heart rate monitor (HRMs)	Steps	3 days	- SAM is an accurate and valid tool in assessing PA levels in children - correlation (r=.49) between both tools - Sex effect significant different p=.042
Kavouras et	10-14 years	Accelerometer RT3	Walking/	Class room	- RT3 is a valid tool in assessing PA in

al. (2008)	n=42 Girls=13, boys=29	Heart rate monitor (HRMs)	running	Experiment	children during running and walking - Correlation between (r=0.633. p<0.001)
Arvidsson et al. (2009)	11-13 years n=20 Girls=11 Boys=9	Accelerometer (ActiReg) vs Indirect calorimetry SenseWear Pro2 Armband vs Doubly labelled water	EE by Walking and running	Treadmill	- Both tools need to be improved in assessing children -Gender effects significantly different p<0.001 - mean PAL values (1.67 ± 0.18)
Ekblom et al. (2012)	8-10 years n= 22 Girls=13 Boys=9	Accelerometer (Actigraph) Indirect calorimetry	TEE	7 days	- There were a correlation between Accelerometer output and TEE (r=0.80, p<0.001) - Accelerometer on waist appeared to be valid assessing physical activity in 8- 10 years old -Significant different between output form Acti- watch and Actigraph p<0.05.
Ojiambo et al. (2012)	4-10 years n=49 Girls= 25 Boys=24	Uniaxial accelerometer with heart-rate (HR) monitoring Triaxial accelerometer doubly labelled water (DLW)	Free-living EE TEE	7 days	- The validity comparison of both type of accelerometer is similar - Both device are valid in assessing free living activity EE in children -Both devices significantly associated with PAL (r=0.51, r=0.49).

Table 3.10: Summary of studies assessing pedometers (Direct vs direct)

Author (year)	Sample	Method tools	Measurements	Duration	Results
Mitre et al. (2009)	9-12 years n=27 Girls=14, boys=13	Pedometer accelerometer	Steps Walking EE	Treadmill	- Commercial pedometer was not valid in assessing walking - Accelerometer showed validity in measuring PA in normal or overweight children - Correlation between steps counts and walking energy expenditure ($r^2 \geq 0.86$).
Hart et al. (2011)	10-11 years n=36 Girls=21, boys=15	Pedometer Accelerometer (ActiGraph)	MVPA Steps	1 day	- Pedometer is capable to estimate MVPA - It is a low-cost and valid to evaluate PA measurements and steps -no sig difference between them. -Used thresholds of 100 steps/mins as MVPA

Table 3.11: Summary of studies assessing the questionnaire (indirect vs direct)

Author (year)	Sample	Method tools	Measurements	Duration	Results
Sallis et al. (1993)	10-11 years n=102 Girls and boys	Questionnaire Heart rate monitor	Physical activity levels	7 days	- Limited validity on young children - Correlation found of (r=0.53, p<0.001).
McMurray et al. (1998)	10-12 years n=45 Girls= 25, boys=20	computerized activity recall (CAR) Accelerometer (Tritrac)	Activity and TEE	5 days (CAR) 1day (Tritrac)	- Both methods are reliable but low level of agreement - Correlation between them for EE (r=0.51, p=0.0003) - CAR underestimated EE - Tritrac overestimated REE
Treuth et al. (2005)	7-19 years n=229 Girls=130, boys=99	Questionnaire (PAQ) Accelerometer (Actigraph)	TEE	2 days	- PAQ has acceptable validity for older children - significant correlation (0.34, p=0.004) - It showed reliability for all age
Basterfield et al. (2008)	6-7 years n=130 Girls=66, boys=64	Questionnaire Accelerometer	MVPA	7 days	- Questionnaire not reliable method - it overestimated MVPA -10000 steps/d used as cut off -- Weak correlation (r=0.26, p=0.02)
Bastos et al. (2008)	10-19 years n=857 Girls=66, boys=64	Pedometer Questionnaire	MVPA	7 days	- Questionnaire has moderate agreement with pedometer data
Saint-Maurice (2009)	9-12 years n=160 Girls=81, boys=79	direct observation (SOPLAY) Accelerometer	MVPA	2 different occasions	- Need more scanning to improve the validity

Huang et al. (2009)	9-12 years n=220 Girls=136, boys=84	Accelerometer Questionnaire (CLASS)	vigorous activity	7 days	- questionnaire overestimated VPA -correlation between both methods in estimating moderate to vigorous intensity was moderate for the girls (r=0.48, p<0.05)
Economos et al. (2010)	6-8 years n=41 Girls=20, boys=21	Self-report (PAS) Accelerometer	Physical activity	7 days	- PAS showed reliability but lack in validation of PA in early school children - test and retest were significant (r range0.57-0.74, p<0.001)
Bielemann et al. (2011)	4-11 years n=369 Girls=177, boys=192	Questionnaire Accelerometer	PA levels	5 days	- Face to face interview failed to be a valid method - Recommendation of using accelerometer -A significant small correlation between EE from both tools r=0.27
Bringolf-Isler et al. (2012)	6-14 years n=189 Girls and boys	Parental Questionnaire Accelerometer Diaries	Physical Activity and Sedentary Behaviour	4 days 24h	- Questionnaire should be improved based on age - Acceptable correlation in all ages (r= 0.55) - It is preferable to combined it with objective measurements awake
Platat and Jarrar (2012)	6-9 Years n=79 Girls=11, boys=9	Pedometer Questionnaire	Running	3 days	- Good reliability between pedometer and questionnaire - Significant correlation between total active time and steps (rho=0.890, p<0.01). - Questionnaire could be adopted in assess changes in PA in Arab children
Teo et al. (2013)	11-16 years n=425	Computer-based PA questionnaire (CPAQ)	Habitual physical activity	7 days	- Questionnaire showed valid and reliable in assessing habitual PA

	Girls=157, boys=168	heart rate monitor			The correlation between both methods with (r =0.72, p<0.001)
Foley et al. (2013)	10-18 years n=32 Girls and boys	Doubly labelled water MARCA consists of a single day (24h) activity recall	TEE and AEE	15 days	- Moderate validity in assessing TEE and AEE - Correlation between both methods in estimating TEE (rho=0.70, p<0.0001). - Moderate correlation in assessing AEE (rho=0.56, p=0.0009).

3.4.3.2 Results assessing the validity of direct measurements of PA: accelerometers and pedometer

In recent decades there have been marked advances in the measurement of PA using accelerometers. These small personal devices have been improved and refined, become more user-friendly, developed so that they have become more accurate and reliable, and cause minimal discomfort for users (Maduro and Frederico, 2009). Uniaxial, or single-plane accelerometers (that is, devices that record movements in only one plane, left and right, forward and backward), came into general use for research in the 1980s though they reportedly had a number of limitations. For example, these devices showed errors when estimating energy expenditure at a given speed, they were relatively insensitive to low-intensity activities, and inadequately register changes when the user was walking or running. Accelerometers record PA data for long periods of time, the data usually being expressed in counts (that is, steps or other physical movements), but these raw scores can be difficult to interpret since physical activities are based on minutes of activity (Welk, 2002). Equations are developed for each model of accelerometer so that the raw data, the activity counts, can be converted into time spent in different categories of activity intensity; however, the equations and their cut-off points vary between models because data obtained from accelerometers have different meanings (Welk et al., 2000). Consequently, with the development of each new device a new validation process must be undertaken.

In response to these shortcomings, several commercial accelerometers have been developed which use a more sophisticated ‘triaxial’ technology; that is, the sensors register movement along three axes – vertical, horizontal, and lateral. This literature search has entailed the examination of many studies into the application of both these types, of which several commercial models have been developed since the 1980s.

Several validation projects were undertaken by Janz (Table 3.9) in the early 1990s. First, Janz (1994) examined an early model CSA accelerometer [manufactured by Computer Science and Applications, Inc. of Florida], and this device was used in conjunction with heart-rate telemetry as a criterion measure. That model was non-intrusive and could be worn by children on various parts of the body – usually waist or wrist. It could record data over several weeks, could be pre-programmed to turn off at night, and could chronologically record several important health-related functions; duration, frequency, and intensity of movement. Trialled with 31 children aged 7-15 years, it was not undertaken in controlled laboratory conditions; rather it was in their usual home, school, and outdoor settings. The project yielded correlation coefficients [between the raw data and the heart-rate monitor] which the author described as 'moderate to high', concluding that this finding "strongly supports its validity and utility as an objective method for measuring physical activity in children in field settings" (Janz, 1994).

Again using a CSA accelerometer, Janz et al. (1995) conducted a validation project which aimed (1) to derive accelerometry summary variables which represented different levels of PA, (2) to evaluate the stability of those variables, and (3) to determine the number of days needed to accurately measure usual physical activity. For the purposes of comparison, the research team used three self-report questionnaires. Using 30 participants (15 boys, 15 girls) aged 7-15 years; the PA was recorded by a uniaxial CSA model attached to the waist (Table 3.9). The accelerometer made readings every minute for three consecutive days, the devices being removed only while showering, sleeping, and swimming. One month later the protocol was repeated so that data for a total of six days were recorded for each child. Results of this study were mixed, the team found that the data for just one or two days of readings showed limited correlations, but after six days the correlations indicated that the accelerometers produced an acceptable measurements. Janz and colleagues (2005) also stressed that while accelerometers are very reliable and consistent in controlled environments, they are less so in field settings where numerous and varied activities can occur.

The researchers also noted that there was little correlation between the accelerometer data and the questionnaire. There was low correlation after three days of data collection, and even after six days the correlation rate remained low (Janz et al, 1995).

Another validation test using a CSA accelerometer was conducted by Trost et al (1998) who evaluated the monitor as a measure of children's PA using energy expenditure (EE) as a criterion measure. On this occasion the monitor was a refined version of earlier models used by Janz et al (1995); here they used the WAM 7164 which was a uniaxial single-plane device which was worn on the waist (though it could be positioned elsewhere on the body). This model could record for six weeks that it could be programmed for start and stop times, and that it could record at short one-second intervals as well as longer intervals. Their work involved 30 children aged 10-14 years who each undertook three five-minute treadmill bouts at different speeds (3, 4, and 6 mph). The participants wore CSA activity monitors on the right and left hips, and oxygen consumption [VO2] was recorded by an automated system. EE was determined by multiplying the average VO_2 by the caloric equivalent of the mean respiratory exchange ratio.

The results showed that both CSA monitors were sensitive to variations in treadmill speed and that the activity counts from the two accelerometers were almost identical at all speeds. Moreover, the activity counts from both CSA units were strongly correlated with EE, and from these the research team developed an EE-prediction equation which proved to yield high correlation between actual and predicted values.

Other modern devices were tested by Puyau et al (2004), on that occasion two accelerometers were employed to measure children's PA, energy expenditure being the criterion measure. Actiwatch and Actical (manufactured by Philips Corp.) monitors were validated against continuous four-hour measurements of EE in a respiratory room calorimeter and one-hour measurements in an exercise laboratory. The participants were 32 children/adolescents aged 7–18 (Table 3.9), all of whom performed a course of highly-structured activities: cleaning, using a computer, playing Nintendo, doing aerobic exercises and treadmill walking and running. Equations were developed to predict EE while taking account of different ages, sex, weight, and height.

Results showed that there some differences between the EE estimates and it was commented that accelerometers might be better applied to groups rather than individuals. The two devices displayed different levels of sensitivity for different activities; sensitivity being highest for activities above the 'vigorous' threshold, though for activities of light or moderate intensity the recordings were of acceptable levels too. Both devices yielded valid measures of children's EE, and could discriminate sedentary, light, moderate, and vigorous PA, although further studies were needed to enable more accurate predictions of EE of individuals.

Several years later Kavouras et al (2008) evaluated the RT3 device (produced by the Stay Healthy Corporation of California). The aims of that investigation were to assess the suitability of the RT3 for children, to compare its accuracy with heart rate monitoring, and to develop an equation to predict EE using RT3 data. Forty-two participants (mean age 12.2 years) used a treadmill at two horizontal walking speeds (4 and 6 km/h), one horizontal running speed (8 km/h), and two speeds (4 and 6 km/h) for an incline of six degrees. Energy expenditure and oxygen consumption (V O_2) served as the criteria measures.

The RT3 is a triaxial accelerometer which is suitable for field studies, as it is quite small and capable of collecting data for periods up to 21 days. Particular attention was given to evaluating the device for use on gradients. This study sought to assess the utility of the RT3 accelerometer for the assessment of physical activity in a mixed group of children, during both horizontal and graded treadmill activities, and compare its accuracy with heart rate monitoring and indirect calorimetry. Conducted in controlled gymnasium conditions, the children undertook treadmill walking at 4 and 6 km/h, horizontal jogging at 6 and 8 km/h, and walking up a six-degree incline at 4 and 6 km/h. Cross-validation statistics indicated that the predicted EE did not differ significantly from the measured energy expenditure. In this there were variations between the monitor data and the EE for a variety of activities.

A rather different evaluation project was undertaken by Maduro and Frederico (2009) who tested the validity of SOPLAY with data from a Biotrainer Pro accelerometer. SOPLAY one of recording objective data tool, it records activities, and levels of PA during leisure times in controlled areas such as school grounds. Using a total of 160 children aged 9-12 years; data were collected over the course of 19 different physical activity sessions. The SOPLAY technique was used to evaluate the activity levels of the groups of children on two different occasions. The researcher tested for any agreements between the accelerometer and the influence of SOPLAY sampling rate.

Results yielded marked difference between observed and recorded activity levels, and these varied depending on what SOPLAY coding was used. There were large and significant differences when a standard scoring system was used for interpreting the SOPLAY, but the differences decreased with increased regularity of observations.

Another study emphasised the importance of wearing place of accelerometer; Ekblom et al (2012) conducted a comparative study using the Actiwatch (worn on the wrist) and the Actigraph which is worn on the hip. Using the Actiwatch they sought to assess the validity of the monitor for estimating EE to determine cut-off values for light, moderate, and vigorous activities, and to assess its reliability. The children wore both devices while indirect calorimetry was used as a criterion measure. All-over correlation between the accelerometer data and EE were found to be quite high (0.80), although EE estimates differed between the Actiwatch and the Actigraph. Actiwatch placed on the waist was valid for measuring the PA of both boys and girls, and they also confirmed that the instruments could reliably be used for estimating EE. Additionally, these devices could be located on either waist or wrist without loss of sensitivity or effective function.

A more complex validation exercise was undertaken by Ojiambo et al (2012) who tested several types of accelerometers using different criteria. The aim of that project was to assess the accuracy of two models of uniaxial devices and one triaxial model. Using 49 European children (25 female, 24 male) aged 4–10 years, this study sought to evaluate the prediction of EE by comparing the validity of uniaxial accelerometry [with heart-rate monitoring as the criterion] against triaxial accelerometry [with doubly-labelled water as the criterion]. The devices to be tested were the uniaxial ActiTrainer with HR, the uniaxial 3DNX, and triaxial 3DNX accelerometry. Total energy expenditure was estimated using doubly-labelled water over a period of one week. The ActiTrainer was a version of the Actigraph, described above, which had the added function of recording heart-rate. The uniaxial and triaxial models of the 3DNX were produced by BioTel Limited of Bristol, UK.

This project was rather different from those described above insofar as three devices were being tested, and both heart-rate and doubly-labelled water were used as criteria. The test program extended for one week and the monitors recorded all PA in an unregulated free-living setting.

The inclusion of heart-rate data added considerably to the value of the ActiTrainer as a measuring device. Locating the devices on the hips of the children, the researchers found that under free-living conditions both the uniaxial accelerometer [with HR monitoring] and the triaxial accelerometer were valid and reliable as measuring devices for assessing EE in young children.

Another study conducted on children aged 9-12 years by Mitre et al. (2009) in order to assess the validity of commercially available pedometer against accelerometer-based Step-counter and has shown less accuracy. Whereas another study carried out on children aged 6-9 years in order to validate the questionnaire against pedometer (Yamax Digiwalker SW-200) showed an acceptable agreement (Platat and Jarrar, 2012) (Table 3.11).

Regardless of the fact that a commercial pedometer failed in accuracy, a study done by Bastos (2008) used a pedometer on 857 boys and girls aged from 10-19 years to validate the Brazilian questionnaire and its used as an assessment tool. This explained that the type of pedometer may effects the data collection therefore many studies used non-commercial pedometers such as Yamax Digiwalker SW-200 or Digi Walker SW 700.

3.4.3.2 Results assessing Subjective Measurements of PA: Questionnaires and Diaries

One such an evaluation of a subjective instrument was performed in California, by Sallis et al. (1993) who surveyed 319 children aged 10-11 years in several schools (Table 3.11).

Efforts were made to recruit a representative cross-section of the populations of several schools and to include obese and lean, active and inactive children. The aim of the investigation was to assess the accuracy of the seven-day recall questionnaire: that is, to test the ability of young people to report the duration, frequency, and intensity of the physical activities. The researchers took detailed demographic and physiological records and heart-rate monitoring (using a 'Heart Watch' device) served as the criterion for assessing the validity of the project. Over the course of several weeks five PA sessions were conducted, these being followed by questionnaire and recall surveys such as the seven-day PA recall and the Godwin-Shephard Survey. This latter is a simple survey system in which the participants are asked to list the number of times in the preceding week they had undertaken 15 minutes or more of light, mild, and strenuous activities.

The ability of children to record their PA was tested and then retested using stringent standards, the recordings of the heart-rate monitors being correlated with the subjective recall. They noted in particular that strenuous activities were recalled and described with greater accuracy than the other, milder, exercises, and as might be expected, it was found that the closer correlations were age-related; that is, older children tended to be more accurate and reliable in their ability to record their PA. The overall conclusions were that the seven-day recall survey was reliable (with a correlation of (r=0.53) for children under about age ten, and those of an older aged could recall with an accuracy equivalent to an adult. While the ability of the participants to recall accurately decreased from (r=0.79) for 2-4 days to (r=0.45) for 5-6 days recording. They recommended that, if possible, participants should record their PA experiences no longer than 7 days and preferably within about 24 hours.

A study by Treuth et al. (2005) likewise sought to identify methods of PA self-reporting that could reliably be undertaken by children and adolescents. Their study, conducted in

Maryland with 229 male and female students from fifth, eighth and eleventh grades, was to assess the reliability and validity of several self-reports systems. Conducted at various intervals over one year, the participants were fitted with an Actiwatch accelerometer for periods of six days at a time, and they were later asked to record their PA by way of a modified Fels PA questionnaire. That questionnaire contains eight items: three are ‘open’ questions for which activities are listed by the participant and the frequency of participation for each activity is listed. The other questions use a Likert scale to evaluate physical activity.

The reliability of this questionnaire for all the children, both girls and boys, and in the elementary, middle, and high school age groups, was quite high and ranged from 0.48 to 0.76. Moreover, the test-retest reliabilities were high, too, at r = 0.77 for the seven-day recall interview and 0.81 for the self-administered survey. Validity of the seven-day recall was determined by comparing heart rate and movement monitoring records with recalls of very hard activities on the same day. The authors noted that, as might be expected, reliability improved with age. It was found that memory skills and obesity status were not related to the reliability of recall, but males were more reliable reporters than females. The research team concluded that validity improved with age, but that the validity coefficients were significantly positive in all age groups. The authors also concluded that physical-activity recalls of children as young as the fifth grade (10 years) are of adequate reliability and validity to use in research on physical activity in children.

It is not possible here to review all such validation studies, however two other recent works are of pertinence. An investigation by Teo et al. (2013) in Malaysia used a computer-based survey approach. Using a cross-sectional study design it examined the PA of 425 adolescent boys and girls. A seven-day physical activity logbook was the subjective record and heart-rate monitors provided the objective criteria. The objective of this enquiry was to assess the validity and reproducibility of a new computer-based physical activity questionnaire to determine the habitual physical activity levels of Malaysian adolescents. The participants were aged 11–16 years who were recruited randomly from four different schools in the state of Kelantan.

The authors were prompted to explore a computer-based methodology because the use of conventional written questionnaires and diaries has inherent limitations; for instance, they can numerically limit the survey population and they can be subject to personal biases of various sorts. The authors claim that the computer-based system has been increasingly accepted as being relatively useful, and cost-effective. It is said to require less time to complete, and less time to assess; this latter is additionally helpful when assessing the information concerning specific health and lifestyle-related behaviour. It is also claimed to reduce potential coding errors, while data collection can be determined more accurately because questions in the computerised system cannot be omitted by the participants. Moreover, this assessment approach is said to increase and maintain participant attention as a novelty assessment approach by using computers. Any potential interview bias can also be significantly reduced, though of course it cannot ensure that questions are answered fully or honestly.

Being conducted over a one-year period, the computer-based system was formulated so as to capture the detailed information on all physical activities performed in that time. Data were sought from most phases of daily life; during school and after school; on weekends, and for sporting activities during school. The computer-based system was developed with two modules, namely: a PA questionnaire module, and a computing analytical module. Seventy-one types of PA that are commonly performed by the participants were identified, these being included in the new questionnaire. Objective criteria were obtained from chest-mounted heart-rate monitors: 42 participant boys and girls were instructed to wear a heart rate monitor each (Model: Polar S810i) for three consecutive days, comprising two weekdays and 1 weekend day.

The authors found that the mean estimated total PA level calculated from the computer-based questionnaire was 14+/-17 hours/week, for the PA written log it was 12 hours/week, and for the heart-rate monitor it was 53 ± 26 min/day. Thus, in general, the mean weekly estimated total PA levels measured by the computer system was higher than the PA levels assessed by the seven-day record in both participant boys and girls.

It is relevant to note a similar study by Philippaerts et al. (2006) reached a similar conclusion. That team stressed the many advantages of computer-based systems, writing that computer networks and the internet are ubiquitous, thus making it possible to conduct much larger studies than before. It is also possible to readily modify PA survey programs to suit all age groups, questions being added or removed according to need.

Not all validation studies yield positive outcomes, one such project being conducted by Basterfield et al. (2008). That research team sought to validate the parent-reported 'Health Survey for England' PA questionnaire which has been used in the UK to shape public policy and programs. The 'Health Survey for England' questionnaire aims to assess the habitual level of moderate and vigorous PA, but unlike self-report systems (discussed above) it relies on parental reports which do not include physical activities undertaken at school. Also, and assumes that all those PAs which are reported are of moderate-to-vigorous levels, light exercises being ignored.

The researchers sought to validate the questionnaire against measurement of PA using accelerometry in children aged 6-7 years. A total of 130 children (64 boys, 66 girls) were recruited, and the survey aimed to identify the levels of habitual moderate-to-vigorous intensity PA. As a point of comparison, objective measures were recorded by means of seven-day accelerometry with the Actigraph (model 7164) accelerometer.

Finally, it must be noted that another tool for validating PA surveys is the use of doubly-labelled water as a criterion. This methodology was not adopted for this thesis because it is relatively expensive, it requires access to analysis laboratories, and in some situations and cultures it might be considered intrusive. However, a recent enquiry by Foley et al. (2013) used that approach in a survey of 32 participants aged 10-18. The researchers concluded that it was a useful and accurate measure of both total daily energy expenditure and activity-related energy expenditure.

3.4.3 Discussion

3.4.3.1 Accelerometer and pedometer

In reviewing the literature, while the CSA accelerometer was a reliable device for recording PA the data did not highly correlate with the subjective questionnaire information – though this may have been because of the inherent shortcomings of the use of recall systems with children.

According to Trost et al. (1998) the CSA model was valid for use in laboratory settings but may be unsuited for field settings. Moreover, when considering the relative merits of uniaxial and triaxial accelerometers both were found useful. They commented that for recording sedentary activities (writing, standing) triaxial accelerometers may outperform uniaxial devices in predicting energy, however uniaxial accelerometers may still provide useful estimates of non-locomotor physical activity because movements in the antero-posterior (forward/backward) and medio-lateral (sideways) planes are typically accompanied by some movement in the vertical plane.

Despite the fact that CSA device was valid and suitable for use with studies of children's' PA in controlled laboratory environments, work on adults has found marked differences between laboratory and field counts, especially for activities of light and vigorous intensity. In conclusion CSA device was reliable for quantifying walking and jogging outdoors on level ground, but laboratory equations for EE may not be appropriate for field settings, especially for light and vigorous activities (Nichols et al., 2000).

Although the RT3 could precisely differentiate intensity variations during walking and running, when manifested as changes in speed, but demonstrated an inability to detect changes in intensity on a gradient; that is, this device would probably be better suited for evaluating horizontal activities rather than those where inclined planes were involved. Observations of PA by way of the SOPLAY system confirm the data from the accelerometer, but it was clear that more frequent scans were needed improve the validity of the estimations of PA.

However, while triaxial accelerometers in general may provide more information that can help ensure accurate measurement of EE under very diverse conditions (such as when children are engaged in complex games and sports), in this test the 3DNX accelerometer did not yield any noticeably better levels of information since only the longitudinal axis was a significant predictor of EE.

Janz et al. (1995) also stressed that while accelerometers are very reliable and consistent in controlled environments and, they are less so in field settings where numerous and varied activities can occur. They speculated that this is especially in regard to children's activities where the devices may not record torso movements or movements in a vertical plane – both of which are very different from the regular rhythmical actions involved in testing for PA on laboratory equipment. Moreover, the writers speculated that with respect to aerobic PA this occurred because the children were unable to accurately report the duration of their various activities (Janz et al, 1995).

While the value of accelerometers as a means of measuring PA has long been accepted, there has always been some concern about the best location for the devices on the body. Wrist, waist, and ankle have been the sites most commonly used, however, each has limitations. Moreover, the siting of the device will depend on the activities to be measured: for instance, as noted above, some waist-mounted uniaxial monitors are well-suited to measuring activities in just one plane (such as walking).

Accelerometers have the advantage of recording frequency, duration, and intensity of PA, being especially useful for such lower-body activities as running and walking (Troiano et al., 2008). But, like pedometers, they are not suited to such activities as cycling or upper-body movements. Another important limitation is that the raw data have to be converted into meaningful units relating to EE so that the information can be processed, analysed and interpreted. Moreover, several studies have produced conclusions of the validity of the accelerometer in order to measure physical activity level in children; however the cost of these instruments is expensive to use in a large study.

Pedometers have the advantages of being inexpensive, objective, re-useable, and nonreactive. If correctly calibrated, they accurately record the number of steps and the distance travelled, however they are limited insofar as they can only detect and count steps over an observational period, being unable to indicate the intensities or patterns of activities performed consequently questionnaire will be used to fill this gap. Several recent reports (Lubans et al., 2015, Clemes and Biddle, 2013, McNamara et al., 2010, Tudor-Locke and Lutes, 2009) have shown that pedometers can be used reliably for large-scale epidemiological studies and interventions, though all admit that the devices have strict limitations.

Recent work by Park et al. (2014) found that modern pedometers work reliably on both flat and uneven terrain. Also, they noted that they can be worn on most parts of the body, though they are usually worn at the waist or on arms; but they were not accurate if stored in pockets or purses. While particularly useful for recording PA in such activities as walking and running, they are not suitable for cycling, and they do not measure features of the activity; for instance, they do not record if the walker is moving up or down an incline (Tudor-Locke and Lutes, 2009). Another concern – although this applies equally to other monitoring methods – is that awareness of the presence of the instrument may prompt the participant to behave in ways that are untypical.

Numerous studies have examined the accuracy, reliability, validity, and suitability of the various commercially-available pedometers for use in research projects. Some instruments have been found to be quite acceptable for research, others less so. Loprinzi and Cardinal (2011), Trost (2007), Schulz et al (2001) and others have conducted reviews of the applicability of pedometers in fitness and obesity projects, reporting that, in general, when used within the recommended guidelines, they are reliable tools for research. Scruggs (2013) compared two commonly-used pedometers, finding that while they performed adequately when recording steps per minute, one was more accurate than the other for discriminating levels of PA. Leicht Leicht and Crowther (2009) tested the Yamax Digiwalker, often used in surveys, reporting that it performed reliably on level surfaces, but if the incline was greater than ten degrees then the results varied - with noticeable differences between recordings of ascents and descents. Results such as these highlight the importance of ensuring the correct calibration of the instrument according to the setting and according to the user – a child obviously taking shorter steps than an adult. Similarly, a meta-analysis by McNamara et al. (2010) identified some shortcomings and limitations, but nevertheless they concluded that pedometers “can effectively be utilized as a valid determinant of physical activity levels among children and adolescents”.

In comparative studies of pedometers and other research approaches, these instruments have been found to correlate closely with direct observations and with convergent validity involving heart-rate monitoring and accelerometers (McNamara et al., 2010, Tudor-Locke and Lutes, 2009). The levels of correlation between pedometers and accelerometers have been found to vary according to the setting and type of activity. For instance, they are more strongly correlated when used in recreational settings than around the home or in classrooms, but overall they show very high levels of correlation regardless of whether the children are very active (running) or moderately active (steady walking) (Tudor-Locke and Lutes, 2009).

Their main function, and their strength as research instruments, is that they are effective for recording regular steps, but they are less useful for recording other movements, or patterns of movements (McNamara et al, 2010). For instance, they are not effective for recording low levels of physical activity, and they are insensitive to non-locomotor forms of movement (that is, non-walking movements that may entail torsional or lateral motion). In addition to these constraints these devices are unable to record the magnitude of the movement detected; for example, whether the steps occurred during walking, running, or jumping. Consequently, pedometers can only provide an estimate of the relative volume of activity performed over a specified time period, assuming that most of the activity performed involves locomotor movement such as walking.

Differences between models in regard to the recording, calibration, use, and data-processing means that there are no agreed protocols for accelerometer use. Numerous researchers have had to devise equations and algorithms to interpret the data, but even now there is a lack of agreement on the best methods for analysing the information provided by accelerometers (Chinapaw et al., 2014, Trost, 2007, Freedson et al., 2005, Crouter et al., 2012). Researchers using such instruments need to be aware of the regular changes to the frequent updates and changes made by manufacturers to the hardware and software; these affect the use of the instruments and they make it difficult to compare outputs over time. Likewise, the use of different systems and units by different manufacturers impede comparison of results of different research studies (Pedišić and Bauman, 2014). There are more recent professional accelerometer devices that could be used depending on the study purpose, such as GT9X Link and wGT3X-bt manufatered by Actigraph. These have been validated by Moran et al. (2016) and Blythe et al. (2017). Several commercial devices are also now available such as Fitbit and Garmin vívofit 3. Although they are relatively new on the market, they have been used recently with children in studies by Klein (2015), Hayes and Van Camp (2015), and Ehrler et al. (2016).

In summary, there are no fixed or 'best' methods for measuring PA by children. Pedometers and accelerometers have evolved to a high standard of reliability, and they are often used to complement other research approaches. It can be seen from the studies outlined above, that the use of tested and valid movement monitors is crucial for all studies into physical activity. Fortunately, there are several reliable accelerometers and pedometers now available, though they must be used according the prescribed protocols.

3.4.3.2 Questionnaire

Bringolf-Isle et al (2012) considered that their questionnaire design was well-suited to allow them to observe patterns of PA and sedentary behaviour across developmentally distinct age groups of children. However, a severe limitation was that self-reports may not accurately capture honest information about sedentary behaviour because of the social desirability of being seen to be active and fit, and these social pressures may contribute to under-reporting biases.

As mentioned above, in many previous studies the use of accelerometry as an objective measure of PA has been validated repeatedly in children, and the evidence on validity and reliability has been reviewed and critically appraised. Basterfield et al (2008) therefore stated that it was reasonable to conclude that any differences in the results obtained by the questionnaire and the accelerometer would be the result of errors in the questionnaire. Also they found that the levels of habitual PA of the participants was very low, and that the data obtained from the questionnaire greatly overestimated the amount of PA of the children by about two hours per day (Basterfield et al., 2008).

The authors dismissed that particular survey method as being unreliable and of little value (Basterfield et al., 2008). They stated that the children's apparent levels of PA from national surveys had been seriously overestimated. It was not clear from their work whether, when completing the questionnaire forms, parents genuinely believed that their children were more active than they were or whether they felt that it was desirable that their children should be seen to be very active; for being active is usually equated to being fit and healthy. It was concluded, too, that the use of the data from UK health surveys should not be used to determine public policies, to assess performance in relation to public health targets, to describe general trends in regard to children's physical activity, or to regard the PA survey data as a measure of children's health.

However, as explained below, PAQs - and especially those for children - have their limitations and so many writers insist that the usefulness of questionnaires can be strengthened if they are complemented with data from objective mechanical methods such as pedometers or accelerometers. Using multiple methods enables triangulation of results and a more comprehensive measure of children's behaviour. Consequently, many writers urge the use of a combination of self-reports, proxy reports, and objective measures by means of such technologies as pedometers or accelerometers (Dyrstad et al 2014: Hills et al 2014: Trost 2007). Hills et al (2014) found that PAQs are notorious for overestimating vigorous PA and underestimating time spent being sedentary. Robinson et al (2011), Helmerhorst et al (2014) and others summarise the main advantages and limitations of subjective questionnaires for children as follows in Table 3.12:

Table 3.12: summary of the advantages and limitations of using PAQ on children

Advantages	Limitations
• Relatively easy to conduct • Require no laboratory equipment • Reliable if conducted appropriately • Able to measure large populations at low costs • In theory, recall does not alter behaviour • Several dimensions of PA can be assessed • Results can be extrapolated to EE • Readily modified for a wide range of populations • Enable comparisons with other similar studies	• Some biases resulting from poor recall • Semantics may be an issue – eg terms such as ‘moderate intensity’ • The possibility of incomplete answers • Limited choice of activities listed in the questions may be inappropriate to some people • The data may not be sufficiently sensitive to slight or subtle changes in levels of activity

Children’s PA is usually unplanned and they experience a range of types of physical activity through a combination of games, sports, free play, incidental behaviour, and transport (i.e. walking, cycling to/from school) in different settings throughout the day (Telford et al 2004). Consequently, it can be difficult for children to accurately recall and quantify their activities using self-report methods. Writers on this subject also note that self-report instruments are inappropriate for children less than about 10 years old because of their limited cognitive abilities (Crocker et al 1997: Robinson et al 2011: Dyrstad et al 2014). For such children proxy reports by parents, guardians, or teachers are often used, though even those observations may have limitations too because children’s activities are accumulated in many different settings during each day and the proxies may not observe all that the children do.

Robinson et al (2011) and Borowski and Bowles (2012) list several questionnaires for surveying young people but a method that has been used in several recent studies of children and early-adolescents [and which was adopted for this project] is the Physical Activity Questionnaire for Children (PAQ – C). Usually conducted over a period of about seven days it was developed by Canadian researchers Kowalski et al (2004) who sought to assess general levels of physical activity of young people aged between 8 and 15. The PAQ-C comprises ten questions, nine of which sought information about the nature and duration of the activities. They sought to elicit data about activities at school and at home, though it would have to be modified to suit the particular context of the survey; that is, the original questions included skiing and ice-hockey, sports not applicable to Saudi Arabia.

Most researchers make comments about the extent of mis-reporting, but there no clear patterns about when this is likely to occur. For example, Telford et al. (2004) found that their child respondents underestimated the time they spent in moderate physical activity by 21 min/day and the time they spent in vigorous PA by 23 min/day. But another similar survey reported the opposite; children overestimated their physical activity by 29 minutes using the self-administered PA checklist and by 48 minutes in interviews (Sallis and Saelens, 2000). Interestingly the parents in the latter project were equally poor at accurately estimating their children's physical activity duration. In this project the questionnaire was moderated by the researcher and by teachers who were present for much of each day.

As part of this research a pilot study was conducted to record the physical activity of the participants (Chapter 4). Considering the review of methods for measuring PA in children above, it was decided to trial using the Yamax Digi-Walker pedometer (model 'CW700 Professional') and a questionnaire based on an established self-reporting recall system, the Physical Activity Questionnaire for Older Children (PAQ-C), although it will be modified slightly and translated into Arabic to cater for the requirements of Saudi culture. As a point of combining and assessing for ascertaining the reliability of the devices the girls will record their daily activities in a physical-activity questionnaire as well as wearing pedometer. Validated in a number of previous studies, the questionnaire records the child's level of physical activity over a period of four days using descriptive categories; 'simple', 'moderate' and 'vigorous' (Crocker et al., 1997). The recent study in Arab children conducted by Platat and Jarrar (2012) (Table 3.11) demonstrated the validity of both methods on children.

3.4.4 Conclusion

The following conclusions can be drawn from the previous studies as there are multiple subjective and objective methods of assessing physical activity in children. The current investigation is limited by costs, population and period of the study; therefore it is difficult to decide the best methods considering all limitations. For the aforementioned reasons, a pedometer and questionnaire were chosen to be piloted in this study (Chapter 4) as they have shown acceptable validity and reliability for measuring the amount and intensity of physical activity in children.

Chapter 4: Phase one: piloting of the study methods in girls 8-11 years in Saudi Arabia

4.1 Introduction

Phase one was a pilot study to evaluate methodology to examine body mass and composition, nutritional intake, and amounts of physical exercise of primary-school girls aged 8-11 in the city of Makkah in western Saudi Arabia. Also, the pilot study will serve as the groundwork to indicate the important phases in executing the participant recruitment then applied in the main study.

4.2 Aims

The aim of this study was to assess the validity, reliability, and acceptability of the methods chosen for measuring body composition, dietary intake, and exercise habits in school girls aged 8-11 years old in Saudi Arabia.

4.2.1 Research questions :

- For this age group, which methods for measuring body composition can be used quickly, are cheap and portable, and are valid and reliable?
- Which of these methods has the minimum disruption to the children and the schools and is acceptable for the girls, teachers, parents, and the school policy?
- Which food-composition tables have been used for estimating energy from fat, protein, carbohydrates in Saudi foods, and how can they be used to construct a suitable database?
- How valid and reliable are the dietary intake methods for estimating the meal portion sizes, the number of meals and snacks, and the composition of meals and snacks?
- What methods are suitable for measuring the type, intensity, and duration of physical activity of this cohort, and how valid and reliable are those methods?

4.3 Subjects and methods

4.3.1 Subjects

Two schools were chosen in Makkah, one public and one private, from which to recruit girls. These two schools were chosen to include lower and high income groups. The researcher and one of the school staff selected the girls. The girls who were invited to take part were chosen to represent a range of BMI categories as far as this was possible from visual assessment of them. Schools' principals sent letters to parents inviting them to a meeting in which the details of the project were explained by the researcher. After parental consent had been received, the girls were also invited to give their consent.

4.3.2 Anthropometric and body fat measurements

The purpose was to evaluate the acceptability of the methods within the cultural environment. Therefore, measurements were conducted in the school laboratory by the researcher. Height was measured twice by one researcher, to the nearest 0.1 cm by means of a portable stadiometer (Seca, UK). Measurements were repeated until within 0.1 cm. The stadiometer was set up and checked by researcher, but not calibrated separately. The students were asked to stand in bare feet on the marks of the foot board and take off any upper hair clips. Their heads were adjusted to Frankfurt plane (the horizontal line from their ear canal to the lower border of the eye socket). After that, the body mass index and body fat percentage were measured by the Tanita Body Composition Analyser (TBF-300M/TBF-300MA, Birmingham, UK). The procedure for this required the student to stand with bare feet for a few seconds for the reading. The BMI was calculated as weight (kg) / height $(m)^2$. The BMI was then plotted on the 2000 CDC growth reference curve to classify the children into obese (95> centile), overweight (86-94 centile); normal weight (5-85 centile) and underweight (<5 centile). The CDC reference scale was considered valid for use with the

Saudi children as it had been validated against the WHO growth reference curves (Al Herbish 2009). The percentile was calculated by the CDC calculation website. The date of birth and the date of recording were entered to ensure the correct decimal age was used. To ensure the calculations were correct, 15 of the girl's BMIs were plotted by hand on a BMI chart to check the precision of the results. Waist circumference was measured twice by the researcher over clothes (thin school dress) to the nearest 0.1 cm by means of a non-stretch tape measure positioned 4 cm above the umbilicus. Measurements were repeated if not within 0.1 cm.

4.3.3 Dietary methods

The two methods which were conducted in this study were the diet diary and Child and Diet Evaluation Tool. The diet diary was constructed from WAKEUP study group, (Peninsula Medical School (Primary Care 2005), adapted for children's diets in KSA and piloted on children of the study age range. Changes were made and the diary was translated into Arabic (Appendix 1). The Child and Diet Evaluation Tool (CADET) (Roberts, 2010) tick-list questionnaire was modified for a Saudi child study and translated into Arabic (Appendix 2). Each girl was given a diary and the CADET tool to record her food intake. Both methods were used for four days during the week. They recorded their food intake over two days during the week (including school days) and then on the two days of the weekend (excluding special days). Each student was interviewed daily during the week to ensure that they had recorded the details correctly and accurately for both methods. Moreover, after the weekend they were interviewed again to review their diary entries. The diets were recorded with accompanying brief explanations of the quantity and frequency of food consumption. For the purpose of estimating under-reporting, the basal metabolic rate (BMR) of each participant was estimated using the Henry equation (Henry, 2005).

4.3.4 Physical activity methods:

The physical activity methods which were piloted in this study were the pedometer (Yamax Digi-Walker CW700 Professional) and the physical activity questionnaire. The questionnaire was based on an established self-reporting recall system, the Physical Activity Questionnaire for Older Children (PAQ-C), although it was modified slightly and translated into Arabic to cater for the requirements of Saudi culture. Validated in a number of previous studies, the questionnaire records the child's level of physical activity over a period of four days each week using descriptive categories; 'simple', 'moderate' and 'vigorous' (Crocker et al., 1997, Kowalski et al., 1997) (See appendix 3).

For four days during the week each participant wore a belt on which a pedometer was attached. The pedometer was removed only when the girl was washing or in bed. Otherwise the pedometer recorded the child's total level of activity throughout the day. To complement this, the physical activity questionnaire aimed to record the intensity and duration of physical activity for the four days.

In addition, to measure reliability of the pedometer a small group were asked to wear the pedometers twice, a week apart. Nine girls from the public school and 5 girls from the private school were asked to wear the pedometer twice to ensure the results were reproducible.

4.3.5 Ethical Consideration:

4.3.5.1 Ethical approval

This phase was approved by the University of Plymouth's Faculty of Science and Technology, Ethics Committee and by the General Administration for Girls' Education in Makkah.

4.3.5.2 Informed consent sheet

Consent sheets (including brief information about the study) were given to selected participants. The parents were invited to a meeting in which the details of the project were explained by the researcher. They were given another information sheet, and when fully informed they were asked if they would grant permission for their daughters to take part (Appendices 4, 5).

4.3.5.3 Confidentiality

Protocols to ensure privacy, confidentiality, and anonymity were applied from the outset, and each girl was coded so that names did not appear on the data. All information has remained strictly confidential and securely held in locked facilities, and has been used only by the researchers.

4.3.6 Data Analysis:

Each child was given a separate code number. Data were collected and filed on a separate record for each child using their unique code number. All the data was coded and entered as a spreadsheet on SPSS analysis program (IBM SPSS Statistics version 20). Data are presented as means and standard deviations. Means were compared using ANOVA (for more than two groups) and the significance was taken as $p < 0.05$. Tukey post hoc tests were applied where significant differences were found using ANOVA. All information has remained strictly confidential and securely held in locked facilities, and it has been used only by the researchers. The dietary data were analysed using the Arabic food-composition tables' software (Arab Food Analysis Programme 1st version 2007). The Programme was modified to provide estimations of portion sizes of the meals for children and also to provide records of the child's gender.

4.4 Results

4.4.1 Subjects recruited.

Thirty-two girls participated, aged between 8-11 years. Fifteen girls were from a private school and 17 from a public school.

4.4.2 Body composition.

It can be seen in table 4.1 that there is a significant difference in the waist circumference, weight, body mass index, and body-fat percentage between the different weight categories which as expected increase over the weight categories.

Table 4.1: Body composition and anthropometric measurements in underweight (UW), healthy-weight (HW), overweight (OW), and obese (OB) girls.

Body composition	**UW n=4**	**HW n=8**	**OW n=5**	**OB n=15**	**Total n=32**
Age (years)	9.75 ±1.25	9.13 ±1.12	10.60 ±0.89	9.67 ±1.23	9.69 ±1.203
Body Fat %* **	3.03 [a] ±.6 (2.5-3.8)	15.7 [b] ±5.8 (7-24.3)	28.0 [c] ±5.3 (23.4-36.4)	36.0 [d] ±4.2 (27.2- 43.4)	26.31 ±12.3
Weight (g)* **	23.6 [a] ±6.6 (16.3-29.1)	30.6 [a] ±5.7 (24.5-38.3)	44.2 [b] ±6.6 (37.5-54.7)	52.2 [b] ±9.6 (34.5-69.6)	41.94 ±13.68
WC (cm)* **	51.3 [a] ±4.0 (47-55)	59.2 [a] ±5.6 (51-67)	71.8 [b] ±7.7 (66-85)	79.2 [c] ±7.4 (67-92)	69.53 ±12.60
Height (cm)	131 ±16.3 (113-145)	135.5 ±9 (121-145)	142.6 ±5.7 (136-151)	140.3 ±9.2 (121-152)	138.19 ±9.68
BMI Percentile * **	1.5 [a] ±.5 (1-2)	46.6 [b] ±25.3 (20-80)	88.8 [c] ±3.5 (86-94)	97.47 [d] ±1.5 (95-99)	

*** P value <.001,
a,b,c,d Tukey post hoc test: means with the same letter indicate no significant difference

4.4.3 Physical Activity.

A small sample was asked to retest the pedometer for the 4 days as before to test the accuracy of recording. There were fewer than 180 steps difference between the two recordings and no significant difference, and so it was concluded that the girls were using them correctly (Table 4.2).

Table 4.2: The results for two readings of the pedometer

Average for the 4 days	First pedometer test	Second pedometer test	P - value
Average steps for the Private school n = (5)	6954 ±948.23	6879 ±1114.62	0.913
Average steps for the Public school n = (9)	7791 ±909.39	7970 ±1500.96	0.614

Physical activity was measured via the questionnaire and by the pedometer (Table 4.3). All the participants wore the pedometer and recorded their daily steps, whereas, not all of them logged their daily activities in the questionnaire.

Table 4.3: Physical activity in underweight (UW), healthy-weight (HW), overweight (OW), and obese (OB) girls using the pedometer and questionnaire.

PA	UW		HW		OW		OB	
Average for 4 days	**n=4**	**NC**	**n=8**	**NC**	**n=5**	**NC**	**n=15**	**NC**
Number of Steps (Pedometer).	8543.7 ±2776.5 (5271-11486)	4	7309.1 ±1633.3 (5323-9690)	8	9677.4 ±5659.6 (2811-15690)	5	6734.9 ±1879.2 (4400-10204)	12
Vigorous activity minutes /d (questionnaire)	3.7 ±7.5 (.0-15.0)	1	2.5 ±7.0 (.0-20.0)	1	.0	0	.7 ±2.3 (.0-8.0)	1
Moderate activity minutes /d * (questionnaire)	52.2 ±29.6 (30-95)	4	45 ±35.5 (.0-90)	7	59.2 ±72.9 (.0-144)	3	13.3 ±19.2 (.0- 50)	5
Simple activity minutes /d (questionnaire)	5 ±10 (.0-20)	1	15 ±29.7 (.0-80)	2	0	0	0	0

n= total number of girls participated, NC= completed data

* Significant P< 0.05 between BMI groups

The overweight group took most steps / d (9677) the obese group took the least (6735), but there were no statistically significant differences in the number of steps between the BMI groups. From the questionnaire data, only three girls undertook any form of vigorous activity over the four days. Between three and seven girls in the different groups reported moderate activity. It can be seen that from Table 4.3 the activity levels were not well recorded as only three girls recorded simple/low intensity activity despite their steps recorded on the pedometer.

4.6.4 Dietary data.

The food composition database included the most commonly consumed food in the Saudi population and was adequate for the majority of food, but some brands named foods were missing. Therefore, brand name foods (like Kit Kat) were compared with similar foods in the database to check the macronutrients to ensure they were fairly comparable. The data were checked for under-reporting and over-reporting. Following this, it was decided to keep all the data in the analysis (see later). Table 4.4, lists the nutrient intake for the four BMI categories of participants calculated from the four day food diaries. It also shows the contribution of different food types to energy intake, and the daily consumption of fruit and vegetables. It has been estimated that the energy intake for the sugary drinks was 36 kcal/ 100 ml and from savoury snacks (mostly crisps) about 500 kcal 100g.

Table 4.4: Nutrient intake and selected food types in underweight (UW), healthy-weight (HW), overweight (OW), and obese (OB) participants from the diary data (calculated from the 4 day diary)

Average for 4 Days	UW n=4	HW n=8	OW n=5	OB n=15
ENERGY kcal/d*	1604 ±351 [a] (1295-1909)	2115 ± 430 [a,b] (1620-2697)	3200 ±1366 [b] (2164-5168)	2533 ± 732 [b] (1595-4040)
PROTEIN (g/d)	64.9 ±21.0 (36.2-86.8)	71.5 ±21.3 (47.8-110.8)	111.0 ± 68.4 (69.7 - 213.3)	82.8 ±22.6 (57.2-122.2)
kcal from protein %	16.5 ±4.7 (11.2-22.3)	13.4 ±2.9 (9.5-18)	14.0 ±2.0 (11.7-16.5)	13.5 ±2.7 (8.0-17.9)
FAT (g/d)	59.2 ±8.4 (48.2-68.7)	80.6 ±26.4 (54.5-116.6)	126.6 ±57.1 (88.2-209.2)	103.3 ±44.2 (50.0-211.2)
kcal from Fat %	33.9 ±5.5 (28.1-41.5)	33.7 ±5 (27.8-39.0)	35.5 ±1.7 (33.0- 36.9)	35.9 ±6.3 (27.4-47.4)
CHO (g/d) *	221.4 ±57.9 [a] (161.4-276)	300.5 ±75.6 [a,b] (223.7-435.5)	431.1 ±152.4 [b] (298.6 -642.2)	349.1 ±84.2 [b] (233.7-492.3)
kcal from CHO %	54.3 ±4.6 (47.5-57.8)	56.8 ±6.3 (43.2-64.5)	54.1 ±3.5 (49.7-57.2)	55.8 ±5.9 (43.8 -67.4)
FRUIT (g/d)	30.3 ±42.4 (.0-90)	60.5 ±73 (.0-200.5)	25.9 ±47.7 (.0-97.5)	48.8 ±100.1 (.0-393.7)
Vegetables (g/d)	24.3 ±24.5 (.0-56.2)	54 ±26.6 (12.5-91.2)	114.6 ±102.2 (.0-236.2)	75.3 ±58.8 (.0-200.0)
Sweets (g/d)	28.5 ±23.5 (.0-55.7)	111.7 ±44.5 (70-205)	163.5 ±82.2 (79.0 - 253.0)	93.4 ±91.9 (.0-313.7)
Sugary drink (ml/d)	171.8 ±105.2 (50-287.5)	287.2 ±223.5 (62.5-775)	315.0 ±264.0 (100-695)	343.8 ±116.2 (162.5-525)
kcal from sugary drinks	72 ±44 (21- 121)	120 ±94 (26-326)	158 ±112 (42- 292)	144 ±49 (68- 221)
Savoury Snacks (g/d)	0	17.1 ±14.4 (.0-37.5)	6.2 ±5.1 (.0- 12.5)	33.6 ±42.6 (.0-125.0)
kcal from Savoury Snacks	0	101 ±72 (.00- 187)	37 ±51 (.00- 125)	168 ±213 (9.00- 625)
Total kcal from Savoury Snacks	72	221	195	312

* P value <.050, a,b Tukey post hoc test: means with the same letter indicate no significant difference

”Sweets” include: chocolate, sweets, biscuits, cakes, desserts and ice cream

“Sugary drinks” include: carbonated drinks, fruit squash, and juice with add sugar

“Savoury snacks” include: crisps and popcorn

The first thing to note from Table 4.4 is that the average energy intake was highest in the overweight group. Indeed one participant recorded a very high calorie intake of 5168 kcal /d, and this had the effect of skewing the average intake of macronutrients markedly upwards. Accordingly the means are higher in this group; otherwise there was a gradual increment according to weight category but a decrease in the obese.

The underweight girls had a significantly lower energy and carbohydrate intake than both the overweight and the obese groups.

The healthy-weight group showed the highest average fruit intake and the overweight group reported the lowest. It is important to note that the average sweet intake rose incrementally between the UW, HW, OW groups, but for the overweight girls the intake of sweet food was even higher than for the obese girls, which is due to the individual reporting a high energy intake. But the differences between groups were not statistically different.

It can be seen in table 4.4 there is a trend for sugary drink consumption with the highest intake in the obese girls and the lowest in the underweight groups.

Basal metabolic rate (BMR) was calculated in order to identify any obvious under-reporting. Figure 4.1 shows energy intake against BMR. The basal metabolic rate was calculated by applying Henry's equation which has been used recently in UK reports on energy requirements (SACN 2011). Two sets of Henry's equations were used in this study based on the age of the participants. The BMR for girls aged between 8 and 10 years was calculated as BMR = (15.9 x weight (Kg)) + (210 x height (m)) + 349: the BMR for those aged 11 years was calculated as BMR = (9.40 x weight (Kg)) + (249 x height (m)) + 462 (Henry 2005).

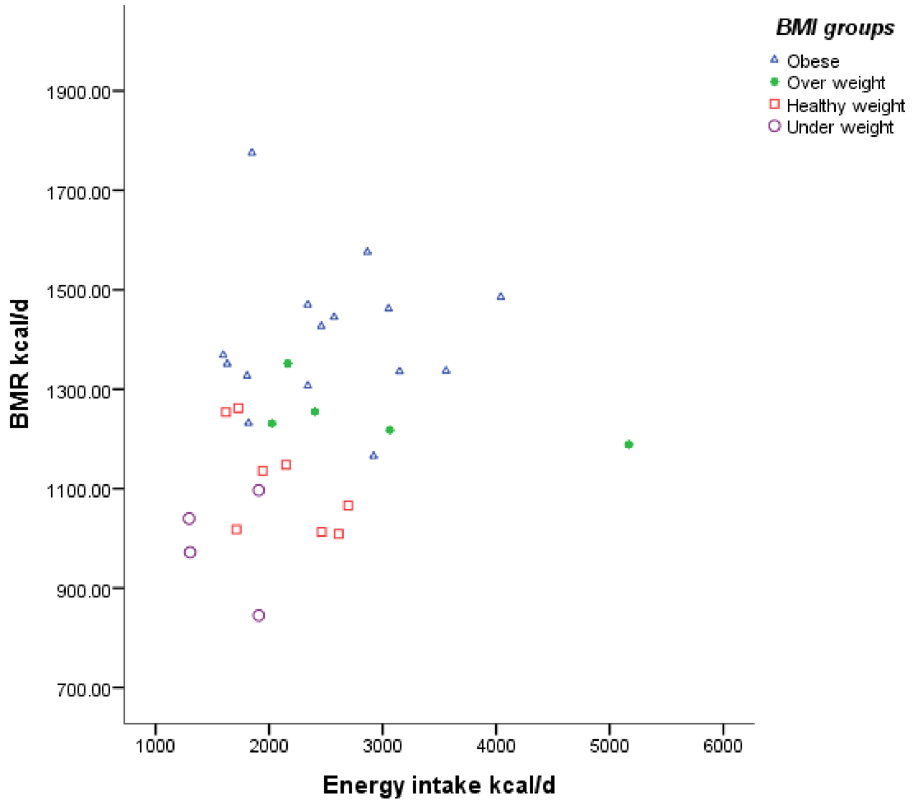


Figure 4.1: Basal metabolic rate (BMR) vs. daily energy intake for underweight, healthy weight, overweight and obese girls.

Figure 4.1 shows the average energy intake recorded compared to the estimation of BMR in order to assess the number of under- reporters. Two outliers were noted, one recorded the details of an obese girl with a BMR of 1775 kcal /day and energy intake of 1848 kcal, but this individual took only 4560 steps. Some under-reporting is likely for this individual. The other outlier consumed 5169 kcal/d with an estimated BMR of 1189 kcal /d. However, she took 12681 steps/d and so was more active than most of the girls. On balance it was decided to keep all the girls in the analysis at this stage as no one reported an intake less than their BMR.

Dietary data were collected via a four-day diary, by a CADET check list, and by interviewing children and parents. All of the participants completed the diet diary and been interviewed whereas only 78% of them completed the CADET. Table 4.5. shows the results of the different sets of data and the times for the interviews.

Table 4.5: Number of completed data and the estimation time for both schools

Student total number 32	Parents contact	Interviews	Estimation time for the interviews	Completed diet diary	Completed CADET*
Public school N (17)	5	17	10 minutes	17	14
Private school N (15)	8	15	10 minutes	15	11
Total	13 40.4%	32 100%		32 100%	25 78%

Parents contacted the researcher to clarify instructions and to check that they had completed the forms correctly. It can be seen that all participants completed the diary but seven individuals did not complete the CADET check list at all or only partially completed it.

Ten participants were chosen at random (5 from the public and 5 from the private school) to compare the dietary information gained from the CADET tool and from the diet diary. It can be seen from table 4.6 there is a difference in the daily average intake of selected foods between the data recorded in the CADET and the diet diary. The frequency of consumption is higher in the diet diary except the average intake of vegetables. Therefore, the information gained from the CADET tool was limited because of the low completion rate.

Table 4.6: Average frequency of consumption of selected foods- comparison of CADET tool vs diet diary (number of portions per day)

Average of 10 girls (random samples)	Average daily intake from the CADET	Average daily intake from the diet diary
Fruits	0.3	0.4
Vegetables	0.55	0.45
Sweets	0.7	1.1
Sugary drinks	0.95	1.25
Snacks	0.1	0.37

4.6.5. Energy balance; energy intake and energy expenditure comparisons

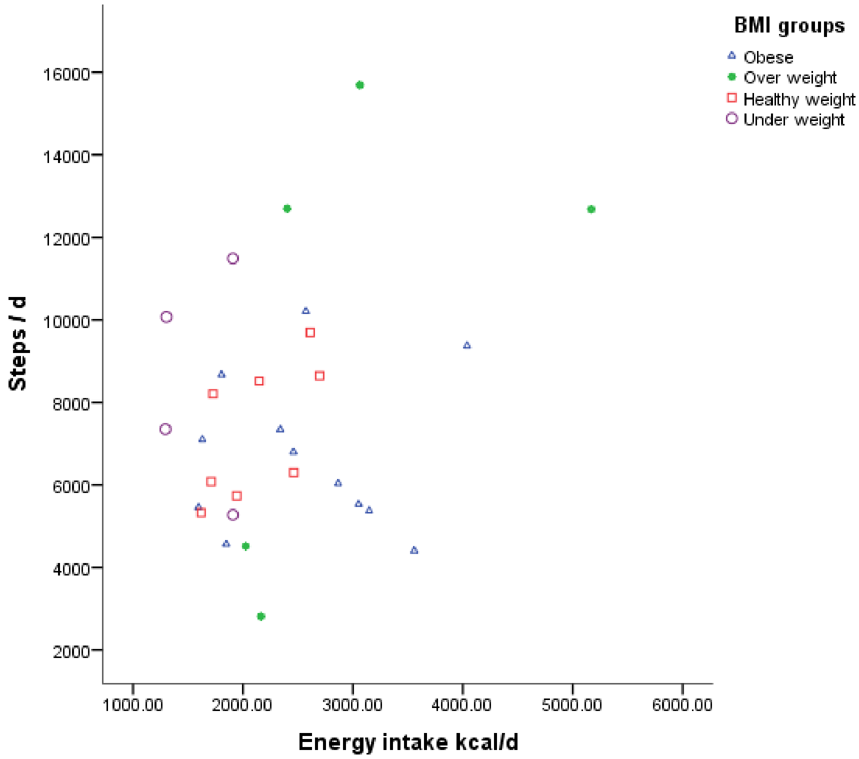


Figure 4.2: Comparison of the steps and the daily energy intake for the underweight, healthy-weight, overweight, and obese girls.

Most of the participants had not reported or completed their activity on the PAQ but the number of steps taken was recorded on the pedometer. Therefore, a comparison between the EI and number of steps/d was conducted to show the level of activity vs energy intake according to their BMI classifications. Two outliers were noted, both being overweight (figure 4.2). One recorded the highest number of steps (15,690 steps/d) and an energy intake of 3063 kcal/d. The other girl had the highest energy intake of 5168 kcal/d while taking 12681steps/d.

4.6.6 Comparison of Schools

All the data were collected from the two schools - one private and the other one public – but their respective number of participants was slightly unequal.

Table 4.7: Numbers of underweight, healthy-weight, overweight, and obese girls and a comparison of energy intake and the number of steps for the students in the two schools

	Public School n (17)	**Private School n (15)**
UW	3	1
HW	3	5
OW	5	0
OB	6	9
Number of steps/day*	8497.18 ±3484.78	6450.17 ±1339.20
EI/day (kcal/d)	2551.65 ±970.17	2186.04 ±585.06

*P value <0.03

It can be seen that there were no overweight girls in the public school, and this may affect the comparison between them. It was found that there was no significant difference in the energy intake of the students in the two schools; however there was a marked difference in the number of steps per day, the public school girls recording about 25 percent more than the girls in the private school.

4.7 Discussion

The present study focused on comparison of the tools and the usefulness of the data in Saudi girls aged 8-11 years, who were selected from two schools in Makkah in Saudi Arabia.

4.7.1 Body composition

The collection of data was achieved without complication, and there was high acceptability from all the participants and from the school administration. Most participants reported that the method of measuring body composition was comfortable and convenient. Moreover, the findings obtained in the present study showed the expected body composition results for all BMI categories. The results show an increase in waist circumference and body fat over the BMI ranges from underweight, healthy or normal weight, overweight, to obese. Results are consistent with other studies in Saudi. In our study the average waist circumference for obese and overweight was 79 and 72 cm. In a study conducted in Riyadh in Saudi Arabia on boys and girls, the girls who were obese and overweight, aged 10-11 years, recorded waist measurements of 78 cm and 70 cm (Collison et al., 2010). Also the average waist circumference of 1459 girls aged 10-13 years in Saudi was 66.3cm (Collison et al., 2010). Also the body fat percentages were similar to that found by McCarthy et al. (2006) in the UK for each BMI percentile. Therefore, in answer to the research questions it is concluded that these methods are suitable for use in the main study.

4.7.2 Physical activity.

One aim of this pilot study was to test the suitability, reliability, and validity of measuring the type, intensity, and duration of physical activity method. The analysis of the participants' physical activity was marred by the failure of many to adequately complete the questionnaires. Only one of the 15 questionnaires completed by the obese girls recorded vigorous activity, and 5 of the15 recorded moderate activity. This might be due to the culture which prevails in KSA where girls are not usually encouraged to perform vigorous physical activity. Of the girls classified as being overweight, only 3 out of 5 recorded moderate levels of activity. However, very few recorded even simple physical activity. The pedometer successfully recorded the number of steps, and it was re-tested with a number of samples to check the reproducibility of the results. However there was under-reporting on the physical activity questionnaires. The two methods were compared to examine the validity; in some samples a high number of steps were recorded but this contradicted some of the questionnaires in which no (or little) physical activity was recorded. Many of the exercises and sports listed in the questionnaire may not have been familiar to the girls as they are not normally practiced by girls in Saudi Arabia. Therefore it is possible that they did not think the questionnaire relevant to them and failed to record even light activity such as walking which was recorded by the pedometer. In a study such as this it is not appropriate to rely on the pedometer alone because it does not record the duration or intensity of the physical activity. Therefore, a possible alternative method in the main study might be the use of an accelerometer. It has been used in many studies and has been shown to be a reliable and valid method for measuring the intensity and duration of physical activity of this cohort (Troiano 2008). It is an additional expense but now shown to be necessary.

In general, physical activity analysis indicated that the public school's girls recorded more steps than the private. The reason for this is uncertain but may result from the design of the school building or from their life style. The public-school building contains two floors and many stairs while the private school is on one floor with few stairs. Moreover, the girls' economic status is different, this being reflected in their transportation; most of the private-school girls were driven to/from school by car whereas more of the public-school girls living near the school walked to and from their school. This preliminary data suggests that it will be important to include participants from both public and private schools to cover a representative sample of girls for the main investigation.

4.7.3 Dietary intake

The two dietary assessment methods recorded different results. The CADET did not provide adequate material for the nutrient content to be calculated because of insufficient information about food portion sizes. Also, the girls did not accurately report (ticking) everything they had eaten or record the descriptions of their food. For example, one girl had recorded in the diet diary that she had a medium bowl of vegetable soup whereas in the CADET she indicated all of the soup ingredients. Table 4.6 shows that the average vegetable intake recorded in the CADET is slightly higher, but this may be due to over-estimations. Therefore it is not possible to be entirely sure whether this is a full and correct representation of what they ate. Based on this evidence the CADET method fails to provide sufficient detail; moreover, the participants did not complete the record and so the results are not sufficiently representative to yield definitive results. Although the CADET recorded the number of snacks which had been eaten, it has been difficult to estimate portion sizes or to determine the compositions of meals and snacks - which is one aim of this study. Although the diary method was better, it could still be improved to help describe portion sizes more accurately. One possible solution in the main study is to use the diet diary and to include in it pictures and descriptions illustrating portion sizes; this would enable them to more accurately indicate the size and composition of each meal (NDNS, 2011).

Moreover, the database (Arab Food Analysis Programme 1st version 2007) that was used to analyse the food consumption did not have so many functions as analysis packages in other countries such as the UK. A disadvantage of the dietary analysis program was that it did not distinguish between starch and sugars. Moreover, it was complex for the researcher to add some food and use it in the analysis. Despite these facts, this program has most of the traditional Arabic food.

4.7.5 Comparison between the schools

Comparing between the private and public schools there were 9 obese girls and no overweight from total 15 girls in private school while there are 6 obese girls and 5 overweight from total 17 girls in the public school.

It wasn’t possible to weight the girls before recruiting them and the researcher was unable to choose them randomly because the sample size was small and all BMI groups needed to be represented. Therefore, we had an uneven group. The researcher met and presented the study aims and methods to the student's parents and they were given the information and the consent sheets to be signed. Most of them took the sheets back home to discuss it with their fathers then returned which took almost two weeks for the recruitment procedure. In the main study it has been suggested to expand the sample size and choose them randomly.

4.9 Conclusion

In summary, it has been shown that the methods for estimating body composition (that is, waist circumference, weight, and height, bioelectrical impedance) were well-suited to a study of young girls in a country such as Saudi Arabia. These measurement methods are non-intrusive, they can be conducted quickly and easily in private, they do not require expensive or difficult equipment, and they can be done with a high degree of consistency and reliability.

Although the pedometer was shown to yield reliable results for measuring the number of steps, it could not provide the intensity of activity. Accordingly it was combined with PA questionnaires to pilot the combination of tools in order to estimate the duration and intensity of physical activity and number of steps. However, as it was not completed fully by most of the participants, the physical activity questionnaire was not a meaningful way of measuring the type, intensity, and duration of physical activity in our sample. Therefore, it is recommended to use an accelerometer in the next part of the study to give more details regarding the type, intensity, and duration of exercise.

Although the CADET was not a valid method to estimate the meal portion sizes, the number of meals and snacks, and the composition of meals and snacks, the diet diary was shown to be a good method for obtaining energy and nutrient data and information on meal and snack composition. The average energy intake from diet diary was compared to BMR in order to assess the under reporters and based on that it was found an acceptable recording of daily intake. However, the diaries will be further enhanced and include images showing a range of typical meal types and portion sizes to aid the dietary intake assessment further.

Chapter 5: Phase two: The nutritional intake, daily physical activity and socio-economic status of girls aged 8-11 years according to BMI

5.1 Aims

The aim of this phase was to investigate body composition, diet and exercise patterns in school girls aged 8 to 11 years living in Makkah, Saudi Arabia, and to draw comparisons between those who were overweight or obese and those who were of a healthy weight.

5.1.1 Research Questions:

1- How do anthropometric measurements vary between BMI groups?

2- How do energy and macronutrient intakes vary between overweight and obese girls compared to healthy weight girls?

3- Which snacks and selected food types contribute to energy intake in obese/ overweight girls compared to girls of a healthy weight?

4- What is the level of activity in the girls and does activity (level and intensity) differ between overweight/obese and normal weight girls?

5- To what degree are 8-11 year old girls of different economic status overweight or obese in schools in the western region in Saudi Arabia?

5.2 Methods

5.2.1 Study design and subjects

This was a cross sectional study. Five schools were randomly chosen by the education department within Makkah in different areas so as to obtain a sample that was representative of the city's schoolgirls. The participants were recruited from two public schools and three private schools to allow inclusion of different socioeconomic groups. After parental consent had been received, the girls were also invited to give their consent.

5.2.2 Anthropometric and body fat measurements

All anthropometric and body fat measurements taken were the same as in phase 1. All measurements were conducted in the school science laboratories by the researcher. Height was measured to the nearest 0.1 centimetre by means of a portable stadiometer (Seca, UK). In this phase, the height was plotted on the Saudi growth chart for stature-age percentile developed by King Abdulaziz City for Science and Technology (El-Mouzan et al., 2007). The students were asked to stand in bare feet; body mass index (BMI) and body fat percentage were then calculated by the Tanita Body Composition Analyser (TBF-300M/TBF-300MA, Birmingham, UK). The procedure for the Tanita required the student to stand with bare feet for a few seconds for the reading. The BMI was calculated as weight (kg) / height $(m)^2$. The BMI was then plotted on the 2000 CDC growth reference curve to classify the children into obese (95> centile); overweight (86-94 centile); normal weight (5-85 centile); and underweight (<5 centile). The CDC reference scale was considered valid for use with Saudi children as it has been validated against the WHO growth reference curves (Al Herbish et al., 2009). Waist circumference was measured to the nearest 0.1 centimetre by means of a non-stretch tape measure positioned 4 cm above the umbilicus.

5.2.3 Diet diaries

Diet diaries, published by WAKEUP study group (Peninsula Medical School Primary care 2005), were piloted and edited in phase 1. Girls were asked to complete these diaries for 4 days (see appendix 1). The girls described portion sizes using household measures and attached pictures to ensure correct estimation of portions during recordings. Participants logged their food intake over two days during the week (including school days) and then on the two days of the weekend (excluding special days). As had been done in phase 1, each student was interviewed daily during the week to ensure that they had logged the details correctly. After the weekend they were interviewed again to review their diary entries.

5.2.4 Analysis of diet diaries

The dietary data were analysed using the Arabic food-composition tables' software (Arab Food Analysis Programme 1st version, 2007). The programme was modified to provide estimations of portion sizes of the meals for children and also to provide records of the child's gender. The weight of non-packaged food (without a known weight) was estimated using pictures of known portion sizes (NDNS, 2011) included with the food diary. Some portions weights (such as fruit and tablespoons of rice) were estimated using the Food Portion Size book (Agency, 1994). It was estimated that the energy intake for sugary drinks was 36 kcal/ 100 ml and from savoury snacks (mostly crisps) about 500 kcal/ 100g. This data was obtained from the Arab food composition programme and used to estimate the contribution to energy intake from these products.

5.2.5 Physical activity data collection with the accelerometers

With the purpose of collecting the intensity levels of the subjects' physical activities, accelerometer monitors (WGT3X-BT Actigraph, Fort Walton, Florida) were used. Subjects were asked to wear the accelerometers for 4 consecutive days (at the same time as recording their diet), 2 days during the week and 2 days during weekends, except at bedtime and during bathing and swimming periods. The accelerometer was attached via an elastic belt around the waist, located on the right hip. Actigraph analysis software was used to analyse data. The monitors were set to the exact (start and end) time and dates for the data collection were noted. The epoch for data collection was 30 seconds to avoid underestimation of MVPA, as recommended by Corder et al. (2007). As the accelerometer was not used for the pilot study, the device was trialled prior to use on three child participants. Initially step counts were checked over short periods of 5 minutes to ensure the devices were working. Over a longer period of 12 hours, the participants wore the devices continually to ensure they were recording different intensities as expected and to check the suitability of positioning on the hip. Similar steps counts were obtained as in the pilot study using the pedometer. A more vigorous pilot was not possible as due to time constraints.

5.2.6 Accelerometer wearing time

There is a wide variation in the number of days and hours of wearing the accelerometer in different studies. Cliff et al. (2009) and Hinkley et al. (2012), suggest that between 3 to 7 days provides a reliable estimate of habitual physical activity. Moreover, Penpraze et al. (2006) suggested that 10 hours per day could produce high levels of reliability measuring physical activity and Robertson et al. (2010) suggested that continuous recording should be for at least ≥ 7 hours a day. Therefore in the current study, acceptance of valid data required at least 3 completed days and each day had to have at least 10 hours of continuous recording.

For each subject, the mean count per minute and the mean daily step count were retrieved from the accelerometer scoring data where the vertical axis was used for the mean counts per minutes (cpm). Activity counts were translated into METs using the Freedson et al (2005) equation:

MET Rate= 2.757 + (0.0015 *CPM) - (0.08957 *Age) - (0.000038* CPM * Age)

Where CPM = Counts per Minute and Age = age in years.

The intensity of the physical activity was calculated by Evenson cut points. Evenson Children (2008): Minutes spent in sedentary physical activity was calculated as <100 CPM, Light physical activity 101 - 2295 CPM, moderate physical activity 2296 - 4011 CPM, and vigorous physical activity 4012 - ∞ CPM accelerometer counts.

5.2.7 Epoch and cut point calibration

There are many factors that could influence which epoch is more suitable for the study such as memory capabilities of the monitor, and age of the population. It has been argued that short epochs are more accurate in estimating different intensities, especially in capturing the vigorous intensity of physical activity (Mcclain et al., 2008). However, Hislop (2013) demonstrated that the epoch does not affect the cut-point values in order to generate an estimation of different intensities. Also intensities that were developed from cut-points using either short or long epochs are comparable.

However, Bailey et al. (1995) suggested that in case of school aged children like in this study, it is important to use a shorter epoch in order to capture the small sporadic bursts of vigorous physical activity including the variations of periods in low or moderate duration activities.

Moreover, according to Corder et al. (2007) using a short epoch may reduce the underestimation of MVPA. Therefore, the epoch for data collection in this study was 30 seconds to ensure better capturing and estimation of MVPA.

Additionally, it is important to select the most appropriate cut points in a study using the accelerometer as it will affect the classification of different intensities. To classify sedentary, light, moderate and vigorous activity different cut points may be used, although in the literature most of them agree on the sedentary time cut point of < 100 cpm in children. But there is validation in the range of the cut points at the other intensities.

Trost et al. (2011) compared 5 published cut points for classifying sedentary, light, moderate, and vigorous activity: Puyau et al. (2002), Treuth et al. (2004), Mattocks et al.

(2007), Freedson et al. (2005) and Evenson et al. (2008). All of the cut points were set at different CPM. Torst et al (2011) validated these different cut points against measured oxygen consumption (VO_2) and found that the Freedson and Evenson cut points had the best agreement with measured VO_2 than the other cut points for estimation of time spent in vigorous and moderate activity. Freedson et al. (2005) cut points are specific for different age groups. However, when using the accelerometer, only an average is given for a wider age range, which is a limitation for using them with accelerometer data.

Table 5.1: Evenson and Freedson cut points for different levels of exercise intensities.

Intensity PA Cut Points	Evenson Children (2008)	Freedson Children (2005)
Sedentary	<100 CPM	<149 CPM
Light	101 - 2295 CPM	150 - 499 CPM
Moderate	2296 - 4011 CPM	500 - 3999 CPM
Vigorous	4012 - ∞ CPM	4000 - 7599 CPM
Very Vigorous		7600 - ∞ CPM

Moreover, Torst et al (2011) recommended that for children, Evenson (EV) cut points should be used to estimate time in sedentary, light, moderate and vigorous activity. Although EV cut points were originally validated in 5 to 9 year-olds, the validation study conducted by Trost et al. observed that they were the most closely matched to VO_2 in all age groups (ranging from 5 to 15 year-olds).

5.2.8 Estimating basal metabolic rate (BMR)

There are several equations used to estimate basal metabolic rate in the literature. The Henry prediction equations for BMR, based on weight, height, age and gender, have been used in many epidemiological studies to predict BMR (Henry, 2005), and they are used to estimate energy requirements in the UK Dietary Reference Values (SACN, 2011). In addition, a validation study by Weijs (2008) found that the Henry equation predicts BMR more closely than the other equations. In a cohort study in the USA on adults, the Henry equations provided a more accurate estimation of BMR than the Schofield equation (IoM, 2005). According to the DRVs 2011, the Schofield equations overestimated BMR in some populations whereas the Henry equation did not. Hence, the Henry equation will be used in this study to estimate the BMR.

5.2.9 Estimation of total energy expenditure from accelerometer data

Two different methods were used to estimate the total energy expenditure (TEE). In one, TEE was calculated using the average MET rates from the accelerometer data multiplied by the BMR: TEE= METs x BMR. The BMR was calculated using Henry equations (Henry, 2005).

In the other, the activity energy expenditure (AEE) was calculated, plus BMR, plus diet-induced thermogenesis (DIT), which was assumed to equate to 10% of BMR (TEE=AEE+BMR+DIT) (Biltoft-Jensen et al., 2013). The AEE is the most variable component in total energy expenditure. This was calculated using the Ekelund et al. equation (2001). The sum counts per minute were recorded on the accelerometer. The modified equation is:

AEE = 66.847 + (cpm x 0.953) – (176.91 x gender).

CPM = Counts per Minute - Gender: boy=0, girl= 1

5.2.10 Comparison of estimation of total energy expenditure

There are several methods to estimate the TEE for children. Viewing the METs rate provided by the recorded data permits a calculation to be made of the TEE based on the accelerometers. Another way of using the accelerometer data is using the Count per Minutes from the accelerometers, and then using the Ecklund’s equation. There is a third way to estimate the TEE which does not use the accelerometer data but instead uses an average Physical Activity Level (PAL). According to Torun et al. (1996), a light level of physical activity for children, depending on the age and sex, is between 1.45-1.60 x BMR, however, these suggestions do not consider the cost of growth. Moreover, Abbott and Davies (2004) suggested that a PAL of 1.32-2.18 should be considered as the minimal daily activity for children. Hence if a value of 1.01 for the cost of growth was incorporated into a PAL of 1.43 on this study population, that would take into account all the contributors to the total energy expenditure. The value of 1.01 to estimate the cost of growth and provide an increase in TEE for growth (of 1%) was used by SACN to estimate energy requirements for children for the DRVs (SACN, 2011). Therefore, a paired sample t-test was conducted to evaluate the PAL of 1.45 adjusted to include the growth cost of (= PAL x 1.01) against TEE_A by Ekelund's equation. There was no statistically significant difference between both calculations (M = 1717kcal, SD = 302.83) and (M = 1684kcal, SD = 276.8), P= 0.150. This PAL (adjusted for growth) therefore seems to be reasonable for estimating the TEE in the sample.

5.2.11 Identification of under-reporters of dietary intake

There are several studies showing different calculations regarding the cut off points for determining under-reporters but there is no specific cut-off methods designed for children to identify under reporters of energy intake (EI) in studies. There is a definition of under-, acceptable and over-reporters of recorded EI in adults, published by Black (2000). She used the ratio of EI: EE and the baseline used as <0.76, for under-reporting, 0.76 - 1.24 as acceptable and >1.24 as over-reporting. In another study by Price et al. (1997), 1.10 was used as a cut off for the EI/BMR and under- reporters were defined as those who recorded an EI less than BMR x1.10. Moreover, another study on adults recommended using less than BMR×1.2 as the cut off for those under-reporting energy intakes (Schutz et al., 2001).

In the current study, the accelerometer estimated the TEE but only for those participants in phase 2. Therefore, under-reporters (from both phases 1 and 2) were identified using a multiple of BMR. EI< BMR x1.2 as a cut off has been used in line with Schutz (2001). If EI / BMR x 1.2 is less than one, the person is considered to be an under-reporter. Therefore, a calculation was made for the average EI over 4 days from the food diaries, and the estimated minimal requirements for energy were calculated by = BMR x1.2, and if EI was < BMR ×1.2, the participant's food and nutrient intake data were excluded from the analysis. This is similar also to Black cut off points for under reporters (<0.76 of BMR × 1.4) (Black 2000).

5.2.12 Socioeconomic (SES) questionnaire

With the purpose of assessing the household socioeconomic status (SES), parents or carers were asked to fill out a questionnaire attached to the diet diary (appendix 6). The questionnaire was designed to record SES indicators, including parental education, income, family size, occupation status, marital status, accommodation, school type, and employment of housemaids, in order to evaluate the income of the family.

In phase 2 the income has been identified according to a study that included 10 thousand Saudi families from across Saudi Arabia. It identified 10 components for "sufficiently line", which included housing, food, clothing, health care, school needs and the needs of infants, luxuries, transportation, basic services, and entertainment. The study showed that the average monthly expense for a family of five people (2 adults and 3 children or one adult and four children) was 8926 Saudi riyals (1487.6 UK pounds), which is 1785 Saudi riyals (297.5 UK pounds) per individual. According to King Khaled Foundation, families classified as mid income have more than 8926 SR per month and they own their house whereas the families classified as high income have more expensive houses, servants and educational level, with a monthly income that totals more than 18000 SR.

Education is an important element for determining health status. Referring to data from the US National Health and Nutrition Examination Survey, the 2005–2008 household education level was classified to examine the prevalence of childhood obesity in college degree graduates, high school graduates and the pre-high school degree sector (Ogden et al., 2010); accordingly, in this study the parents' education level was classified as 'educated parent holding a university degree and above' while the partly-educated parents are described as 'one or both of the parents who have a high school degree'. Non-educated parents are categorised as 'left school early before completing high school'.

5.2.13 Merged data from all phases

In order to investigate whether data from phase 1 could be merged with phase 2, comparisons were made between phase 1 and 2 data. Subjects in phase 1 and 2 completed the same body composition measurements and dietary diaries. Steps data obtained from pedometers were used in phase 1, whereas in phase 2 the accelerometer had been employed (see Section 5.4.3). However, merging data could allow a larger sample size for analysis.

5.2.14 Data analysis

As in phase 1, each subject was coded separately. Data was collected and filed, and a separate record for each child was made using their unique code number. All the data was coded and entered on an SPSS analysis program (IBM SPSS Statistics version 20).

To conduct statistical analysis, most of the key points were considered according to which technique to be applied. One of the general assumptions for the parametric techniques is normal distribution. In addition, some other assumptions should be checked based on the techniques will be applied. Nevertheless, data for this study was not checked for normality distribution as Pallant (2011) stated that large sample size (>30) is not affected by violating of normal distribution. Data was presented in tables as mean and standard deviation. While the T-test was used to compare two groups, one-way analysis of variance (ANOVA) was used to determine whether there are any statistically significant differences between the means of more than two groups. Post hoc test (Tukey) was run to confirm where the differences occurred between groups.

Chi squared test was performed to investigate categorical data. Pearson correlation coefficients were calculated to evaluate the relationships between the factors with the level of significance of $P < 0.05$. To assess the relationship between BMI category and the other variables, multiple regressions were fitted.

To generate a prediction equation to estimate body fat percentage linear regression analysis was used with weight, height, age, and waist circumference as covariates. The body fat percentage which was estimated from the equation was tested against the percentage body fat values obtained from the instrument (Tanita) in this sample. The waist circumference was also estimated from a prediction equation and then tested against the measured value from the Saudi samples.

5.2.15 Ethical consideration

5.2.15.1 Ethical approval

As mentioned in chapter 4 (4.3.5.1).

5.2.15.2 Informed consent sheet

Consent sheets (including brief information about the study) were given to all 2nd, 3rd, 4th and 5th grade students by school staff. The parents were invited to a meeting in which the details of the project were explained by the researcher. They were given another information sheet, and when fully informed they were asked if they would grant permission for their daughters to take part.

5.2.15.3 Confidentiality

As mentioned in chapter 4 (4.3.5.3).

5.3 Results

5.3.1 Phase one (pilot study 2013)

Subjects recruited.

A total of 32 girls participated, aged between 8-11 years. 15 girls were from a private school and 17 from a public school. The subjects in phase 1 completed the diet diary and wore the pedometer for 4 days (section 4.4.3).

5.3.2 Phase 2 (main study 2014)

Subjects recruited.

Although 375 information sheets were given out, only 234 students agreed to be involved in the anthropometric measurements (62.4%), and just 134 participants actually completed the dietary and physical activity measurements (35.7 %). A total of 234 girls participated, aged between 8-11 years: 162 girls were from public schools and 72 were from private institutions. All subjects completed the body composition measurements.

Table 5.2: Number of subjects who completed body composition measurements -in both phases by BMI group

BMI groups	UW	HW	OW	OB
Number of subjects phase 1	4	8	5	15
% from n=32	12.5%	25%	15.6%	46.8%
Number of subjects phase 2	39	136	25	34
% from n=234	16.6%	58.1%	10.6%	14.5%

Table 5.3: Number of subjects in public or private schools by weight status – in both phases

BMI groups	UW	HW	OW	OB	Total
Public School n = 179	38	99	21	21	266
Private School n = 87	5	45	9	28	

Table 5.4: Number of subjects who completed the diet diary and wore the accelerometer for 4 days in public or private school by weight status in phase 2

BMI groups	UW	HW	OW	OB	Total
Public School n = 69	10	38	9	12	134
Private School n = 65	4	38	7	16	
% from n=134	10.4%	56.7%	11.9%	20.9%	

Although 234 girls were weighed and measured, only 134 of them agreed to complete diet intake records and wear an accelerometer for 4 days, including the weekends.

5.3.3 Comparison between phase 1 and phase 2.

Results from phase 1 (2013) and phase 2 (2014) were compared to see if the data were similar. This would allow the merging of data sets to form a large sample size. Both studies had the same methods for collection of dietary data and anthropometrics and step count. Participants were excluded for under-reporting their diet or for incomplete accelerometer wearing (see section 5.4.4).

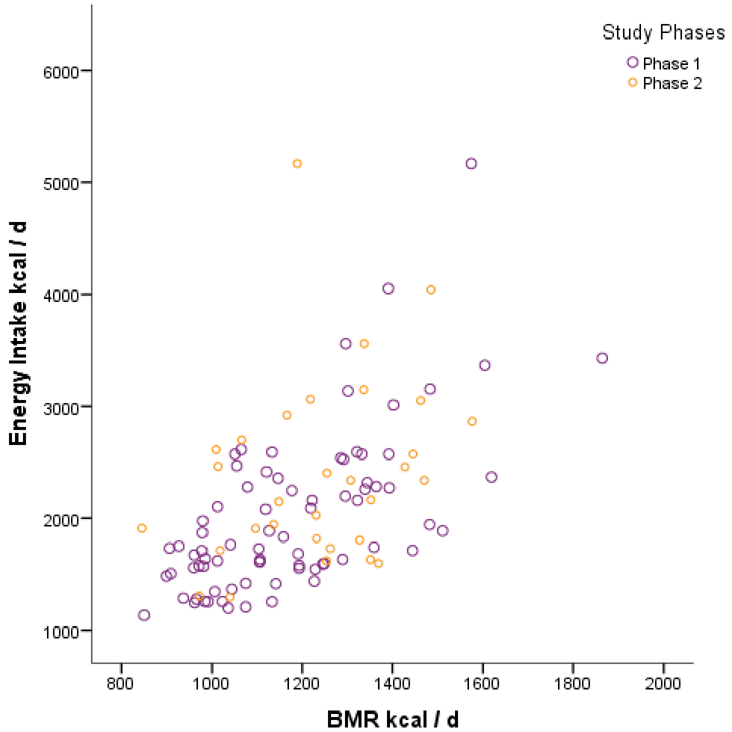


Figure 5.1: Comparison of mean energy intake EI (kcal) and BMR (kcal) in both phases

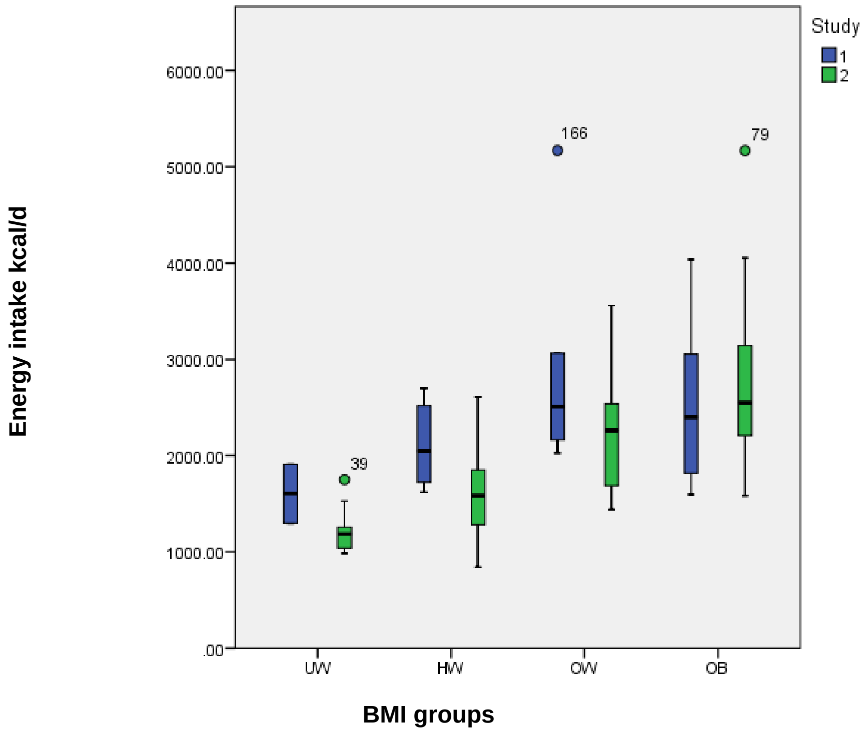


Figure 5.2: Comparison between mean energy intakes (kcal/d) according to BMI categories in both phases

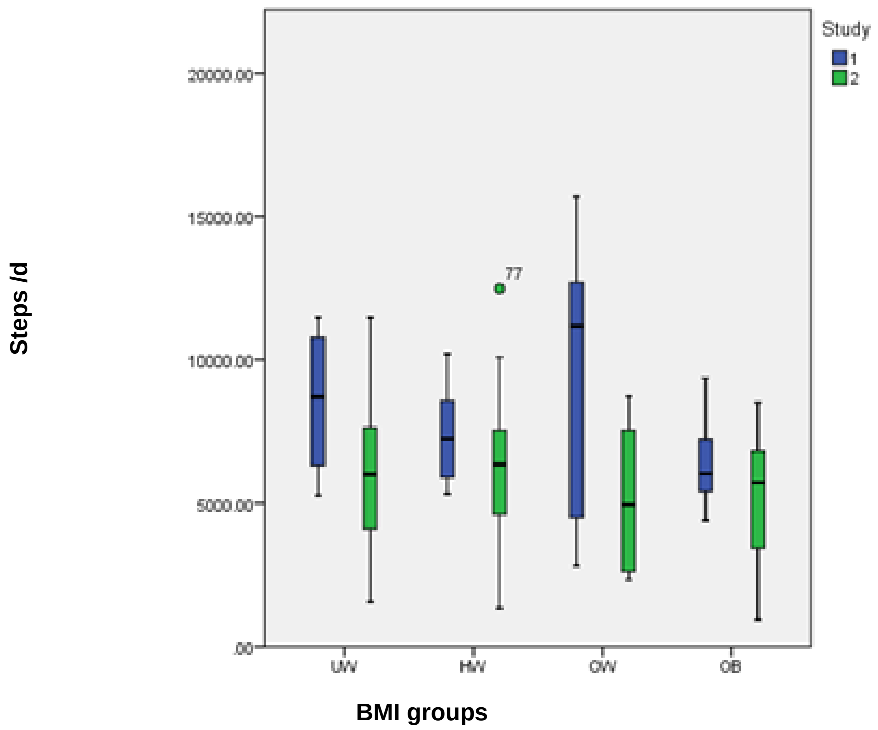


Figure 5.3: Comparison between average number of steps/day vs. BMI categories in both phases.

KEY: UW = Underweight: HW = healthy weight; OW = overweight; OB = obese

Figures 5.1-5.3 showed that estimated BMR, energy intake data and number of steps between both studies are similar and it seems that they are a homogeneous group. Nevertheless, the mean energy intake for healthy weight showed there is a difference in means, but the distribution for both studies is similar (see Figure 5.1). It was therefore decided to combine the groups.

Table 5.5: energy intake and steps comparison between both studies among BMI groups

BMI groups	Study	Mean EI	Mean Steps
UW	1= 4	1604	8406
	2 =7	1303	6406
HW	1= 8	1748**	6772
	2= 42	2110	7373
OW	1= 6	2906	9679
	2= 10	2239	6096
OB	1=13	2582	6236
	2=19	2741	5968

** p=0.018

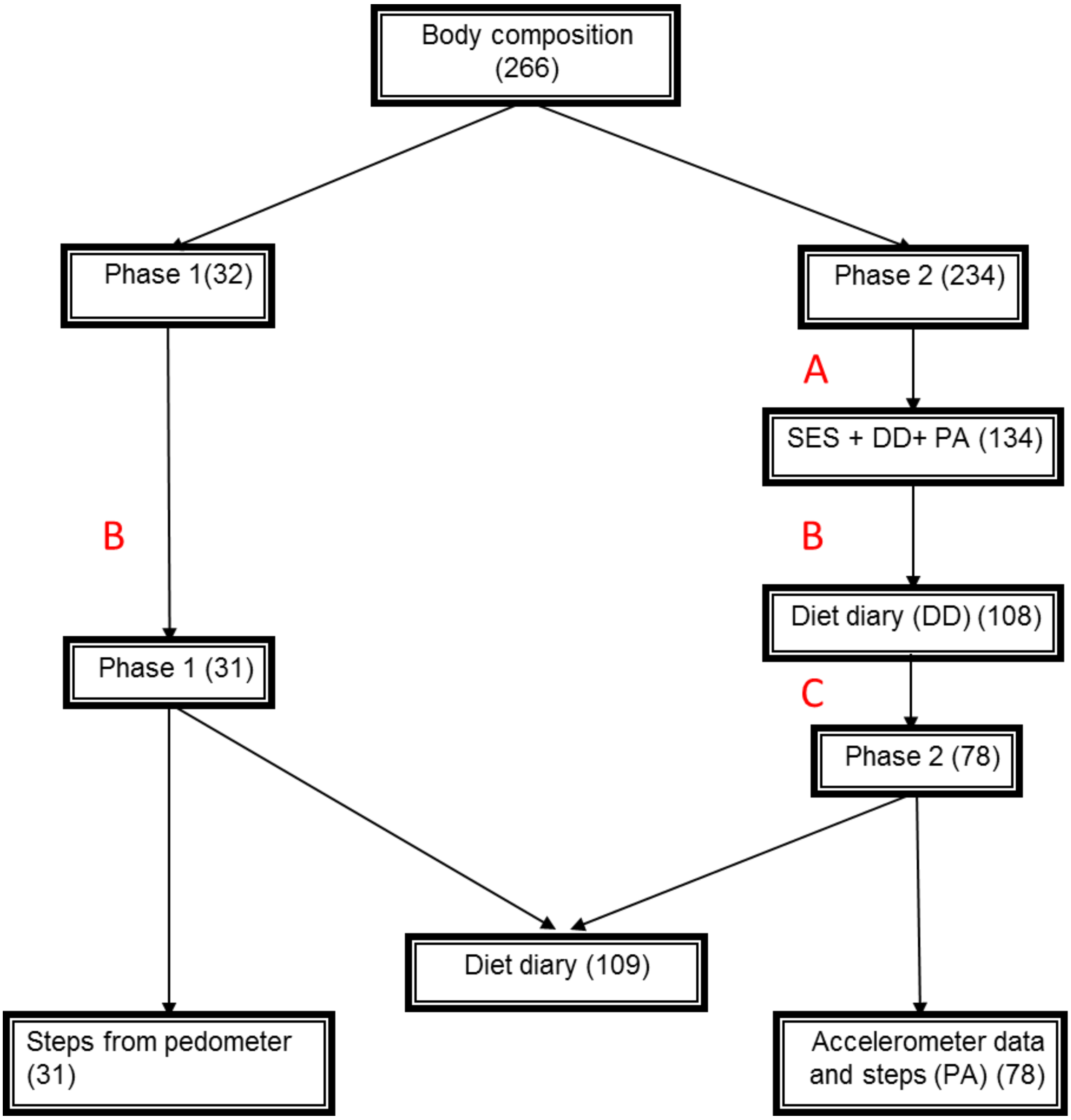


Figure 5.4: diagram for the number of subjects in each measurement, A = number of subjects agreed to continue, B= number of subjects after excluding dietary intake under reporters, C= number of subjects after excluding the accelerometer data recording.

SES= socioeconomic status, DD= diet diary, PA= physical activity

5.3.4 Exclusion

5.3.4.1 The estimated total energy expenditure (TEE) vs the average energy intake (EI)/day EI for both phases.

In order to define the under-reporters, a comparison between the mean estimated TEE and EI in both phases was made for exclusion of subjects. The total number of subjects who completed the diet diary was 166 (Table 5.6). (All of these also had body composition measurements completed).

Table 5.6: The number of subjects from two phases who completed the diet intake and Est-TEE before excluding in both phases

	OB	OW	HW	UW
Number	43	21	84	18
percentage	25.9%	12.6%	50.6%	10.8%
total	166			

OB =obese; OW = overweight; HW = healthy weight; UW = underweight

As stated in Section 5.2.11, subjects were excluded if their dietary energy intake was < BMR ×1.2. A total of 27 subjects were found to have EI lower than this value and were excluded from the analysis (Figures 5.6). Figure 5.5 shows the under-reporters (below the line) and Figure 5.6 shows the results with under-reporters removed.

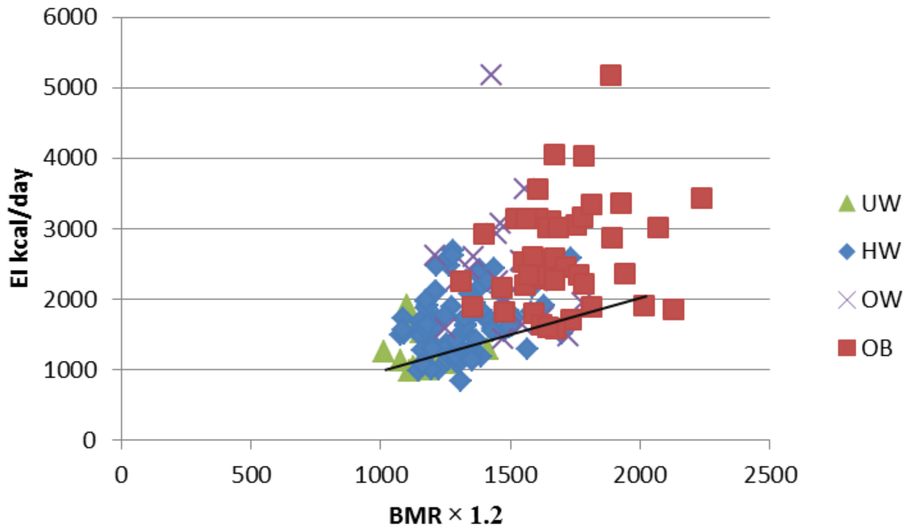


Figure 5.5: Average EI (kcal/ day) vs. estimated TEE (kcal/d) for both phases

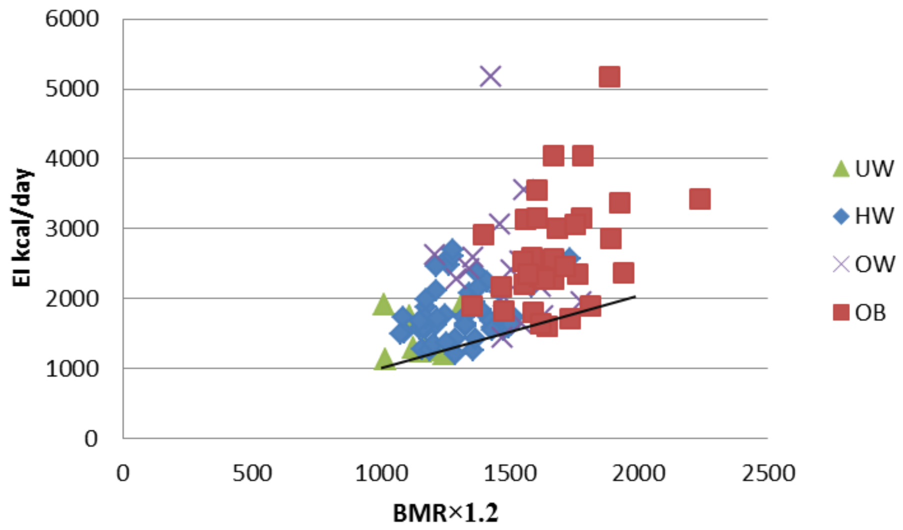


Figure 5.6: Average EI (kcal/d) vs. estimated TEE (kcal/d) after excluding the under-reporters.

The majority of the under-reporters were of a healthy weight. Nearly 66.7 % of under-reporters were healthy weight, whereas; 3.7 %, 11.1% were overweight and obese (respectively).

5.3.4.2 Exclusion from the accelerometer data phase 2.

The girls had been asked to wear the accelerometer for 4 days, two days on school days and two days at the weekends and to remove them at bed time and for showers. Not all the accelerometer records were completed. Accelerometer data were only included in the analysis if there was at least 3 completed days of data available. The completed day was defined as one accepted day if there were ≥10 hours continuous records (Robertson et al., 2010).

After exclusion for under-reporting in the diet diary, the number was 108 girls from phase 2. Only 78 of these completed accelerometer data. 30.7% girls completed 3 days and 69.2% had completed 4 days. Therefore the total number from phase 2 with acceptable diet and accelerometer data was 78.

5.3.5 Total energy expenditure.

5.3.5.1 Calculation of the total energy expenditure via the METs rate phase 2.

The METs rate was calculated by the Freedson et al (2005) equation obtained from the accelerometer recorded data. The METs average was multiplied by BMR in order to estimate TEE_M.

In Figure 5.7 below, a comparison of the mean energy intake is plotted against the mean TEE_M calculated by METs rate. The distribution gradually increased according to their BMI group, as expected. There was a significant positive correlation between energy intake and the TEE_M according the METs rate (Pearson r=0.500, $P < 0.001$).

5.3.5.2 Calculation of the Activity Energy Expenditure (AEE).

The activity energy expenditure AEE is the most variable component in TEE_A. This was calculated using the Ekelund et al. equation (2001). The sum counts per minute were recorded on the accelerometer. The modified equation is

AEE = 66.847 + (cpm x 0.953) – (176.91 x gender). CPM = Counts per Minute - Gender: boy=0, girl=1.

5.3.5.3 Total energy expenditure using Ekelund equation (TEE_A).

The other way to calculate TEE is by (TEE=AEE+BMR+DIT) diet-induced thermogenesis DIT, which was assumed to account for 10% of BMR (Biltoft-Jensen 2013). Figure 5.7 shows the distribution for the mean of energy intake against the mean TEE based on AEE. Figures 5.7 and 5.8 are slightly different due to the difference in TEE calculation. But statistically there is no significant difference between both calculations among UW, HW, OW, and OB groups with (P-value = 0.418, 0.850, 0.970, 0.714 respectively). Moreover, there is no significant difference between ($TEE_{M,}$ TEE_A) and $TEE_{1.45}$ (P= 0.274, p= 0.120) respectively (see Table 5.7).

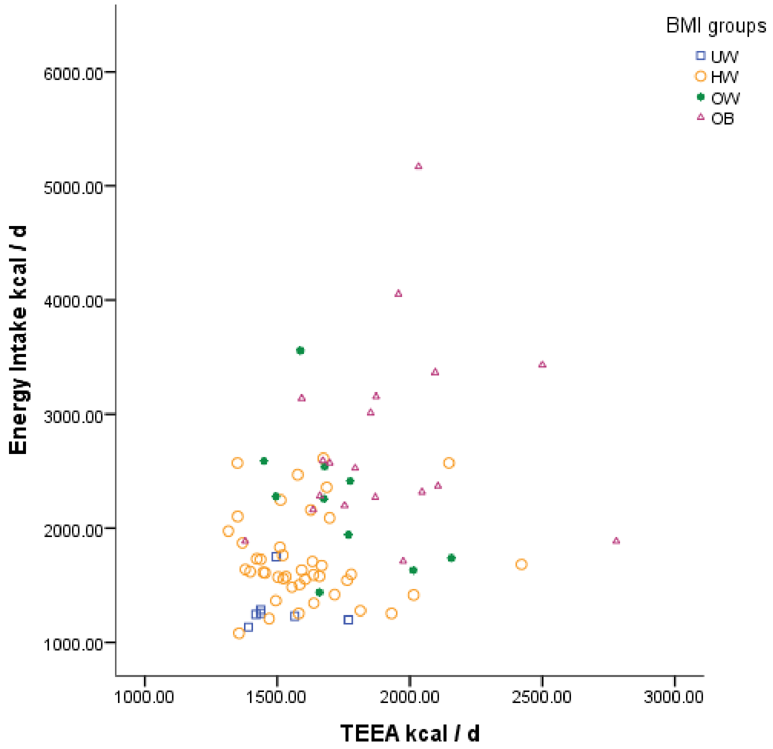


Figure 5.7: Average energy intake (kcal/d) vs the accelerometer TEE_A (kcal/d) by the Ecklund's equation for phase 2

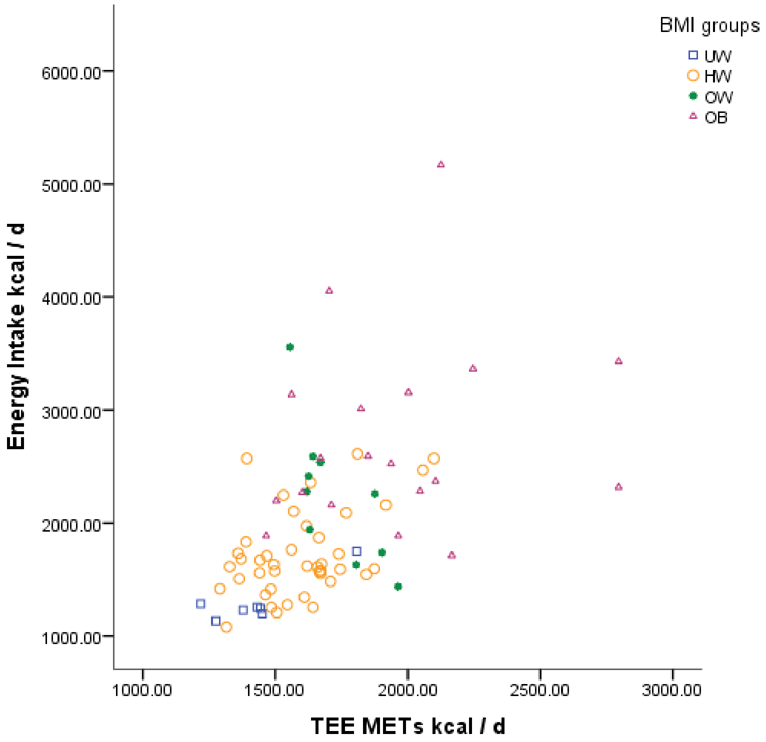


Figure 5.8: Average energy intake (kcal/d) vs the accelerometer TEE_M (kcal/d) and weight status for phase 2

A Pearson's r was computed to assess the relationship between average energy intake and $TEE_{A,}$ and there is a positive correlation between them (r= 0.335, P=0.003). Table 5.7 shows the difference in mean TEE calculations among the different BMI groups.

Table 5.7: Comparison between the TEE calculations

BMI groups	**n**	**EI/day Kcal**	**BMR kcal**	**TEE kcal**		
				Ecklund's equation	**METs**	**Est TEE BMR×1.45**
Under Weight	7	1299 ±204	959 ±63.3	1501 ±130	1429 ±189	1343.8 ±88.6
Healthy weight	42	1724 ±387	1097 ±169.3	1602 ±220	1594 ±191	1536.4 ±237
Over weight	10	2239 ±608	1261 ±123.5	1725 ±218	1728 ±143	1765.4 ±172.9
Obese	19	2741 ±845	1418 ±166.6	1908 ±323	1950 ±377	1985.2 ±233
Total number	78			1684* ±276.9	1684* ±293.6	1717* ±313.6

*No significant difference p=0.720

5.3.6 Comparisons of TEEA between the number of days recorded

5.3.6.1 Validation of the PA data according to differences in number of days recording with the accelerometer.

From the total of 78 with acceptable accelerometer records, 18 girls recorded 3 valid days with a minimum 10 hours per day, whereas 60 of them recorded 4 days with a minimum of 10 hours per day. In order to see whether the number of days 3 or 4 produced different results, a t-test was performed between recording data and it showed no significant difference between the data recorded for the three days and four days (Table 5.8).

Table 5.8: T-test for differences between TEE_A recorded for 3 or 4 days

Number of recording days in accelerometer	Number of subjects	Mean TEE	P value
3	18	1758 ±380	0.20
4	60	1662 ±237.2	
Total	78		

Therefore all data (whether 3 or 4 days) were kept in the analysis.

5.3.6.2 The validity of different number of days logged in diet diary in phase 2.

5.3.6.2.1 Comparison in energy intake between the subjects

A total of 11 girls out of 78 logged 3 valid days in the diet diaries, including a minimum of 1 weekend day, whereas 67 completed 4 days with 2 weekdays and 2 weekends. Moreover, statistically there was no significant difference between the data logged for the three days and four days (Table 5.9). Therefore data was included for 3 and 4 days records.

Table 5.9: T-test for difference in EI between those who recorded for 3 days and those who recorded for 4 days

Number of recording days in diet diary	Number of subjects	Mean EI kcal/d	P value
3	11	2226 ±869.9	.267
4	67	1963 ±696.8	
Total	78		

5.3.6.2.2 Comparison between the same diaries logged

13 girls who recorded their dietary intake for 4 days from different BMI groups were selected to test the validity of the differences in number of days of logging in the diet diary. One day from each one was excluded randomly and then the average of the three days was calculated. Table 5.10 shows that there was no significant difference between the data recorded within the three days and four days in the same subjects.

Table 5.10: T-test for the EI between the diet diary recording dates for the same 13 subjects

Number of recording days in diet diary	Number of subjects	Mean EI	P value
3	13	2089.1 ± 593.3	.426
4	13	2352.4 ±1011.6	

5.3.7 Completed valid measurements after exclusions.

The study population in both phases consisted of 266 girls and only 29.3 % of them were involved in all the measurements. All of them completed the body composition measurements. Table 5.11 summarises the numbers of participants who took part in each component.

Table 5.11: Number of subjects for each measurement from both phases after excluding

	Body composition	Accelerometer	Estimated TEE	Steps	SES	Dietary intake
Phase 1	32	-	31	31	-	31
Phase 2	234	78	78	78	134	78
Total	266	78	109	109	134	109

5.3.7.1 Body composition.

Valid data was obtained from 266 individuals from both phases. According to Table 5.12, there were significant differences in all body composition elements between the BMI groups. Unsurprisingly obese subjects had significantly greater waist circumferences, with a maximum 104 cm and there was an increase across the BMI groups. According to the international age- and gender-specific child BMI cut-off points, 30% of the study population was classified as overweight/obese.

Table 5.12: Body composition and anthropometric measurements in underweight (UW), healthy-weight (HW), overweight (OW), and obese (OB) girls. (n=266)

Body composition	UW N=43	HW N=143	OW N=34	OB N=46
Age (years)	9.5 ± 1.27	9.6 ± 1.1	9.9 ± 1.2	9.3 ± 1.2
Body Fat %* **	9.9 [a] ±4.4 2.50-26.5	18.1 [b] ±4.6 3-29.7	29.5 [c] ±3.4 22.7-36.6	36.7 [d] ±3.9 27.2-49.3
Weight (kg)* **	22.9[a] ±4.8 15.6-35.7	29.3[b] ±6.4 19.4-47	41.4[c] ±7.1 27.5-54.9	50.3[d] ±11.4 31.2-91.8
FM (kg)* **	3.4 [a] ±2.6 0.41-5.30	5.3 [a] ±2.4 0.76-13.84	12.2 [b] ±3.5 1.72-19.91	18.5 [c] ±6.7 10.47-45.26
FFM (kg)* **	19.5 [a] ±4.1 14.70-28.29	24.0 [a,b] ±4.8 16.02-35.96	29.2 [b,c] ±5.0 21.14-35.67	31.8 [c] ±5.9 20.40-46.54
WC (cm)* **	53.7 [a] ±4.0 46-66	59.2 [b] ±5.7 45-74	72.1[c] ±5.3 58-85	79.8 [d] ±7.9 63-104
Height (cm)* **	130.1 [a] ±11.6 109-159	132.9 [a,b,c] ±10.4 112-159	138.5 [a,b,c] ±8.4 121-152	138.7 [c] ±10 117-161
BMI Percentile* (CDC)**	1.6 [a] ±.9 (1-4)	39.5 [b] ±23.8 (5-84)	90 [c] ±3.6 (85-94)	97.9 [d] ±0.9 (95-99)
Stature percentile* (UK)**	34 [a] ±32.1 (0-97)	46 [b] ±30.7 (0-97)	59.6 [c] ±27 (5-97)	72.5 [d] ±26.1 (10-97)

***Levels of significance according to BMI group based on one-way ANOVA tests ($p < .001$)

[a,b,c,d] Tukey Post hoc test: means with the same letter indicate no significant difference. Any difference between two means carrying different letters is significant at 1%.

Obese girls were significantly taller than underweight girls but there was no difference in mean age between all the BMI groups. The body fat percentage increased significantly over the BMI groups. The FFM and FM also increased over the BMI groups; however, there was overlap in FFM and FM between BMI groups and a large variation in values.

According to Table 5.13, private schools have a noticeably higher recorded percentage of obese and overweight girls than public schools. 42.4% of the girls measured in the private schools were obese and overweight compared to 24% in the public schools. Moreover, the percentage of underweight girls in public schools was 21.2%, while in private schools it was nearly 6%.

Table 5.13: Number of underweight (UW), healthy-weight (HW), overweight (OW), and obese (OB) in private and public schools (n = 266)

	UW N=43	**HW N=143**	**OW N=34**	**OB N=46**	**Total n=266**	**P-Value**
Private Schools	5 5.7% *14.06	45 51.7% *46.77	10 11.4% *11.12	27 31% *15.05	87	< 0.001
Public Schools	38 21.2% *28.94	98 54.7% *96.23	24 13.4% *22.88	19 10.6% *30.95	179	

*Chi-Sq expected count. DF = 3

The Chi-Square test was highly significant (Chi-Square = 23.064 P<0.001). There was a highly significant association between obesity and private schools; in contrast, there was a link between being underweight and attending a public school.

5.3.7.2 Prediction equations for fat percentage and waist circumference

In order to develop a new method of predicting fat percentage and waist circumference in similar populations, after checking all the assumptions (residuals normally distributed and the model diagnostic for outliers) (see appendix 7), regression equations were formulated from this study population. In order to test their validity, these prediction equations could be applied in future work with different participants.

5.3.7.2.1 Fat percentage regression equation

Body fat percentage was estimated using four variable combinations from this population (weight, height, age, and waist circumference)

Fat % = -10.90 + 0.0254 × wt (kg) - 0.1135 × ht(cm) – 0.696 ×age (years) + 0.8386× WC (cm)

This equation has a higher r^2=88.97, (p<0.001) compared to another study in the USA (r^2= 0.79) (Deurenberg et al., 1991). The estimation of body fat percentage from the Tanita was compared with the one calculated according to the above formula. The correlation coefficient between both methods was highly significant (r = 0.900, p ≤ 0.005), but this would expected as the data is derived from the same population. To test the predicted value the new equation would need to be tested in a similar sample consisting of different participants.

Table 5.14: A comparison of body fat % estimation using Tanita and calculation by the prediction equation

Calculation methods	Age 8 years n=74	Age 9 years n=54	Age 10 years n=58	Age11years n=80
Body Fat % measured Tanita*	22.0 ± 9.5	19.2 ± 9.4	22.2 ± 9.8	22.4 ± 10.0
Body Fat % predicted equation*	20.8 ± 8.3	19.8 ± 5.9	23.7 ±10.2	22.2 ± 9.3

5.3.7.2.2 Waist circumference regression equation

Waist circumference was estimated using two other variables BMI, and age (r^2=88.17, p<0.001).

$$\mathbf{WC = -13 + 1.522 \times BMI + 8.43 \times age - 0.478 \times age^2 + 0.0748 \times BMI \times age}$$

There was a strong correlation between the measured and calculated value (r = 0.917, p ≤ 0.005), but again, to test the validity, the equation would need to be tested in a new sample.

Table 5.15: A comparison of measured waist circumference and the estimation from prediction equation

	Age 8 years n=74	Age 9 years n=54	Age 10 years n=58	Age 11years n=80
WC measured	61.0 ± 11.2	61.5 ± 8.1	64.7 ± 13.0	66.8 ± 11.0
WC predicted equation	62.0 ± 9.4	61.4 ± 7.9	65.9 ± 10.5	65.1 ± 12.7

5.3.7.3 Comparison of height and weight data according to different centile charts

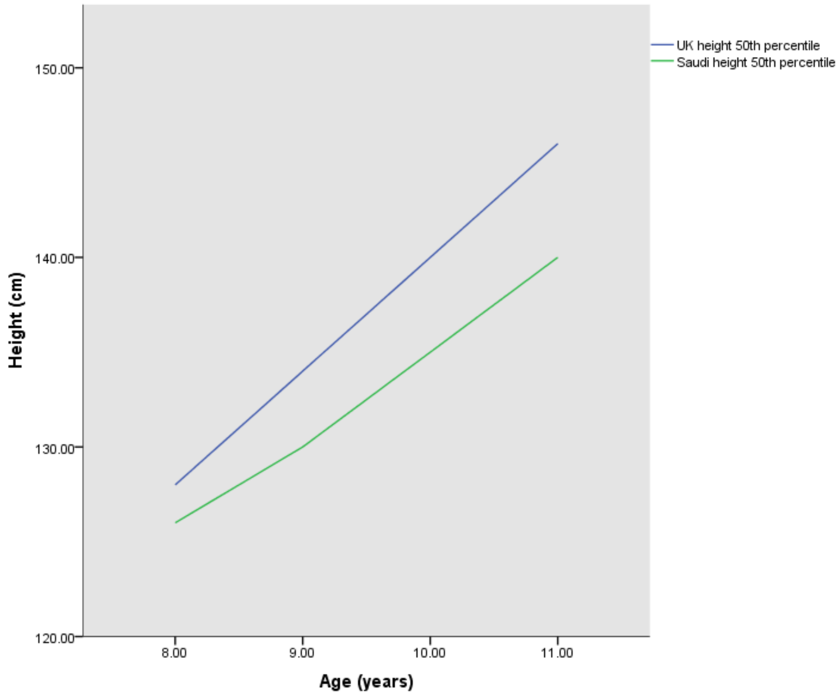


Figure 5.9: Comparisons of KSA and UK height-age percentile.

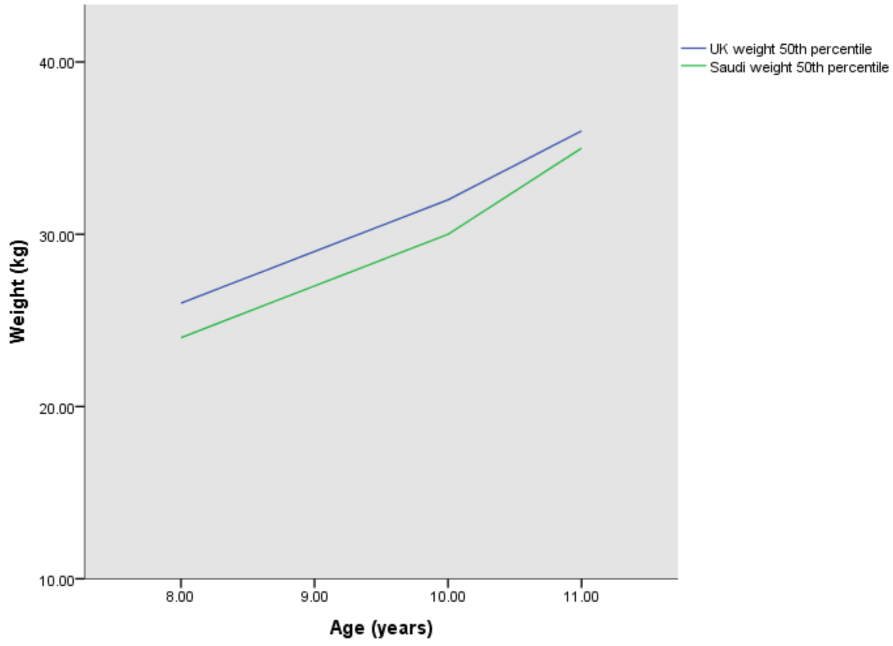


Figure 5.10: Comparisons of KSA and UK weight-age percentile

Table 5.16: Number of subjects in 50th -75th and > 97th centiles in UK and Saudi height and weight charts

	8 years		9 years		10 years		11 years		Total	
	UK	Saudi	UK	Saudi	UK	Saudi	UK	Saudi	UK	Saudi
Height 50th -75th percentile	17	28	12	19	13	18	35	40	77	105
Total means *									60.06 ±12.34	61.19 ±12.49
Height >97th percentile	5	9	1	4	3	6	5	7	14	26
Total means *									98.34 ±0.68	97.00 ±0.00
Weight 50th -75th percentile	14	11	5	5	11	10	27	15	57	75
Total means *									60.96 ±12.51	61.33 ±12.52
Weight >97th percentile	17	20	4	6	6	8	11	10	38	44
Total means *									98.63 ±0.79	97.00 ±0.00

*differences in mean centiles were p<0.001 for both height and weight

Using the exact centile for each child, a mean centile was calculated for each chart. A comparison between the UK and KSA age-height percentile (Figure 5.9) shows that statistically there was a significant difference in mean centile using a t-test in both 50th -75th percentile and >97th percentile ($p < 0.001$) and there was a significant difference in the comparison between the UK and KSA age-weight percentile both 50th -75th percentile and >97th percentile (Figure 5.10), with p-value < 0.001. Although the Saudi chart is published in 2007 by El Mouzen et al, the UK growth chart was updated in 2013.

The number of subjects in each centile category varies according to which centile charts were used (Saudi or UK). Therefore, in order to compare this study's findings with the other studies in UK, the UK centile charts were used.

There is also potential to classify obesity differently depending on which charts were used: the UK body-fat reference charts by McCarthy et al. (2006), or the BMI percentile chart from CDC. Accordingly, McCarthy cut offs for the 2nd, 85th, and 95th centiles are considered as underfat, overfat, and obese. Using McCarthy's classification, 106 girls were plotted on the 2nd centile or less, while according to CDC BMI centiles 43 girls were considered as underweight. Moreover, 55 girls on 95th centile or above were defined as obese according to their body fat centile but only 46 of them were considered obese using the CDC BMI centiles. A total of 13 girls were plotted between the 85th -94th centile while 34 girls were considered as overweight according to CDC BMI centile charts. These differences could be explained by the differences between the populations for both charts. McCarthy's chart is based only on Caucasian UK children. Whereas the CDC chart is representative for all ethnicities in USA and therefore is perhaps more suitable for a Saudi population. Another possible explanation is that BMI centile is based on two components, height and weight, without defining amount of the lean tissue. However, the body fat percentage chart distinguishes fat mass and fat free mass and so may more accurately estimate the number of the under-fat girls.

Table 5.17: A comparison between the different classifications according to McCarthy et al. (2006) body fat reference curves and CDC centile chart (n= 266)

	Body fat reference chart by McCarthy		BMI centile chart (CDC)	
Underweight	n= 106 2 ±0.00	≤ 2nd	n= 43 1.67 ±0.969	< 5th
Healthy weight	n= 92 36.5 ±22.8	>2nd - <85th	n= 143 39.51 ±23.83	5th - 84th
Overweight	n= 13 89.61 ±3.45	≥ 85th - <95th	n= 34 89.61 ±3.45	85th - 94th
Obese	n= 55 97.73 ±1.13	≥ 95th	n= 46 97.73 ±1.13	≥ 95th

Table 5.18: The percentage of girls who completed all diet and physical activity measurements from the total number for all BMI categories

	Both phases Total no=266
Obese	91.3%
Overweight	64.7%
Healthy weight	58.7%
Underweight	41.8%

According to Table 5.18, the percentage of obese and overweight girls that responded and completed the food diaries and physical activity measurements was higher than the healthy and underweight girls.

5.3.8 Dietary intake

Table 5.19, below, lists the nutrient intake for the four BMI categories of participants. It also shows the contribution of different food types to energy intake, and the daily consumption of fruit and vegetables.

The first thing to note from Table 5.19 is that the average energy intake and other macronutrient intake increased significantly according to weight category.

The overweight group recorded the highest vegetable consumption (105 g/d), which was significantly higher than the healthy weight (52.3g) and the underweight girls (18.3g/d), but not significantly different to the obese group (84.3 g/d). There was a gradual increasing intake of sugary drinks and sweets across the BMI groups with the obese group consuming significantly higher amounts (124.2ml, 147.7g) than healthy weight (84.6ml, 98.5g) and underweight girls (64.4ml, 59.2g).

Table 5.19: Nutrient intake and selected food types in underweight (UW), healthy-weight (HW), overweight (OW), and obese (OB) participants from the diary data. (n =109)

Average for 4 Days	**UW N=11**	**HW N=50**	**OW N=16**	**OB N=32**
ENERGY kcal***	1412 ±291[a] (1133-1909)	1806 ± 403 [a] (1207-2697)	2489 ±887 [b] (1438-5168)	2677 ± 804 [b] (1595-5168)
EI (kcal /kg Body wt)	66 ± 20.32 (47.1 -117.16)	62 ± 16.8 (37.17 - 98)	64 ± 26.6 (37.58 -127.62)	53 ± 14 (27.7 - 89.88)
EI kcal /kg FFM)	68 ±10.2 (53.2-82.1)	75 ±19.3 (45.1- 123.6)	80± 25.6 (54.4- 112.12)	86 ± 20.5 (53.5- 143.9)
PROTEIN(g/d) ***	52.9 ±19 [a] (36.2-86.8)	66.3 ±24 [a] (25.4-118.2)	79.1 ± 39 [a,b] (39.2-213.3)	87.8 ±35 [b] (37.7-213.3)
kcal from protein ***	211±76 [a] (132-347)	264 ±100 [a] (102-473)	312 ±159 [a,b] (157-853)	359 ±137 [b] (202-853)
% kcal from protein	14.2% ±3.2 (10.6-20.8)	14.5% ±3.9 (5.4-25.8)	12.2% ±1.9 (9-16.5)	13.5% ±2.9 (7.9-17.9)
FAT (g/d) ***	50.5 ±11[a] (35.8-68.7)	68.8 ±24.3 [a] (5.3-117.8)	104.5 ±39 [b] (52-209.2)	108.2 ±44 [b] (50.0-211.2)
kcal from Fat ***	454 ±99 [a] (618-322)	624 ±211 [a] (200-1061)	940 ±351 [b] (468-1883)	974 ±396 [b] (450-1901)
% kcal from fat	32.2% ±4 (28.1-41.7)	34% ±6 (12.5-42.9)	38.2% ±9.1 (27.5-67.9)	35.6% ±5.8 (27.4-47.4)
CHO (g/d) ***	199.2 ±42.4 [a] (161.4-276)	236.5 ±62.3 [a] (53.6-435.5)	347.4 ±109.9 [b] (191.8 -642.2)	362 ±93 [b] (233.7-642.2)
kcal from CHO ***	796 ±169 [a] (646-1104)	946 ±249 [a] (214-1742)	1389 ±439 [b] (767-2569)	1442 ±370 [b] (935-2563)
% kcal from CHO	56.4% ±3.5 (49.5-63)	52.6% ±9.2 (13.26-67.8)	57% ±12.5 (39.4-98.6)	54.7% ±6.1 (39.6-67.9)
Fruits (g/d)	28.9 ±39.5 (.0-105)	35.2 ±43.5 (.0-200.5)	29.5 ±54.8 (.0-200)	32.9 ±72.7 (.0-393.7)
Vegetables (g/d) **	18.3 ±22 [a] (.00-61.2)	52.3 ±44.4 [a] (.00-220)	105 ±114.7 [b] (.00-400)	84.3 ±73.8 [a,b] (.0-348.7)
Sweets (g/d) [1] ***	59.2 ±37.5 [a] (.0-145)	98.5 ±53.4 [a] (.00-237.5)	129.9 ±67.4 [a,b] (12-253)	147.7 ±97.7 [b] (.0-361.7)
Sugary drink (ml/d) [2] ***	64.4 ±40.6 [a] (.0-125)	84.6 ±51[a] (.0-212)	104.4 ±70.4 [a,b] (.0-250)	124.2 ±52.2 [b] (42-283)
kcal from sugary drink **	72 ±44 [a] (21- 121)	120 ±94 [a] (26-326)	158 ±112 [a, b] (42- 292)	144 ±49 [b] (68- 221)
% kcal from sugary drinks	4.5% ±3 (.00-11)	4.6% ±2.9 (.00-13.1)	4.2% ±3.1 (.00-11.3)	4.7% ±2 (2-10.60)
Savoury Snack (g/d) [3] **	1.5 ±3.5 [a] (.0-8.7)	20 ±24.5 [a,b] (.0-120)	22.7 ±3.6 [a,b] (.0- 125)	37 ±44 [b] (.0-187)
kcal from Savoury Snack **	8 ±17.7 [a] (.00-44)	100 ±123 [a,b] (.00- 600)	117 ±167 [a,b] (.00- 625)	186 ±220 [b] (.00-937)
% kcal from Savoury Snack	0.6% ±1.4 (.00-3.60)	5.6% ±6.8 (.00-28.8)	4.8% ±7.1 (.00-27)	6.2% ±6 (.00-23)

* significant differences p≤ 0.05, ** p≤ 0.01, *** p≤ 0.001 for the effect of the BMI groups

[a,b,c] Tukey Post hoc test: means with the same letter indicate no significant difference. Any difference between two means carrying different letters is significant at 1%.

[1] Sweets" include: chocolate, sweets, biscuits, cakes, desserts and ice cream.

[2] "Sugary drinks" include: carbonated drinks, fruit squash, and juice with add sugar.

[3] "Savoury snacks" include: crisps and popcorn.

Note: the total daily energy intakes do not exactly equal the energy intake from fat, protein and CHO because the average conversion factor values of 9kcal/g for fat and 4kcal/g for protein and CHO respectively were used to calculate the energy contributions per gram. These are not exact but estimations of the energy intake from fat, protein and CHO.

The differences between the EI at BMI group level was evaluated by comparing means, using post hoc (Tukey) test. There was a significant difference (p = 0.05) between all groups except between overweight and obese groups, where there was no difference (P=0.327).

The recommended protein allowances for Saudi children aged 7-9y and 10-12y are 31g/d and 43 g/d respectively (Khan 1997). Table 5.19 shows that the mean protein intake among all groups (52.9, 66.3, 79.1, and 87.8 g/d respectively) exceeded the recommended amount. According to UK DRVs (1991), the recommendation for energy derived from fat should not exceed 35% of the total energy intake per day, whereas in the overweight group the percentage of energy derived from fat was above this (38.2%) and just slightly over in the obese group (35.6%). The healthy weight and underweight groups has a slightly lower percentage of energy derived from fat (34% and 32.2% respectively), but there were no significant differences between them.

Although the UK DRVs stated that the recommendations for percent energy from carbohydrates should be 50%, most of the groups had slightly more than this (DRVs 2007). The WHO definition of “free sugars include monosaccharides and disaccharides added to foods by the manufacturer, cook or consumer, and sugars naturally present in honey, syrups, fruit juices and fruit juice concentrates”. It is recommended that free sugars contribute below 5% of the daily total energy intake (WHO 2015). This study showed that the mean % energy from sugary drinks alone was almost 5% among all the groups. In a comparison between the subjects’ intake from different schools, the girls from private schools recorded higher energy intake from savoury snacks and a higher fruit intake than those from public schools, although no significant difference in average daily energy intake between the girls from both schools was found (Table 5.20).

Table 5.20: Nutrient intake and selected food types in private and public schools from the diary data (n =109)

	Private school n= 57	**Public school n=52**
Energy intake kcal/d	2240 ±712.12	1994 ±807.06
EI (kcal /kg Body wt)	63.08 ±19.02	56.98 ±17.78
EI (kcal /kg FFM)*	85.53 ±21.44	68.92 ±14.98
PROTEIN(g/d)	75.62 ±31.86	70.56 ±32.32
kcal from protein	306 ±127.25	281 ±129.99
% kcal from protein	13.65% ±3.59	14.18 ±3.25
FAT (g/d)	90.22 ±36.24	76.80 ±40.62
kcal from Fat	808 ±332.87	700 ±355.15
% kcal from fat	35.39 % ±5.89	34.50 % ±7.19
CHO (g/d)	298.65 ±110.7	271.89 ±129.99
kcal from CHO	1194 ±363.64	1084 ±439.76
% kcal from CHO	53.86 % ±7.11	54.78 % ±10.21
Fruits (g/d) *	42.75 ±64.45	22.53 ±38.25
Vegetables (g/d)	65 ±67.71	67.20 ±74.20
Sweets (g/d) [1]	124.51 ±82.3	101.14 ±63.84
Sugary drink (ml/d) [2]	275.04 ±148.6	234.4 ±165.48
kcal from sugary drink	102 ±51.54	92 ±61.88
% kcal from sugary drinks	4.66 % ±2.42	4.52 % ±3.01
Savoury Snack (g/d) [3]	29.76 ±38.19	16.8 ±25.15
kcal from Savoury Snack *	148 ±191.31	87 ±127.05
% kcal from Savoury Snack	6.27 % ±7.5	4.04 % ±4.79

*significant difference P=0.05

[1] Sweets" include: chocolate, sweets, biscuits, cakes, desserts and ice cream.

[2] "Sugary drinks" include: carbonated drinks, fruit squash, and juice with add sugar.

[3] "Savoury snacks" include: crisps and popcorn.

Note: the total daily energy intakes do not exactly equal the energy intake from fat, protein and CHO because the average conversion factor values of 9kcal/g for fat and 4kcal/g for protein and CHO respectively were used to calculate the energy contributions per gram. These are not exact but estimations of the energy intake from fat, protein and CHO.

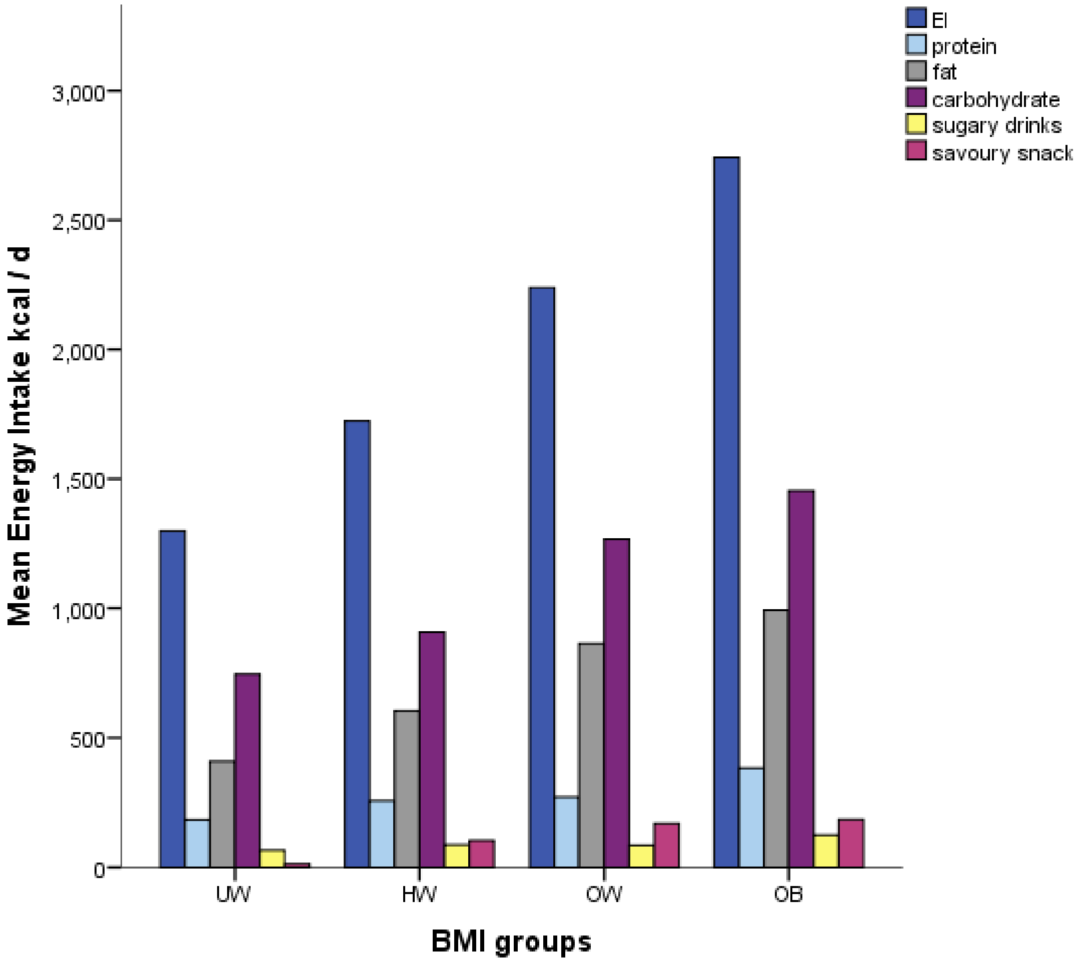


Figure 5.11: Average total energy intake per day and average energy from the protein, fat, carbohydrates, savoury snack and sugary drinks for BMI groups.

There was a weak positive correlation between the average percentage energy from fat intake per day and waist circumference (Pearson's r=0.192, P=0.045), as the WC increased the percentage energy from fat per day increased (Figure 5.12). Moreover, a significant positive but weak correlation between body fat percentage and the percentage of energy intake from fat was found (Pearson's r=0.242, P< 0.05).

Likewise, to investigate the relationship between daily protein intake and body fat percentage Pearson's correlation carried out and found they were correlated positively (Pearson's r=0.377, P< 0.01).

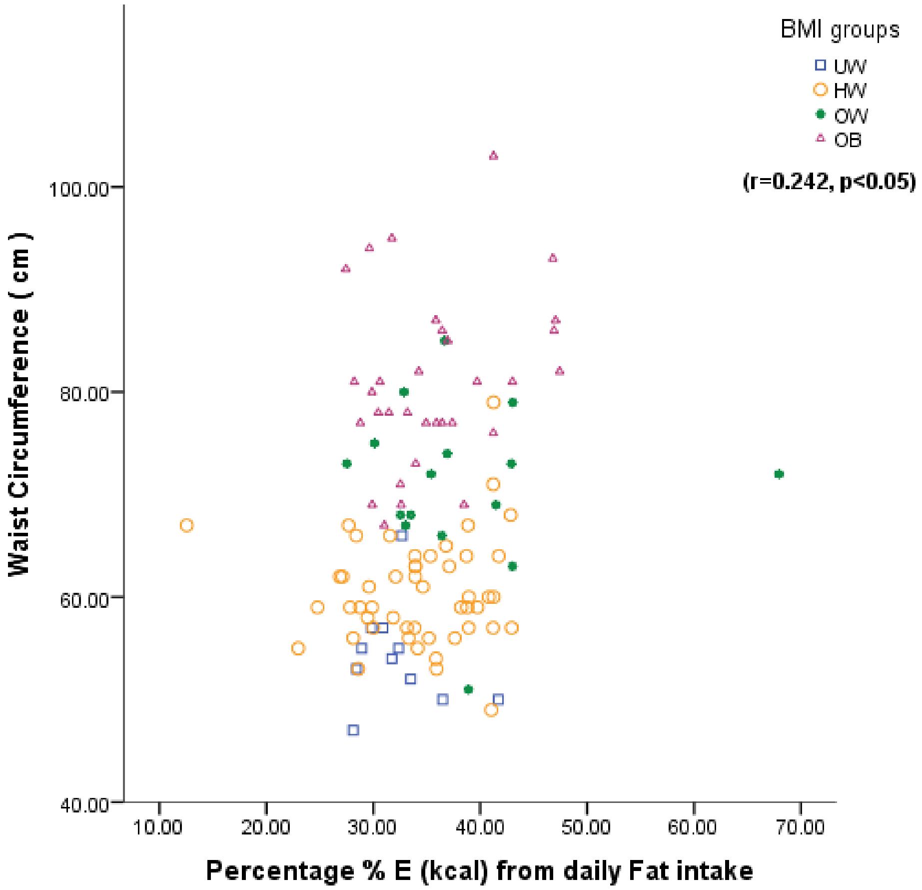


Figure 5.12: Percentage of energy from daily fat intake vs waist circumference according to BMI classification.

The relationship between variables according to energy intake per kg of fat free mass and body weight were investigated using the Pearson product-moment correlation coefficient. Preliminary analyses were performed to ensure no violation of the assumptions of normality, linearity and homoscedasticity. There was a moderate, negative correlation between fat free body mass and daily energy intake per kg body weight (EI/Bwt (Kg)), r = –.46, n = 78, p < 0.01, with high levels of energy intake associated with lower levels of FFM (Figure 5.12).

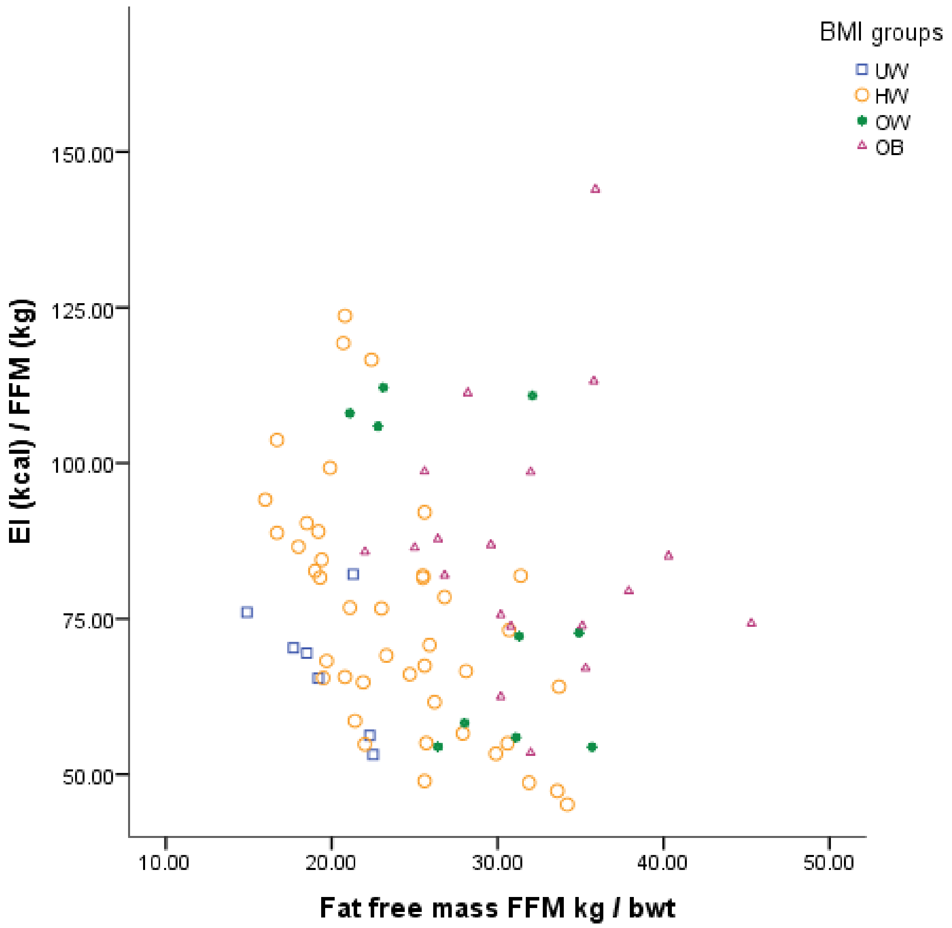


Figure 5.13: fat free mass vs daily energy intake per FFM kg/BW according to BMI classification

There was a correlation between EI and FFM in all BMI groups. Free fat mass showed a significant positive correlation with the energy intake at the 0.01 level and Pearson's r=0.599.

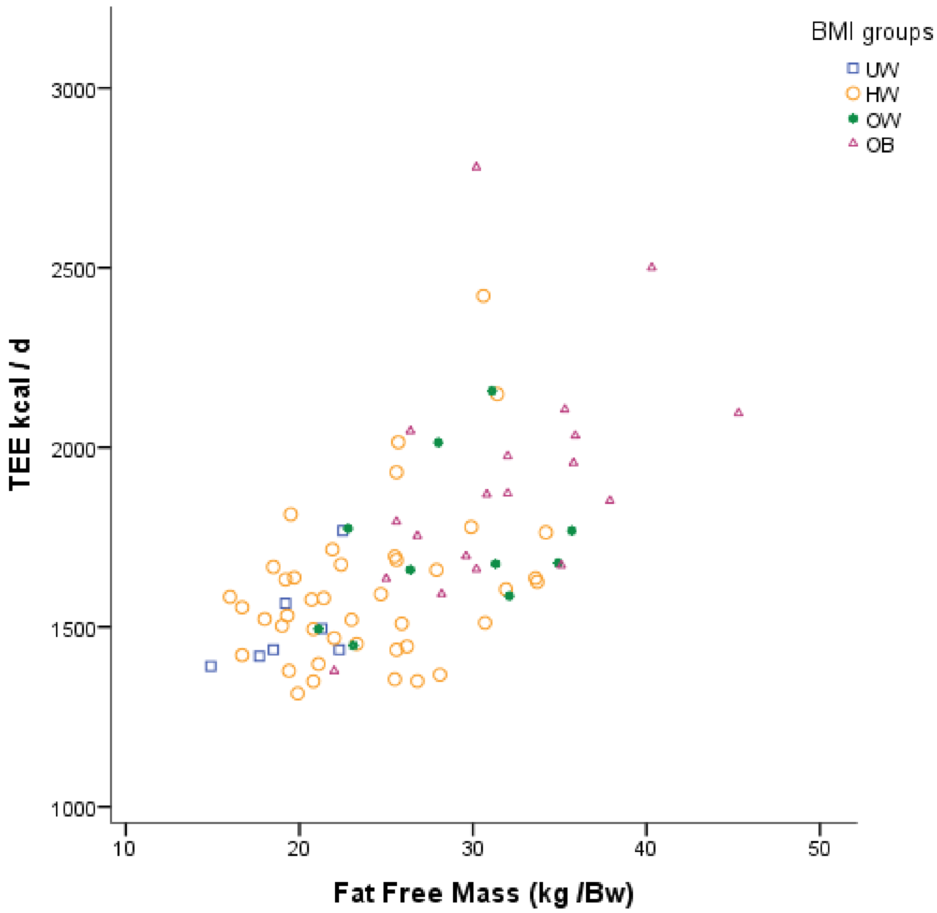


Figure 5.14: fat free mass vs daily total energy expenditure (TEE) according to BMI classification

In order to predict which nutrients contributed to body weight, a multiple linear regression was carried out to ascertain the extent of macronutrients contributing to energy intake in gaining weight. Preliminary analyses were conducted to ensure no violation of the assumptions of normality, multicollinearity and the outliers. The testing was calculated to predict the body weight level based on the daily energy intake from fat, protein, and carbohydrate. It was found that these variables explain a significant amount of the variance in the obesity level (F (3, 105) = 20.24, $p < 0.001$, $R^2 = 0.366$).

The analysis shows that the energy intake from fat and protein did not significantly predict body weight (Beta = 0.178, 0.136) p= 0.30, 0.20), but daily energy intake from carbohydrate significantly predicted body weight (Beta = 0.375, p = 0.008).

In order to investigate further, another multiple linear regression was carried out to ascertain the extent of the selected food types in contributing to body weight. The analyses were conducted to ensure no violation of the assumptions. The testing was calculated to predict the body weight level based on the intake (g/d) from sweets, sugary drinks and savoury snacks. It was found that these variables explain a significant amount of the variance in the obesity level ($F (3, 105) = 8.5$, $p < 0.001$, $R^2 = 0.196$). Daily intake from savoury snacks did not significantly predict body weight level (Beta = 0.154) p= 0.089), however daily intake from sweets and sugary drinks significantly predicted the level of body weight (Beta = 0.201, 0.274, p = 0.33, 0.004).

5.3.9 Physical activity data

Table 5.21 shows the mean number of minutes/day spent in MVPA and the other intensities of exercise according to two different cut points (Freedson 2005, Evenson 2008). There was a significant difference in estimated time being spent in sedentary, light, moderate and vigorous activities between both cut points.

Table 5.21 Comparison between Freedson's and Evenson's cut points at different intensities of exercise in this study.

	Evenson cut point min/d	**Freedson cut points min/d**
Minutes in vigorous PA*	3.108 ± 3.0	2.82 ± 2.5
Minutes in moderate PA*	16.98 ± 8.4	192.1 ± 64.8
Minutes in vigorous to moderate PA*	20.1 ±10.5	195 ± 65.8
Minutes in light PA*	360.31 ± 103.3	146.2 ± 40.7
Minutes in sedentary PA*	455.8 ± 167.1	481.9 ±178.3

* T-test between different cut points p<0.001

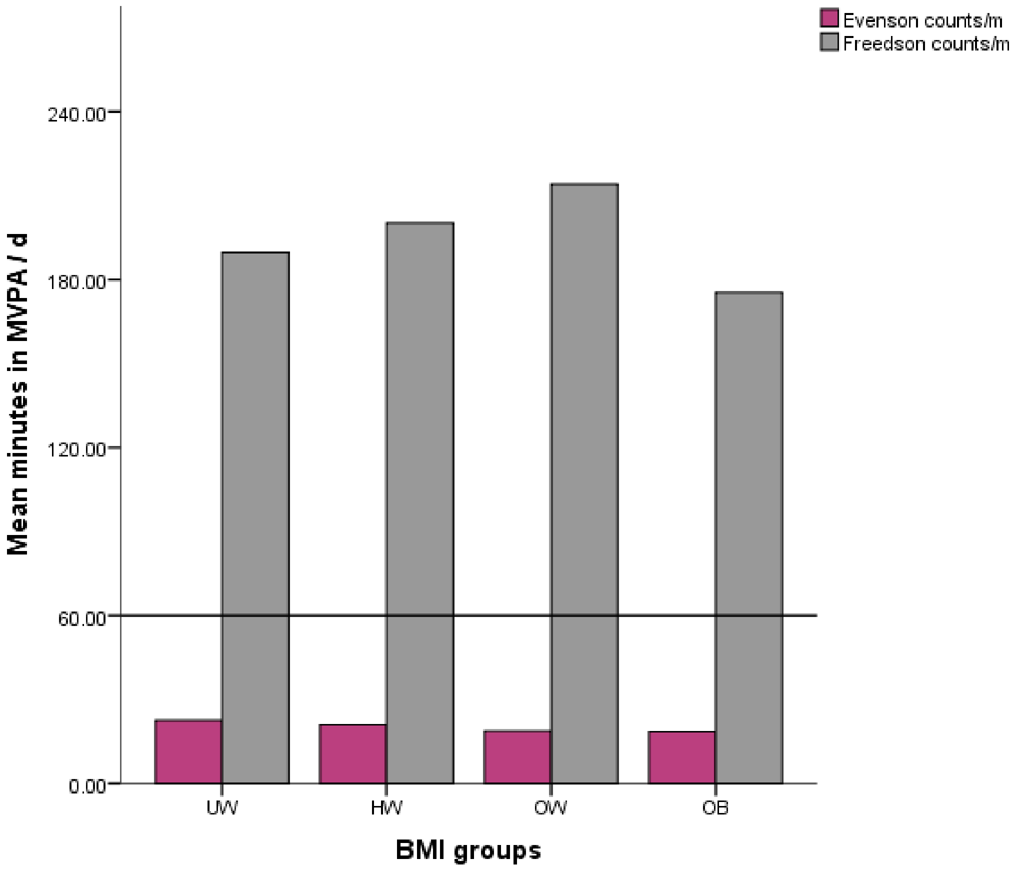


Figure 5.15: Moderate-to-vigorous physical activity, the black line indicates the recommended 60 minutes/ day of MVPA for children.

Figure 5.15 shows the mean minutes of MVPA for both Freedson and Evenson cut points. According to the Freedson cuts points, most of the children have exceeded the recommended 60 minutes/day of MVPA (NHS 2011), while none of them have reached the 60 minutes/day of MVPA when Evenson cut points are used. There was a particularly large difference in estimated time spent in MVPA between the two cut points. Considering the low number of steps taken by all groups of girls in this study (Table 5.22), it seems unlikely that they fulfilled the recommended number of minutes in MVPA. It therefore seems more likely that the Freedson cut points have over-estimated the MVPA in this sample.

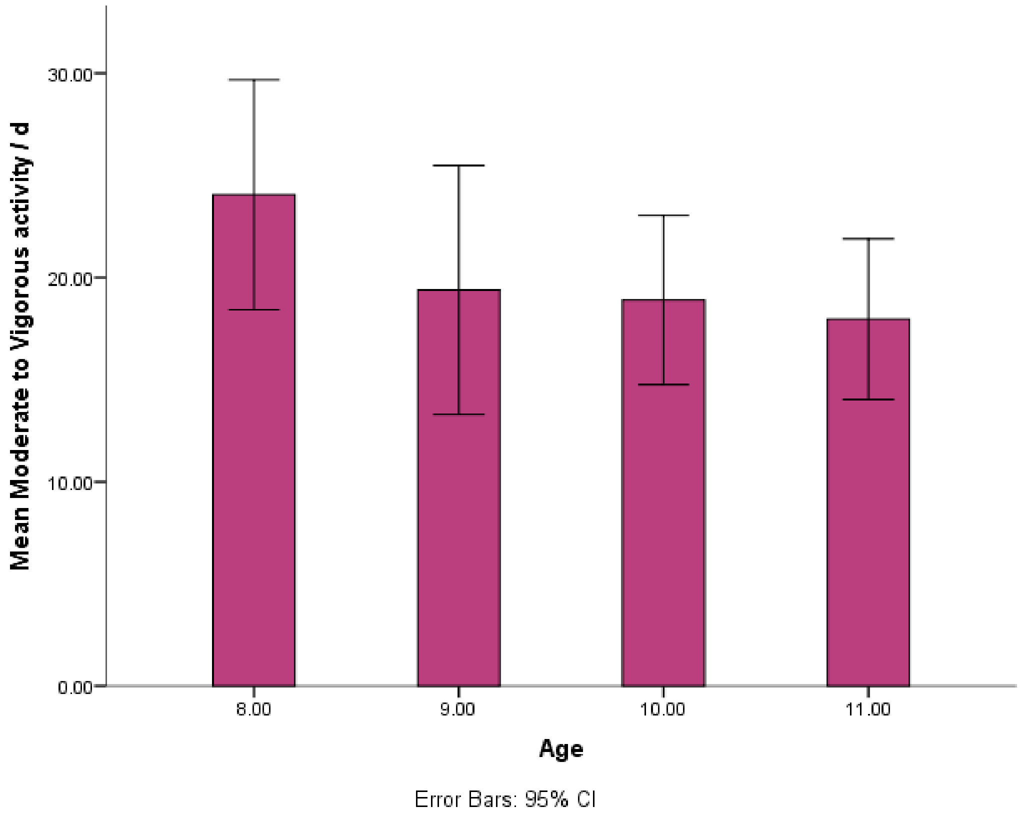


Figure 5.16: Mean minutes in MVPA according to age (years), using Evenson cut points

Using Evenson cut points, there were no girls who met the recommended activity guidelines of 60 minutes of MVPA per day. There was no significant difference between all the girls in minutes spent in MVPA/day according to age, but Figure 5.16 shows that the average minutes per day decreased according to the age. At 8 years, girls engaged in approximately 24 minutes per day of MVPA, while at 11 years girls were only engaging in 17 minutes per

day. There was a significant positive relationship between free fat mass and TEE (Pearson's r=-0.581, P -value 0.001). When the FFM increases, the TEE increases as well.

According to Table 5.22, there was a significant difference between the BMI groups in terms of the TEE, and there was a gradual increase across the BMI groups, but there was no significant difference in MVPA between the BMI groups. The underweight group recorded the highest average minutes per day in vigorous activity (4 mins/d), whereas the overweight spent less time (1.5 mins/d). The highest percentage of sedentary activity was spent by the obese group, but it was not significantly different to the other groups. Nevertheless, there is a negative correlation between the age and the time spend in MVPA at significant level (r=-0.228, p=0.05) which explained that there is a reduction in time spend in VMPA where age increased.

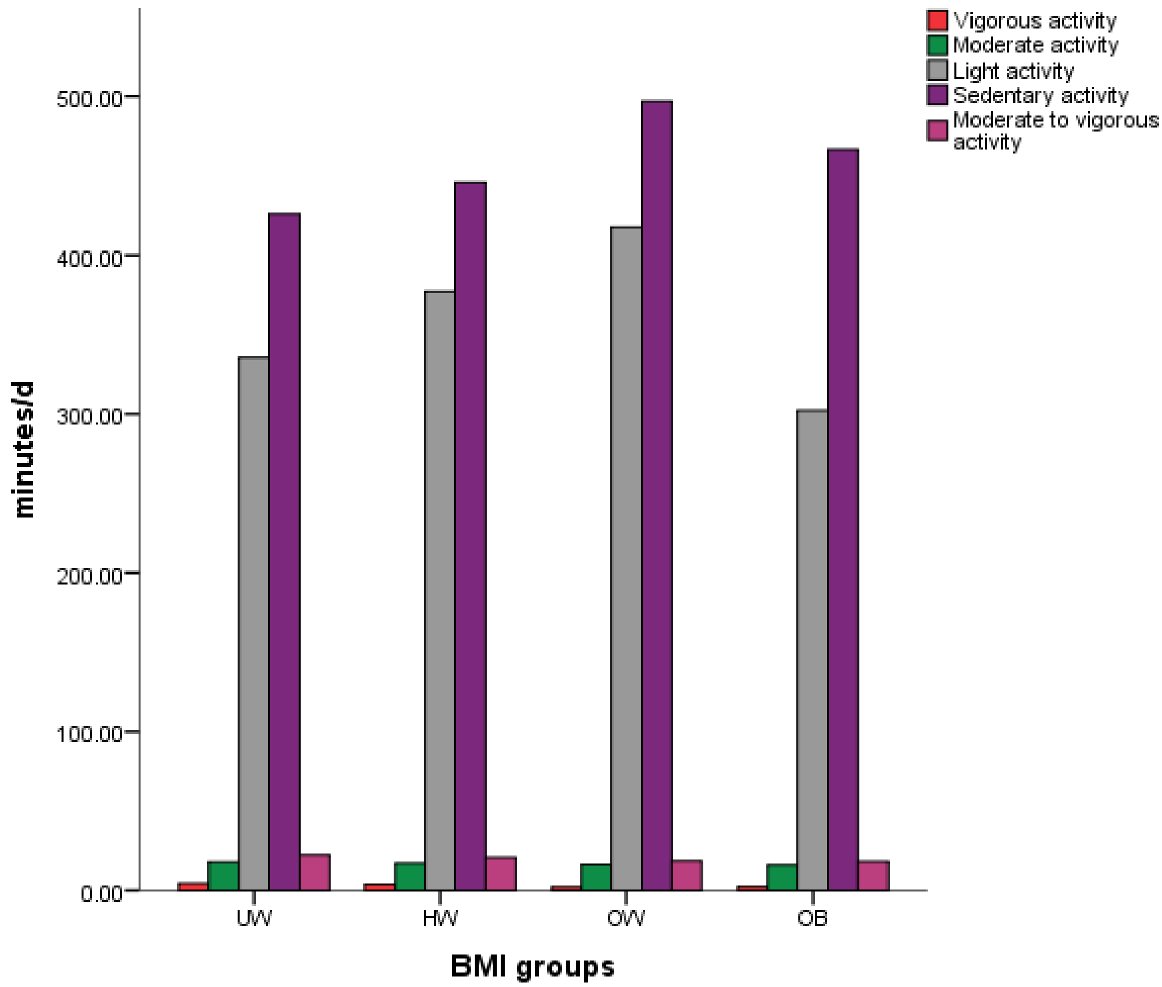
Table 5.22 shows that there was almost no vigorous activity. The highest mean recording was 4 minutes/d in the UW group, and the underweight group also had the highest mins/d in moderate-to-vigorous, an average of 22 minutes per day.

Table 5.22: Physical activity in underweight (UW), healthy-weight (HW), overweight (OW), and obese (OB) girls using the accelerometer. (n=78)

Evenson cut points	**Underweight no= 7**	**Healthy weight no=42**	**Over weight no=10**	**Obese no=19**
Total energy expenditure kcal/d* **	1501.8 [a] ±130.7 (1390-1768)	1602.9 [a] ±220.6 (1315-2421)	1725.4 [a,b] ±218.9 (1448-2157)	1908.7 [b] ±323.6 (1378-2779)
TEE/ body weight/d kcal/kg/d* **	70.9 [a] ±8.3	56.4 [b] ±11.2	43.8 [c] ±7.27	37.8 [c] ±6.7
Steps / day	6406 ±2805.7 (3087-11479)	6773 ±1788 (3250-12480)	6097 ±2324.5 (2458-8726)	5969 ±1786.6 (2322-8512)
Minutes in vigorous physical activity 4012 - ∞ CPM	4.42 ±6.31	3.65 ±2.97	2.20 ±2.0	2.26 ±1.5
Minutes in moderate to vigorous physical activity >2296 CPM	22.53 ±16.5 (4.5-53.5)	20.91 ±11.2 (5-51.25)	18.6 ±7.5 (6-28.50)	18.4 ±7.7 (4.50-33.75)
Minutes in moderate physical activity 2296 - 4011 CPM	18.10 ±11.21	17.26 ±8.83	16.47 ±7.91	16.22 ±6.89
Minutes in light physical activity* 101 - 2295 CPM	335.64 [a] ±95.15	377.06 [b] ±92.36	417.62 [b] ±105.52	302.18 [a] ±98.74
Minutes in sedentary physical activity<100 CPM	426.07 ±138.99	445.8 ±169.92	496.77 ±195.69	466.44 ±156.90

*significant difference p<0.05, ***p< 0.001

[a,b,c] Tukey Post hoc test: means with the same letter indicate no significant difference. Any difference between two means carrying different letters is significant at 5%.



Figures 5.17: Average minutes per day spent on vigorous, moderate, light and sedentary physical activity for the weight groups

According to Table 5.22, there were no significant differences in the average number of steps per day between the BMI groups. The healthy weight group took more steps and the obese group took fewer. However, differences were not statistically significant. Although the mean value among all groups was between 6773 and 5969 steps, only 9.1% of the girls had

10000 steps or more per day. Figure 5.17 shows no clear pattern according to BMI groups or age.

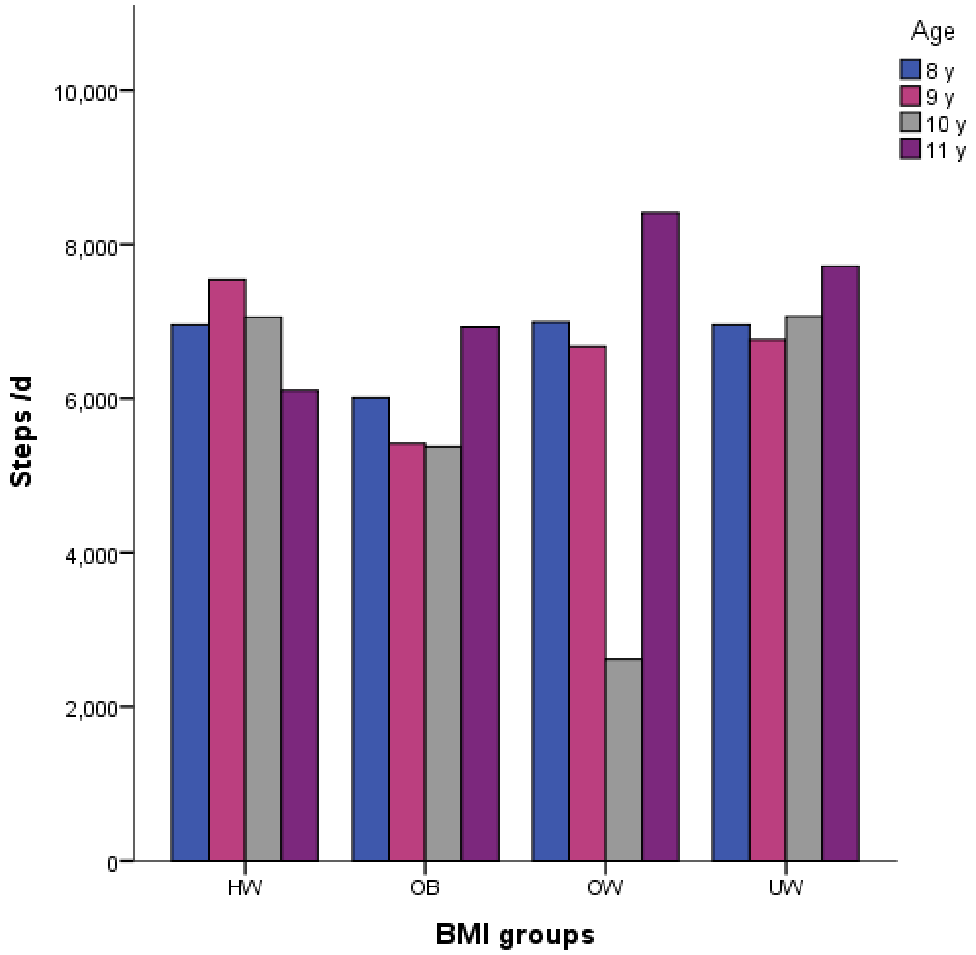


Figure 5.18: Average steps per day among the BMI groups and the age

The girls from public schools had a significantly higher mean number of steps than the girls from the private school (7416 and 6518 steps respectively) (p= 0.039) (Figure 5.18).

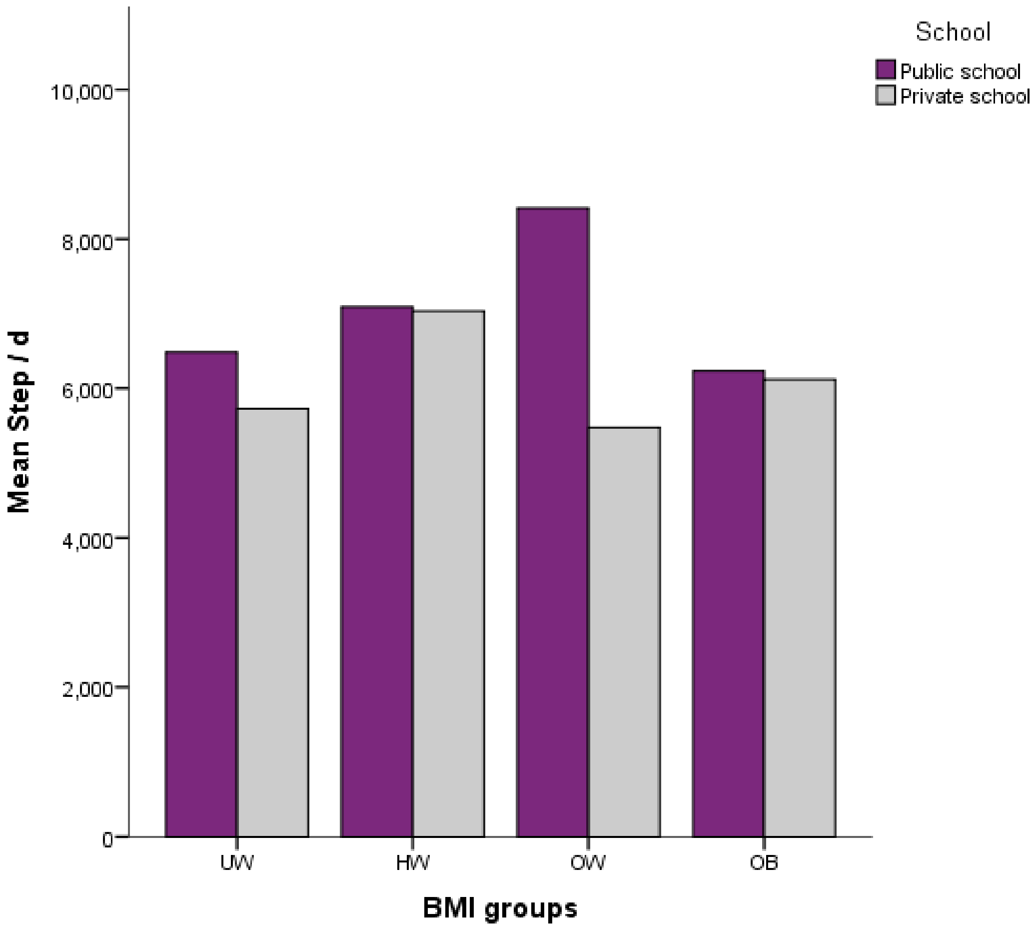


Figure 5.19: average steps/d among BMI groups in the public and private schools.

Preliminary analyses were conducted to ensure no violation of the assumptions of normality, multicollinearity and the outliers. A multiple linear regression was calculated to predict the body weight in the girls based on the daily energy intake, number of steps /d, time spending in moderate to vigorous activity and daily total energy expenditure per body weight (kg). It was found that these variables explain a significant amount of the variance in the obesity level (F (4, 73) = 62.5, p < 0.001, R^2 = 0.774). The analysis shows that daily number of steps did not significantly predict obesity level (Beta = -.113), p=0.847). However, EI and MVPA have a positive significant influence on body weight (Beta = 0.218, 0.199, p < .01), whereas, TEE/Bw (kg) has a significant negative influence on body weight (Beta= -0.776, p<0.001).

It is apparent from table 5.23 that the underweight group has a negative energy balance unlike the other BMI groups. There is a significant difference between the energy balance (>0.001) between all the groups.

Table 5.23: Mean of energy storage according to BMI group total (n= 78)

	UW N=7	HW N=42	OW N=10	OB N=19
Energy intake kcal/d* **	1299.14 [a] ±204.65	1724.61 [a] ±387.62	2239.30 [b] ±608.51	2741.84 [b] ±845.51
Energy expenditure kcal/d* **	1501.8 [a] ±130.7 (1390.9-1768.1)	1602.9 [a] ±220.6 (1315.1-2421.6)	1725.4 [a,b] ±218.9 (1448.6-2157)	1908.7 [b] ±323.6 (1378-2779.5)
Energy storage kcal/d* **	-202.73 [a] ± 248.15	121.70 [a,b] ± 445.73	513.84 [b,c] ± 749.53	833.13 [c] ± 860.52
EI/EE %* **	-10.5 % [a] ±11.3	3.1 % [a] ± 16.2	13.6 % [a,b] ± 21.0	19.9 % [b] ± 17.7

***significant different (>0.001)
[a,b,c] Tukey Post hoc test: means with the same letter indicate no significant difference. Any difference between two means carrying different letters is significant at 1%.

The relationship between energy storage or positive energy balance and waist circumference was investigated using Pearson correlation, there was a weak to moderate positive correlation between these two variable, r= 0.395, p<0.01, the high rate of energy storage associated with the increasing in waist circumference. Similarly, the body fat percentage has a positive correlation with energy storage, r= 0.354, p<0.01.

5.3.10 Socio-economic status data

The questionnaire captured data on education, income, and occupational status. Table 5.24 shows that high-income families have the highest percentage of overweight and obese girls. On the other hand, low-income families have the lowest percentage of overweight girls and the uppermost percentage of underweight girls. 17 out of 28 obese subjects were from high-income families, whereas 50% of the underweight girls were from low-income families.

Nevertheless, chi-square was not significant, which means family income did not affect the BMI status (Chi-Square =5.151- P=0.272).

Table 5.24: Number of underweight, healthy weight, overweight and obese subjects and their socioeconomic status

Income status	**UW** **n=14**	**HW** **n=76**	**OW & OB** **n=44**
High income	5 35.7%	30 39.5%	19 43.2%
Middle income	2 14.2%	28 36.8%	13 %29.5
Low income	7 50%	18 23.7%	12 27%
Total	134		

In addition, there was a pattern in daily energy intake and some selected daily food consumption amongst the girls according to different income, excluding the daily intake of vegetables.

Table 5.25: Daily energy intake and selected food consumption in girls from different income status (n =78)

	High income	Mid income	Low income
Energy intake kcal/d	2217* ±908.50	2000 ±562.43	1783* ±609.02
Sweets (g/d)**	159.53 [a] ±78.04	105.67 [a] ±63.36	89.47 [b] ±59.09
Savoury snacks (g/d)	33.98 ±44.49	24.16 ±30.31	15.47 ±18.81
Sugary drinks (ml/d)*	290 [a] ±145.93	224.46 [a, b] ±128.45	180.07 [b] ±133.05
Fruits (g/d)**	48.66 [a] ±49.70	15.23 [a] ±27.20	16.34 [b] ±24.45
Vegetables (g/d)	71.80 ±76.61	52.58 ±62.17	70.36 ±85.46

*Significant difference p< 0.05, ** Significant difference p = 0.001

[a,b] Tukey Post hoc test: means with the same letter indicate no significant difference. Any difference between two means carrying different letters is significant at 5%.

According to table 5.25, there were significant differences in sweets, sugary drinks, and daily intakes of fruit between the groups, according to their income status. Furthermore, there was a significant difference in the energy intake between girls who came from low-income families and girls who come from high-income families: as the family income increased the girls' energy intake increased. This was investigated using the Pearson product-moment correlation coefficient. Preliminary analyses were performed to ensure no violation of the assumptions of normality, linearity and homoscedasticity. There was a positive correlation between the two variables ($r = 0.22$, $n = 134$, $p < .0.05$), with high levels of energy intake associated with high levels of income.

There was also a positive correlation between the income status and daily sweet consumption: as the income became higher the consumption of the sweets increased ($r = 0.395$, $n= 78$, $p = 0.01$). This was also true of the sugary drinks and snack consumption, with ($r = 0.320$, $n=78$, $p = 0.01$), and ($r = 0.228$, $n=78$, $p = 0.05$) respectively.

Additionally, the daily fruit intake showed a positive correlation with the family income status ($r = 0.345$, $p < 0.05$). Nevertheless, there was no correlation found between the income state and vegetable intakes.

As indicated in table 5.26, there was no trend in daily physical activity related to income state. Moreover, none of the associations were significant between the physical activity data and income group.

Table 5.26: Physical activity in girls from different income status using the accelerometer (n= 78)

	High income	**Mid income**	**Low income**
Steps / day	6894 ±2003	6527 ±1770	6736 ±1987
TEE kcal /d	1692 ± 287.70	1622 ±186.58	1738 ±333.87
VMPA / d	19.4 ±2.33	21.5 ±11.16	19.5 ±11.7
LPA /d	368.8 ±85.9	370.5 ±103.4	341.5 ±115.0
SPA / d	465.8 ±162.0	467.38 ±177.0	433.5 ±162.3

The above table shows that there was no significant difference in the daily TEE among the girls from different income groups. Moreover, there was no difference in the time spent in different intensities of PA; accordingly, none of the girls spent 60 min/d in MVPA, which was recommended for children of this age by the NHS (NHS, 2017). There was a significant different between the daily number of steps in the girls who walk to school with mean of 7942 steps/d and the girls who are driven with mean of 6452 steps/d ($P=0.007$) .

The prevalence of overweight and obesity in this study was higher for girls with educated parents. 38.6% of the overweight and obese group were living with an educated parent, and 36.3% of them were living with a partly educated parent, whereas just 25% were living with an uneducated parent. Notably, the educated parent had the highest percentage of obese and overweight children, while the uneducated parent had the lowest percentage although the difference was not significant (Table 5.27).

Table 5.27: Number of subjects with educated, partly educated and uneducated parents (n=134)

Parents education level	UW n=14	HW n=76	OW & OB n=44
Educated parents	4 28.5%	33 43.4%	17 38.6%
Partly educated	5 35.7%	29 38.2%	16 36.3%
Uneducated parents	5 35.7%	14 36.3%	11 25%
Total	134		

*Chi-Sq expected count. DF = 6

The Chi-Square test was not significant (Chi-Square =6.76- p=0.343), and so the parents' education level did not affect the BMI status.

There was no clear pattern of parents' education level differential in the energy and selected food intake. As table 5.28 shows, there was some indication that the girls from educated parents tended to have a higher energy intake, as they recorded a mean daily energy intake of 2110 Kcal/d, but this was not significant.

Table 5.28: Daily energy intake and selected food consumption in girls from different level of educated families (n = 78)

	Uneducated parents	**Half-educated parents**	**Educated parents**
Energy intake kcal/d	1937 ±751.54	1861 ±503.50	2110 ±811.62
Sweets (g/d)*	159.53 [a] ±65.16	114.98 [a] ±75.87	136.15 [b] ±70.45
Snacks (g/d)	22.72 ±23.26	25.92 ±33.32	24.59 ±37.90
Sugary drinks (ml/d)	216.75 ±127.81	217.95 ±128.42	247.81 ±156.63
Fruits (g/d)	15.90 ±27.06	20.06 ±26.00	35.75 ±46.82
Vegetables (g/d)	53.90 ±46.35	58.20 ±87.88	74.02 ±78.30

*Significant different p< 0.05
[a,b] Tukey Post hoc test: means with the same letter indicate no significant difference. Any difference between two means carrying different letters is significant at 5 %.

The results show that there was no difference in most of the selected foods between girls from different levels of educated parents, apart from daily sweet consumption – where there was a higher intake in families with a higher educated parent.

Moreover, there was a positive correlation between the sweet consumption and the level of education of the parents (r = 283, p< 0.05); when the parents were more educated the girls have consumed more sweets per day. This correlation was also found for daily fruit intake (r =0.223, p< 0.05).

Table 5.29: Physical activity in girls from different levels of educated families using the accelerometer (n = 78)

	Uneducated parents	Half-educated parents	Educated parents
Steps / day	6706 ±1883.54	6078 ±1805.94	6559 ±2085
Total energy expenditure kcal /d	1669 ± 270.07	1632 ±215.77	1721 ±310.54
MVPA / d	20.50 ±14.91	21.01 ±9.00	19.55 ±9.08
Light PA /d	335.16 ±99.03	366.47 ±105.63	368.65 ±101.43
Sedentary PA / d	498.88 ±159.90	420.0 ±159.90	455.7 ±171.16

According to the results in table 5.29, there was no difference in TEE between the groups in relation to the parents' level of education. Similarly, the daily number of steps and the time spent in different intensities were not different between groups. Nevertheless, the girls who were from non-educated parents recorded a greater number of daily steps, although they had not reached the recommended daily number of steps.

5.4 Discussion

In this study, the associations between several lifestyle factors and overweight/obesity in Saudi girls aged 8-11 years were investigated. To the best of the author's knowledge, this is the first study in Saudi Arabia that investigated such factors using the accelerometer and diet diary simultaneously. There was a very low level of physical activity especially of moderate / vigorous intensity in girls of this age group which did not differ according to weight status. There were however, differences in dietary intake between the BMI groups with obese and overweight girls consuming more total energy, and savoury / sweet snacks and drinks than healthy or underweight girls. It was estimated that overweight and obese girls were in positive energy balance by over 500 and 800kcal/d respectively due to very high energy intakes, 2489, 2677 kcal/d respectively. This seems a large amount; however, where especially large portion sizes were reported they were double checked with participants to ensure reports were accurate. It is important to appreciate that EI and TEE were estimated as accurately as possible but it is likely there is still some measurements errors in their estimation.

5.4.1 Body composition

According to the results of this study, the prevalence of obese and overweight girls was 30%. A total of 17% were obese, which is slightly higher than levels found in some studies conducted Saudi Arabia in different regions. In Riyadh, a study reported a prevalence of obesity among females aged 9-12 years of 14.9 % (Alam, 2008). In a more recent large cross sectional study, Al Alwan et al. (2013) investigated the prevalence of obesity in Riyadh and showed that 9.3 % of females aged 6-16 years were obese, whereas; 30.6 % were overweight and obese combined.

The rate of overweight and obesity found in this study is comparable to that found in some Western countries such as the USA and UK. An obesity rate of 17.7 % was found among children aged 6-11 years in the USA (Ogden et al., 2014). Additionally, the rate of obesity and overweight was found to be 32% among children aged 6-15 years in a survey conducted in the UK in 2014 (World-Obesity-Federation, 2014).

The findings obtained in the present study showed the expected range of body composition for all BMI categories. Results indicated an overall increase in waist circumference and body fat over the BMI ranges from underweight, healthy or normal weight, overweight, to obese. In this study the average waist circumference for overweight girls was 72cm and for obese girls was 79 cm. These results are very similar to a study conducted on boys and girls in the capital city, Riyadh. Overweight girls (aged 10-11 years) recorded an average waist measurement of 70 cm, and for obese girls the figure was 78 cm (Collison et al., 2010). In that same study, it was noted that the average waist circumference of 1459 girls, from all regions of the country, aged 10-13 years was 66.3 cm. The average waist circumference in our study was 63.6 cm, but the children were slightly younger. Furthermore, in this study population, waist circumference was highly correlated with the increasing energy storage, which is a predictable measurement not only for obesity but also with the association with the coronary heart disease later in life (Dalton et al., 2003). Moreover, there have been several investigations into the causes of cancers of the colon, liver, and pancreas in adults and it was found that energy imbalance and the increase of waist circumference could lead to these diseases (Tsugane and Inoue, 2010).

In this study population the obese girls were significantly taller than the underweight girls, and height and weight were significantly correlated ($r=0.728$, $p< 0.001$). This is similar to the findings of longitudinal studies investigating the height of obese and overweight children, where they found that obese children were taller than healthy children (Mamun et al., 2009, Rzehak and Heinrich, 2006). Body fat and its hormones could play a key role in the increase rate of growth. Leptin, which is secreted from adipocytes, induces the chondrocytes to proliferate and differentiate causing skeletal growth. As obese children have higher leptin levels due to more adipose tissue, growth can be accelerated in obese children (Leonard et al., 2004). Additionally, ghrelin promotes the release of growth hormone and has a central role in appetite control; it increases appetite and facilitates fat storage. Research suggests that there may be variations in the ghrelin gene that contribute to childhood obesity and tall stature (Korbonits et al., 2002).

It is important to highlight that this study population were classified as obese, overweight, healthy weight and underweight according to their BMI (kg/m^2), which is a measurement based just on height and weight. Although BMI is often used as surrogate to predict overweight and obesity, it does not distinguish differences in body composition. This is a limitation of its use. Therefore, a large overlap in FFM and FM values were observed between the different groups.

5.4.2 Physical activity

Most girls in this study reported less than 12,000 steps/d.The recommendations for girls are 10000- 12000 steps/ day (Tudor-Locke et al., 2011) and only 10% of girls in this study met this target. Whereas, a study conducted in Saudi boys aged 8-12 years reported the mean number of daily steps per day for obese boys was 12682±5236 (Al-Hazzaa, 2007). This is double the number of steps found in the obese girls in our study (6735 steps/day). Therefore, it seems that obese girls are much less active than obese boys, however, boys are generally more likely to be active than girls. Reviewing a study of 2000 girls aged 6-12 years in Australia, Sweden and the USA, Catrine (2004) reported that their average number of daily steps was 12000. By contrast, the average of this study sample recorded only 6757 steps per day showing a marked lack of activity in this age group in Saudi Arabia.

There are different socioeconomic groups in this study and these factors may affect children's levels of physical activity (Burkert et al., 2013). It has been reported in a study in the USA that the students of a lower socioeconomic status are less active and have a higher level of body fat (Vincent et al., 2003). In Saudi, however, the reverse may be true, as those in the present study with a higher socioeconomic status were taking fewer steps per day as the wealthy drive and have chauffeurs so may be less likely to walk (Musaiger, 2007).

According to Nader et al. (2008), age is one of the most important determinants of MVPA. Other studies also show that there is a decrease in the amount of MVPA level according to age. According to National Health and Nutritional Examination Survey (NHANES) 2008 data (a representative US sample in children using an accelerometer), there is a clear decrease in physical activity across age groups between childhood and adolescence, and continually into adulthood. Similarly, the results of this study indicate that there was an inverse relationship between age and time spent in MVPA. These findings are consistent with the review by Dumith et al. (2011), where the decline in physical activity according to age was identified in many studies among both genders by 7.2 %, and for girls only reported to be 6.2 % annually.

There are several possible explanations for this result in Saudi Arabia as girls grow up many cultural restrictions will be a barrier to exercise outdoors. When girls reach puberty, they should be wearing head scarfs and long clothes and some girls from the age of 10 years, even they have not reached puberty, should wear long clothes without covering the head. Also, it is not acceptable for them to be playing sports or exercising outdoors. Another factor to be taking in consideration is the hot climate (40ºC and above) in Saudi which make indoor activities such as watching television preferable. Nowadays, social determinants are slightly shifting and that is manifested by the establishment of walking/jogging public areas, however, these public areas are not mainly designed for children and supervision is required. These factors may explain the relatively low levels of physical activity.

Nader et al. (2008) found similar results in a longitudinal study on children aged 9-15 years old in the US, with older age and females associated with less physical activity. Most of the 9 year old girls in the US study achieved the recommended 60 minutes of MVPA/d, in contrast to the 9 year-old girls in this study, who have recorded only 19.3 minutes/day, which is considerably less than the minimum recommended in UK of 60 minutes per day (NHS, 2017). One difference in methodology between Nader et al. (2008) and the current study is that Nader used Freedson's cut points, although he did use the defined age cut points. Applying Freedson's cut points to the longitudinal study by Nader et al. 2008, and the baseline and follow up, the cut point of the MVPA for 9 year-olds is 910 CPM, whereas for 15 year-olds it is 1710 CPM, which is markedly different. It is critical to note that using Freedson's cut points might cause an overestimation of the MVPA and this may explain the high number achieving the recommendation of 60 min/d. This can be illustrated briefly by the sample of this study, as most of girls exceeded the recommended 60 mins/d when Freedson's cut points were applied. Contrary to expectations of being active according to Freedson's cut points, the girls in this study have not met the recommendations of >10000 steps/d which is considered as inactive (World-Health-Organization, 2010, Tudor-Locke et al., 2011). Graf et al. (2014), reports that 60 mins/d in MVPA is equivalent to approximately 12000 steps/d. However, the observed difference between daily number of steps and their time spent on moderate to vigorous activity per day in this study shows how Freedson's cut off points could overestimate MVPA. If the error of minutes' calculation in each type of activity and sleeping time per day were considered, it would be found that Evenson cut-point suggested 12 hours/d of sleep. Whereas Freedson cut- point suggested 4 hours/d of sleeping period, which is highly unlikely. These are reasons that could explain how Freedson cut-points might overestimate PA.

Therefore, Evenson's cut points provided better agreement with the daily number of steps recorded in this study.

Two calculations were applied to estimate the total energy expenditure using the accelerometer data. Accordingly, a PAL value of 1.45 (adjusted for growth 1%) was evaluated by comparing it with TEE estimated by Ecklund's equation (TEE_A) and by METs (TEE_M). All three calculations showed highly similar results with no significant differences between them p=0.720. Also a PAL range of 1.38-1.44 was showed to be suitable for this study population and comparable to the other calculations (TEE_M, TEE_A). Potentially, this range could be used and validated for Saudi girls aged between 8-11 years in order to estimate the physical activity level without using the accelerometer. According to a previous study on US children, a PAL of between 1.4 and 1.6 (different according to age groups) was considered as low activity to estimate the total activity (Huang et al., 2004). Similarly, another study on adults suggested similar PAL values of ($\geq 1.4 < 1.6$) to estimate low activity, which is equal to 3 miles of walking per day for a person with a body weight of 44 kg (Trumbo et al., 2002). Another study conducted on Australian children aged 5 -10.5 years used varied PALs between 1.32- 2.18. Therefore, using a PAL of 1.45 adjusted for growth could reasonably predict the level of activity in the present study population as they have recorded few daily numbers of steps.

5.4.3 Dietary intake

Overall, the mean energy intake of girls in this study was 2122 kcal/d which is higher than average energy intake in the UK National Diet and Nutrition Survey (NDNS) of nearly 1800 kcal/d for this age group. The average energy intake recorded by obese and overweight girls was (2677, 2489 kcal/d respectively) which is 27.3 % higher than the UK recommendations of 2032 kcal/d for aged 11 years female (Department-of-Health, 2011, NDNS, 2011).

The average energy intake among the BMI groups were similar to another study which investigated the effects of fast-food consumption on children and adolescents, and they reported an average EI between 1798, 2078 kcal/d (Powell and Nguyen, 2013).

However, this pattern of increasing EI among BMI groups was different than the outcomes of Skinner et al. (2012), who investigated the relationship between children's energy intake and their BMI categories according to age and gender. They found that the healthy weight group had a greater EI than very obese, and overweight, whereas the obese groups had the greatest EI in girls aged 9-11 years.

Although the World Health Organization’s Global Strategy for Diet and Physical Activity recommends reducing energy intakes from fats, limiting the intake of free sugars, and increasing fruit and vegetable consumption, the findings here showed that the overall daily consumption of sugary drinks, sweets, and snacks was higher than the intake of vegetables and fruits (WHO 2004). Carbohydrates represented more than half of the total daily average energy intake – a figure which matches the level recommended by the Dietary
Reference Values (>50%) (DRVs) in the UK (Department-of-Health, 1991) – and fat constituted between 34% and 36% of the energy intake close to the UK recommended level of <35% (DRVs). Nevertheless, the obese and overweight girls recorded average energy intakes that were more than 25% higher than the UK recommendations (SACN 2011). According to the Department of Health’s recommendations, the energy intake from non-milk extrinsic sugars (NMES) should not exceed 5% of the total daily energy intake. The average energy intake from sugary drinks alone was calculated in this study as 5.6% for obese and 4.9% for overweight girls. Higher BMI was associated with increased consumption of savoury snacks and sugary drinks, there were significant increases across weight categories. In comparison with UK children, girls in this study consumed more sugary drinks (225 g/d vs 130 g/d)(Whitton et al., 2011)
The Ministry of Health in Saudi Arabia recommended 6 servings of fruit and vegetables per day for this age group, however weight of recommended portion is not specified (Al- Dkheel, 2012) . For most girls the daily consumption of fruit and vegetables was markedly less than the daily portions recommended for UK children by the UK Department of Health. For children of this age this can be between 200-400g/d (Department-of-Health, 2011).

Whereas in this study the means for daily consumption of fruits and vegetables were 47.2 g/d for underweight, 87.5 g/d for healthy weight, 134.5 g/d for overweight, and 117.2 g/d for obese. A disadvantage of the dietary analysis program was that it did not distinguish between starch and sugars or NMES and intrinsic sugars, and so an overall estimation of NMES could not be established.

High consumption of sugary drinks has been observed in studies of older girls in Saudi Arabia and this has been correlated to increases in waist circumference Al-Hazzaa et al. (2011) found one third of girls aged between 14-19 years consumed sugary drinks daily and 60% consumed them 3 to 6 times per week. Similar findings were reported by Shaath (2008) who found that 74.5% of girls aged 12–18 years drank sweetened carbonated beverages daily. Likewise Al-Muammar et al. (2014) reported that 90% of Saudi adolescents consumed carbonated drinks and sweets daily. Overall the role of sugar in children's diet has been discussed in other studies and the advice to consume less sugar to reduce obesity prevalence (Malik et al., 2006). Therefore, another possible way to analyse dietary intake in more detail in this study population, would be to use another database and input the food ingredients manually to distinguish the breakdown of the macronutrients (e.g. starch and sugar) for a more detailed analysis.

There was no significant difference between the BMI groups in EI/kg body weight. In a study by Gazzaniga and Burns (1993), 48 children (boys and girls) were examined in order to investigate the relationship between the diet composition and body fatness, and it was found that the non-obese group consumed nearly 49 kcal/kg body weight, and obese children 40 kcal/kg body weight. In this study, by contrast, obese girls have recorded nearly 56 kcal/ kg body weight and HW girls 59 kcal/kg body weight which is slightly higher than the other study.

Gazzaniga and Burns (1993) also found that there was a relationship between the total percentage of energy from fat intake and body fat percentage, and, like this study, there is a weak positive correlation between the percentage energy from fat intake and the body fat percentage (r=0.242, p= 0.05). McGloin et al. (2002), in a comparison between lean children who were at high and low risk of obesity, they examined fat and energy intake and body fat. They found that percentage energy intake from fat was the only predictor of body fat.

According to Pearson's correlation, in our study the percentage of energy intake from fat was significantly correlated with body fat percentage but the correlation was weak and it wasn't significant in the regression analysis.

Reinehr et al. (2005) investigated the relationship between low-fat high-carbohydrate diets in obese children and the appetite-stimulatory signal ghrelin and found a positive correlation between carbohydrate and the ghrelin level. Ghrelin, the hunger hormone, has been found to influence obesity risk (Klok et al., 2007). Also carbohydrate has been identified as one of the major factors for increasing ghrelin levels which plays a role in hunger rating (Erdmann et al., 2004). Another study showed that the level of this hormone was decreased when consuming low carbohydrate meals and reduced the hunger level daylong (Nuttall et al., 2016). These findings could explain the results of the linear regression in this study, which showed that carbohydrate intake per day was the main predictor of gaining weight.

In this study the obese and overweight girls had significantly higher total energy expenditure due to greater body weight, when TEE was expressed per kg body weight, the pattern changed between the BMI groups, and the underweight group had higher TEE/kg of BW than obese (70 kcal/kg, 37.8 kcal/kg, respectively). It has been suggested that the reduction in energy expenditure could increase the risk of becoming obese (Sanguanrungsirikul et al., 2001). In the present study the regression analysis showed that TEE / Bwt (kg) negatively correlated with the body weight and so a low TEE / kg is a strong predictor of gaining weight (77%). Therefore, the reduction in energy expenditure would be likely to increase the risk of becoming obese.

5.4.4 Energy imbalance

The underweight group had a negative energy balance which might explain their weight status. In contrast, the other BMI groups had a positive energy balance.

Continuous negative energy balance in the underweight group could affect formation of muscle fat mass, metabolic functions and eventually growth rate. In contrast, continuous energy storage will promote weight gain and possible conversion to higher BMI classifications. As a consequence of growth and usage of energy in structuring new tissues, healthy children appear to increase by nearly one unit in BMI percentile chart annually. An increase of more than 3 BMI units a year could be considered a causative factor of increasing in body fat (Barlow and Dietz, 1998). In addition, Butte and Ellis (2003) suggested that healthy weight children with more than 104 kcal energy storage/ day gain over 6 kg per year. Their study also showed that some healthy weight children might convert to overweight. Accordingly, the mean energy storage of healthy weight group in this study is more than 120 kcal/d, which could contribute to excess weight gain and convert the children to overweight.

This study shows a clear gap between the energy intake and energy expenditure which is causing a positive energy balance for many of the girls. In considering these results, it should be acknowledged that there is margin of error in estimating EI and TEE and there is a large variation between participants in both EI and TEE (indicated by a large SD). According to Hill et al. (2003) recommendations to close the energy gap by 100 kcal/d can be achieved by two factors: increasing energy expenditure (15 mins of walking) and decreasing the energy intake by reduction in portion sizes. Therefore, by applying Hill's assumption to produce an energy balance of 100 kcal/d in this study population, that will reduce energy storage in healthy weight girls and change their storage rate. On the other hand, this assumption is insufficient for overweight and obese groups to close the gap; they require a larger reduction in energy intake > 500 kcal/d.

Whereas, if Butte and Ellis's (2003) assumption for closing the gap as a deficit of 502 kcal/d was considered, this might gradually change weight status of the overweight group to healthy weight. This recommendation is comparable to walking between 60 to 120 minutes per day; or 6000-12000 steps/d which is equivalent 3 to 6 miles per day (Tudor-Locke et al., 2011, Lubans et al., 2015). This amount does not seem feasible for girls of this age in Saudi Arabia as the outdoor heat and cultural expectations prevent walking outside for long periods. However, walking around school and organised games and activities would promote and raise the current level of activity in girls.

5.4.5 Socio-economic status

One aim of this study was to evaluate the prevalence of obesity and overweight in association with socioeconomic status in Makkah. According to the results of this study, the prevalence of obese and overweight girls in high-income families was greater than their peers in low-income families; these are similar findings to the study conducted in Riyadh 2013 of 43.1% obesity and overweight combined for both gender (Al Alwan et al., 2013). In the central region, specifically in Riyadh city, 14.9% of girls are obese, and it has been detected that 95% lived in big houses (which indicate higher wealth status) (Alam, 2008). High-income families tend to meet the expenses of various snacks and meals, regular restaurant excursions, ordering takeaways, and purchasing snack food. Low-income families, on the other hand, have limitations to living such luxurious lives (Mirmiran et al., 2010).

These findings are in contrast to the UK, where the prevalence of obesity tends to be higher in low-income household (NOO, 2012). The Income Deprivation Affecting Children Index (IDACI) 2010 measured the obesity
prevalence across England and stated that obesity prevalence for children in Year 6 was approximately 24.2% in poor areas while in the least deprived areas it was only half this figure (NOO, 2012). Also data from the National Health and Nutrition Examination Survey carried out in the USA (2010) found that low-income children are more likely to be obese than children from high-income families. This is likely to be due to the fact that parents in higher income households in the West are more educated, are more aware of the importance of a healthy diet and lifestyle, and spend more of their income on healthy foods such as fruits and vegetables and afterschool activities such as sports clubs (Gable and Lutz, 2000, Wang and Zhang, 2006).

The results of this study indicate that overweight and obesity in Saudi Arabian children are associated with educated families. The data shows a prevalence of obese and overweight girls in educated parents, nearly 39%, whereas 25% are from uneducated parents. These findings agree with a study conducted in Riyadh, where it was observed that mothers' education levels had an influence on obesity levels (Al Alwan et al., 2013). Continuous absences of parents during the day may lead children into having unobserved meals and snacks. The association between meal times and mothers' long absences has been detected; accordingly, it has been shown that children's breakfast patterns were not associated with unhealthy meals (Gaina et al., 2009). This may be a result of the supervision of the intake in the morning (Gaina et al., 2009), whereas long parental absences from the house during the rest of day allow unhealthy eating and unlimited snacking (Al Alwan et al., 2013, Gaina et al., 2009).

Using data from the NCHS that was collected in the USA in 2008, it was found that children who lived with parents who had a college degree were less likely to be obese than children who had less educated parents (Ogden et al., 2010). In this study, the obese and overweight group was higher in number in the educated parents' category than in the uneducated parents' bracket.

A study in Riyadh, Saudi Arabia showed slightly higher figures (13.3% obese and 19.6% overweight in public schools) whereas; the prevalence of the obese and overweight girls in the public school in this study was 10.6% and 13.4% respectively (Al Alwan et al., 2013). Notably, this study covered just one city (Makkah) and was not representative for the whole country.

As its been expected the girls who walk to school have recorded higher number of steps than the girls who were driven, and most of these girl who walk come from low income families. However, the observed difference between daily number of steps and income statues in this study was not significant.

5.5 Conclusion

Results of this study agree with previous studies measuring prevalence of childhood overweight and obesity in Saudi Arabia. Findings suggest that overweight and obesity in girls of this age are linked to excessive energy intake from all macronutrients and high intakes of snack foods and sugary drinks. Low levels of total activity and MVPA were seen across the sample. These findings and the wider implications will be discussed more in the next chapter (chapter 6).

Chapter 6: General discussion

6.1 Introduction

Recent developments in Saudi Arabia have heightened the need for further investigation of the level of obesity in children. Inappropriate food choices, insufficient physical activity, and the rising socioeconomic status of families are all contributing to increasing rates of obesity in children. Previous chapters examined these factors by reviewing recently published research. This project has researched further aspects of this problem, and the methodology employed here consisted of two phases. First, it piloted the methods for surveying a sample population of girls aged 8- 11 years in Saudi; the second phase entailed data collection on aspects of physical condition, physical activity, and dietary intake.

A summary of main results can be seen in figure 6.1. The present study is the first to our knowledge that tested some points summarised as listed below.

1. This study estimated energy and macronutrient intake using the diet diary in a sample of Saudi girls and quantified the positive energy balance according to BMI.

2. Exploration of under-reporting in this age group in Saudi Arabia – this has not previously been reported.

3. Objectively recorded the low numbers of steps/ day and MVPA in a sample of pre-adolescent Saudi girls

4. Estimation of total energy expenditure in this age group of girls in Saudi Arabia – this has not previously been reported

5. Waist circumference and body fat percentage equations were formulated to help estimate those two measurements in epidemiological studies.

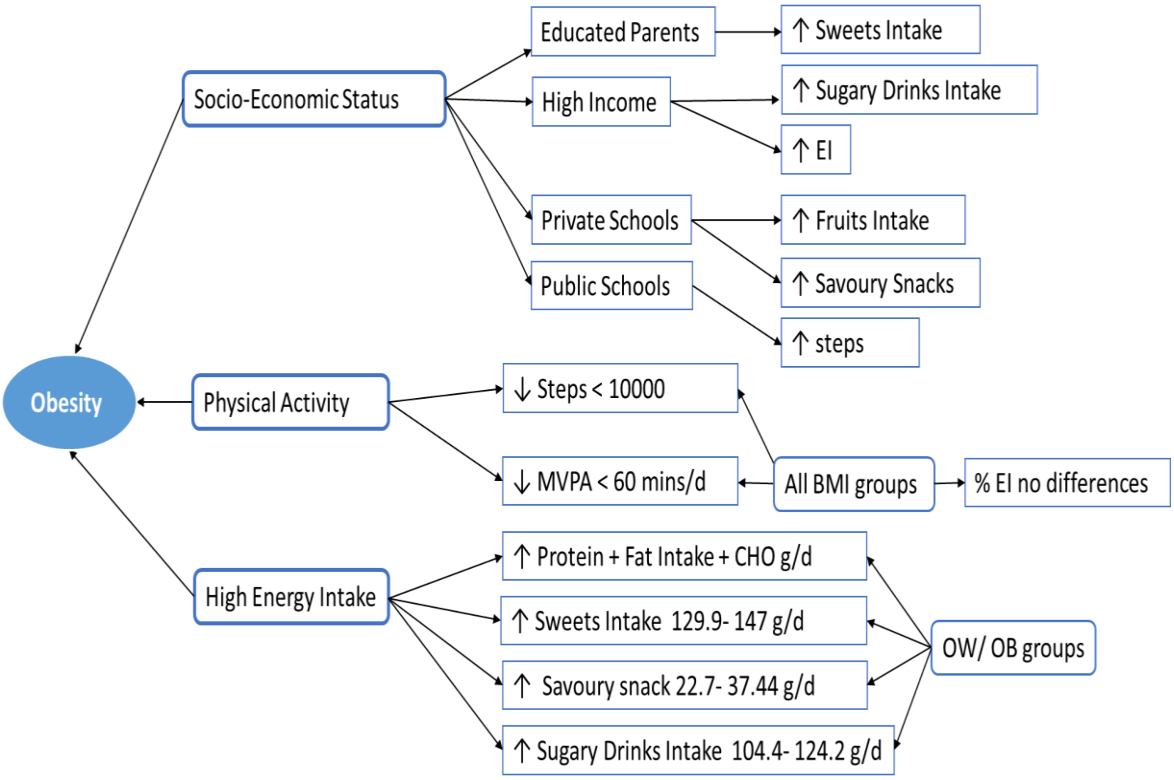


Figure 6.1: Summary of the findings on aspects of SES, physical activity and dietary intake

6.2 The implications of the findings

The first set of analyses examined the prevalence of overweight and obesity in the participants, finding that of the 266 school girls 30% were overweight or obese. Further evaluation of these findings leads to a number of important implications which are discussed in the following sections, although this is not a prevalence study as it is just in one region, data agree with larger scale findings in Saudi.

6.2.1 Implications of socio-economic factors

The assessment of socio economic status is important because in most circumstances it influences lifestyles and hence contributes to the prevalence of obesity. A considerable amount of literature has been published on the influence of SES on children’s body weight, however these data indicated no association between the SES and obesity – a result which is in agreement with a study in the eastern region in Saudi Arabia (Al-Saeed et al., 2007). Despite our findings of no correlation observed between obesity and family income, other studies in developed countries showed correlations between obesity and poverty income ratio and education level of the household (Shrewsbury and Wardle, 2008, Ogden et al., 2010).

Moreover, some literature about Western developed countries reported that individuals from low income communities had high levels of obesity, which is inconsistent with the findings here (O Dea, 2003). In this study the high rate of obesity in high-income families may be partly explained by the positive correlation between family income and daily energy intake ($r=0.22$, $P < 0.05$). This significant relationship is implicated in weight gain as indicated by the linear regression showing that energy intake is the major predictor of obesity. It is presumed that high-income families can afford high-quality meals, snacks, and visits to restaurants. High incomes can also lead to luxurious, indulgent lifestyles which include owning large homes and employing domestic workers so that the householders may have few physical tasks to compensate for the consumption of energy-dense meals (Mirmiran et al., 2010). As evidence of these patterns, our results confirm that there was a significantly higher intake of sweet sugary drinks and fruits in high-income individuals than in those with a low income.

Some studies in the UK and USA have shown an association between obesity and parents’ educational levels (Howe et al., 2011, Singh et al., 2010). Those projects yielded negative correlations between parents’ education and children’s obesity; by contrast, the findings in this study showed high levels of overweight and obesity (38.6%) among girls whose parents were educated. There have been several possible explanations for this pattern: one is that educated mothers spend more time out of the home in order to study, to work, or to socialize, and in such situations the unsupervised children may have access to unhealthy meals or snacks. As well as the parental absence, some families depend on servants who themselves are likely to be uneducated and thus unaware of what constitutes healthy meals (Gaina et al., 2009). In this study population 60% of participants lived in homes with domestic servants, and another recent study reported that 89% of Saudi families have at least one servant (Al Alwan et al., 2013).

These results are in agreement with other studies conducted in Saudi Arabia, though in different regions. Alam (2008), Amin et al. (2008) and Al Alwan et al. (2013) all found that high SES correlated positively with obesity levels. Nevertheless, all these socio-economic determinants require further investigation if comprehensive interventions are to be developed, and this point is listed below in the recommendations section (6.3).

6.2.2 The implications of energy balance and food intake, physical activity

This study showed lack of activity and daily number of steps among all BMI groups. Also, an association between obesity and the consumption of energy dense food was found.

6.2.2.1 Energy balance

It is worth noting the relationship between energy intake and energy expenditure in children to predict their energy balance. In Table 5.22, positive energy balance was found among the healthy weight, overweight and obese groups. Thus, to regulate energy balance and to control body weight shifting one of the two main components: energy intake or energy expenditure needs to be achieved. According to Jéquier (2002), continuous positive energy balance plays a crucial role of the weight increased, hence if energy intake was 5% higher than the energy expenditure each day, this will result in gaining 5 kg fat mass per year. By applying this on the present findings, the daily energy intake exceeded the daily energy expenditure for overweight and obese girls (13.6 % and 19.9% respectively), which could cause a high rate of fat mass gain and if this was sustained for several years, it could lead to morbid obesity (Jéquier, 2002).

6.2.2.2. Protein

The data were analysed to examine the relationship between protein intake and the percentage of body fat in the girls. Overall, the results demonstrated that most of the girls had markedly higher intakes of protein (52.9 – 87.8 g/d)

than the UK Reference Nutrient Intake (RNI) values (28.3- 42.1 g/d) (Department-of-Health, 1991). A recent study conducted in the UK by Jenkins et al. (2015) involved 581 children aged 9-11 years. They found that the daily intake of protein in girls was 53.8 g/d. Whereas in the present study the mean of daily intake from protein for all BMI groups was 73.2 g/d which is 30.5% higher than Jenkins et al. results. This amount is more than the RNI for protein for adult women in the UK (45 g/d). The protein intakes in this study were also higher than what adult women recorded in another study in the UK of 60.6 g/d (Reid et al., 2014). Nevertheless, the findings of the current study are consistent with those of Al-shammari (2007) who found that the average daily protein consumption in overweight and obese Kuwaiti girls aged 6-13 years was 84.8 g/d. The high consumption of protein in the current study was partly due to consumption of common traditional meals such as fried and rotisserie chicken and mandi, which is a dish of lamb and rice. These dishes were commonly eaten at the weekend for lunch, which is the main meal of the day, and then eaten again reheated for the evening meal. This common practice of reheating the protein–

rich main meal and eating this again in the evening, contributed to the high protein intakes of many of the children.

The excessive consumption of protein in association with a general lack of physical activity is seen as major contributor to the storage of body fat, therefore increasing physical activity is one strategy required in order to maintain energy balance (Millward, 2004). These results showing a positive correlation between proportion of body fat and daily protein consumption also corroborate the recent work of Koletzko et al. (2016) who suggested that consuming large quantities of animal protein will lead to weight gain. Moreover, the high intake of protein and their amino acids could diminish renal function in children, with serious consequences for their health in adult life (Alexy et al., 2005). Other deleterious effects have been cited by Alexy et al. (2005) who stated that the effects of continuous consumption of a high-protein diet in childhood might be reflected in the remodelling of bones and may affect the cortical area. Among the sample of this study, protein contributed 12.2 -14.5% of the total energy intake to all BMI groups, a level similar to the recommendations of COMA (Department-of-Health, 1991). However, the girls in present study consumed levels of protein ≈ 50% more than the actual protein intake g/d in girls in Alexy et al study, and that may affect the girls' kidney functions and bone development as well as their body composition (Alexy et al., 2005). The 'safe' level of protein intake recommended by FAO (2013) for children aged 11-12 years is 1.00 g/kg/Bwt/d, and the UK RNI for protein for children aged 7-10 years is also 1g/kg/ Bwt/d (Department-of-Health, 1991), however, it is not clear what level would be considered deleterious for children. For adults, it has been suggested that 1.5g/kg/Bwt/d should be avoided. The daily protein intake in this study exceeded these levels among all ages (8 years, 2.4 g/kg/d), (9 years, 2.2 g/kg/d), (10 years, 2.0 g/kg/d), and (11 years, 1.7 g/kg/d), but whether there are adverse effects of these intakes is unclear. Another study investigated the influence of protein intake in early childhood, and found that 10 g/d of protein more than the child's requirements could lead to greater weight, height and BMI at age 10 years (Hoppe et al., 2004).

In addition, the protein intake, either dairy or 'animal' meat, has associations with adiposity as well as the early onset of puberty (Günther et al., 2010). Obesity is considered as a marker of maturation and it has associations with age at menarche (Williams and Dickson, 2002). A previous cohort study found an inverse association between the level of SHBG and adiposity; lower SHBG predicted earlier puberty (Pinkney et al., 2014).

6.2.2.3. Fat

In the current study the total daily fat intake in overweight and obese girls (104.5 -108.2 g/d respectively) was higher than the values recommended for the UK (Department of Health, 1991; 2003). The daily fat consumption of the overweight and obese girls was 38% higher than the consumption levels among UK adult females (61 g/d) and higher (67 g/d) than for girls in the UK aged 11-18 years (Whitton et al., 2011). In addition, the percentage of energy intake from fat was more than 35%. The recommendation for total fat consumption as a percentage of energy intake for children should not exceed 35%, whereas the total percentage in the NDNS was lower than 33.4% (NDNS 2014). It would have been useful to determine the proportion of saturated fat in total fat intake, but the food consumption tables used did not provide this level of detail (see 6.3.3). A high saturated fat intake has other far-reaching implications for the health of the participants in later life, as it often leads to raised cholesterol levels and increased mortality (de Souza et al., 2015).

Although some studies have found a relation between fat intake (% from EI) and adiposity (McGloin et al., 2002) others have shown none (Maffeis et al., 2000); however, the results of one study which compared obese and lean children found a similar EI between the groups - but the obese group consumed significantly more fat (McGloin et al., 2002). Dietary fat intake has been found to predict gain in percentage body fat in adolescent girls (Sarnblad et al., 2006). Despite that, multiple regressions on our data did not find that energy from fat intake was the main predictor of obesity.

6.2.2.4. Carbohydrates including sweets, sugary drinks and snacks

The average intake of carbohydrate in the overweight and obese participants was 347-362 g/d respectively, which is far above the UK intake (193 g/d) for healthy female adults aged 19-64 years [as reported in the National Diet and Nutrition Survey] and more than the level of 211 g/d for UK children of a similar age (Department of Health, 1991; 2003). However, in this study population, carbohydrates contributed an average of between 54% and 57% of total daily energy intake, which is comparable to the recommendations of the UK dietary reference value of >50% (SACN 2015). However, it was not possible to determine the proportion of energy from starch, extrinsic or intrinsic sugars.

In the present study, obese girls consumed 124.2 ml/d of sugary drinks and the percentage for energy intake from sugary drinks among all the BMI groups was between 4.2- 4.7%. In many countries the source of high levels of carbohydrate intake is sweetened sugar-rich drinks, and this applies to Saudi Arabia too. Collison et al. (2010) reported that the consumption of sugary drinks observed in studies of older girls in Saudi Arabia was correlated to increases in waist circumference. Similarly, research by Al-Hazzaa et al. (2011) found that of girls aged 14-19 years about one-third consumed sugary drinks each day, and 60% consumed one or more glasses (or containers) between three and six times each week. Another study of Saudi girls aged 12–18 years noted that 74.5% of participants drank sweetened carbonated beverages every day (Shaath, 2008). An even higher rate was reported by Al-Muammar et al. (2014) who found that 90% of their survey participants consumed carbonated drinks and sweets daily. Our data showed that daily intake from sweets and sugary drinks significantly predicted the level of body weight in regression analysis – 19.6% was explained by sweets and sugary drinks. Clearly reducing sugar sweetened beverages should be key target of obesity prevention interventions.

6.2.2.5. Fruits and vegetables

This study found that the daily consumption of fruits and vegetables did not reach the daily recommendation for children. Obese and overweight girls consumed (32.9 - 29.5 g/d respectively) from fruits and (84.3 -105g/d) from the vegetables, however, there was no evidence for associations between these quantities and body weight. In spite of that, a study suggested that increasing the daily intake from fruits and vegetables can help to reduce the intake from energy dense food (Sarnblad et al., 2006). Another study, in agreement with these suggestions, found a negative relationship between fruit and vegetable intake and high-fat/high-sugar intake (Epstein et al., 2001).

6.2.3 Evaluation of physical activity among girls

As has often been reported, physical activity is an important factor that influences children's health and lack of PA in children can lead to adiposity (Bailey, 2006, Telama, 2009). An important finding of this investigation is that inactivity was prevalent in this sample of girls. However, our findings showed that there was no significant difference between obese and non-obese girls in regard to their daily number of steps (6773- 5969 steps/d) – though these are less than the daily recommendation 10,000 steps a day. To reach the recommendation for daily number of steps an increase of about 3000 steps/d would be needed. This would be equivalent to 30 minutes of walking or 15 minutes of MVPA (Slaght et al., 2017, Tudor-Locke et al., 2011). The daily MVPA also showed no differences between the BMI groups; the time spend in MVPA ranged 18.10- 14.90 min/d. None of the girls reached the recommendation of 60 min in MVPA per day. The observed correlation between MVPA and body fat mass was explained by Janz et al. (2009) who investigated this correlation in 333 children aged 5, 8, and 11 years and found that increasing the daily MVPA in childhood will produce reductions of body fat mass later.

Many studies have confirmed the benefits of physical activity in preventing an increase in body fat, and results have demonstrated that spending greater time in vigorous activity will successfully reduce body fat (Dencker et al., 2006, Mcmurray et al., 2002). The importance of vigorous activity has long been established as has the relationship between physical activity and cardiovascular disease and its influence on the level of total cholesterol in children (Kawabe et al., 2000, Strong et al., 2005).

In the current study, a comparison of the mean number of daily steps of the girls who walked to school (7320 steps/d) and those who were driven (6268 steps/d) shows a marked difference. These findings endorse the suggestion of Sallis and Glanz (2006) that an effective, simple way of promoting physical activity is by arranging for children to walk to school. However, despite the worthiness of this proposal there are various cultural barriers to such an activity in Saudi Arabia - and besides, for much of the year the hot climate is unsuited for long walks (El-Hazmi and Warsy, 2002). Nevertheless, planning indoor programs for schools, and involving local health centres, are strategies for promoting sustainable levels of activity for children.

Despite the urgency of this problem of obesity, and despite the evidence in support of more physical activities for girls, Saudi public schools have neither in-school physical education programs nor are there public or private activity centres where young children (especially girls) can exercise. In this regard, the implications of this study are that the inability of girls to exercise, and the failure within the education system to address this problem, lead to increased risk of obesity and to the many forms of adult ill-health and morbidity that can follow. Therefore, attempts should be commenced to set new policies and to develop new practices which will elevate the activity levels of Saudi school-age girls.

Several studies have observed a positive relationship between physical activity, physical fitness, and academic performance (Grissom, 2005). The association between increasing exercise and growth factors, as well as brain-derived neurotrophic factors (BDNF), were tested by Cotman and Berchtold (2002) who found positive effects on maintaining brain function and promotion. Similarly, these mechanistic studies of cognitive function also showed positive impacts of physical activity on intellectual performance (Cotman and Berchtold, 2002). Moreover, a cross sectional study assessing the relationship between PA and cognition found that low levels of PA negatively affect some areas of the brain which support cognitive function (Drollette et al., 2014).

6.3. Limitations

Like all research, this project has been constrained by several limitations which should be considered when interpreting the results. It was a cross- sectional analysis and therefore any associations identified should not be interpreted as causal.

6.3.1 Sample size and time constraint

The main limitation encountered in this project was the sample size. 266 subjects was relatively small and not fully representative of the Saudi population, and it would have been desirable if a larger cohort could have been recruited. There is no 'ideal' number for such a survey but this investigation was arguably representative of children of this age group in the western part of the country. Also, the small number does not diminish the validity or value of the results, though a larger number of participants, including some from other regions and other population groups, might have yielded a wider range of findings and been more representative of the country as a whole. The size of the sample was also limited by the need to exclude a number of under-reporters (27 subjects).

Another limitation concerned the time available for the project. This is often an obstacle for researchers, and in this instance the many preliminary steps prior to implementing the survey had the effect of restricting the time for data collection, and this restriction was also a constraint on the sample size. While the study was conducted according to established methodology, and it was not compromised in any way, nevertheless there was considerable time pressure for completion of the actual survey.

6.3.2 Cut off points for under-reporting of dietary intake

Another consideration was the difficulty of identifying the under-reporters because there was no clear point for determining the under-reported data. Obvious under-reporters of diet were excluded for recording an EI < BMR x 1.2, but some of the remaining participants could have also under-reported to some extent. However, there was no evidence that obese or overweight girls under-reported any more than healthy weight girls

6.3.3 Arabic food compositions tables

A considerable limitation was that the food composition tables listing typical Arab foods did not contain sufficient information about nutritional factors such as types of fats and carbohydrates, and these tables were not available in the database. A more complete database of nutrient composition would have added an additional level of data to the results. However, it was important to use a database that contained foods applicable to the population, and so the Arab database was used in preference to a more sophisticated UK analysis programme.

6.3.4 Measuring physical activity

Another limitation concerned the measurement of PA. The accuracy required when measuring body movement was critical for determining current levels of physical activity. Time constraints limited the number of days over which the data could be collected, and only the minimum number of days for validity and reliability could be achieved. Moreover, the participants were young and could not be entirely trusted to use the device as prescribed; neither could they be relied on in regard to wearing the device for the required four days. Some of the participants did not achieve the minimum wear time of 10 hours and so were excluded from the analysis. Also, some of those included might not have worn it for all the time they were active and thus under-estimated their total PA. Although the researcher had no reason to question the honesty of any child, nevertheless it was necessary to oversee the children as much as possible and to interview them all.

6.3.5 Measuring body fat

Body fat percentages, fat mass and fat free mass were estimated using the Tanita bioelectrical impendence analyser. This method of analysis assumes that subjects are adequately but not over-hydrated. Children were asked to void urine and measurements were taken in the morning to reduce the effect of changing hydration status. Also older girls were asked if they were menstruating and if they were, measurement was delayed until the following week. However under or over-estimation of body fat due to over or dehydration cannot be ruled out. Also, the Tanita model used here only measured fat in the lower limbs, and estimated whole body fat percent based on these measures. The equations used to estimate body fat percentage were not validated specifically for Saudi children, but the model used here was suitable for use with children.

6.4. Recommendations for reducing obesity in girls

The findings of this study have a number of important implications for future practice and should be considered to prevent childhood obesity in Saudi Arabia.

Table 6.1 Recommended outlines for interaction between stake-holders to improve current childhood obesity trends and school health

Target groups	Elements to focus on
School-age girls	1. Increase physical activity 2. Dietary education
School environment and education	1. Physical activity education 2. School meal / catering control 3. Nutrition and food education
Parental involvement	1. Parental participation and cooperation with school or local health centres 2. Promote healthier lifestyle and physical activity 3. Nutrition and food choices education
Governments Policy and public health authority	1. Control school food suppliers / food policy 2. Inspect of the implementation of Saudi dietary references values 3. Review physical education at schools/ local community/ health centres 4. Involve health professionals to monitor the body composition of girls 5. Tracking the rate of obesity in girls 6. Update Saudi Food Composition Tables.

1. Target school-age girls: that is, give priority to the provision of facilities for young girls so that they can participate in vigorous physical activities such as games and sports. Furthermore, particular attention must be given to educating the children about food and healthy diets. Nutrition knowledge or education has been shown to influence behaviour (Worsley, 2002) and educating parents and children can promote better

eating behaviours and healthier food choices in children (Savage et al., 2007). Therefore, it is suggested that nutrition education should be encouraged along with other interventions as suggested below.

2. Changing the school environment. At present school campuses are generally unconducive to fostering physical activities, and neither are they suitable models of healthy food and meals. Attention needs to be given to improving facilities for physical activity, such providing sports halls and playing areas and providing suitable equipment such as balls, nets, rackets and climbing frames, and to providing healthy school meals.

3. Parental involvement. Children's health entails collaboration between school and home. Teaching in schools about healthy food and healthy lifestyles could be less effective if the lessons are not re-affirmed in the family environment. There is a need for close parental participation and cooperation with school and with local health centres.

4. Government policies and public health authorities. Schools do not function in isolation; they reflect government policies and priorities, and so it is important that initiatives for addressing this issue should be defined by national government agencies so that a nation-wide effort can be implemented. This might entail a review of curricula and related school activities; monitoring and control of school food suppliers; the development of Saudi food intake reference tables; greater involvement in school activities by local community health centres and healthcare practitioners; and projects for the on-going monitoring of obesity levels in children.

Several important recommendations emerge from these findings. Firstly, steps need to be taken to address the malnutrition of the children found to be underweight. According to the health ministry of Saudi Arabia, unbalanced malnutrition is defined as a form of malnutrition, which is caused by eating some of macronutrients more than others, and resulting to some disease including obesity (Ministry-of-Health, 2012). Additionally, it is recommended that particular attention be given to working with parents and children in schools in order to decrease the rate of underweight. As with so many issues linked to health, weight, and body composition, education is important (Raphael, 2006). Parents need to be aware of the health problems related to obesity and to be provided with information about a healthy diet and exercise. Changes to improve dietary intake are unlikely to be achieved without changes in attitudes: attitudes change only slowly, but parents need to be fully informed so that improvements in lifestyles can be affected (Raphael, 2006, Nyberg et al., 2016, CDC, 2013).

The emphasis on education is not new – indeed it has been a central tenet of many research and studies (Hamam et al., 2017, Al-Hazzaa et al., 2012, Al Alwan et al., 2013) – but it needs to be considered nationally, perhaps with added urgency. Focusing on education of children is vital to promote individual’s health (Raphael, 2006), consequently; education is thought to be a fundamental component to help reverse the epidemic of obesity in children.

Another key recommendation is to greatly emphasise the importance of organising physical activities for girls. It was evident from the findings that most of the population had insufficient physical activity. This problem cannot be rectified by the school alone and it will entail action by both school and parents to encourage activity that is acceptable within the cultural restrictions for girls. Moreover, sustained involvement of parents as well as schools beneficially affects the physical activity and can help reduce the obesity epidemic (Davison et al., 2003). At school, it is recommended to provide more facilities to enable games and sports such as running, team building activities, ball games and racket sports –as these can be vigorous in nature.

Nevertheless, parents as well, must encourage girls to be active at their leisure hours at home. Currently in Saudi Arabia this is difficult as facilities need to be indoors due to the cultural restrictions and the climate, and the required segregated facilities for women and girls are rarely available. They would, however not need to entail expensive equipment; providing indoor spaces and simple items such as skipping ropes, bats and balls should be sufficient for most children. However, parental support and involvement would be required.

Finally, on-going effort must be made to educate parents about nutrition. Young children are unaware of nutritional values of food, if children were given a choice, they will generally select food high in fats and sugars. It is the parents who are responsible for guiding them and so it is the parents – not only mothers– who need to be informed about all food issues. For several generations, food information has been readily available in the forms of magazine articles, television programs, and other media, but too often it is overwhelming and supplanted by the attractions of energy-rich snacks and fast foods. It is recommended that more assertive forms of educational campaigns (similar to those warning of the dangers of smoking) be devised because it is clear that -so far- the benefits of ‘soft’ education has been of limited effect.

In the UK there are school food standards (Children’s Food Trust) (CORE, 2016) and physical education classes, yet there are still no reductions in the prevalence of obesity in children. The prevalence of obesity in girls aged 10-11 years in 2011 was 15.8 %, but in 2016 it was 17.9% (PHE, 2017b). School and community based interventions in the UK tend to produce small changes in activity and diet without any significant changes in the level of obesity and overweight (Warren et al., 2003, Mears and Jago, 2016). This perhaps highlights the importance of the influence of the wider environment such as the food industry, the impact of media and culture. While nutrition education and health promotion in schools are an important starting point for Saudi Arabia, it cannot be expected for these to be sufficient to reduce obesity. The UK is taking further steps such as introducing a sugar levy on soft drinks and encouraging reformulation of manufactured products to reduce sugar content (PHE, 2017a).

6.5 Examples of preventive strategies and programmes to combat obesity in Saudi Arabia

There are some countries worldwide that have established comprehensive strategies to prevent rising of the prevalence of obesity. Equivalent programs in certain Arab regions have been implemented as these countries share similar weather conditions and cultural barriers. Programmes that raise awareness regarding healthy diets, eating habits, and increasing the level of physical activity among Saudi children will benefit their health. Moreover, most realistic approaches to prevent childhood obesity are to implement programmes regarding social and environmental perspectives. To evaluate our recommendations, Table 6.2 illustrates programs from certain countries to exemplify obesity prevention and improve children’s health.

Table 6.2 examples of prevention and promotion programmes in other countries

Factors	Country	Programs
Physical activity	Qatar	1- Qatar Active Schools (QAS) 2- Haraka-wa-Seha (HWS)
Nutritional and activity aspects	Abu Dhabi	1- Eat right get active 2010-2011.
Nutrition and food habits	Qatar Qatar	1- Healthy chef for young girl (Aspire, 2014c). 2- Healthy chef for mother (Aspire, 2014b).

1- Qatar is one of the Arab countries, which has similar environmental and cultural concerns to Saudi Arabia. Several programmes have been adopted to promote children's health focusing on healthy eating, physical activity and parental involvement. Firstly, collective collaboration between Aspetar and Supreme Education Council were demonstrated to promote diverse physical activity opportunities in the school environment. Qatar Active School (QAS) is a programme started in 2014 across five primary schools (Zimmo, 2015). It aimed to highlight the level of physical activity at an early age and to increase the level of PA by 20% by 2020. Qatari children spend approximately 30% of their awake time at school, and so for that reason the programme runs during school time, introducing PA into morning assembly, break times and providing additional physical activity classes. It has not yet been evaluated.

   Another program conducted in Qatar (2014) was developed in order to introduce interactive sport-based health education after school (Aspire, 2014a). It was designed for children aged 9-12 years attending a supervised one hour session for four days a week. During the sessions, fitness measurements were conducted by qualified scientific and medical staff to evaluate and ensure the validity of the programme aims. This programme is located in Khalifa International Stadium and is sponsored by Aspetar. Although these programs have not published any evaluation reports yet, they can illustrate the steps taken towards promoting children's physical activity levels.

2- The Eat Right and Get Active campaign was established in UAE, 2010/ 2011, in elementary schools and it consists of educational activities involving students and their parents (Health-Authority, 2010). It aims to encourage children to eat healthily and be active. The campaign provides some key messages such as increasing the daily consumption of fruits and vegetables, reducing high fat / sugar snack foods, healthy portion sizes, combined with 30 minutes of physical activity per day. Schools collaborate to help evaluate the program and determine which activities are suitable and meet the need of the students. Several booklets are available to simplify the program implementation, which are accessible via the Health Authority of Abu Dhabi (HAAD) website. HAAD report that the programme has resulted in significant improvements in nutritional intake and physical activity of the participating school children and it been recommended for adoption in other Arab countries (Gulf-News, 2013). However the results have not been published in the scientific literature.

3- In England, the National Child Measurement Programme (NCMP) was established in 2006 to provide and assess the prevalence of overweight and obesity in school age children in reception (aged 4-5 years) and in year 6 (aged 10-11 years) (NHS, 2006). Annually, key findings of this program are analysed in order to target and facilitate delivering suitable support to the local authority areas most in need. This monitoring tool can be used to evaluate the effect of policy and interventions on obesity rates nationally / locally. Moreover, it can be considered as a useful tool to be considered for adoption by the Saudi ministry of health to monitor the prevalence of obesity in children.

6.6 Future research

Stemming from this research are many important areas requiring further detailed investigation. It would be particularly useful if a similar study could be undertaken, but on a larger scale. That is, one which could take into account differences in geographic region, social grouping, and cultures. However, it is recommended that the focus should remain on young children because it is in the formative years that patterns and habits of eating are acquired, and it is in the early years that intractable weight problems can emerge (Singh et al., 2008).

Another particularly beneficial area for future improvement is the development of Arabic food composition tables. Future research, and the information which will guide government policies, depend on accurate and up-to-date tables, and it became evident here that the existing tables are inadequate; that is, they need to be corrected in accordance with recent food research data because they fail to reflect the varieties and quantities of food currently available in shops and the foods being provided at home and insufficient nutrients on the database.

A final proposal for future research is in the use of modern technologies. It is likely that future projects similar to this may yield more nuanced results and findings when newly-developed equipment is used. For example, tracker devices may open-up the possibility of a range of new survey methods in the future (Shields, 2017, Colley et al., 2011).

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Appendices

Appendix 1 Food Diary

Food Diary

PUPIL NAME:
PUPIL CODE:

How to complete your food diary

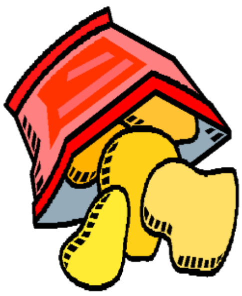
1. Try and complete the food diary for at least 3 days in a row.
2. Avoid completing it over your birthday OR around other major celebrations!
3. The purpose of the diary is to help you look at <u>everything</u> you eat or drink, including snacks, juices etc. Therefore, it is important that you are accurate and remember to put down all your food, even the very little things that you eat
4. Try to describe the food you eat and how it was prepared. For example if you had fish for lunch, was it in batter or breadcrumbs, was it fried or grilled? If you had a cup of tea, how many sugars did it have? What sort of bread, rice or pasta was it – brown or white?
5. Your food diary should be a record of what you eat now, and should contain even the things that you know are not so healthy for you.

<u>An example</u> of how you might write your food diary *before* you have made any changes to what you eat. Can you pick out which things on this list you might cut down on and which you could eat more of?

Day & Date	Time	Food Description & Preparation	Amount
Monday **24/11 /05**	6.30am	White toast, two spoon spared chees (craft) Boiled egg Chocolate milk 200 ml (Nadec)	2 pieces 1 2 cups
	10.30 am	Coffee & 2 tea spoon of white sugars KitKat two fingers	1 cup 1 whole bar
	12.30 pm	Cheese & salad sandwich, mayonnaise & butter Apple Orange juice(alsafi) Bag of Maltesers	2 rounds of white bread) Small carton Whole bag
	3pm	Tea & one sugar Lay's potato chips 28g Grapes	1 cup 1 bag 5 grapes
	5.30pm	Crisps	3 crisps
	6.30pm	Roast beef, Pasta with white sauce, roast potatoes, boiled peas. Custard Pepsi	1 large plate + small seconds One bowl Half a bottle

Day 1

Day & Date	Time	Food Description & Preparation	Amount
Day: …………………… Date: /____/____			



Day 2

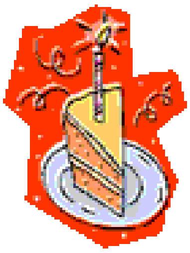
Day & Date	Time	Food Description & Preparation	Amount
Day: …………………… Date: /____/____			

Day 3

Day & Date	Time	Food Description & Preparation	Amount
Day: …………………… **Date:** **/____/____**			

Day 4

Day & Date	Time	Food Description & Preparation	Amount
Day: …………………… Date: /____/____			



Appendix 2 CADET

CADET

Child and Diet Evaluation Tool

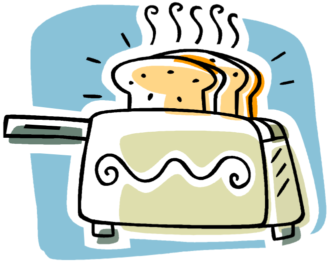
This diary belongs to:

Pupil Name:

Code number:

Grade:

When you have filled in this diary please make sure it is placed in your child's bag and sent back to school



Dear Parent or Carer

This diary will record everything your child eats and drinks over 24 hours (from morning break today to morning break tomorrow). All you need to do is to tick the food and drink your child eats while not at school. There are some additional questions that we would like you to complete at the end of the diary (pages 12 & 13).

How to fill in the CADET DIARY

Starting with the column headed ‘Before tea’ tick 4all the items of food and drink that your child eats and drinks after finishing school today until their evening meal.

In the next two columns, tick ✓ everything your child eats or drinks during their evening meal and afterwards until breakfast the next day.

In the morning, tick ✓all the items of food and drink your child has eaten at home in the ‘Breakfast’ column (if your child eats anywhere else, this will be filled in by a teacher). If this is a Saturday, all food and drink consumed up to 10.00am needs to be recorded by a parent/carer.

If they do not have anything to eat or drink at a mealtime, please tick ✓ ‘nothing to eat’ and/or ‘nothing to drink’ on page 11.

Make sure you ask your child if she/he ate or drank anything between leaving school and getting home. If your child ate or drank with someone else after school, ask your child or the person they were with what they ate and tick ✓ the foods and drinks they consumed (if your child attended an after-school club on school premises, any food/drink consumed by your child will have been filled in by a teacher, but you should tick ✓ any food or drink your child consumed at any other club).

School staff will have ticked everything your child has eaten and drunk at school today. If your child only attends school for half a day, please ensure you tick all items of food and drink consumed when your child is with you or another carer (and if they are off school sick). You should record all food and drink consumed since your child left the school.

Try not to leave out anything your child has eaten and drunk at home today. Remember all drinks and snacks eaten during the night also count.

If for some reason your child is not at school tomorrow please return the diary as soon as possible. If your child is not well please do your best to record what she ate.

If you cannot find the exact food or drink listed, please tick ✓the item you think is the closest match e.g. the nearest match to:

Fruit Winder is: sweets, crisps etc ✓

Spaghetti Bolognese is: pasta with meat, fish (sauce) ✓

Milk shake is: milk, milky drink ✓

Popodom is: crisps/savoury snack ✓

When the diary is completed, please make sure it is placed in your child’s bag and sent back to school

Example

If your child ate a bowl of Rice Krispies with milk and sugar at breakfast - tick 4 Rice Krispies and milk in the column labelled 'Breakfast/before school'. The sugar that was added can be ticked in the diary (see Q9 on page 13).

To be ticked ✓ by parents/carers (or school staff if child goes to after school club on the school premises or if breakfast is consumed outside the home).

To be ticked ✓ by school staff (or parent/ carer if child attends half days only)

To be ticked ✓ by parent/carer

Example (do not complete this page)

A	CEREAL	Morning break (1)	Lunch time (2)	Afternoon break (3)	Before tea (after school) (4)	Evening meal/tea (5)	After tea/ during night (6)	Breakfast/ before school (7)
1	Cornflakes, Rice Krispies etc	☐	☐	☐	☐	☐	☐	☐
2	Sugar coated e.g. Frosties, SugarPuffs	☐	☐	☐	☐	☐	☐	✓
3	Hi-fibre e.g. Branflakes, Weetabix, Shreddies, Muesli	☐	☐	☐	☐	☐	☐	☐
4	Milk on Cereal	☐	☐	☐	☐	☐	☐	✓
5	Porridge, Ready Brek	☐	☐	☐	☐	☐	☐	☐

All sugar eaten is recorded in Q9 on page 13

Please look through the pages of this diary and then you are ready to start

1. Please tick in each column the food or drink your child has today.

Remember, anything your child ate or drank at school will have already been ticked (including anything eaten and drunk at an after-school club on the school premises).

		Morning break (1)	Lunch time (2)	Afternoon break (3)	(after school) (4)	Evining meal/tea (5)	After tea during night (6)	Breakfast/ before school (7)
A	**CEREALS**							
1	Sugar-coated e.g. Frosties, Sugar Puffs							
2	Hi-fibre e.g. Branflakes, Weetabix, Shreddies, Muesli							
3	Other e.g. Cornflakes, Rice Krispies etc							
4	Milk on cereal							
5	Porridge, Ready Brek							

All sugar eaten is recorded in Q9 on page 13

		Morning break (1)	Lunch time (2)	Afternoon break (3)	(after school) (4)	Evining meal/tea (5)	After tea during night (6)	Breakfast/ before school (7)
B	**SANDWICH, BREADS, CAKES, BISCUITS**							
1	Sandwich (tick filling separately), bread, roll, toast, crumpet etc							
2	Croissant, sweet waffles, pop tarts							
3	Garlic bread, naan							
4	Chapatti, pitta bread etc							
5	Cracker, crispbread etc							
6	Cake, bun, sponge pudding							
7	Sweet pies, tarts, crumbles							

8	Cereal bar, muesli bar, flapjack							
9	Chocolate biscuit							
10	Other biscuit							
C	SPREADS, SAUCES, SOUP							
1	Margarine, butter							
2	Tomato ketchup, brown sauce							
3	Mayonnaise, salad cream							
4	Sweet spread e.g. jam, honey							
5	Savory spread e.g. marmite, paté							
6	Gravy							
7	Soup							
D	CHEESE, EGGS							
1	Hard cheese, e.g. cheddar, red Leicester							
2	Cheese spread, triangle, string							
3	Cottage cheese							
4	Quiche - meat, fish or vegetable							

D. Continued overleaf

(D)		Morning break (1)	Lunch time (2)	Afternoon break (3)	Before tea (after school) (4)	Evening meal/tea (5)	After tea/ during night (6)	Breakfast/ before school (7)
5	Scrambled egg, omelette, fried egg							
6	Poached, boiled egg							
E	CHICKEN, TURKEY							
1	......sliced							
2	......nuggets, dippers, kiev etc							
3	......in a creamy sauce, curry							
F	OTHER MEATS e.g.							
1	......sliced, roast, steak, chops							
2	......stew, casserole, mince, curry							
3	......beef burger, lamb burger							
4	Bacon beef							
5	Camel							
6	Sausages							
7	Sausage rolls, meat pie, pasty							

8	Corned beef, luncheon meats, salami, pepperoni	☐	☐	☐	☐	☐	☐	☐
9	Offal, e.g. liver, kidney	☐	☐	☐	☐	☐	☐	☐
G	**FISH**							
1	Fish fingers	☐	☐	☐	☐	☐	☐	☐
2	Fried fish in batter (as in fish & chips)	☐	☐	☐	☐	☐	☐	☐
3	White fish (not fried) e.g. cod, haddock, plaice	☐	☐	☐	☐	☐	☐	☐
4	Tuna or other oily fish e.g. salmon (including canned and fresh)	☐	☐	☐	☐	☐	☐	☐
5	Shellfish e.g. prawns, mussels	☐	☐	☐	☐	☐	☐	☐
H	**VEGETARIAN**							
1	Vegetable pie, pasty	☐	☐	☐	☐	☐	☐	☐
2	Samosa, pakora, bhajee	☐	☐	☐	☐	☐	☐	☐
3	Quorn, veggie mince, sausages etc	☐	☐	☐	☐	☐	☐	☐
I	**PIZZA, PASTA, RICE ETC**							
1	Pizza	☐	☐	☐	☐	☐	☐	☐
2	Boiled rice	☐	☐	☐	☐	☐	☐	☐
3	Fried rice	☐	☐	☐	☐	☐	☐	☐
4	Noodles	☐	☐	☐	☐	☐	☐	☐

I. Continued overleaf

		Morning break (1)	Lunch time (2)	Afternoon break (3)	Before tea (after school) (4)	Evening meal/tea (5)	After tea/ during night (6)	Breakfast/ before school (7)
(I)								
5	Pasta - plain	☐	☐	☐	☐	☐	☐	☐
6	Pasta with tomato sauce (no meat)	☐	☐	☐	☐	☐	☐	☐
7	Pasta with cheese sauce	☐	☐	☐	☐	☐	☐	☐
8	Pasta with meat, fish (and sauce)	☐	☐	☐	☐	☐	☐	☐
J	DESSERTS, PUDDINGS ETC							
1	Yoghurt	☐	☐	☐	☐	☐	☐	☐
2	Jelly, ice lolly	☐	☐	☐	☐	☐	☐	☐
3	Ice cream, frozen dessert (Vienetta)	☐	☐	☐	☐	☐	☐	☐
K	SWEETS, CRISPS ETC							
1	Sweets, toffees, mints	☐	☐	☐	☐	☐	☐	☐
2	Chocolate bar, e.g. Mars, Galaxy	☐	☐	☐	☐	☐	☐	☐
3	Crisps, savoury snacks (e.g. Cheddars)	☐	☐	☐	☐	☐	☐	☐
4	Nuts	☐	☐	☐	☐	☐	☐	☐

L VEGETABLES & BEANS

1	Cucumber	☐	☐	☐	☐	☐	☐	☐
2	Tomatoes	☐	☐	☐	☐	☐	☐	☐
3	Celery	☐	☐	☐	☐	☐	☐	☐
4	Coleslaw	☐	☐	☐	☐	☐	☐	☐
5	Other salad vegetable e.g. lettuce	☐	☐	☐	☐	☐	☐	☐
6	Stir-fried vegetables	☐	☐	☐	☐	☐	☐	☐
7	Broccoli, brussel sprouts, cabbage	☐	☐	☐	☐	☐	☐	☐
8	Carrots	☐	☐	☐	☐	☐	☐	☐
9	Cauliflower	☐	☐	☐	☐	☐	☐	☐
10	Peas, sweetcorn	☐	☐	☐	☐	☐	☐	☐
11	Mixed vegetables	☐	☐	☐	☐	☐	☐	☐
12	Celeriac/swede	☐	☐	☐	☐	☐	☐	☐
13	Peppers, red, green, yellow etc	☐	☐	☐	☐	☐	☐	☐
14	Other vegetable	☐	☐	☐	☐	☐	☐	☐
15	Baked beans	☐	☐	☐	☐	☐	☐	☐

L. Continued overleaf

		Morning break (1)	Lunch time (2)	Afternoon break (3)	Before tea (after school) (4)	Evening meal/tea (5)	After tea/ during night (6)	Breakfast/ before school (7)
(L)								
16	Lentils, Dahl	☐	☐	☐	☐	☐	☐	☐
17	Other beans, pulses	☐	☐	☐	☐	☐	☐	☐
18	Seeds, e.g. sunflower, sesame	☐	☐	☐	☐	☐	☐	☐
M	POTATO							
1	Boiled, mashed, jacket	☐	☐	☐	☐	☐	☐	☐
2	Chips, roast, potato faces etc	☐	☐	☐	☐	☐	☐	☐
N	FRUIT							
1	Apple	☐	☐	☐	☐	☐	☐	☐
2	Pear	☐	☐	☐	☐	☐	☐	☐
3	Banana	☐	☐	☐	☐	☐	☐	☐
4	Orange, satsuma etc	☐	☐	☐	☐	☐	☐	☐
5	Grapes	☐	☐	☐	☐	☐	☐	☐
6	Melon	☐	☐	☐	☐	☐	☐	☐
7	Pineapple	☐	☐	☐	☐	☐	☐	☐
8	Strawberry, raspberry etc	☐	☐	☐	☐	☐	☐	☐

9	Peach, nectarine, plum, apricot, mango								
10	Kiwi								
11	Fruit salad (tinned or fresh)								
12	Other fruit								
13	Dried fruit								
O1 NOTHING TO EAT									
P	DRINKS								
1	Milk, milky drink								
2	Tea, coffee								
3	Drinking chocolate etc								
4	Fizzy drink (pop), squash, fruit drink (e.g. Ribena)								
5	Diet, low calorie drink (including fizzy low calorie)								
6	Fruit juice (pure)								
7	Water								
Q1 NOTHING TO DRINK									

R

This section is to be filled in by parents/carers

These questions provide us with more detail about the amounts and types of food and drink usually eaten by your child on an average day. Please tick 4 the closest answer.

1. How much milk in total does your child usually have on an average day e.g.on cereal and drinks? (one average child's beaker = ¼ pint)

none ☐ 1 ¼ pint ☐ 2 ½ pint ☐ 3 ¾ pint ☐ 4 1 pint ☐ 5 more than 1 pint ☐ 6

2. What type of milk does your child usually have? (tick all that apply)

full cream (silver top, sterilised) ☐ 1 semi-skimmed (half fat) ☐ 2 skimmed ☐ 3 other ☐ 4

3. What type of bread/roll/toast does your child usually eat? (tick all that apply)

none ☐ 1 white ☐ 2 white with added fibre ☐ 3 wholemeal ☐ 4 granary brown ☐ 5 other ☐ 6

4. What type of fat spread does your child usually eat? (tick all that apply)

Butter e.g. Anchor, Lurpak ☐ 1
Butter-type spread e.g. Utterly Butterly, Golden Churn, Clover ☐ 2
Soft Margarine e.g. Stork ☐ 3
Polyunsaturated e.g. Flora, Benecol, Vitalite ☐ 4
Olive spread e.g. Olivio, Asda Olive Gold ☐ 5
Low-fat spread e.g. Flora Light, Asda Olive Gold Light ☐ 6
Does not have spread ☐ 7

5. How much pure fruit juice in total does your child usually drink on an average day? (one average child's beaker = ¼ pint)

none ☐ 1 ¼ pint ☐ 2 ½ pint ☐ 3 ¾ pint ☐ 4 1 pint ☐ 5 more than 1 pint ☐ 6

6. How many servings of fruit in total (fruit eaten at home and school) does your child usually have on an average day? (A serving of fruit is classed as a whole fruit e.g. an apple, a banana.)

none ☐ 1 ¼ ☐ 2 ½ ☐ 3 one ☐ 4 two ☐ 5 three ☐ 6 four ☐ 7 five ☐ 8 six ☐ 9

7. How many servings of vegetables and salad in total (vegetables eaten at home and school) does your child usually have on an average day? A serving of vegetables or salad is classed as a heaped serving spoon, or whole vegetable. Potatoes are not included.

none ☐ 1 ¼ ☐ 2 ½ ☐ 3 one ☐ 4 two ☐ 5 three ☐ 6 four ☐ 7 five ☐ 8 six ☐ 9

8. When your child eats fruit, how much of the whole fruit e.g. apple, banana, orange is usually eaten?

a bite ☐ 1 ¼ ☐ 2 ½ ☐ 3 ¾ ☐ 4 whole thing (excluding skin, pips etc) ☐ 5

9. How much sugar in total does your child usually have added to food or drink on an average day?
(2 teaspoons = 1 dessert spoon)

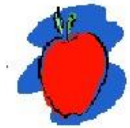
none ☐ 1 1-2 teaspoons ☐ 2 3-4 teaspoons ☐ 3 5-6 teaspoons ☐ 4 7 + teaspoons ☐ 5

10. Where did your child eat today? (tick all places)

home ☐ 1 school ☐ 2 friend/relative ☐ 3 childcare ☐ 4 other ☐ 5

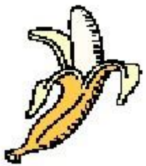
Thank You

Thank you for taking the time to fill in this CADET diary.
Don't forget to give it to your child to bring back to school tomorrow ready to hand in to her class teacher.



If you would like to ask any questions about completing this questionnaire please contact:

Rabab Alkutbe
+966555514462



Appendix 3 Physical Activity Questionnaire PAQ

Physical Activity Questionnaire

Name:_________________________ Age:___________

Grade:__________

We are trying to find out about your level of physical activity from ***4 days***. This includes sports or dance that make you sweat or make your legs feel tired, or games that make you breathe hard, like tag, skipping, running, climbing, and others.

Remember:

1. There are no right and wrong answers — this is not a test.
2. Please answer all the questions as honestly and accurately as you can — this is very important.

---

1. Physical activity in your spare time: Have you done any of the following activities in 4 days? If yes, how many times? (Mark only one circle per row.)

	No	1-2	3-4	5-6	7 times or more
Skipping					
Rowing/canoeing					
In-line skating					
Tag					
Walking for exercise					
Bicycling					
Jogging or running					
Aerobics					
Swimming					
Baseball, softball					
Dance					
Football					
Badminton					
Skateboarding					
Soccer					
Street hockey					
Volleyball					
Floor hockey					
Basketball					
Ice skating					
Cross-country skiing					
Ice hockey/ringette					
Other: _________________________					

2. In 4 days, during your physical education (PE) classes, how often were you very active (playing hard, running, jumping, throwing)? (Check one only.)

I don't do PE ....•
Hardly ever ....
Sometimes ....
Quite often ....
Always ....

3. In 4 days, what did you do most of the time *at recess*? (Check one only.) Sat

down (talking, reading, doing schoolwork)……•
Stood around or walked around ....•
Ran or played a little bit ....
Ran around and played quite a bit ....
Ran and played hard most of the time ....

4. In 4 days, what did you normally do *at lunch* (besides eating lunch)? (Check one only.)

Sat down (talking, reading, doing schoolwork)…....•
Stood around or walked around ....•
Ran or played a little bit ....
Ran around and played quite a bit ....
Ran and played hard most of the time ....

5. In 4 days, on how many days *right after school*, did you do sports, dance, or play games in which you were very active? (Check one only.)

None ....•
1 time last week ....
2 or 3 times last week ....
4 times last week ....
5 times last week ....

6. In 4 days, on how many *evenings* did you do sports, dance, or play games in which you were very active? (Check one only.)

None ....
1 time last week ....
2 or 3 times last week ....
4 or 5 last week ....•
6 or 7 times last week ....

7. *On the weekend*, how many times did you do sports, dance, or play games in which you were very active? (Check one only.)

None ....
1 time ....
2 — 3 times ....
4 — 5 times ....
6 or more times ....

8. Which *one* of the following describes you best for the last week? Read *all five* statements before deciding on the *one* answer that describes you.

A. All or most of my free time was spent doing things that involve little physical effort ……………………………

B. I sometimes (1 — 2 times last week) did physical things in my free time (e.g. played sports, went running, swimming, bike riding, did aerobics) ......…………

C. I often (3 — 4 times last week) did physical things in my free time ......………..

D. I quite often (5 — 6 times last week) did physical things in my free time ………..

E. I very often (7 or more times last week) did physical things in my free time ……..

9. Mark how often you did physical activity (like playing sports, games, doing dance, or any other physical activity) for each day last week.

	None	Little bit	Medium	Often	Very often
Monday ....•					
Tuesday					
Wednesday					
Thursday					
Friday ....•					
Saturday					
Sunday					

10. Were you sick last week, or did anything prevent you from doing your normal physical activities? (Check one.)

Yes ....……•
No ....•

If Yes, what prevented you?

Appendix 4 Consent and information sheet

UNIVERSITY OF PLYMOUTH

FACULTY OF SCIENCE AND TECHNOLOGY

Human Ethics Committee Sample Consent Form

CONSENT TO PARTICIPATE IN RESEARCH PROJECT / PRACTICAL STUDY

Name of Principal Investigator: Rabab Bade Muhammad Alkutbe

Title of Research: An investigation into the dietary intake, physical activity and body composition of girls aged 8-11 years in Saudi Arabia.

The aim of the research will be recommendations about how these results could be used to develop an intervention to reduce obesity in girls of this age group.
Description of procedure

1. Anthropometric measurements - It will include:
- Height and weight will be measured.
- Waist circumference will be measured by measuring tape
- Body composition - will be estimated by using Tanita bioelectrical impedance analysis (BIA). Subjects will be asked to remove their shoes and socks. To ensure normal hydration status for BIA testing.
2. Accelerometer- Participants will wear the accelerometer during the day for 4 days
3. Food diary - Participants will be asked to record details of foods and beverages consumed at the time of consumption for 4 days

I am the *parent /legal guardian of ________________________________

The objectives of this research have been explained to me.

I understand that she is free to withdraw from the research at any stage, and ask for her data to be destroyed if I wish.

I understand that her anonymity is guaranteed, unless I expressly state otherwise.

I understand that the Principal Investigator of this work will have attempted, as far as possible, to avoid any risks, and that safety and health risks will have been separately assessed by appropriate authorities.

Under these circumstances, I agree for her to participate in the research.

Name:……………………………………

Signature: ....……………..   Date: ....

Appendix 5 Information sheet and consent sheet for children

UNIVERSITY OF PLYMOUTH
FACULTY OF SCIENCE AND TECHNOLOGY

RESEARCH INFORMATION SHEET AND CONSENT SHEET FOR CHILDREN

Name of Principal Investigator: Rabab Bade Muhammad Alkutbe

An investigation into the dietary intake, physical activity and body composition of girls aged 8-11 years in Saudi Arabia.

- This project will collect diet and exercise information from girls of different body weights.
- Results could be used to help girls to be healthier.
- Your height and weight will be measured.
- Also, you will have to fill some diaries to know your dietary intake.
- You will be also asked to wear a small tool to count your steps.
- You have the right to stop whenever you want.
- All the information will be saved and used only by me.
- At the end I will give you a summary of your work.

If you are willing to be a part of this project, please sign below.

Yes I am happy to do it.

Name:……………… Sign:…………………………..

Appendix 6 Socio-economic status questionnaire

Name:……………………………………………………….

School: ……………………………………………………….

1-Father's qualification: ………………………………..

2-Mother's qualification ………………………………...

3-Father's occupation: …………………………………..

4-Mother's occupation: ……………………………….....

5- The house that the student lives in:

a) Rent b) Owned

6- House type:

a) Flat b) Villa

7- Number of siblings: ……………………………..

8- Who does the student live with:

a) Parents b) Father c) Mother d) Other

9- Family's annual income:

a) Less than 3000 SR b) Between 3100 SR – 7000 SR c) Between 7100 SR – 12000 SR

d) More than 12100 SR

10- How does the student travel to school:

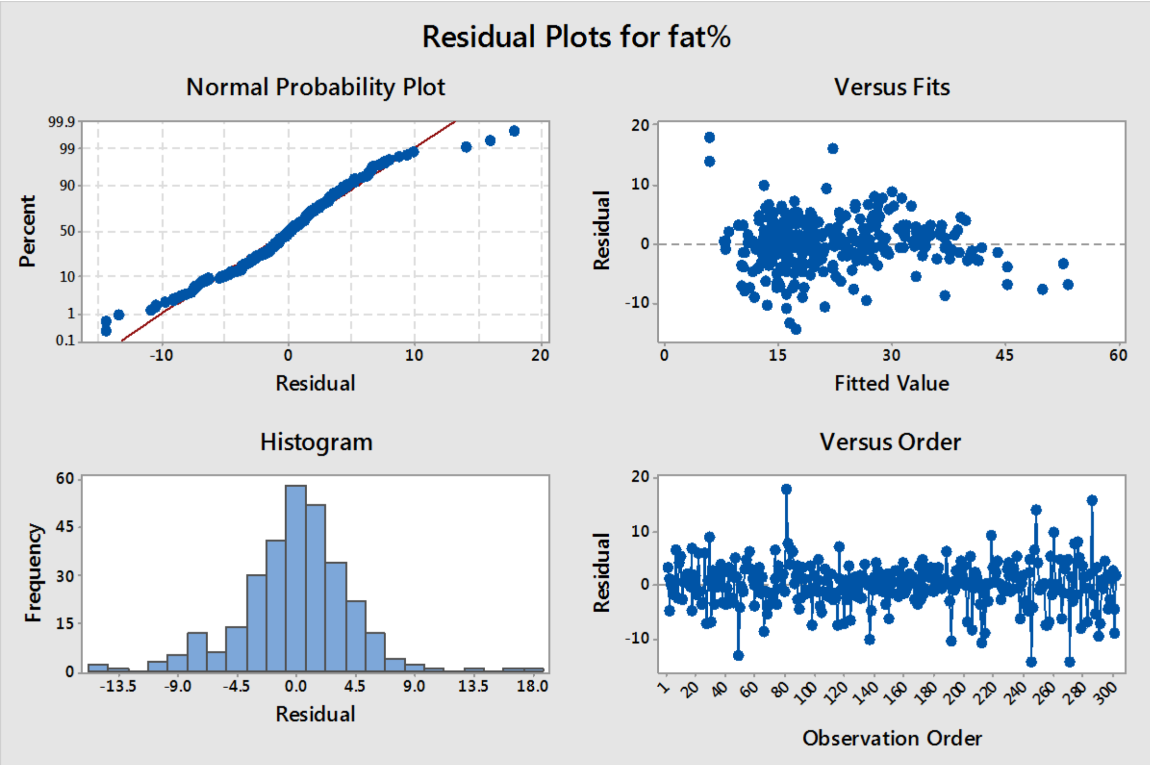
a) Walk b) Car c) School bus

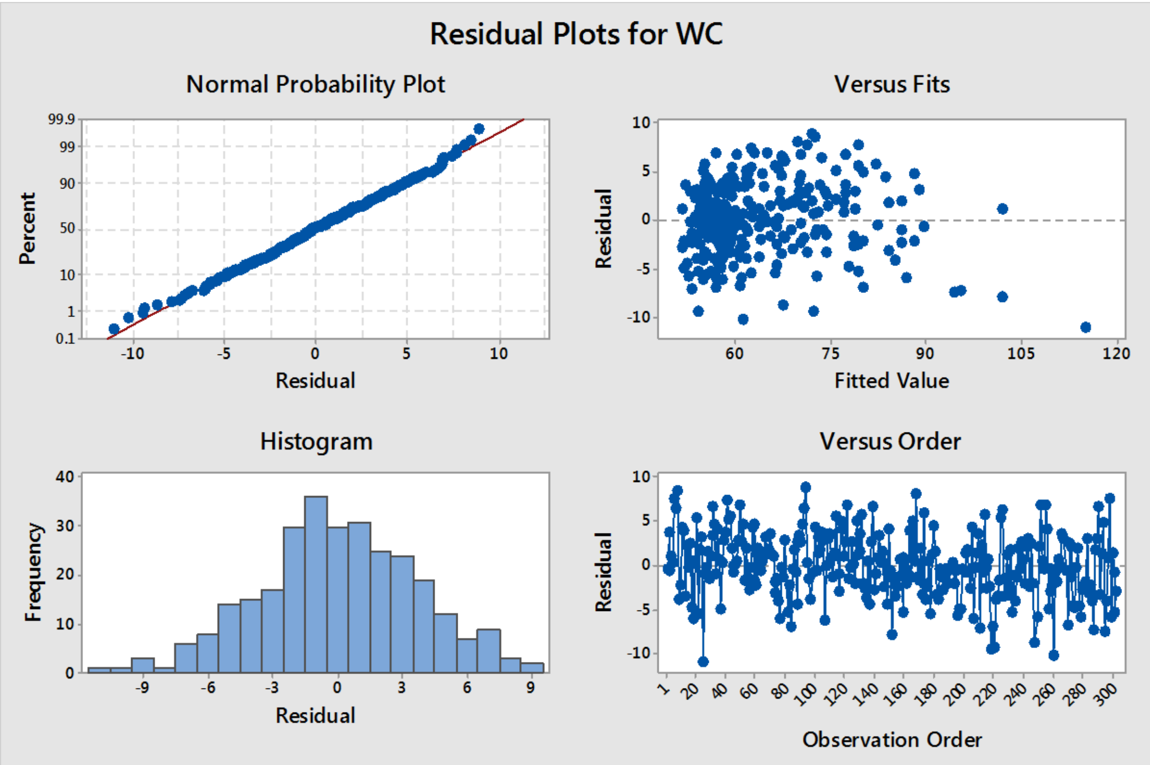
11- Is there a housemaid at the student's house:

a) Yes b) No

12- Who does the cooking at the house: …………………………….

Appendix 7: Regressions equations models


Residual Plots for fat%
Normal Probability Plot
Percent
99.9
99
90
50
10
1
0.1
-10
0
10
20
Residual
Versus Fits
Residual
20
10
0
-10
0
15
30
45
60
Fitted Value
Histogram
Frequency
60
45
30
15
0
-13.5
-9.0
-4.5
0.0
4.5
9.0
13.5
18.0
Residual
Versus Order
Residual
20
10
0
-10
1
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
Observation Order


Residual Plots for WC
Normal Probability Plot
Percent
99.9
99
90
50
10
1
0.1
-10
-5
0
5
10
Residual
Versus Fits
Residual
10
5
0
-5
-10
60
75
90
105
120
Fitted Value
Histogram
Frequency
40
30
20
10
0
-9
-6
-3
0
3
6
9
Residual
Versus Order
Residual
10
5
0
-5
-10
1
20
40
60
80
100
120
140
160
180
200
220
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280
300
Observation Order

Al-Kutbe et al. BMC Public Health (2017) 17:592
DOI 10.1186/s12889-017-4506-2

BMC Public Health

RESEARCH ARTICLE

Open Access

A comparison of nutritional intake and daily physical activity of girls aged 8-11 years old in Makkah, Saudi Arabia according to weight status

Rabab Al-Kutbe[1], Anne Payne[2], Anne de Looy[2] and Gail A. Rees[1*]

Abstract

Background: Obesity rates in Saudi Arabia are amongst the highest in the world. It is known that teenage girls are less active than teenage boys, but less is known about the diet and activity patterns in younger girls. Therefore this study sought to investigate dietary intake and daily physical activity in girls aged 8-11 years old in Saudi Arabia.

Methods: This was a cross- sectional observational study conducted in seven schools across the city of Makkah. A total of 266 girls had anthropometric measurements taken including height, weight, waist circumference and body fat estimations. Dietary assessment using a 4 day unweighed diet diary was undertaken in 136 of these participants, and 134 agreed to monitor their physical activity for the 4 days using an accelerometer. After exclusion for under-reporting, 109 remained in the dietary analysis and 78 in the physical activity analyses. Differences in means between BMI groups were determined using one-way ANOVA with post hoc Tukey test. Multivariable linear regression analysis was performed to look at the effect of multiple variables on body weight.

Results: A total of 30% of participants were classified obese or overweight. There was a significant difference in the mean daily energy intake between the BMI groups with the obese group having the highest energy, fat, carbohydrate and protein intake (obese group: 2677 ± 804 kcal/d; healthy weight group: 1806 ± 403 kcal/d, $p < 0.001$), but the percentage contribution of the macronutrients to energy intake remained the same across the BMI groups. There were no differences in number of steps taken per day or time spent in moderate to vigorous intensity exercise according to BMI category. Most of the girls did not meet daily physical activity guidelines (5969 to 6773 steps per day and 18.5 - 22.5 mins per day of moderate to vigorous activity). Multiple linear regression showed that energy intake positively predicted body weight (Beta = 0.279, p =0 .001), whereas, total energy expenditure per kg of body weight and family income had a significant negative influence on body weight (Beta = −0.661, $p < 0.001$; −0.131, $p = 0.028$ respectively).

Conclusions: The results of this cross sectional analysis suggest that obesity in girls aged 8-11 years is linked to excessive energy intake from all macronutrients and the majority of girls in all weight categories are inactive. Research should be conducted to further investigate causal relationships in longitudinal studies and develop interventions to promote dietary change and activity that is culturally acceptable for girls in Saudi Arabia.

Keywords: Dietary habits, Energy intake, Girls, Nutrient intake, Physical activity, Saudi Arabia

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Background

Obesity has become a widespread public health concern in most developed nations and the prevalence of obesity varies by region and according to sociodemographic variables [1]. According to a recent systematic review [2], Saudi Arabia has the second highest rate of obesity among females in the Middle Eastern countries of the Gulf Cooperation Council at 38.4%, with Qatar at 45.3%. This is higher than female obesity rates in England (27%) and the USA (35.8%). Saudi Arabia has changed very rapidly since the 1960s. The country has developed economically, and with it has come profound social and lifestyle changes [3]. For instance, economic transitions facilitate access to modern transportation, western imports as well as the availability of fast food [3]. In 2002 El-Hazmi et al. [4] found higher rates of overweight (27.6%) and obesity (13.8%) in the eastern oil-field provinces and lower rates in the mountainous south-west (11.0% and 4.3% respectively), where lifestyles are more traditional.

The prevalence of overweight and obesity in children in Saudi Arabia has been estimated at 23.1% and 11.3% respectively [5]. Tackling obesity in children is important as it might reduce the risk of adulthood obesity [3]. Research has also shown that being overweight or obese in childhood is associated with mental and psychological health problems such as depression, anxiety and low self-esteem [6], and obesity adversely affects the physical health and development of the child. Increasing adiposity has been associated with higher inflammatory markers and with lower sex hormone binding globulin (SHBG) levels between the ages of 5 and 15 years [7]. Lower SHBG levels anticipated earlier puberty. In particular, excess body fat contributes to altered levels of sex hormones, and this, in turn, seems to be a major contributor to the earlier onset of puberty, especially in girls [7]. Therefore, preventing obesity in pre-adolescents will benefit the child's health now and in the future.

Several factors have been identified as contributing to the high incidence of obesity amongst Saudi children. As in many other countries worldwide, a general lack of physical activity, sedentary behavior from prolonged use of computers and screen-based devices, and watching television while simultaneously eating energy-dense snacks have been found to be common [3, 8]. A previous study has suggested that 60% of children in Saudi Arabia do not participate in sufficient physical activity [9]. A recent large-scale study in Saudi Arabia highlighted the problem of poor dietary habits and sedentary behaviour in teenagers aged 14-19 years [10]. By this age, children are making their own lifestyle choices and some girls will enter into marriage after the age of 16 years.

There is less information available about the dietary and exercise habits of younger children, particularly girls of differing weight status. There are cultural restrictions for girls and women that make exercise less accepted and the climate restricts outdoor activity. Excessive body mass has been shown to have many adverse consequences for all phases and aspects of reproduction such as complications for the birth and obesity negatively affects the mother's health during pregnancy [11]. Therefore it is particularly important to prevent obesity in girls prior to the adolescent period.

Previous studies have not undertaken anthropometric measurements and prospective assessment of activity and diet simultaneously in girls of this age group. Therefore, with particular attention to robust methods of measurement, this study sought to determine how nutritional intake, and amounts of physical exercise differed according to weight status in primary-school girls aged 8-11 years old in the city of Makkah in western Saudi Arabia.

Methods

Study sample

This was a cross-sectional school-based study. Seven girls' schools (3 public and 4 private) were nominated by the Makkah Education Department, different areas being selected so as to obtain a sample representative of the city's school population. Schools gave their consent for the research to take place and information and consent sheets were given to all 2nd, 3rd, 4th and 5th grade students (aged 8-11 years old). Parent and child gave written informed consent to participate in the study and children were allowed to withdraw themselves from the study any time. Approval was granted by the Faculty of Science and Technology Research Ethics Committee at Plymouth University and The School Health Affairs Committee in Saudi Arabia. Permission was also granted by the General Directorate of School Education in Makkah.

Anthropometric and body-fat measurements

All measurements were conducted in the school laboratories by one researcher (January to May 2014). Using a portable stadiometer (Seca, UK), participants stood with bare feet and height was measured to the nearest 0.1 cm. Each participant's information (height, age and gender) were entered into the Tanita Body Composition Analyser (TBF-300 M/TBF-300MA, Birmingham, UK) to calculate BMI [weight (kg) / height $(m)^2$] and body-fat percentage. The BMI was plotted on the 2000 CDC growth reference curve to classify the children into obese (95 > centile), overweight (86-94 centile), normal weight (5-85 centile), and underweight (<5 centile). The CDC reference scale was considered valid for use with Saudi children as it had been validated against the WHO growth reference curves [12]. Waist circumference was measured to the nearest 0.1 cm by means of a non-stretch tape-measure positioned 4 cm above the umbilicus. All measurements were taken once by one trained nutritionist.

Diet diaries

Diet diaries, developed by the WAKEUP Study Group Peninsula Medical School [13], were adapted for children's diets in Saudi Arabia and piloted on children of the study age-range. In response to pilot feedback, adjustments were made to include pictures for estimating portion sizes for some meals and drinks, and the diary was translated into Arabic. Girls were asked to complete their diaries for 4 days using standard household measurements. Participants logged their food intake over two school days and then on the 2 days of the weekend (excluding special occasions e.g. parties). Each student was interviewed daily during the week by the nutritionist to ensure that they had logged the details correctly. After the weekend they were interviewed again to review their diary entries. The diets were recorded with accompanying explanations of the quantity and then dietary data were analysed using Arabic food-composition tables' software (Arab Food Analysis Programme, 1st version, 2007).

Physical activity methods

To record physical activity, accelerometers (WGT3X-BT Actigraph, Fort Walton, Florida) were worn for the 4 days that diet was recorded. These monitors have previously been assessed for their validity in another epidemiological study on children [14]. Each participant wore a belt to which the accelerometer was attached on the right site. These devices were removed only when the girl was washing or in bed; otherwise, they recorded the child's total level of activity and number of steps taken throughout the day. The intensities of physical activity were measured according to Evenson cut points [15]. Data were excluded if there was less than 10 h per day wear time over 3 days [15, 16].

Calculation of the total energy expenditure (TEE) via the METs

The METs rate was calculated using the Freedson et al. (2005) [17] equation obtained from the accelerometer data. The METs average was multiplied by the estimated BMR in order to estimate TEE.

Identification of under-reporters of dietary intake

Participants who under-reported their diet were identified by applying the formula energy intake (EI) < basal metabolic rate (BMR) ×1.2 which has been used by Schutz et al. [18] to indicate a cut-off point. BMR was estimated using the Henry equations [19]. Therefore, using the food diaries, a calculation was made for the average energy intake over 4 days, and if EI was < BMR × 1.2, the participant's food and nutrient intake data were excluded from the analysis.

Data analysis

The data were coded and entered into SPSS analysis program (IBM SPSS Statistics version 20). The data are presented as means and standard deviations. Differences in means were determined using one-way ANOVA (for more than two groups with post hoc Tukey test). Pearson correlation coefficients were calculated for evaluating the relationships between the factors. Differences in age and anthropometric measures between those undertaking just the body composition measurements and those also participating in the dietary analysis were assessed using an independent T-test. A multiple linear regression was calculated to predict the body weight in the girls based on the daily energy intake, age, family income, number of steps/d and TEE per kg body weight. A level of significance of $p \leq 0.05$ was used.

Results

Four hundred and seven students were invited to participate, and of these 266 (65.3%) students agreed to be involved in the anthropometric measurements. A total of 109 of these participants completed the diet diary and 78 completed the physical activity components of the study (Fig. 1).

Body composition

As shown in Table 1, there were highly statistically significant differences in all elements of body composition between BMI groups. Unsurprisingly, obese subjects had significantly greater waist circumferences, with a maximum 104 cm, and there was an overall increase in WC across the BMI groups. A total of 30% of the study population was found to be overweight or obese.

There was a positive correlation between the height and waist circumference (Pearson's $r = 0.487$, $p < 0.001$); that is, WC increased with height. Similarly, body fat percentage and height were positively correlated (Pearson's $r = 0.36$, $p < 0.01$).

An independent T-test was carried out on the age, weight, height and waist circumference between those only undertaking the body composition measurements ($n = 157$) and those who also agreed to record their diet ($n = 109$). There were no significant differences between the two groups in age (9.6 vs 9.5 years) and height (135.6 vs 133.8 cm). However, those girls who only took part in the anthropometric measures were significantly heavier (37.4 vs 32.4 kg, $P < 0.002$) and had a larger mean waist circumference (67.9 vs 62.7 cm, $P < 0.020$) than those who also agreed to record their diet.

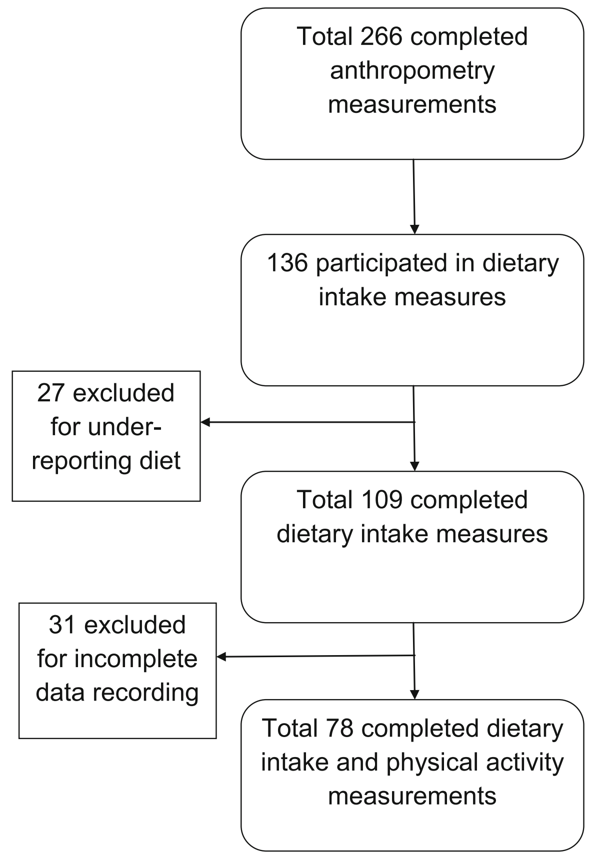

Fig. 1 Number of subjects in each measurement

Dietary intake

The total number of subjects who completed the diet diary was 109, all with body-composition measurements completed. A total of 27 subjects were found to have EI lower than BMR ×1.2 and were excluded from the analysis (Fig. 1).

Table 2 displays the nutrient intake according to BMI categories. It also shows the contribution of different food types to energy intake, and the daily consumption of fruit and vegetables. Average energy intake and other macronutrient intake increased gradually according to weight category (Table 2).

The healthy-weight group showed the highest average fruit intake whereas the underweight group reported the lowest, although the difference was not statistically significant. With regard to vegetable consumption, the highest intake was recorded by the overweight group, and the underweight group recording the lowest. As can be seen in Table 2 there was a noticeable pattern in the consumption of sugary drinks, sweet, and savoury snacks, with the highest intake in the obese girls and the lowest in the underweight group.

The differences between the energy intake (EI) for each BMI group were calculated by comparing means using ANOVA and a post hoc (Tukey) test. There was a significant difference ($p < 0.05$) between all groups, except between the overweight and obese groups which showed no difference ($p = 0.327$). There were no significant differences between the groups for the EI per kg of FFM, although there was a gradual increment across the BMI groups, but EI per kg BW was different between the groups (66 kcal/kg BW in underweight to 53 kcal/kg BW in obese group) (Table 2).

In order to assess the energy intake from different sources, a breakdown of nutrient and selected foods are shown in Table 3. Energy provided by fat, protein and carbohydrate increased across the BMI groups, but once corrected for energy intake (% of total energy), there were no differences between groups. Likewise for savoury snacks and sugary drinks, overweight and obese groups consumed more than the healthy weight and underweight groups, but the percentage contribution to energy intake did not differ between the groups. The obese group obtained more than 6 % of their total daily energy intake from savoury snacks alone but this was not significantly different to the other groups.

Table 1 Body composition and anthropometric measurements in underweight (UW), healthy-weight (HW), overweight (OW), and obese (OB) girls. $n = 266$

Body composition	UW	HW	OW	OB
	$N = 43$	$N = 143$	$N = 34$	$N = 46$
Age (years)	9.5 ± 1.27	9.6 ± 1.1	9.9 ± 1.2	9.3 ± 1.2
Body Fat %***	9.9 ± 4.4^{a}	18.1 ± 4.6^{b}	29.5 ± 3.4^{c}	36.7 ± 3.9^{d}
Weight (kg)***	22.9 ± 4.8^{a}	29.3 ± 6.4^{b}	41.4 ± 7.1^{c}	50.3 ± 11.4^{d}
WC (cm)***	53.7 ± 4.0^{a}	59.2 ± 5.7^{b}	72.1 ± 5.3^{c}	79.8 ± 7.9^{d}
Height (cm)***	130.1 ± 11.6^{a}	132.9 ± 10.4^{a,b,c}	138.5 ± 8.4^{a,b,c}	138.7 ± 10^{c}
BMI Percentile***	1.6 ± 0.9^{a}	39.5 ± 23.8^{b}	90 ± 3.6^{c}	97.9 ± 0.9^{d}
Height Percentile***	34 ± 32.1^{a}	46 ± 30.7^{b}	59.6 ± 27^{c}	72.5 ± 26.1^{d}

Data are means and standard deviations
One way ANOVA: ***significant differences $p < 0.001$ between BMI groups
^{a,b,c,d}Tukey Post hoc test: means with the same letter indicate no significant difference. Any difference between two means carrying different letters is significant at 1%

Table 2 Nutrient intake, and selected food consumption in underweight (UW), healthy-weight (HW), overweight (OW), and obese (OB) participants. $n = 109$

Average for 4 Days	UW	HW	OW	OB
	$N = 11$	$N = 50$	$N = 16$	$N = 32$
Age (years)	9.5 ± 1.27	9.6 ± 1.1	9.9 ± 1.2	9.3 ± 1.2
Energy (kcal)***	1412 ± 291[a] (1133-1909)	1806 ± 403[a] (1207-2697)	2489 ± 887[b] (1438-5168)	2677 ± 804[b] (1595-5168)
EI (Kcal/kg Body wt)*	66 ± 20.32 (47.1 -117.16)	62 ± 16.8 (37.17 - 98)	64 ± 26.6 (37.58 -127.62)	53 ± 14 (27.7 - 89.88)
EI Kcal/kg FFM)	68 ± 10.2 (53.2-82.1)	75 ± 19.3 (45.1- 123.6)	80 ± 25.6 (54.4- 112.12)	86 ± 20.5 (53.5- 143.9)
Protein (g/d)***	52.9 ± 19[a] (36.2-86.8)	66.3 ± 24[a] (25.4-118.2)	79.1 ± 39[a,b] (39.2-213.3)	87.8 ± 35[b] (37.7-213.3)
Fat (g/d)***	50.5 ± 11[a] (35.8-68.7)	68.8 ± 24.3[a] (5.3-117.8)	104.5 ± 39[b] (52-209.2)	108.2 ± 44[b] (50.0-211.2)
CHO (g/d)***	199.2 ± 42.4[a] (161.4-276)	236.5 ± 62.3[a] (53.6-435.5)	347.4 ± 109.9[b] (191.8 -642.2)	362 ± 93[b] (233.7-642.2)
Fruits (g/d)	28.9 ± 39.5 (0.0-105)	35.2 ± 43.5 (0.0-200.5)	29.5 ± 54.8 (0.0-200)	32.9 ± 72.7 (0.0-393.7)
Vegetables (g/d)**	18.3 ± 22[a] (.00-61.2)	52.3 ± 44.4[a] (.00-220)	105 ± 114.7[b] (.00-400)	84.3 ± 73.8[a,b] (.0-348.7)
Sweets (g/d)***	59.2 ± 37.5[a] (.0-145)	98.5 ± 53.4[a] (.00-237.5)	129.9 ± 67.4[a,b] (12-253)	147.7 ± 97.7[b] (.0-361.7)
Sugary drink (ml/d)***	64.4 ± 40.6[a] (.0-125)	84.6 ± 51[a] (.0-212)	104.4 ± 70.4[a,b] (.0-250)	124.2 ± 52.2[b] (42-283)
Savoury Snack (g/d)*	1.5 ± 3.5[a] (0.0-8.7)	20 ± 24.5[a, b] (0.0-120)	22.7 ± 3.6[a, b] (0.0- 125)	37 ± 44[b] (0.0-187)

*** Significant differences $p < 0.001$; *significant differences $p < 0.05$ for the effect of the BMI groups
[a,b,c]Tukey Post hoc test: means with the same letter indicate no significant difference. Any difference between two means carrying different letters is significant at 1%
"Sweets" include: chocolate, sweets, biscuits, cakes, desserts and ice cream
"Sugary drinks" include: carbonated drinks, fruit squash, and juice with added sugar
"Savoury snacks" include: crisps and popcorn

Number of steps and total energy expenditure (TEE)

As expected, there was a highly statistically significant increase in TEE as BMI increased, but there was no significant difference in minutes spent in moderate to vigorous intensity of physical activity between the BMI groups. The underweight group recorded the highest average minutes per day in vigorous activity (4 mins/d), whereas the overweight spent less time (1.5 mins/d). The highest percentage of time in sedentary activity was spent by the obese group, but it was not significantly different to the other groups (Table 4). There were no significant differences in the average number of steps per day between the BMI groups. The mean value for the whole group was 6757 steps/day and only 9.1% of the girls took 10,000 steps or more per day.

Table 5 shows a highly statistically significant difference in energy balance between the groups with the underweight group showing negative energy balance, a

Table 3 The contribution of macronutrients and selected foods to energy intake in underweight (UW), healthy-weight (HW), overweight (OW), and obese (OB) participants. $n = 109$

Average for 4 Days	UW	HW	OW	OB
	$N = 11$	$N = 50$	$N = 16$	$N = 32$
Energy (kcal)***	1412 ± 291[a] (1133-1909)	1806 ± 403[a] (1207-2697)	2489 ± 887[b] (1438-5168)	2677 ± 804[b] (1595-5168)
Energy from protein (kcal)***	211 ± 76[a] (132-347)	264 ± 100[a] (102-473)	312 ± 159[a,b] (157-853)	359 ± 137[b] (202-853)
% energy from protein	14.2% ±3.2 (10.6-20.8)	14.5% ±3.9 (5.4-25.8)	12.2% ±1.9 (9-16.5)	13.5% ±2.9 (7.9-17.9)
Energy from Fat (kcal)***	454 ± 99[a] (618-322)	624 ± 211[a] (200-1061)	940 ± 351[b] (468-1883)	974 ± 396[b] (450-1901)
% energy from fat	32.2% ±4 (28.1-41.7)	34% ±6 (12.5-42.9)	38.2% ±9.1 (27.5-67.9)	35.6% ±5.8 (27.4-47.4)
Energy from CHO (kcal)***	796 ± 169[a] (646-1104)	946 ± 249[a] (214-1742)	1389 ± 439[b] (767-2569)	1442 ± 370[b] (935-2563)
% energy from CHO	56.4% ±3.5 (49.5-63)	52.6% ±9.2 (13.26-67.8)	57% ±12.5 (39.4-98.6)	54.7% ±6.1 (39.6-67.9)
Energy from Savoury Snacks (kcal)**	8 ± 17.7[a] (.00-44)	100 ± 123[a,b] (.00- 600)	117 ± 167[a,b] (.00- 625)	186 ± 220[b] (.00-937)
% energy from Savoury Snacks	0.6% ±1.4 (.00-3.60)	5.6% ±6.8 (.00-28.8)	4.8% ±7.1 (.00-27)	6.2% ±6 (.00-23)
Energy from sugary drinks (kcal)**	72 ± 44[a] (21- 121)	120 ± 94[a] (26-326)	158 ± 112[a, b] (42- 292)	144 ± 49[b] (68- 221)
% energy from sugary drinks	4.5% ±3 (.00-11)	4.6% ±2.9 (.00-13.1)	4.2% ±3.1 (.00-11.3)	4.7% ±2 (2-10.60)

***Significant differences $p < 0.001$; **significant differences $p < 0.01$ for the effect of the BMI groups
[a,b,c]Tukey Post hoc test: means with the same letter indicate no significant difference. Any difference between two means carrying different letters is significant at 1%

Table 4 Physical activity in underweight (UW), healthy-weight (HW), overweight (OW), and obese (OB) girls n = 78

	UW	HW	OW	OB
	n = 7	n = 42	n = 10	n = 19
Total energy expenditure (kcal / day)***	1501.8[a] ± 130.7 (1390-1768)	1602.9[a] ± 220.6 (1315-2421)	1725.4[a,b] ± 218.9 (1448-2157)	1908.7[b] ± 323.6 (1378-2779)
TEE/ body weight/d (kcal/kg/d)***	70.9[a] ± 8.3	56.4[b] ± 11.2	43.8[c] ± 7.27	37.8[c] ± 6.7
Minutes in sedentary PA >100 CPM	426.07 ± 138.99	442.33 ± 173.15	513.55 ± 186.37	466.44 ± 156.90
Minutes in light PA 101 - 2295 CPM*	335.64[a] ± 95.15	366.87[b] ± 98.36	392.57[b] ± 115.91	302.18[a] ± 98.74
Minutes in moderate PA 2296 - 4011 CPM	18.10 ± 11.21	17.26 ± 8.83	14.90 ± 7.91	16.22 ± 6.89
Minutes in vigorous PA 4012 - ∞ CPM	4.42 ± 6.31	3.65 ± 2.97	1.5 ± 1.2	2.26 ± 1.5
Minutes in moderate to vigorous PA <2296 CPM	22.53 ± 16.5 (4.5-53.5)	20.91 ± 11.2 (5-51.25)	18.6 ± 7.5 (6-28.50)	18.4 ± 7.7 (4.50-33.75)
Steps / day	6406 ± 2805.7 (3087-11,479)	6773 ± 1788 (3250-12,480)	6097 ± 2324.5 (2458-8726)	5969 ± 1786.6 (2322-8512)

***Significant difference (p < 0.001); *significant difference (p < 0.05)
[a,b,c]Tukey Post hoc test: means with the same letter indicate no significant difference. Any difference between two means carrying different letters is significant at 5%
For light activity, there was a significant difference; the results of the post-hoc test showed the differences were between the obese group and healthy and underweight groups

small positive energy balance in the healthy weight group, but increasingly large positive energy balance in the overweight and obese groups.

Preliminary analyses were conducted to ensure no violation of the assumptions of normality, multicollinearity and the outliers. A multiple linear regression was calculated to predict body weight in the girls based on daily energy intake, number of steps/d, daily TEE per kg body weight, age and family income. It was found that these variables explain a significant amount of the variance in the weight (F (4, 73) = 48.07, p < 0.001, R2 = 0.770). The analysis showed that daily number of steps and age did not significantly predict weight (Beta = 0.034, 0.058), p = 0.575, 0.368 respectively). However, EI positively predicted body weight (Beta = 0.279, p = 0.001), whereas, TEE/BW (kg) and income had a significant negative influence on body weight (Beta = −0.661, −0.131, p < 0.001, p = 0.028 respectively).

Discussion

To the best of the authors' knowledge this is the first study measuring physical activity in girls objectively using accelerometers and recording diet prospectively in Saudi Arabia. An important finding of this study is the very low levels of total and moderate to vigorous intensity physical activity in girls aged 8-11 years in all of the BMI groups. None of the girls reached the recommendation of 60 min of moderate to vigorous activity per day and there were no differences between the groups in amount of moderate to vigorous activity. The number of steps per day was not a significant predictor of weight, but importantly less than 10% of all girls met the recommended daily number of steps (10000-12,000 steps/day). A study of Saudi boys aged 8-12 years reported that the mean number of daily steps per day for obese boys was 12,682 [20]; double the number of steps found in the obese girls in our study. Research in western countries [21] report that the average number of daily steps of girls aged 6-12 years was 12,000/d – again almost double that recorded here.

There are several possible explanations for this. One is that boys are more likely to play vigorous sports and games during their free time at school or at home [22]. Also, girls in Saudi Arabia are not able to play publically and are more confined at home and school. Public schools in Saudi do not have physical education programs and there are no public or private activity centres where young children can exercise. Any facilities would need to be separate for males and females.

Table 5 Estimated energy balance in underweight (UW), healthy-weight (HW), overweight (OW), and obese (OB) girls n = 78

	UW	HW	OW	OB
	n = 7	n = 42	n = 10	n = 19
Energy intake (kcal/d)***	1299.14 ± 204.65	1724.61 ± 387.62	2239.30 ± 608.51	2741.84 ± 845.51
Energy expenditure (kcal/d)***	1501.8 ± 130.7 (1390.9-1768.1)	1602.9 ± 220.6 (1315.1-2421.6)	1725.4 ± 218.9 (1448.6-2157)	1908.7 ± 323.6 (1378-2779.5)
Energy storage (kcal/d)***	−202.73 ± 248.15	121.70 ± 445.73	513.84 ± 749.53	833.13 ± 860.52

***significantly different (p < 0.001)

Another consideration is that Makkah is regarded as a holy city, a place where citizens (including children) are expected to behave with decorum which negatively affects physical activity level. The climate is another consideration as it is too hot for long walks or more vigorous outdoor activity.

The implications of this study are that the inability of girls to exercise lead to increased risk of obesity and to the many forms of adult ill-health and morbidity that can follow. Several studies have observed a positive relationship between physical activity, physical fitness, and academic performance [23].

Another important finding from this study was the clear differences in dietary intake between the BMI groups, with obese girls consuming more total energy, sweet snacks and sugary drinks than healthy weight girls. It was estimated that overweight and obese girls were in positive energy balance by over 500 and 800 kcal/d respectively. The average energy intake recorded by obese and overweight girls was 25% higher than the UK energy recommendations for this age group [24].

Total intakes of fat, protein and carbohydrate increased significantly over the BMI groups but the percentage contribution to energy remained the same. The percentage contributions of macronutrients to energy are broadly in line with recommendations (> 50% of energy from carbohydrate; 35% energy from fat (UK, DRVs [24]). However, the UK Department of Health [24] and WHO recommended that energy intake from free sugars should not exceed 5 % of the total daily energy, but in this study the average energy intake from sugary drinks alone was 4-5% in all groups.

High consumption of sugary drinks has been observed in studies of older girls in Saudi Arabia and this has been correlated to increases in waist circumference [25]. Al-Hazzaa et al. (2011) [10] found one third of girls aged between 14 and 19 years consumed sugary drinks daily and 60% consumed them 3 to 6 times per week. Similar findings were reported by Shaath et al. [26] who found that 74.5% of girls aged 12–18 years drank sweetened carbonated beverages daily. Our research shows that sugar sweetened beverage consumption is too high in younger girls as well and contributes substantially to energy intakes. Strategies need to be put in place to reduce consumption at school, to work with parents on restricting the consumption at home and to more widely promote healthier choices.

The Ministry of Health in Saudi Arabia recommend 6 servings of fruit and vegetables per day for this age group, however the weight of a recommended portion is not specified [27]. For most girls the daily consumption of fruit and vegetables was markedly less than the daily portions recommended for UK children in the UK i.e. between 200 and 400 g/d [24]. Teenage girls in Saudi are also known to have low intakes [10] with 15% not eating any on a daily basis [28].

The finding that income was negatively associated with weight in the regression analysis was not in agreement with other studies conducted in Saudi Arabia. Other studies have all found that high SES correlated positively with obesity levels [29–31]. However this is similar to what have been found in the UK and USA [32]. There are different measures of socio-economic status and these require further investigation if comprehensive interventions are to be developed and targeted at those most in need.

The prevalence of overweight and obesity found in this study (30%) is in agreement with the findings of a study conducted in Riyadh city in Saudi Arabia in 2015 where 31.7% of girls aged 8-15 years old were overweight and obese (16.8%, 14.9% respectively) [33]. Also the average waist circumferences for overweight (72 cm) and obese girls (79 cm) are very similar to a study conducted Riyadh where overweight and obese girls (10-11 years) had an average waist measurement of 70 cm, and 78 cm respectively [25]. Therefore, although our sample was relatively small and from one city, it can be considered representative of the expected range of body compositions of girls of this age in Saudi Arabia.

Limitations to this research

A disadvantage of the dietary-analysis programme used in this study was that it has no capability to distinguish between starch and sugars, or between non-milk extrinsic sugars (NMES) and intrinsic sugars, and so an overall estimation of NMES could not be made. However, it included many of the Arabic foods required for this research.

Many children who were invited to take part declined or did not record their diet and activity which reduced the sample size and representation of the population. Those girls who only took part in the anthropometric measures were significantly heavier and had a larger mean waist circumference than those who also agreed to record their diet. Therefore some selection bias was introduced, which is difficult to overcome. There was some under-reporting of dietary intake but obese and overweight children did not under-report their diet any more than healthy weight girls. The wear time of the accelerometers might also have been insufficient for some individuals and therefore under-estimated some of the physical activity, although those obviously under-reporting were removed from the analysis. Also, as this was a cross sectional analysis, inference about causation of obesity should be made with caution.

Conclusion

The findings of this study have a number of important implications for prevention of childhood obesity in Saudi Arabia. Findings suggest that obesity in girls of this age is linked to excessive energy intake from all macronutrients. Sugary drinks and snack foods were consumed in high quantities and contribute to positive energy balance. Although there was no relationship found between weight and the number of steps or the time spent in moderate to vigorous activity, physical activity was exceptionally low in all weight categories.

This work highlights the need for government policy to address the issues of inadequate activity and poor diet in girls of this age. Priority needs to be given to the provision of facilities and sports teachers to enable young girls to participate in games and sports. Attention needs to be given to providing healthy school meals and promotion of a healthier diet to parents and children. Further investigations are required to formulate and evaluate interventions targeted to address excess energy intake, low fruit and vegetable consumption and the low physical activity in girls in Saudi Arabia.

Abbreviations

BMI: Body Mass Index; BMR: Basal Metabolic Rate; CDC: Centres for Disease Control; DH: Department of Health (UK); DRV: Dietary References Values; EI: Energy Intake; NMES: Non-Milk Extrinsic Sugars; TEE: Total Energy Expenditure; WHO: World Health Organisation.

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Availability of data and materials

The datasets generated and analysed during the current study are not publicly available due the impending examination of RA for a postgraduate degree but are available from the corresponding author on reasonable request.

Authors' contributions

RA carried out the initial piloting work and performed all the measurements, analysed data and wrote the paper. GR contributed to the study design, analysis and co-wrote the paper. AdL contributed to the study design and analysis of the results. AP contributed to the data analysis and preparation of the paper. All authors contributed to the paper and agreed the final version.

Authors' information

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Consent for publication

Not applicable.

Ethics approval and consent to participate

Ethical approval was granted by the Faculty of Science and Technology Human Ethics Committee, University of Plymouth. The School Health Affairs Committee in Saudi Arabia (which has authority over projects conducted in schools) also assessed the risks and procedures involved in the study and approved the project. Following this, the Projects Management Committee in the General Directorate of School Education in Makkah granted permission for the involvement of the schools. Parents and children were fully informed about the study aims, requirements and use of their data, and both parent and child gave written informed consent.

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