Physical activity and obesity in Lebanese adolescents: prevalences, measurements and associations
Abdallah Fazah

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Discipline: Sciences et Techniques des Activités Physiques et Sportives (STAPS)

PHYSICAL ACTIVITY AND OBESITY IN LEBANESE ADOLESCENTS: PREVALENCES, MEASUREMENTS AND ASSOCIATIONS

ACTIVITÉ PHYSIQUE ET OBÉSITÉ CHEZ LES ADOLESCENTS LIBANAIS: PRÉVALENCES, MESURES ET ASSOCIATIONS

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Dedication

To my wife, for everything
To my father and mother, for their sacrifice and patience
To my sister, for her love and support
To my friends for their constant support and unquestionable belief
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<td>ADP</td>
<td>Air Displacement Plethysmography</td>
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<td>BF</td>
<td>Body Fat Mass</td>
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<td>BIA</td>
<td>Bioelectrical Impedance Analysis</td>
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<td>BMI</td>
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<td>DXA</td>
<td>Dual Energy X-ray Absorptiometry</td>
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<td>Fat-Free Mass</td>
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<td>TBW</td>
<td>Total Body Water</td>
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INTRODUCTION

Obesity is a complex and multidimensional condition that is caused by the interaction of several factors. In general, it is accepted that increases in bodyweight that lead to obesity are caused primarily by a disruption of the balance between energy intake and energy expenditure. In other words, a marked reduction in physical activity accompanied with diets rich in fats and simple sugars are considered two of the most important contributing factors.

Research shows that the prevalence of obesity is on the rise among adults and children in developed and developing countries. Studies also show that obesity is associated with the onset of disease and premature death. On the other hand, increasing physical activity level has demonstrated benefit against the co-morbidities of obesity. However, obese individuals generally have low physical activity levels as their bodyweight poses an extra burden on movement. A further understanding of this relation may significantly contribute to solving the issue of hazardous weight gain.

In Lebanon, an Asian republic located at the East end of the Mediterranean, research on obesity is still in its early stages. However, evidence suggests that obesity is following the same trend as in developed countries.

This thesis addresses the ever increasing problem of adolescent obesity. It is divided into two parts. In part 1, the first chapter covers all aspects of obesity ranging from assessment and prevalence to causes and consequences. The second chapter defines physical activity and discusses issues related to assessment, patterns and trends, quality and quantity, in addition to the role of physical activity in the development of obesity. In part II, the author provides his personal contribution through a series of studies that deal with BMI-defined overweight and obesity among Lebanese adolescents in relation to physical activity, inactivity, quality of life, and body fat levels.
PART 1:
REVIEW OF LITERATURE
PART 1: REVIEW OF LITERATURE

1. Obesity

The existence of obesity has long been with humanity. Ever since the Stone Age, our ancestors left us with valuable drawings which depicted massive cases of obesity [Bray, 1990]. About 2000 years ago, Hippocrates observed that death and illness is more common in those who are naturally fat than in the lean [Bain, 2006].

Around the 1950s, few reports dealing with public health concerns and weight status appeared [Jaret, 1986; Breslow, 2006]. However, it was not until 1985 where the National Institutes of Health held a Consensus Development Conference and issued a formal conclusion linking obesity to undesired health risks [Burton and Foster, 1985].

Perhaps the rise of obesity was masked by the public health concern of cigarette smoking and lung cancer which emerged during the same period [Breslow 2006], and thus resulted in a delay in realizing the issue of obesity.

1.1. Definition

Nowadays, various statements exist for the definition of obesity. However, most would agree to the medical description stating that obesity is a condition characterized by an unusually high proportion of body fat (BF), which is associated with an increased risk of developing many medical disorders and possibly leading to reduced life expectancy. Simply defined, obesity is a pathological excess of BF [Haslam and James, 2005].

1.2. Assessment

Based on the definition of obesity, there is a need to determine exactly how much fat is considered as excess. Therefore, accurate methods of measuring BF are essential in obesity research. In recent years, various techniques have been developed for the estimation of fat and fat free mass. They are classified as reference or field methods with each having its advantages and disadvantages.

1.2.1. Reference Methods

Several methods for measuring body composition have been described through the literature. These include underwater weighing (densitometry) and air displacement plethysmography (ADP), Dual energy X-ray absorptiometry (DXA), Dilution method (hydrometry), magnetic resonance imaging (MRI) and computer tomography (CT). These methods are highly accurate and can provide valuable information concerning the distribution of fat within the body. In fact, BF
distribution has been associated with an increased risk of developing certain diseases, irrespective of its amount [Vague, 1956]. Reference methods are not suitable for epidemiological studies and large scale screening because of their high cost, limited accessibility and technical complexity. Therefore, their use has proved to be significant in the validation of other more simple methods of measuring BF [Ashwell et al., 1985].

1.2.1.1. Densitometry and Air-Displacement Plethysmography

Densitometry involves the accurate measurement of bodyweight both in air and underwater. Body mass is then divided by body volume to find out the total body density, which is used to estimate body composition through the use of prediction equations [Siri, 1993; Brozek, 1963]. This requires the knowledge of the specific densities of fat and fat-free mass (FFM). The disadvantage of this process is that the density of FFM may be influenced by several factors such as age, gender, and ethnicity [Lohman, 1986]. Moreover, another concern is the need to adjust for residual lung volume. Failure to do so may result in significant methodological inaccuracy [Heymsfield, 1998]. For these reasons, the use of densitometry is not recommended in children, elderly, and obese subjects.

Current advances have provided the ADP. This new technique utilizes a machine known as the BodPod. It replaces water with air and may be of more practical use since it is less invasive [Dempster P et al., 1995]. However, more recently, in some studies, ADP has been shown to underestimate %BF in children and adolescents as compared to DXA measurements [Lazzer et al., 2008; Lockner et al., 2000]

1.2.1.2. Dual Energy X-ray Absortiometry

The DXA is based on the principle that the two x-ray beams are diluted differently by bone mineral, soft tissue, fat tissue and FFM. Initially invented for the diagnosis of osteoporosis, its use has quickly spread. It is now one of the most reliable methods for assessing whole body composition as well as local measurements of bone mass, lean mass and fat mass [Mazess et al., 1990; Ley et al., 1992]. Moreover, DXA measurements have been verified by comparison with chemical analysis of animal cadavers [Pintauro et al., 1996; Svendsen et al., 1993] and studies have reported high long term reproducibility of DXA measurements (Hologic QDR 4500A absorptiometer) [Cordero-MacIntyre et al., 2002]. However, the use of different models and differences in calibration procedures and software application may lead to considerable variations in body composition results [Tothill et al., 1994 a; Tothill et al., 1994 b; Schoeller et al., 2005]. Based on this, comparison or interpretation of results obtained from different machines or with varying software applications should be done with caution.
In addition to the above mentioned complications, DXA has some other limitations [Tataranni and Ravussin, 1995], such as the size of the scanning area which may not accommodate morbidly obese subjects and its inability to differentiate subcutaneous adipose tissue from intra-abdominal adipose tissue [Goran et al., 1998] which is extremely important when investigating the relation of these two parameters with the health risks of obesity. Despite this, its accuracy, noninvasive approach, quick scan time (<20min), and low radiation dose make it a highly recommended method for measuring body composition.

.1.2.1.3. Hydrometry

This technique is based on the use of isotopes, specifically deuterium, tritium, and oxygen-18-labelled water, to measure total body water (TBW). Based on the assumption that the proportion of body water to FFM is stable at 0.73, TBW is calculated using validated equations depending on the degree of the dilution of the isotope by total body fluid. Then, FFM is determined as TBW/0.73 and total BF is derived from the difference between bodyweight and FFM [Schoeller 2005].

Although this technique is valuable in measuring the body composition of individuals with morbid obesity, the assumption of a constant ratio of TBW to FFM has been questioned in these subjects [Schoeller 2005]. Moreover, it has been shown that this ratio may also be influenced by several health conditions such as obesity, immunodeficiency syndrome, chronic renal failure, edema with malnutrition, and sepsis.

.1.2.1.4. Magnetic Resonance Imaging and Computer Tomography

These are considered the most accurate methods for assessing body composition and determining the distribution of fat and muscle through high resolution imaging [Ross and Janssen, 2005]. In fact, their accuracy in assessing local fat or muscle content has been validated against human cadavers [Ross and Janssen, 2005].

MRI emits no radiation and, therefore, its use is safe for children and pregnant women. On the other hand, CT is faster and more accurate than MRI in assessing visceral adipose tissue [Seidall et al., 1990]. However, the major disadvantage of CT is the risk of exposure to high radiation as compared to DXA screening. Because of this, some studies have provided evidence of a possibility to significantly reduce the radiation dose [Starck et al., 1998; Starck et al., 2002].

.1.2.2. Field Methods

As with all methods of assessing body composition, these are not without flaws. However their widespread is attributed to their relative simplicity which
requires little subject cooperation at a low cost. These methods include: Bioelectrical Impedance analysis (BIA) and anthropometric measurements.

.1.2.2.1. Bioelectrical Impedance Analysis

This technique measures electrical resistance in the body to an imperceptible frequency (50 kHz). It is based on the concept that electricity passes through lean tissue faster than it passes through fat tissue. The reason for that is because lean tissue has a high water content, while fat tissue contains less water therefore conductivity is impeded [Thomasset 1962]. There are two main disadvantages of BIA. The first method gives an estimate of TBW, which must then be converted into FFM. This cannot be done without knowing the hydration of FFM, which is usually constant in adults [Pace et al., 1995] but known to vary in children [Fomon et al., 1982]. Second, this technique should be used carefully with special attention given for electrode placement, subject's body position, hydration status, and skin temperature. Even under ideal conditions BIA tends to over predict BF in lean and athletic subjects [Segal 1996] as well as under predict BF in obese persons [Sun et al., 2005].

A more advanced method, known as bioelectrical impedance spectroscopy, has been developed. It uses multi-frequency currents (50-300 kHz) and divides the body into a series of cylinders. One major difference with the single-frequency BIA is that it separately estimates intracellular water and extracellular water. This new technology may provide more accurate measurements of body composition than single-frequency BIA [Kyle et al., 2004]. However, compared to DXA measurements, it underestimated lean tissue in normal weight subjects and overestimated it in obese subjects [Ward et al., 2007].

.1.2.2.2. Anthropometry

The measurement of physical dimensions of the human body is referred to as Anthropometry. It is the most commonly used method to assess size and body composition. It is inexpensive and noninvasive, and it can provide information about health, physical performance and survival [de Onis and Habicht, 1996]. Anthropometry includes skinfold thickness, circumference measurements, and weight and height based indexes.

.1.2.2.2.1. Skinfold Measurement

Skinfold measurement has been traditionally used to estimate BF. A special caliper is used to measure the thickness of a layer of skin and the underlying fat at certain fixed locations [WHO, 1995]. Then, BF and %BF are estimated using prediction equations. Among these, the equations of Durnin and Womersley [Durnin and Womersley, 1974] used for adults and the Slaughter
equation used for children and adolescents [Janz et al., 1993] have been shown to predict BF reasonably well. However, many studies have questioned this approach especially since the skinfold measurement is poorly reproducible and prone to inter user variation [Marks et al., 1989; WHO, 1995]. Moreover, it has been suggested that the errors associated with the estimation of BF via skinfold measurement are significantly higher in obese subjects compared to those in non-obese subjects [Gray et al., 1990]. Recently, a study conducted in obese children and adolescents demonstrated that skinfold measurement is poorly predictive of abdominal and total BF as compared to DXA measurements [Watts et al., 2006].

**1.2.2.2. Circumferences**

Measuring body circumferences is simple, cheap and highly reproducible. Research has shown that waist circumference can be self reported with significant accuracy [Rimm et al., 1990]. As mentioned earlier, because BF distribution is independently associated with several diseases [Eckel et al., 2005], the use of circumference measurements may be beneficial, especially, since both waist and hip circumference are good predictors of intra-abdominal fat [Goran et al., 1998]. In addition, waist circumference is significantly associated with cardiovascular diseases [de Koning et al., 2007] and increased mortality [Koster et al., 2008]. Based on this, its use is recommended in the assessment of cardiometabolic disease risks, where many cut-offs have been developed for this reason [WHO 2000]. Moreover, it has also been suggested that the waist to hip ratio is a useful measure of central obesity and a valid anthropometric index in predicting a wide range of risk factors and related health conditions [Akpinar et al., 2007].

**1.2.2.2.3. Weigh Based Indexes**

Body weight especially at very high levels, tends to be associated with BF levels. However, by itself it cannot accurately measure BF, since weight is correlated with height [Troiano and Flegal, 1999]. Based on this, several measures of weight in relation to height were developed. Among these are Benn's Index, Rohrer's Index (RI), and the Body Mass Index (BMI).

**1.2.2.2.3.1. Benn’s Index**

Benn's Index is defined as weight (kg)/height $^p$ where the value $p$ which is uncorrelated with height is between 1.18-1.5 for females and 1.65-1.83 for males [Garn and Pesick, 1982]. However, $p$ is calculated using complicated mathematical equations and the index itself is not significantly more accurate than other weight based indexes, therefore this index is rarely used [Chinn et al., 1992; Poskitt, 1995].
.1.2.2.3.2. Rohrer’s Index

Rohrer’s Index is defined as weight (kg)/height$^3$. Several studies have compared the RI to the BMI in its ability to predict BF levels. One study suggested that RI may be a much better choice than BMI at assessing gender and race-specific risks of adult overweight [Valdez et al., 1996]. Another study found that age specific BMI is better than age specific RI in predicting underweight or overweight in children and adolescents aged 2-19 years [Mei et al., 2002]. However, the use of RI is not as widespread as the BMI.

.1.2.2.3.3. Body Mass Index

Defined as weight (kg)/height$^2$, it was developed in 1835 by Quetelet, a Belgian astronomer. He observed that bodyweight was proportional to the square of the height [Eknoyan 2008]. In 1972, the Quetelet index was termed the BMI in a study which reported high correlations between BMI and BF as assessed by skinfold and densitometry [Keys et al., 1972].

BMI is the most commonly used tool for classifying obesity. In adults, cut-off points of 25 kg/m$^2$ and 30 kg/m$^2$ have been suggested to determine overweight and obesity, respectively [Garrow and Webster, 1985]. More recently, in 1993, the World Health Organization committee on physical status classified BMI based on the increase in the risk of co-morbidities as follows: 25-29.9 kg/m$^2$ as overweight (increased risk), 30-34.9 kg/m$^2$ as obese class one (moderate risk), 35-39.9 kg/m$^2$ as obese class two (severe risk), and 40 kg/m$^2$ and above as obesity class three (very severe risk) [WHO 1995].

Defining overweight and obesity in children is more complicated than in adults because weight varies with height as children grow. This process is best described by Horlick in the title of his article, "Measuring a Moving Target" [Horlick 2001]. During maturation, males develop more lean tissue mass than females [Malina 2005]. Although it is highly correlated, BMI is not a direct measure of BF. It can only detect changes in bodyweight [Pietrobelli et al 1998; Goran et al., 1996]. Therefore, the use of cut-off points should be based on age and gender. The earliest published charts of BMI were for French children. The importance of these charts is that they provided an index to compare a child’s measurements with those of other children in the same age group and adiposity is estimated using percentile ranges [Rolland-Cachera et al., 1982]. Latter on, data compiled from six different countries were used to develop age and gender specific BMI cut-off points [Cole et al., 2000]. One of the advantages of this study is that it provides a unified definition for child obesity which allows for easy comparison between studies. However, it remains to be seen whether these cut-offs are applicable across different populations.

The association of BMI and mortality in adults has been researched extensively. In fact, the results of a recent meta-analysis of 56 studies found that
at a BMI of 30-35 kg/m², average survival is reduced by 2-4 years, and at 40-45 kg/m² it is reduced by 8-10 years [Whitlock et al., 2009]. In children and adolescents, the relation between BMI and mortality is less pronounced than in adults. However, significant associations have been found between BMI and serious health complications [Dietz and Robinson, 1998]. Moreover, in another study, overweight adolescents had an increased risk of future obesity-related morbidity as compared to their normal weight peers [Must et al., 1992].

Numerous studies have assessed the validity of BMI in predicting BF as measured by criterion methods. Several studies have demonstrated that BMI is highly correlated with both BF mass and %BF in adults [Gallagher et al., 1996; Blew et al., 2002]. Studies conducted in youth report similar results [Goulding et al., 1996]. These findings confirm that BMI is a reliable indicator of BF. Based on this, several equations have been developed to predict BF from BMI for children and adults [Deurenberg et al., 1991; Pongchayakul et al., 2005; Pietrobelli et al., 1998]. However, these equations are seldom used.

The relation between BMI and body composition has been shown to be affected by several factors such as ethnicity and body structure [Malina 2005; Deurenberg and Deurenberg, 2001]. Although one previous study reported that despite higher BMI values for African Americans, %BF as assessed by DXA was not significantly different from Caucasians [Gallagher et al., 1996]. A more recent review reported that, for a given BMI, African Americans were found to have lower %BF than Caucasians [Wagner and Heyward, 2000].

The influence of ethnicity is more consistent between Caucasians and Asians. In fact, for a given BMI, the %BF in Asians was found to be higher than in Caucasians [Deurenberg et al., 2002]. Moreover, there is also evidence that the relation between BMI and BF might differ even between sub populations in Asia [Deurenberg et al., 2000]. These differences among adult populations may also exist among children. In fact very recent reports have provided evidence for ethnic influence on this relation among children and adolescents [Navder et al., 2009; Freedman et al., 2008].

Despite certain limitations, BMI is simple and easy to calculate. Its accuracy depends on selecting appropriate cut-off points based on age, gender, and ethnicity. Used by itself or in conjunction with other methods, BMI is considered the method of choice for assessing overweight and obesity in large epidemiological studies.

1.2.3. Summary

A summary for the commonly used body composition methods is provided in table 1. Available methods have greatly contributed to our understanding of the diverse causes of obesity and its numerous complications. Based on this, success in the prevention or management of obesity depends greatly on the
progress of body composition assessment. For this reason, the search for a unified and flawless methodology continues to pose a challenge for all. In the meantime, reference methods, such as Dual-energy X-ray absorptiometry, are highly accurate. However, their expensive cost, technical complexity, and limited availability restrict their use in large scale studies. Field methods may be more suitable alternatives. Of these, the simplest and most widely used is the BMI. Research shows that it is highly correlated with measures of BF, disease incidence, and mortality. However, results using this simple method should be interpreted carefully while taking into account that BMI is an indirect measure of BF that is age-, sex- and ethnicity-specific.

Table 1. Characteristics of body composition measuring methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
<th>Advantage</th>
<th>Disadvantage</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Densitometry</td>
<td>Weight is measured in air and underwater, BF is then calculated</td>
<td>High accuracy</td>
<td>Burdensome, requires cooperation</td>
<td>Unsuitable for children and older subjects</td>
</tr>
<tr>
<td>DXA</td>
<td>Two x-ray beams are diluted differently through various body tissues</td>
<td>High accuracy and reproducibility, low radiation exposure</td>
<td>Costly and importable.</td>
<td>Unsuitable for pregnant women</td>
</tr>
<tr>
<td>Hydrometry</td>
<td>Isotopes provide measures of total body water</td>
<td>Noninvasive, simple and safe</td>
<td>Ratio of TBW to FFM may vary.</td>
<td>Morbidly obese patients</td>
</tr>
<tr>
<td>MRI &amp; CT</td>
<td>Magnetic resonance of proton to capture images. CT images are created by a computer that interprets X-ray images</td>
<td>Extremely accurate for assessing body composition and fat distribution. MRI has no radiation exposure</td>
<td>Very expensive and not always available, may not accommodate morbidly obese subjects</td>
<td>MRI suitable for pregnant women, infants and elderly</td>
</tr>
<tr>
<td>BIA</td>
<td>Measures electrical resistance based on variation of water content in body tissues</td>
<td>Inexpensive, portable, simple.</td>
<td>No standardized prediction equations affected by several factors</td>
<td>may underestimate BF in obese subjects</td>
</tr>
<tr>
<td>Skinfold thickness</td>
<td>A special caliper is used to measure the thickness of a double layer of skin, equations are used to estimate BF</td>
<td>Inexpensive and relatively simple procedure</td>
<td>Subject to inter-user variations</td>
<td>Not suitable for obese subjects</td>
</tr>
<tr>
<td>Circumference measurements</td>
<td>Use of measuring tape to determine circumference of waist and/or hip</td>
<td>Simple. Validated with DXA results</td>
<td>Procedure not entirely standardized</td>
<td>Suitable for all populations</td>
</tr>
<tr>
<td>Weight based indexes</td>
<td>Most known is BMI, calculated as weight/height$^2$</td>
<td>Validated against reference methods</td>
<td>Does not distinguish fat mass from FFM</td>
<td>Less accuracy in older subjects</td>
</tr>
</tbody>
</table>

1.3. Prevalence of Obesity

Over the past couple of years, rates of overweight and obesity have increased rapidly in many parts of the world. Globally, it is estimated that 1.6 billion adults are overweight and 400 million are obese [WHO 2006]. An even
more alarming concern is the high prevalence among children. In fact, it is reported that 155 million are overweight, including at least 30 million obese children [Lobstein et al., 2004].

The prevalence of overweight and obesity does not seem to be confined to more developed countries. Low and middle income countries have also reported increased prevalence [WHO 2006]. In fact, in certain countries, such as Gambia for example, obesity coexists with undernutrition (BMI<18 kg/m²) [van der Sand et al., 2001]. This condition has been manifested in many countries [Mendez et al., 2005], thus posing a double burden for disease. Moreover, it is estimated that by 2015, approximately 2.3 billion adults will be overweight and more than 700 million will be obese [WHO 2006].

1.3.1. Europe

Prevalence of overweight and obesity among adults in the European Union is 35.9% and 17.2% respectively. It is estimated that more males than females are overweight (BMI 25-29.9). In contrast, a higher rate of obesity is reported among females [IASO 2008]. As seen in table 2, the United Kingdom, Greece, and Lithuania have some of the highest prevalence of obesity, whereas Sweden and Italy have the lowest. However, it is also striking that the prevalence of overweight is elevated among both males (BMI range: 26.0 - 46.2) and females (BMI range: 19.4 - 40.0) in all European countries. In total, the combined prevalence of overweight and obesity among the adult population of the European Union is over 53% [IASO 2008].

Recent reports show high prevalence rates among children in the European Union. For example, in Spain 35% of boys and 32% of girls are overweight. Prevalence among children in Portugal, Greece and England are also among the highest [IASO 2009]. In fact, one study concluded that the number of children who are overweight is expected to rise by 1.3 million children per year, with more than 300,000 of them becoming obese each year. The study also estimated that by 2010, 26 million children in E.U. countries will be overweight, including 6.4 million who will be obese [Kosti and Panagiotakos, 2006].
### Table 2. Overweight and obesity among adults in the European Union (EU)*

<table>
<thead>
<tr>
<th>Countries</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OW</td>
<td>OB</td>
</tr>
<tr>
<td>UK</td>
<td>42.6</td>
<td>23.2</td>
</tr>
<tr>
<td>Greece</td>
<td>38.7</td>
<td>22.3</td>
</tr>
<tr>
<td>Lithuania</td>
<td>35.5</td>
<td>20.8</td>
</tr>
<tr>
<td>Ireland</td>
<td>46.2</td>
<td>19.3</td>
</tr>
<tr>
<td>France</td>
<td>40.8</td>
<td>15.3</td>
</tr>
<tr>
<td>Sweden</td>
<td>26.0</td>
<td>7.0</td>
</tr>
<tr>
<td>Italy</td>
<td>36.5</td>
<td>7.9</td>
</tr>
<tr>
<td>EU*</td>
<td>42.8</td>
<td>16.2</td>
</tr>
</tbody>
</table>

OW: overweight (BMI:25-29.9); OB: obese (BMI:≥30); Combined: OW + OB (BMI≥25)

Modified from the International Association for the Study of Obesity (IASO), July 2008 (www.iotf.org/database/)

* 27 countries excluding Luxembourg and Slovenia

### 1.3.2. Americas

Adult obesity in America increased from 12.0% in 1991 to 17.9% in 1998 [Mokdad et al., 1999]. Recent reports show continuous increases in prevalence. In fact in 2006, a study reported that 66.3% and 32.2% of American adults are overweight and obese respectively [Ogden et al., 2006]. In Canada prevalence rates have increased markedly since 1970 Estimates show that 50.7% of Canadian adults are overweight and 14.9% are obese [Katzmarzyk 2002], with more recent studies showing a continued increase [Belanger-Ducharme and Tremblay, 2005]. Other countries have also experienced a rising tide in obesity [Ford and Mokdad, 2008]. For example, in Mexico, the estimated prevalence of obesity is 24.2% in men and 34.5% in women [Olaiz et al., 2006]. In Brazil, 8.8% of men and 13.0% of women were obese in 2003. These figures are higher than those reported in 1975 (2.7% and 7.4% respectively). This suggests an increasing trend in the prevalence of obesity [Monteiro et al, 2007]. Moreover, it has been reported that the combined prevalence of overweight and obesity (BMI ≥ 25kg/m²) is high in several Latin American countries. For example, the combined prevalence is 68% in Paraguay, 60% in Argentine, and 53% in Peru [Filozof et al., 2001].

Among children and adolescents living in the United States, the prevalence of at risk of overweight (BMI for age at 85th percentile or higher) and overweight (BMI for age at 95th percentile or higher) was high with a significant upward trend. The prevalence of overweight in females aged 2-19 years increased from 13.8% in 1999-2000 to 16.0% in 2003-2004. In 2-19 year old
males, the prevalence increased from 14.0% to 18.2% [Ogden et al., 2006]. Recently, it was reported that the occurrence of severe obesity (BMI $\geq 99^{th}$ percentile) among children and adolescents has tripled over the past 25 years [Skelton et al., 2009].

Studies on the prevalence of overweight and obesity in other American countries have also expressed concern. For example, based on national BMI for age cut-off points, the prevalence of overweight and obesity among adolescents in Bolivia is 14.0% and 5.0% respectively [Perez-Cueto et al., 2009]. Among Brazilian children and adolescents, the prevalence of overweight and obesity in males increased from 2.9% in 1974-1975 to 13.1% in 1996-1997, among females, prevalence increased from 5.3% to 14.8% [Wang et al., 2002]. In Canada, overweight and obesity also exhibited increasing trends. The prevalence of overweight among boys increased from 15% in 1981 to 28.8% in 1996 and among girls from 15% to 23.6%. The prevalence of obesity in children more than doubled over that period, from 5% to 13.5% in boys and 11.8% in girls [Tremblay and Willms, 2000]. In 2004, the Canadian Community Health Survey reported that among adolescents aged 12 to 17, overweight has more than doubled and obesity rate has tripled over the past 25 years [Shields 2005].

1.3.3. Africa

Surprisingly, studies show that some African countries are following the global trend of an increase in the prevalence of overweight and obesity. For example, according to the South Africa Demographic Health Survey, the prevalence of overweight and obesity among men aged fifteen years and older was 21% and 8.8% respectively. Among women, the prevalence was 28% and 27% respectively [SADHS 2003]. A study conducted among 6-13 year old children reported that the prevalence of overweight and obesity among boys was 10.9% and 2.4% respectively, while the prevalence among girls was 17.5% and 4.8%. The study also suggests that these trends are similar to those found in developed countries ten year ago [Armstrong et al., 2006]. Alarming trends are also found in some countries in Northern Africa. For instance, the prevalence of obesity in Morocco and Tunisia was 12.2% and 14.4% respectively. Overweight was prevalent in more than half of the female population in both countries [Mokhtar et al., 2001]. In general, most African countries have very low rates of obesity among children. The prevalence is restricted mostly to the adult population [Prentice 2009].

1.3.4. Asia

The prevalence of overweight and obesity in Asia demands significant concern, especially since studies have shown that for certain populations the risk of developing medical complications starts to increase at BMI values lower than 25kg/m² [Wen et al., 2009]. Based on universal cut-off points, the combined prevalence of overweight and obesity has increased considerably in many South
Asian countries. In 1996, the overweight-obesity prevalence was 10.6% in India, 1.6% in Nepal, and 2.7% in Bangladesh. In 2006 these rates increased to 14.8%, 10.1%, and 8.9% respectively [Balarajan and Villamor, 2009]. In Malaysia, a study using the National Health Survey data revealed that among adults 20.7% were overweight and 5.8% were obese, and obesity was significantly higher in women [Ismail et al., 2002].

In Far East Asia, obesity is also a public health problem. For example, in Japan, based on the National Nutrition Survey (2000), the prevalence of overweight was 24.5% in males and 17.8% in females, whereas that for obesity was 2.3% in males and 3.4% in females [Yoshiike et al., 2002]. In China, the prevalence of overweight and obesity was 24.1% and 2.8% in men and 26.1% and 5.0% in women, respectively [Reynolds et al., 2007]. However, another study using the World Health Organization recommended cut-off points for Asians (overweight: BMI \( \geq 23 \) kg/m\(^2\), Obesity: BMI \( \geq 27.5 \) kg/m\(^2\)) reported that the prevalence of overweight and obesity among Chinese men was 48.6% and 10.5%, respectively [Lee et al., 2008]. Among children and adolescents, the prevalence in 1985 was less than 0.2% for obesity and between 1% and 2% for overweight. In 1995, the prevalence of overweight increased two to three folds, and the prevalence of obesity was 6%. In 2000, the combined prevalence of overweight and obesity in 7-12 year old Chinese children had exceeded 25% in boys and 14% in girls [Ji et al., 2004].

Data on overweight and obesity in the Eastern Mediterranean is limited. However, reports show elevated prevalence in many countries. In Turkey for example, the prevalence of overweight and obesity was 36.0% and 30.4% respectively [Oguz et al., 2008]. High prevalence was also reported among Iranian adults, 31.8% were overweight and 11.1% of men and 25.2% of women were obese [Janghorbani et al., 2007]. Obesity was detected in 38.2% of Syrian adults [Maziak et al., 2007]. Saudi Arabia reported that overweight was prevalent in 30.7% of men and 28.4% of women, while obesity was prevalent in 14.2% of men and 23.6% of women [Al-Othaimeen et al., 2007]. Studies also show that over 40% of the female adult populations in Kuwait and Qatar are obese [Al Rashdan and Nesef, 2009; Bener and Tewfik, 2006]. The prevalence of overweight among adults in Lebanon was 57.7% in women and 49.4% in men, while 18.8% of women and 14.3% of men were reported as obese [Sibai et al., 2003 a].

A summary of the estimated prevalence of overweight and obesity in most countries of the Middle East is presented in table 3. Obesity is widespread and it is more common among women than men. However, even though these values provide an idea about the prevalence of obesity, calculations were based on international BMI cut-off points which have yet to be assessed for their validity in detecting overweight and obesity among the populations of this region. This is important especially since studies have found that for certain Asian populations,
it is recommended that overweight and obesity be defined at lower BMI points [Chang et al., 2003; Deurenberg et al., 2002; Deurenberg et al., 2000].

**Table 3.** Prevalence of adult overweight and obesity in the Middle East*

<table>
<thead>
<tr>
<th>Country</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OW</td>
<td>OB</td>
</tr>
<tr>
<td>Turkey [Oguz et al., 2008]</td>
<td>41.5</td>
<td>20.6</td>
</tr>
<tr>
<td>20-90 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iran [Janghorbani et al., 2007]</td>
<td>42.8</td>
<td>11.1</td>
</tr>
<tr>
<td>15-65 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lebanon [Sibai et al., 2003]</td>
<td>57.7</td>
<td>14.3</td>
</tr>
<tr>
<td>over 20 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Syria [Maziak et al., 2007]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18-65 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saudi Arabia [Al Othaimeen et al., 2007]</td>
<td>30.7</td>
<td>14.2</td>
</tr>
<tr>
<td>Over 18 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kuwait [Al Rahdan &amp; Nesef, 2009]</td>
<td>38.8</td>
<td>39.2</td>
</tr>
<tr>
<td>Over 18 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Qatar [Bener &amp; Tewfik, 2006]</td>
<td>34.4</td>
<td>34.6</td>
</tr>
<tr>
<td>Over 18 years</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*OW: overweight (BMI: 25-29.9); OB: obese (BMI: ≥30)

*not all countries included

Studies conducted in children and adolescents also show elevated prevalence rates in many countries. In Lebanon for example, a study conducted in 10-18 year olds reported that overweight and obesity prevalence was 24.4% and 7.5% respectively [Chakar and Salameh, 2006]. In Syria, prevalence rates among 15-18 year old adolescents were estimated at 18.9% for overweight and 8.6% for obesity [Nasreddine et al., 2009]. Among Qatari adolescents, the prevalence of overweight and obesity was 28.6% and 7.9% respectively among boys, and 18.9% and 4.7% respectively among girls [Bener 2006]. In Jordan, overweight and obesity prevalence among 6-12 year old children was reported at 19.4% and 5.6% respectively [Khader et al., 2009]. In Kuwait, among 10-14 year old children, 30.7% were overweight and 14.6% were obese [El-Bayoumy et al., 2009]. Among 5-17 year old children living in the United Arab Emirates, 21.5% were overweight and 13.7% were obese [Malik and Bakir, 2007]. In Iran, 17.9% were overweight and 7.1% were obese [Moayeri et al., 2006]. In Turkey, the prevalence of overweight and obesity among 12-17 year old adolescents is 10.6% and 2.1% in girls and 11.3% and 1.6% in boys [Oner et al, 2004].

Even though BMI is commonly used to assess overweight and obesity prevalence among populations, comparing results from different studies is challenging. Several factors should be considered, for example, the use of different BMI cutoff points, whether BMI was based on self report or measured weight and height, is the study sample nationally representative,
1.3.5. Summary

The increasing prevalence of obesity is clearly visible throughout the world. The countries with the highest prevalence of obesity worldwide are those located in the Western Pacific region. Reports show that the prevalence of obesity is 78.53% in Nauru and 56% in Tonga [Keke et al., 2007; Coyne et al., 2000].

In Europe, more than half of the population is either overweight or obese, and more men than women are overweight. In America, one out of three adults is obese and almost two out of three are overweight, while in neighboring Canadian, almost half of the adult population is reported as overweight. Prevalence in Africa is heterogeneous, with high rates in North Africa. Most other African countries report very low prevalence rates for obesity. However, the co-existence of obesity with undernutrition poses a double burden for disease. In Asia, it has been shown that many adult populations are susceptible to disease at lower BMI values. In general, the prevalence of overweight and obesity is lower than that found in Europe and America. However reports show rapidly increasing trends. In the Middle East, obesity is higher among women. Prevalence rates are not far from those reported among countries in Europe and America. If current trends are not altered, it is estimated that by 2025 the prevalence of adult obesity is expected to exceed 40% in the United States, 30% in England, and 20% in Brazil [Kopelman 2000].

In children, the use of different definitions for obesity, and the lack of nationally representative systematic surveys especially in developing countries limit the ability to assess prevalence and trends in childhood obesity and pose a challenge in comparing rates across populations. Nonetheless, available studies show that pediatric obesity is growing with the highest prevalence reported in Northern America and the lowest found in Africa. The overall global childhood prevalence is estimated at 10% for overweight and 2-3% for obesity [Lobstein et al., 2004].

1.4. Causes of Obesity

Obesity is a global epidemic associated with major health problems. Its suggested causes are numerous and are heavily debated. Environments with an abundance of food and an increasingly sedentary lifestyle may cause a caloric imbalance which favors fat storage. However, it is noticeable that not all people living in these environments will become obese nor will they develop the same medical complications. This variation in how people respond to the same environmental conditions suggests a genetic influence on the development of obesity.
1.4.1. Genetics

Although it is well established that genetics have a role in the cause of obesity, the degree of their contribution is not clear [Bouchard et al., 1988; Vogler et al., 1995; Stunkard et al., 1990]. Humans are born with different degrees of genetic predisposition to obesity, but it is the interaction of this predisposition with several environmental factors that determines obesity. For example, the Pima Indians of Arizona were a group of lean and healthy people who were physically active and ate a healthy diet. As they adopted a more westernized lifestyle, they stopped farming and they increased their consumption of high fat foods and alcohol. As a result their bodyweight increased drastically. On the other hand, another group of Pima Indians who lived in Northern Mexico have maintained a healthy lifestyle by working on farms with no use of motorized equipment; and consuming a diet high in carbohydrates and low in fats. As the means and standard deviation figures in figure 1 show, the Pima Indians of Arizona had increased weight (90.2 +/- 21.1 vs. 64.2 +/- 13.9 kg), BMI (33.4 +/- 7.5 vs. 24.9 +/- 4.0 kg/m2), and plasma cholesterol (174 +/- 31 vs. 146 +/- 30 mg/dl) compared to those living in Mexico [Ravussin et al., 1994].

Figure 1. Weight (kg), BMI (kg/m²), and Plasma cholesterol levels (mg/dl) of Pima Indians living in Arizona and Mexico.

1.4.2. Nutrition

In general, an increase in weight occurs when energy intake exceeds energy output. However, evidence shows that even though total energy intake has decreased in the United States and Great Britain [Cavadini et al, 2000; Prentice et al, 1995], obesity rates have risen in both countries [Ebbeling et al, 2002]. This rise may be partly explained by a decrease in the consumption of nutritious meals and milk and an increase in the consumption of fast food meals.
and soft drinks [Cavadini et al, 2000]. Another equally important possibility is that the energy requirements of physical activity (PA) may have witnessed a greater decline than that of energy intake [Prentice et al, 1995].

1.4.2.1. Fast Food Consumption

The increase in the consumption of fast food in many developed and westernized countries may be a strong contributor to the prevalence of obesity. Saturated fats, carbohydrates with a high glycemic index, low nutrition profile, and large portion size are all suited descriptions of fast food meals. Studies show a strong association between the frequency of visits to fast food restaurants and increases in body weight and insulin resistance [Pereira et al., 2005]. Fast food consumption is also strongly associated with weight gain and with the prevalence of obesity [Binkley et al., 2000]. Moreover, fast food consumption is also correlated with higher BMI levels, and the possibility of being obese increased as the frequency of fast food consumption increased [Schröder et al., 2007]. This is supported by another study which reported that energy intakes were higher on days where subjects consumed fast food than on non-fast food days [Bowman and Vinyard, 2004]. Most meals at typical fast food chains are characterized by their high fat and caloric content [Dumanovsky et al., 2009]. This has led to the suggestion that the high energy densities of fast foods challenge human appetite control systems with conditions for which they were never designed. This may lead to passive over-consumption [Prentice and Jebb, 2003].

Other nutritional factors such as breakfast consumption [Farshchi et al., 2005], portion size [McConahy et al., 2002], and dietary behavior [Newby et al., 2004] have also been suggested as contributors to the cause of obesity.

1.4.3. Parental Influence

Excluding hereditary factors, a study reported that parental obesity more than doubles the risk of adult obesity among both obese and non-obese children less than 10 years of age [Whitaker et al., 1997]. Another study concluded that parents with unhealthy eating habits may foster the development of excess BF in their children [Hood et al., 2000]. In the same manner, parents who force their children to eat more may lead them to over consume and thus cause an increase in weight [Klesges et al., 1983]. Based on these findings, some studies have suggested that the treatment of childhood obesity should incorporate family based behavioral interventions [Wrotniak et al., 2004].

1.4.4. Environmental Changes

In 1996, Battle and Brownell wrote, “it is hard to envision an environment more effective than ours [in the USA] for producing obesity” [Battle and Brownell, 1996]. This statement may be applicable to many parts of the world following the
same westernized way of life. Along with the technological development, several environmental factors may contribute to the prevalence of obesity. Examples of these factors are; greater availability and affordability of food, limited access to adequate space (ex. parks, playgrounds, walking routes) for PA mostly as a result of urban sprawl, reduced occupational PA, and increased use of vehicles for transportation [Davey 2004; Kipke et al., 2007; Brownson et al., 2005].

1.4.5. Sedentary Activity

Sedentary activity can be defined as an action in which physical inactivity is dominant, or in other words, the resulting energy expenditure is close to energy expenditure at rest which is less than or equal to 1.5 METs. One metabolic equivalent (MET) for the average adult is equivalent to 1kcal per kg of body weight per hour [Ainsworth et al., 1993 a].

Changes in lifestyle in addition to the lack of opportunities for being physically active may have led to an increase in sedentary activity through greater use of computers, televisions, and video games. In many studies, time spent watching television is the only form of sedentary activity studied. A self report study of 8 to 16 year olds found that those who watched television for more than four hours had the highest BMI and trunk skin fold measurement, whereas those who watched television for less than an hour had the lowest BMI [Anderson et al., 1998]. These findings are similar to those reported in other studies which measured television viewing combined with other sedentary activities such as playing videogames, reading books and/or using computers [Hanley et al., 2000; Crespo et al., 2001]. On the other hand, some studies found no relation between TV viewing time and obesity. In one self reported study of 6 and 7 grade girls, no relation was found between BMI, triceps skin fold, and TV viewing [Robinson et al., 1999]. Another study conducted in children reported similar findings [Durant et al., 1994].

Television viewing may lead to weight gain not only by limiting energy expenditure, but also by causing an increase in energy intake. In fact, one study reported that increased television viewing time may be associated with elevated consumption of high-fat and high-sugar foods resulting in increased daily energy intake [Manios et al., 2009; Utter et al., 2006]. This finding is supported by other studies that reported that US and British children are exposed to about ten food commercials per hour of television time, most focusing on fast food, soft drinks, and sweets [Kotz et al., 1994; Lewis and Hill, 1998, Batada et al., 2008]. It is now well established that, independent of PA, prolonged television viewing is a risk factor for obesity both in children [Gortmaker et al., 1996; Andersen et al., 1998] and adults [Hu et al., 2001 a; Hu et al., 2003]. For this reason, the most effective intervention programs to prevent obesity in children and adolescents have included recommendations to limit television viewing [Gortmaker et al., 1999; Robinson et al., 2003]
1.4.6. Physical Activity

The relation between various PA parameters and the development of obesity has received great attention. However, as seen in the next section, methodological limitations in the assessment of PA pose a serious challenge for researchers.

1.4.7. Summary

Obesity may be viewed as the consequence of a complex interaction between predisposition to obesity (genetics) and several environmental factors (lifestyle). This may result in a small but cumulative disruption in the homeostasis of the energy balance equation. An ever changing environment characterized by boundless food availability, and an increasingly sedentary lifestyle with less chances for PA creates the perfect milieu for obesity to thrive.

1.5. Consequences of Obesity

It is well established that excess weight increases the risk of developing medical complications that affect nearly every major organ in the body. This relation is established through the association of BMI with morbidity. In fact, as presented in Table 4, a study conducted by the Lewin group clearly demonstrates the direct correlation between increases in BMI and elevated risk of developing arthritis, type-2 diabetes, gallstone disease, hypertension and heart disease. Their findings are consistent with other studies which have shown that overweight (BMI $\geq 25$) and obesity (BMI $\geq 30$) are correlated with the prevalence of hypertension [Stamler et al., 1978; Despres et al., 1990], coronary heart disease [Hubert et al., 1983], diabetes [Golay and Ybarra, 2005], gallbladder disease [Diehl 1991], osteoarthritis [Felson et al., 1988], obstructive sleep apnea [Loube et al., 1994], and certain types of cancers [Garfinkel, 1985]. Some of these complications are discussed below.

Table 4. Relative risk of morbidity with BMI status in adults.

<table>
<thead>
<tr>
<th>Disease</th>
<th>BMI $\leq 25$</th>
<th>BMI $&gt;25 &lt; 30$</th>
<th>BMI $\geq 30 &lt; 35$</th>
<th>BMI $\geq 35$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arthritis</td>
<td>1.00</td>
<td>1.56</td>
<td>1.87</td>
<td>2.39</td>
</tr>
<tr>
<td>Heart disease</td>
<td>1.00</td>
<td>1.39</td>
<td>1.86</td>
<td>1.67</td>
</tr>
<tr>
<td>Diabetes (type-2)</td>
<td>1.00</td>
<td>2.42</td>
<td>3.35</td>
<td>6.16</td>
</tr>
<tr>
<td>Gallstones</td>
<td>1.00</td>
<td>1.97</td>
<td>3.30</td>
<td>5.48</td>
</tr>
<tr>
<td>Hypertension</td>
<td>1.00</td>
<td>1.92</td>
<td>2.82</td>
<td>3.77</td>
</tr>
<tr>
<td>Stroke</td>
<td>1.00</td>
<td>1.53</td>
<td>1.59</td>
<td>1.75</td>
</tr>
</tbody>
</table>

Source: Centers for Disease Control. Third National Health and Nutrition Examination Survey, Analysis by the Lewin Group, 1999
1.5.1. Hypertension

A person is considered hypertensive in the case of the presence of a mean systolic blood pressure of ≥140 mm Hg or a mean diastolic blood pressure ≥90 [Chobanian et al., 2003]. High blood pressure increases as BMI rises. In one study, the prevalence of high blood pressure and mean levels of systolic and diastolic blood pressure among adults under 60 years increased as BMI increased. In fact, at a BMI of greater than 30, 49.1% of men and 37.8% of women were diagnosed with hypertension compared to 14.9% and 15.2% respectively at a BMI of less than 25 [Brown et al., 2000]. In another study it was reported that a ten kilogram difference in bodyweight in adults is associated with higher systolic and diastolic blood pressure. Differences of 2-3 mmHg in systolic blood pressure on a population basis have been shown to be associated with differences in stroke mortality rates of 6-9 % and in coronary death rates of 4-6 % [Dyer and Elliot, 1989]. In adolescents, it has been shown that obese individuals have a much higher risk of developing hypertension as compared to non-obese individuals [Lauer et al., 1975]. In the same manner, overweight adolescents were 8.3 times more likely to develop hypertension during young adulthood [Srinivasan et al., 1996].

1.5.2. Dyslipidemia

Dyslipidemia is characterized by an abnormal lipid profile in the blood, mainly a total cholesterol level over 240 mg/dL. It is often accompanied by hypertension. Increased bodyweight is associated with higher levels of cholesterol in both men [Denke et al., 1993] and women [Denke et al., 1994]. Being overweight as an adolescent is associated with a 2.4 fold increase in the prevalence of high cholesterol during young adulthood [Srinivasan et al., 1996]. Moreover, cholesterol levels are more elevated in individuals with increased abdominal obesity [Reeder et al., 1992] suggesting that the distribution of BF may also have an effect irrelevant of the quantity of BF. Other contributors to Dyslipidemia, such as elevated triglycerides [Denke et al., 1993; Denke et al., 1994] and lower high density lipoproteins [Glueck et al., 1980] have also been known to be associated with BMI levels. In adolescents, abnormal lipid profiles are more commonly found in obese boys [Lauer et al., 1988].

1.5.3. Type 2 Diabetes

Non-insulin-dependant diabetes mellitus or type-2 diabetes originates as insulin resistance. It occurs when the cells cannot use insulin properly, as the need for insulin rises; the pancreas loses its ability to secrete it. Overweight and obesity are strong risk factors for the development of type 2 diabetes. A study using a self report questionnaire found that starting from a BMI as low as 22.0 kg/m², the risk of developing type 2 diabetes begins to rise [Colditz et al., 1990]. In the Nurses Health Study, compared to a BMI of less than 23 kg/m², it was
reported that for a BMI between 30.0 and 34.9 kg/m², the relative risk of developing Type-2 diabetes was 20.1, and for a BMI greater than 35.0 kg/m² the relative risk was 38.8 [Hu et al., 2001 b]. In a follow up study from 1976 to 1990 among a large group of nurses who were free from diabetes at baseline, the relative risk for developing diabetes compared with those whose weight remained stable was 1.9. For those with a weight gain between 5.0 and 7.9 kilograms, 2.7 for a weight gain of 8.0 to 10.9 kilograms, and 12.3 for an increase of over 20.0 kg. On the other hand, those who lost more than 5.0 kilograms reduced their risk by at least 50% [Colditz et al., 1995]. Some studies have found that alternative measures of body weight such as waist circumference and waist to hip ratio are also highly correlated with type 2 diabetes, thus suggesting an independent role for central adiposity [Wang et al., 2005; Balkau et al., 2007]. Moreover, it was suggested that because of its additional effect on risk prediction, waist circumference should be measured in addition to BMI to assess the risk of type 2 diabetes in both men and women [Meisinger et al., 2006]. However, other studies have found that BMI, waist circumference, and waist to hip ratio have similar associations with diabetes. Thus further research is needed to determine the usefulness of waist circumference or waist to hip ratio over BMI [Vazquez et al., 2007].

Once common in adults only, the prevalence of type 2 diabetes among children and adolescents is also on the rise [Wabitsch et al., 2004; Weigand et al., 2004; Rosenbloom et al., 1999]. A study conducted among 10-19 year old subjects reported that 90.0% of those diagnosed with diabetes had a BMI above the 90th percentile, and that the prevalence of type-2 diabetes has increased ten-fold over the same period in which childhood obesity increased [Pinhas-Hamiel et al., 1996]. Elevated insulin secretion in overweight and obese children and adolescents has been significantly associated with morbidity during later adult life [Must et al., 1992; Mossberg 1989]. For example, one large study reported that 2.4% of overweight adolescents developed type-2 diabetes by the age of 30, while none of the adolescents in the lean group were diagnosed with type-2 diabetes at that stage [Srinivasan et al., 1996]. Early recognition of risk factors and prevalence of type-2 diabetes in pediatric populations may help prevent the disease from developing or even reverse its progression. In fact, it has been reported that losing weight can help pre-diabetic subjects by preventing onset of diabetes and reducing blood glucose to normal levels [CDC 2005].

.1.5.4. Gallbladder Disease

Studies have shown that the risk of gallstone disease increases as weight increases, its prevalence being lower among men [Sun et al., 2009]. In women, for those with a BMI under 24 kg/m², the disease prevalence is 3.0 per 1000. Those with a BMI over 40, the prevalence increases to 20 per 1000 [Stampfer et al., 1992]. Obesity is a strong risk factor for the development of gallstones. This risk has been shown to increase even further in obese individuals after adopting a very low calorie diet [Everhart 1993].

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Gallstone disease also occurs among children and adolescents. Studies suggest that the disease is rare among prepubertal children. However, it is highly prevalent among obese adolescents who were previously treated with dietary interventions [Kaechele et al., 2006]. Moreover, it may also occur among adolescents who undergo bariatric surgery [Fernstrom and Courcoulas, 2008].

1.5.5. Osteoarthritis and Orthopedic Complications

Osteoarthritis occurs as a result of breakdown of cartilage in the joints, especially the knees, hips and lower back. Individuals who are overweight or obese are at an increased risk of developing osteoarthritis [Hochberg et al., 1995; Cicuttini et al., 1996].

The association between obesity and knee osteoarthritis is documented [Felson et al., 1997; Gelber et al., 1999]. However, the relation between obesity and hand osteoarthritis is still controversial [Woolf et al., 2006]. In one study it was concluded that the risk of developing osteoarthritis in the joints of the hands increases 9-13% for every one kilogram increase in bodyweight [Cicuttini et al., 1996]. On the other hand, studies in both sexes reported no significant association between obesity and hand osteoarthritis [Hochberg et al., 1991; Hochberg et al., 1993]. Unlike other diseases, it has been shown that osteoarthritis in the hands, feet, and knees is not associated with the pattern of BF distribution [Davis et al., 1990].

Studies have suggested that certain types of physical activities may result in large improvements in physical function and decrease pain associated with chronic knee and hip osteoarthritis [Fransen et al., 2007]. Another study suggested that minor weight reduction may be used as a preventive health measure for osteoarthritis [Cicuttini et al., 1996].

In children and adolescents, certain orthopedic complications have been associated with obesity. For example, in children, arching of the legs below the knee or Blount’s disease has been reported in obese subjects. Although the condition is not common, 60-80% of children diagnosed with the disease are obese [Dietz et al., 1982]. In adolescents, a rare condition known as slipped capital femoral epiphysis has been reported to be more prevalent among the overweight. This could be possibly due to the increased downward force on the growth plate of the hips [Taylor et al., 2006].

1.5.6. Metabolic Syndrome

This term is used to describe the co-prevalence of a combination of medical disorders and central obesity. More precisely, the condition involves the presence of cardiovascular risk factors such as obesity, hypertension, dyslipidemia, and insulin resistance [Liese et al., 1998]. Studies have shown that
the metabolic syndrome strongly predicts future risk of cardiovascular diseases [Ford 2005; Dekker 2005]. In 2005, the International Diabetes Federation redefined the metabolic syndrome as central obesity plus any two of the following conditions: hypertension, hypertriglyceridemia, reduced HDL cholesterol, or impaired fasting glucose [Alberti et al., 2005]. Table 5 presents the criteria for diagnosing the metabolic syndrome as recommended by the American Heart Association, the National Heart, Lung, and Blood Institute, and the International Diabetes Federation. The prevalence of the metabolic syndrome among adult populations worldwide is elevated [Ford et al., 2002; Magi et al., 2005; Gupta et al., 2004; Al-Lawati et al., 2003; Ozsahin et al., 2004]. Studies conducted in many countries have also reported a high prevalence of the metabolic syndrome among overweight and obese children and adolescents [Cook et al., 2003; Li et al., 2008; Cruz et al., 2004; Bokor et al., 2008]. These reports are very alarming especially since it has been shown that the components of the metabolic syndrome track from childhood to adulthood [Bao et al., 1997; Srinivasan et al., 2003], and thus the prevalence of the syndrome among adults is likely to increase dramatically in the future. Despite this, some studies have suggested that PA may have a positive effect on the problem. In fact, it has been reported that relatively small increases in PA may reduce the risk of the metabolic syndrome in healthy children [Ekelund et al., 2009]. In the same manner another study concluded that maintaining a physically active lifestyle across the lifespan may also prevent or delay the onset of metabolic syndrome in young male and female adults [Yang et al., 2008].

**Table 5.** Definition of Metabolic Syndrome in children, adolescents, and adults

<table>
<thead>
<tr>
<th>Age</th>
<th>Obesity (WC)</th>
<th>Triglycerides</th>
<th>HDL-C</th>
<th>Blood pressure</th>
<th>Glucose</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-&lt;10*</td>
<td>≥90th percentile</td>
<td>≥150mg/dl</td>
<td>&lt;40mg/dl</td>
<td>Systolic BP ≥130 or diastolic ≥85 mm Hg</td>
<td>FPG 100mg/dl or T2DM</td>
</tr>
<tr>
<td>10-&lt;16</td>
<td>≥90th percentile</td>
<td>≥150mg/dl</td>
<td>&lt;40mg/dl</td>
<td>Systolic BP ≥130 or diastolic ≥85 mm Hg</td>
<td>FPG 100mg/dl or T2DM</td>
</tr>
<tr>
<td>16+</td>
<td>WC ≥ 94cm for Europid males and ≥ 80cm for Europid females, with ethnic-specific values for other groups</td>
<td>≥150mg/dl or specific treatment for high triglycerides</td>
<td>&lt;40mg/dl in males and &lt;50mg/dl in females, or specific treatment for low HDL</td>
<td>Systolic BP ≥130 or diastolic ≥85 mm Hg, treatment of previously diagnosed hypertension</td>
<td>FPG 100mg/dl or T2DM</td>
</tr>
</tbody>
</table>

BP: blood pressure; HDL-C: high-density lipoprotein cholesterol; FPG: fasting plasma glucose; T2DM: type 2 diabetes mellitus; WC: waist circumference.

Metabolic syndrome cannot be diagnosed, but further measurements should be made if there is a family history of metabolic syndrome, T2DM, dyslipidemia, cardiovascular disease, hypertension and/or obesity. Diagnosing the metabolic syndrome requires the presence of central adiposity plus any two of the other four factors.
.1.5.7. Psychosocial Consequences

Research suggests that overweight and obesity may also have an effect on the psychological wellbeing of individuals. Studies show that since early childhood, children are more likely to express negative attitudes towards overweight peers [Hill et al., 1995] and regard overweight classmates as the least preferable friends [Strauss et al., 1985]. A study conducted among 8 to 13 year old children demonstrated that adiposity is associated with increased psychological suffering manifested by low self esteem, body image dissatisfaction, and eating disorder symptoms [Gibson et al., 2008]. Moreover, findings from a longitudinal study concluded that the perception of being overweight during adolescence, but not measured overweight, is a significant risk factor for depression in young adult men and women [Al Mamun et al., 2007].

.1.5.8. Health Related Quality of Life

The concept of Health-related quality of life (HRQOL) refers to an individual’s subjective evaluation of his or her physical, social, and psychological health over time [Testa and Simonson, 1996].

It has been shown that in adults all domains of HRQOL are negatively affected by elevated BMI [Soltoft et al., 2009]. Other studies have reported that obesity is more associated with decreased physical health [Goins et al., 2003; Huang et al., 2006]. In children and adolescents, a review which analyzed data from thirteen studies using the Pediatric Quality of Life Questionnaire found that physical and social functioning scores consistently decrease as BMI increases [Tsiros et al., 2009]. Another study using a different questionnaire, reported that obese children have low scores for several health related quality of life domains and overweight children have significantly lower physical functioning scores than their normal weight peers [Friedlander et al., 2003].

.1.5.9. Summary

Research in the field of obesity is heavily driven by the impact that this condition has on the health and well being of individuals. Several studies have generated enough evidence to consistently state that obesity is a major contributor to the occurrence of many cardiovascular, metabolic, and orthopedic complications, with recent evidence suggesting that certain ethnicities are more vulnerable than others. The consequences of obesity are also depicted through its effect on the quality of life even without the presence of medical complications.

.1.6. Economic Cost of Obesity

The impact of obesity on society is multidimensional. In other words, it is not confined to the medical complications associated with such a condition. From
a public perspective, obesity imposes a dramatic economic burden on society. For example, in 1995, the estimated cost of obesity in the United States was $99 billion dollars [Wolf and Colditz, 1998]. In 2000, the figure increased to $117 billion. These numbers were calculated as the sum of direct costs of medical care and indirect costs of lost productivity [U.S. Department of Health and Human Services 2001]. In Canada, the total direct health care cost in 1997 was estimated at over $1.8 billion [Birmingham et al., 1999]. In fact, it has been shown that obesity has an immense impact on the economies of numerous countries throughout the world [Thomson and Wolf, 2001; Zhao et al., 2008].

With the increase in the global prevalence of obesity, the ramifications of the problem are likely to grow and therefore place more pressure on the public and private sector to implement strategies aimed at reducing the economic effect of obesity.
2. Physical Activity and Energy Expenditure

PA represents the sole component of energy expenditure that can be altered by will. As a result, it has received great attention in various aspects of obesity research.

Obesity is a condition triggered by the interaction of genes with the environment. Put simply, it is caused by a recurring imbalance in the thermodynamic equation, with energy intake exceeding energy expenditure [WHO 1998].

2.1. Definition of Physical Activity

The term physical activity has been used interchangeably with several other words such as exercise, fitness, physical education, etc. However the actual phrase has a clear definition. Physical activity is any bodily movement that is caused by skeletal muscle contraction and resulting in energy expenditure [Caspersen et al., 1985]. Therefore it incorporates all activities ranging from the slightest movement to the most strenuous exercise.

PA can be assessed based on either the quantification of the related energy expenditure of movement or on the characteristics (type, frequency, and intensity) of activity.

2.2. Components of Total Energy Expenditure

Total energy expenditure can be separated into three components: Resting metabolic rate, thermic effect of food, and activity related energy expenditure [Hill 1994].

2.2.1. Resting Metabolic Rate

The first component, resting metabolic rate, is the amount of energy needed by the body to maintain normal physiologic function at rest in a post-absorbptive state. It may represent up to 70 % of the daily energy expenditure [Sharp et al., 1992]. Previously, it has been reported that energy expenditure of the resting metabolic rate is higher in obese children and adolescents as compared to normal weight youth [Epstein et al., 1989; Bandini et al., 1990 b]. This may be explained by the larger fat free mass of obese individuals. Recently, it was demonstrated that after adjustment for age, sex, and body composition, energy expenditure associated with resting metabolic rate did not differ between obese and normal weight children [Fontvieille et al., 1992].
2.2.2. Thermic Effect of Food

The second component of total energy expenditure is the thermic effect of food. It involves the energetic cost of the digestion process. It may account for 10% of the total daily energy expenditure [Horton 1983]. Although not significant, some studies have suggested that the thermic effect of food may be slightly lower in obese children as compared to normal weight peers [Molnar et al., 1985].

The effect of macronutrient ingestion on the thermic effect of meals has been investigated thoroughly. Of the three macronutrients, proteins have the highest thermogenic effect and fats have the lowest [Nair et al., 1983]. Interestingly, some studies show that obese and post-obese individuals display an increased preference for dietary fat relative to lean controls [Drewnoski and Greenwood, 1983; Drewoski et al., 1992]. Moreover, in a study that compared the effect of macronutrient ingestion on the thermic effect between obese and non-obese individuals. Results show that the thermic effect of carbohydrates and proteins was not different between obese and non-obese subjects. However, obese individuals show a reduced thermogenic response to fat [Swaminathan et al., 1985].

2.2.3. Physical Activity Energy Expenditure

The last component of energy expenditure is related to PA. Depending on several factors [Livingstone et al., 1990] it may range between 15 and 50% of total energy expenditure.

2.3. Quantitative Aspect of Physical Activity

The total amount of PA energy expenditure is a result of the sum of the energetic cost of activities associated with daily living, planned exercise, and spontaneous activity such as fidgeting and shivering. Studies have shown that PA energy expenditure of obese children and adolescents is higher than non-obese subjects possibly due to their increased bodyweight and elevated fat free mass [Bandini et al., 1991a; Maffeis et al., 1996; Treuth et al., 1998]. These findings provide a paradoxical suggestion in that PA energy expenditure is not correlated with obesity.

2.4. Qualitative Aspect of Physical Activity

PA can be measured in terms of behavior without referring to its related energy expenditure. As such, the qualitative context of PA (type, intensity, duration, and frequency) can be measured and assessed.

The paradox of increased PA energy expenditure in obese subjects as compared to their non-obese counterparts may be further understood by using a
qualitative approach. One study used objective criterion methods to measure both the qualitative and quantitative aspects of PA. The study reported that although PA energy expenditure was not significantly different between obese and normal weight adolescents, PA level was lower in the obese group [Ekelund et al., 2002]. Similar findings were reported in another study which concluded that PA energy expenditure in prepubertal children did not explain the variance in BF mass. However, a small proportion of the variance was explained by the time spent in recreational activities, as assessed by a questionnaire [Goran et al., 1997].

These findings suggest that PA cannot be viewed exclusively as equivalent to the energy cost of performing the activity, and therefore, the caloric expenditure of different forms of PA does not necessarily reflect the health benefits of these activities.

.2.5. Assessment of Physical Activity

Measuring PA faces many difficulties perhaps due to its complexity and multidimensional attributes. Current methods can assess PA in three ways, either as a behavior, or its resulting energetic cost, or both [Lamonte and Ainsworth, 2001]. The need for accuracy in measuring PA is necessary in order to evaluate interventions, determine trends, and perform comparisons between various populations [Wareham and Rennie, 1998]. However, the lack of an ideal standard makes the validation of new techniques even more challenging. Despite this, several methods have been developed. These include objective methods, such as direct calorimetry, indirect calorimetry, Doubly-labeled water (DLW), heart rate monitoring, accelerometry, and pedometry, and subjective methods such as questionnaires.

.2.5.1. Objective Methods

.2.5.1.1. Direct Calorimetry

This method dates back to the late 1800s. It measures body heat production directly through the use of a closed airtight chamber which is also known as a calorimeter [Webb 1991]. Besides being expensive, it cannot track rapid changes in energy release during exercise which makes it time consuming and burdensome. Therefore, this method is rarely used in research.

.2.5.1.2. Indirect Calorimetry

In this method, energy expenditure is calculated from the measurement of Oxygen uptake and carbon dioxide production using prediction equations [da Rocha et al., 2006]. Usually subjects are required to wear a mouthpiece which is connected to a system that measures gas exchange. This approach is somewhat burdensome. However, because of its high accuracy, it is widely used for the
validation of other methods. Nevertheless, studies conducted in children show significant reliability for new portable versions of indirect calorimetry [Nieman et al., 2005].

### 2.5.1.3. Doubly-Labeled Water

This method is considered the most precise and noninvasive way to measure total energy expenditure with high accuracy [Sirard and Pate, 2001]. It has been used widely in animals and humans including children and pregnant women. It was first applied to small animals by Lifson in the 1950s [Visser et al., 2000]. However, it was not until the 1980s that the method was applicable to humans [Schoeller 1988]. The technique involves the administration of specific isotopes orally or intravenously. Then, the difference in the rate of clearance of the isotopes from the body provides a measure of carbon dioxide production. From this, energy expenditure is calculated [Trabulsi and Schoeller, 2001]. This technique is useful for assessing energy expenditure in free living conditions, therefore minimizing the alterations that may occur in PA as a result of changing the natural environment, such as in a laboratory setting [Schoeller and Fjeld, 1991]. However, due to its high cost, technical complexity, and its inability to measure all dimensions of PA. It has been limited to the validation of other more simple methods of measuring PA energy expenditure.

### 2.5.1.4. Heart Rate Monitors

Usually, a transmitter is placed on the chest and a device is worn on the belt or wrist. These devices are often used in research to provide estimates of energy expenditure of PA based on the relation between heart rate and oxygen consumption. However, assuming that this relation is universal can lead to less accuracy. In fact, a study conducted in adolescents demonstrated that failure to apply individual calibrations may lead to decreased accuracy in estimating energy expenditure [Ekelund et al., 2001]. Some have also suggested that the precision of heart rate monitors decreases in sedentary individuals because the relation between heart rate and oxygen consumption is much weaker during low-level PA [Saris 1986; Meijer et al., 1989]. Moreover, several factors such as fitness level [Kappagoda et al., 1979], environmental conditions [Sengupta et al., 1979], and emotional state [Brage et al., 2004] have also been known to influence heart rate. The use of heart rate monitors in combination with other methods has been shown to improve its accuracy in assessing PA [Strath et al., 2001; Strath et al., 2002].

### 2.5.1.5. Accelerometry

This method is based on the use of a small portable device which has built in transducers (energy converter) and microprocessors to convert body accelerations into activity counts. It is the most commonly used method to assess PA in free living subjects. In fact, compared to other objective methods, its use
has increased greatly across all age groups [Rowlands 2007]. Studies conducted in children [Freedson et al., 2005] and adults [Matthews 2005] have shown that movement counts recorded by accelerometers are strongly correlated with results obtained from other objective methods such as doubly labeled water and oxygen uptake. Accelerometers vary in accuracy and reliability. However, no single accelerometer can be considered for use over the others because till now, direct comparisons of different models are not abundant [Plasqui and Westerterp, 2007]. Although using accelerometers in field studies is well accepted, certain limitations exist. First, they cannot detect changes in running velocities [Brage et al., 2003] or changes in muscular resistance. Second, the cost of some advanced models may limit their use in large scale studies.

### 2.5.1.6. Pedometry

Similar to accelerometry, this method involves the use of small devices known as pedometers. They may be worn at the ankle, wrist, or hip. Pedometers measure vertical vibrations and provide a record of total steps. They were designed initially to assess walking. However, the first models were inaccurate and unreliable [Gayle et al., 1977; Washburn et al., 1980]. Newer models have better accuracy [Schneider et al., 2004]. Being a cheaper alternative to accelerometers, they are more widely used in large scale assessment of PA. Furthermore, because pedometers count steps/day they provide the advantage of straightforward comparison of results between various populations. Despite this, their use has some significant limitations. First, their accuracy may decrease during low intensity activities [Kemper et al., 1977] and therefore their ability to assess subjects with low intensity PA may be less precise. Second, there is some concern that excess BF around the pelvic area in overweight adults may cause the pedometer to tilt and result in less accurate readings [Melanson et al., 2004; Shepherd et al., 1999], although another study reported that the placement of the pedometer on various locations on the waistband did not affect the accuracy of the device for counting steps [Swartz et al., 2003]. Third, pedometers are limited to providing information on walking. It was recently demonstrated that their ability to measure activities such as skipping, galloping, sliding, and hoping may not be accurate [Smith and Schroeder, 2008]. This is especially important since these movements are typical of children activities.

### 2.5.2. Subjective Methods

These are usually self-report methods. They are practical and inexpensive which makes them useful for large scale studies.

#### 2.5.2.1. Physical Activity Questionnaires

PA questionnaires are classified into 4 categories: diary surveys, recall surveys, quantitative histories surveys, and general surveys [LaPorte et al., 1985]. Questionnaires are well suited for large epidemiological studies [Pereira et
A variety of questionnaires exist, most are developed to estimate occupational PA [Ainsworth et al., 1993 b; Reis et al., 2005], leisure time PA [Lamb and Brodie, 1990; Richardson et al., 1994], or total PA [Sallis et al., 1985]. Several questionnaires have also been developed to assess PA across different populations and in different age groups such as children [Goran 1998] and elderly [Bonnefoy et al., 2001].

Questionnaires may provide estimates of energy expenditure through the use of various grading scales such as kcal, METs, points, and indexes. Among these, the MET score has been widely used to reflect the caloric expenditure and intensity of activity. A good example of this would be the questionnaire originally developed by Kriska et al [Kriska et al., 1990], which was then modified and used in other studies [Deheeger et al., 1997]. One MET is the metabolic equivalent of energy expended at rest. Therefore, using previously estimated values, the energy cost of each activity may be expressed as multiples of resting metabolic rate [Ainsworth et al., 1993 a].

Studies have shown varying correlations between questionnaires and different types of methods. However, questionnaires have received criticism for achieving low validity when assessed against other more objective methods in adults [Hertogh et al., 2008; Bonnefoy et al., 2001; Starling et al., 1999; Prince et al., 2008] and in pediatric populations [Adamo et al., 2009]. These findings may be explained by several factors. First, the lack of a gold standard to measure PA implies that all methods are prone to errors. Second, questionnaires reflect various dimensions of PA ranging from a few days up to a lifetime, whereas techniques such as the DLW measures energy expenditure of activities within a few days. These issues may cause objective methods to generally underestimate the validity of questionnaires to accurately assess PA [Neilson et al., 2008]. Despite this, questionnaires are still the most feasible and applicable method for assessing PA in large-scale studies across all populations.

.2.5.3. Summary

PA is a highly modifiable component of total energy expenditure that varies greatly between individuals. PA is a very broad term that may incorporate any movement resulting from skeletal muscle contraction. As such, it can be expressed using several features each of which may act independently on health. These include energy expenditure, intensity, duration, frequency, and type. Accurate assessment of these features is necessary for obesity related research.

Although, the lack of a gold standard against which to assess other methods is problematic. Nevertheless, as depicted in table4, available
techniques include: objective methods such as doubly labeled water, accelerometers, and heart rate monitors and subjective methods such as questionnaires. Each of these methods has certain advantages and weaknesses. Objective methods are highly accurate. However, they may not be feasible in large scale studies. Among the subjective methods, recalls are reasonably accurate, but they may require significant commitment from participants. Thus, other types of questionnaires are recommended for assessing PA in large scale studies.

**Table 4.** Characteristics of physical activity assessment methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
<th>Advantage</th>
<th>Disadvantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct calorimetry</td>
<td>Directly measures body heat production using specialized chamber</td>
<td>Accurate</td>
<td>Limited availability, cannot track rapid changes in energy release during exercise</td>
</tr>
<tr>
<td>Indirect calorimetry</td>
<td>Measures oxygen uptake and Carbon Dioxide production to estimate energy expenditure</td>
<td>Accurate, portable</td>
<td>High cost, requires high participant cooperation</td>
</tr>
<tr>
<td>Doubly-labeled water</td>
<td>Measure energy expenditure from Carbon Dioxide production through the use of isotopes</td>
<td>Precise, noninvasive, used in free-living conditions, considered as the &quot;gold standard&quot;</td>
<td>expensive, cannot measure qualitative aspects of PA</td>
</tr>
<tr>
<td>Heart rate monitor</td>
<td>Measures heart rate (beats/minute) to provide estimates of energy expenditure</td>
<td>Minute by minute monitoring of heart rate during exercise</td>
<td>Limited to aerobic activities, may increase despite no physical movement</td>
</tr>
<tr>
<td>Accelerometry</td>
<td>Measures movement counts</td>
<td>Objective measure, easy to collect data, extended monitoring periods</td>
<td>May not capture all types of movements, high cost</td>
</tr>
<tr>
<td>Pedometry</td>
<td>Measures steps</td>
<td>Inexpensive, noninvasive, may alter behavior</td>
<td>Reduced accuracy when jogging or running</td>
</tr>
<tr>
<td>Questionnaire</td>
<td>Provides qualitative and quantitative data</td>
<td>Inexpensive, suitable for large scale studies</td>
<td>Difficulty with recall of activity, possibility for bias</td>
</tr>
</tbody>
</table>

**2.6. Physical Activity and Health**

As the prevalence of overweight and obesity continues to rise worldwide, health related complications are expected to concurrently increase as well. Given the numerous health benefits of PA and the detriments of being inactive, the need to increase PA has been stressed thoroughly.

Research consistently links PA to numerous health improvements. Several studies which evaluated the association between PA and BMI with the risk of cardiovascular disease have reported that PA is significantly associated
with cardiovascular diseases even after controlling for obesity [Lee et al., 1999; Stevens et al., 2002]. Indeed, increased PA has been shown to predict lower risk of cardiovascular disease independent of obesity [Blair et al., 1998]. It has also been suggested that PA plays a role in managing and reducing the risk of developing hypertension [Basset et al., 2002].

PA may also decrease insulin resistance and play a role in the prevention and management of type 2 diabetes [Knowler et al., 2002; Tuomilehto et al., 2001]. In fact studies have reported an inverse relationship between PA and insulin resistance which is known to cause type 2 diabetes [Eriksson and Lingarde, 1996; Helmrich et al., 1991].

PA has also shown benefits in obese subject who are considerably active. A number of studies reported that PA lowers the risk of being overweight and obese, and overweight or obese subjects with a high PA level have a lower mortality rate when compared to normal weight sedentary subjects [Blair and Brodney, 1999; Hu et al., 2001 a; Hu et al., 2001 c].

Another way in which PA affects health can be observed through the impact of weight loss on HRQOL. In a study conducted on 141 women and 20 men with an average BMI of 41.1 kg/m² and an average age of 44.9 years, researchers assessed the effect of a one year outpatient weight reduction program. They concluded that physical function and self esteem were significantly affected by weight loss [Kolotkin et al., 2001]. This is consistent with another study conducted on 212,000 respondents which reported that among people with arthritis, a condition related to obesity, recommended levels of PA were associated with fewer mean physically and mentally unhealthy days and a decreased probability of having severely impaired physical or mental HRQOL [Abell et al., 2005].

.2.7. Patterns and Trends in Physical Activity

Research dealing with PA is challenged by the lack of instruments that can accurately measure all aspects of PA. The matter is further complicated by the methodological differences that are present between studies [Armstrong and Welsman, 2006]. Nevertheless, after reviewing the available literature on the patterns and trends in physical activities, several conclusions can be drawn.

In general, results from the Youth Risk Behavior Surveillance System in the United States report higher PA levels in boys than girls [Kann et al., 1998], similarly, another study suggested that European boys are more active than girls especially when vigorous PA is considered [Armstrong and Welsman, 2006]. These findings are also supported by data showing that even among 5 to 6 year old children, boys are more active than girls [Gutin et al., 1990]. In contrast, a study from china, reported that among adolescents, more females than males participate in school sports activities [Tudor-Locke et al., 2007].
PA tends to decline from childhood to adolescence [Kann et al., 1998]. This is supported by two other studies. The first study, conducted on data from 32 countries, reported that older children are significantly less active than younger children [Borracinno et al., 2009]. The second study reported that PA decreases before high school and tends to drop through the high school grade levels [Sallis 1993]. Children are also more active in the winter than in the summer and on weekends compared to weekdays [Sallis et al., 1992]. Interestingly, another study reported that obese children are less active on weekends than during the week [Aires et al., 2007]. In a recent review which included 41 studies that met the inclusion criteria, researchers concluded that total PA among children and adolescents seems to be decreasing over time and activity levels in physical education classes are also decreasing [Knuth and Hallal, 2009].

2.8. Social Influence on Physical Activity

Studies show that among adolescents, confidence to perform exercise is a strong predictor of future PA pattern [Reynolds et al., 1990]. Moreover, it has been suggested that social support (parents and friends) for PA significantly affects adolescents' perceptions of and engagement in PA [King et al., 2008]. This is consistent with another study which concluded that during early adolescence, the participation of girls in sports is particularly affected by the social influence of peers (e.g. friends, classmates, boyfriends) [Keresztes et al., 2008]. In another study conducted in 3352 10-18 year olds several findings were reported. First, children with high socioeconomic status were more involved in sports. Second, girls show a greater tendency to participate in sports activities when their mothers participated. Third, the influence of a physical education teacher had no effect on the level of participation in sports activities [Seabra et al., 2008]. These findings should be taken into account when designing an intervention program.

3. Synopsis

Obesity is a pathological condition characterized by excess adiposity. Several methods have been developed for the assessment of body composition, with each having certain strengths and weaknesses. Among these, the BMI is a widely used tool for assessing obesity in large scale studies. Using this simple method, research reported high prevalence for obesity among children and adults worldwide.

In general, obesity is caused by small but cumulative disruptions in the energy balance equation. An evolving environment characterized by boundless food availability, and an increasingly sedentary lifestyle coupled with less chances for PA creates the perfect milieu for obesity. Because of this, the relation between nutrition, PA, and body composition has received great attention in obesity-related studies.
Although the association is not yet fully understood, studies show a consistent relation between reduced PA and increased prevalence of obesity. Since PA is a highly modifiable and variable component of total energy expenditure. It may be viewed as a potential cause of weight gain.

If success in the field of obesity is driven by the need for prevention and management, then, improving the assessment of body composition and PA may lead to a deeper comprehension of this relation.
PERSONAL CONTRIBUTION
**Thesis Objective and Aims**

There is consistent evidence that obesity is associated with serious health complications. There can be little doubt that the global increase in childhood and adolescent obesity will have major public health implications for many countries. Obesity related research in Lebanon is not yet viewed with the attention it deserves. Despite this, BMI-based results show that obesity among adolescents is comparable to many other countries. A physically inactive lifestyle is a risk factor for weight gain. Previous studies show that the prevalence of overweight and obesity is lower in girls. An understanding of these factors is essential for setting future policies and interventions.

The studies included in this thesis were guided by specific aims derived from the available literature. The following aims were investigated in the course of this study.

**Specific Aim One**

Assess the prevalence of overweight and obesity and examine their relation with physical activity, inactivity and quality of life among school-based Lebanese adolescents.

**Specific Aim Two**

Determine the relation between BMI and body fat in Lebanese adolescent girls.

**Specific Aim Three**

Asses the effect of physical activity level on the relation between BMI and body fat among Lebanese adolescent girls.
GENERAL METHODOLOGY
The procedures implemented in this study received approval from the institutional ethics committees of the University of Balamand and the University of Rennes 2.

1. Research Design

The project was conducted over a period of four months starting from March till June of the year 2005. The research design is cross-sectional in nature. It is divided into two phases. Data from phase one was used in study 1, and data from phase two was used in studies 2 and 3. The total number of subjects included in the three studies was 1047 participants.

1.1. Phase 1

The project director contacted the schools by telephone and scheduled appointments after obtaining verbal approval from each school administrator. Nine out of eleven schools agreed to take part in the study (National Orthodox School of Akkar, National Orthodox School of Mina, Lycee Jamhour, Lady of Balamand School, Lycee Verdun, Ecole des Apotres Junieh, Haret Sakher Public School, Rahbe Public School, and Kousba Public School). Six of these schools were private and three were public. Each school was visited during a physical education session. The questionnaire was administered to Grades 9 through 12. After a brief explanation of the study, the students provided verbal approval to participate. Then the questionnaires were distributed and the completion process commenced as the investigators aided the students and answered all their inquiries. The students were allowed to complete the questionnaires at home. Out of 1500 distributed questionnaires, 1000 were recollected on second visits.

1.1.1. Phase 1: Subjects

1000 subjects participated in completing the questionnaire. After a detailed examination, eighteen questionnaires were excluded because some subjects were older than 18 years of age and some questionnaires were incomplete. As a result, questionnaires from 422 boys and 560 girls between the ages of 14 and 18 were included.

1.1.2. Phase 1: Instruments

The distributed file was made up of four questionnaires. These are explained below

1.1.2.1. General questionnaire

In this two part section, subjects report information on age, sex, weight and height, in addition to some questions on TV viewing, computer use, and videogames (Appendix A)
1.1.2.2. Physical activity questionnaire

A validated two page questionnaire in children and adolescents [Deheeger 1997] was used as a measure of PA in the study subjects. It is a self-report recall questionnaire that may be completed in about 10 minutes. It can provide details regarding type, duration, and intensity of PA.

Subjects were asked to report information concerning PA across four domains: School, club, house, and leisure time (Appendix B). Results were presented as multiples of the resting metabolic rate where 1 MET is the amount of energy expended at rest or in other words, 1 MET is equivalent to 1Kcal/kg/hour. Using previously determined Metabolic Equivalent (MET) values [Ainsworth et al., 1993], a MET score was calculated for each reported activity using the following calculation: (Sessions per week) x (duration of each session) x (relative MET value) = MET score. Then the result of the MET scores of school, club, house, and leisure time were added as the total PA level per week.

1.1.2.3. Pediatric Quality of life Questionnaire

The Pediatric Quality of Life Questionnaire (PedsQL 4.0) French version [Varni et al., 1999; Varni et al., 2003] was used to evaluate the health related quality of life of the study subjects. This questionnaire has been validated, with internal consistency reliability >0.7. It can be completed in less than 5 minutes. It is made up of a total of 24 questions divided across four domains: physical (nine items), emotional (five items), social (five items), and school functioning (five items). The number of questions in each domain is divided by the total score in each domain and then multiplied by 100. For example, if a participant scores a sum of 18 on the physical domain, then his score is: (9 ÷ 18) * 100 = 50.

The total score is then calculated as the average of all four components of the questionnaire. Scores range from 0 to 100, with higher scores representing a better quality of life. (Appendix C)

1.2. Phase 2

In this phase of the project, subjects were recruited by personal contact. The objective and procedures of the study were explained thoroughly before approval to take part was obtained. Body weight and height were measured by standard anthropometric procedures and DXA whole body scans were performed. Additionally, a PA questionnaire was also completed. Participation was voluntary and subjects were free to withdraw at any time.

1.2.1. Phase 2: Subjects

The participants in phase 2 were healthy Lebanese females aged between 12 and 18 years. Recruitment was performed based on age and sex specific BMI.
cut-off values [Cole et al., 2000]. The initial aim was to create three BMI groups with 20 subjects in each group. However, subject recruitment was challenging especially for obese girls. Despite this, in study 2, fifty-one subjects were recruited. In study 3, the subjects increased to sixty-five participants (see below).

The following inclusion criteria was established to identify subjects for this study

- Self identify as Lebanese Female
- 12 to 18 years of age at the time of participation
- Self-report as at least twelve months past first menstruation
- No significant health disorder
- No use of medication
- Attend Physical Education classes regularly
- Not on any kind of nutritional diet

1.2.1.1. Phase 2: Study 2

51 adolescent girls participated in this study. BMI sorting was based on the cutoff points provided by Cole et al. Subjects were classified as follows.

<table>
<thead>
<tr>
<th>Normal weight</th>
<th>Overweight</th>
<th>Obese</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>24</td>
<td>11</td>
</tr>
</tbody>
</table>

1.2.1.2. Phase 2: Study 3

Total number of participating subjects was increased to 65 adolescent girls. BMI sorting was based on the cutoff points provided by Cole et al. Subjects were classified as follows.

<table>
<thead>
<tr>
<th>Normal weight</th>
<th>Overweight</th>
<th>Obese</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>25</td>
<td>19</td>
</tr>
</tbody>
</table>

1.2.2. Phase 2: Instruments

1.2.2.1. Anthropometric assessment

In studies 2 and 3, height and weight were assessed using the same instruments. Subjects were required to remove shoes and heavy outer clothing before commencing measurement. Bodyweight was measured on a Taurus mechanic scale with a precision of 140kg/100g. Height was measured to the nearest 1mm with a Seca stadiometer (model 222). BMI was calculated as \( \text{Weight kg} / \text{height m}^2 \).
1.2.2.2. Dual Energy X-ray Absorptiometry measurements

In studies 2 and 3, body composition was measured by dual-energy absorptiometry DXA (DXA Hologic QDR-4500W; Waltham, MA, USA). This method has been previously validated in obese and non-obese children and adolescents [Gutin et al., 1996; Thomas et al., 2005; Goran 1998]. Testing took place in a hospital setting by an accredited technician which performed the same procedure for all measurements. The in vivo coefficients of variation were 1.13 and 0.54% for fat and FFM, respectively. The DXA measurements were completed using the instrument previously described. BF mass and FFM were determined. %BF was then calculated as the ratio of fat mass to weight multiplied by 100.

1.2.2.3. Physical activity questionnaire

In study 3, subjects were required to complete a physical activity questionnaire (see section 1.1.2.2)

2. Data transfer

The data collected from the questionnaires, anthropometric measures, and whole body DXA scans were recorded in a Microsoft Excel computer spreadsheet using identification codes. DXA results were shared with the participant after they became available.

3. Data analysis

Two researchers were in charge of data input and analysis. The study sample was described using measures of central tendency (means) and variability (standard deviation). Descriptive data included age, height, weight, BMI scores, PA and inactivity variables, quality of life scores, and whole body DXA scans (BF, %BF, and FFM). Comparisons were performed using one way analysis of variance (ANOVA). Linear regression analysis was used to assess the relation between variables.

Data was analyzed using SIGMA STAT 1.0 (Jandel Scientific, San Jose, CA, USA) and NCSS 2001 (NCSS LLC, Kaysville, UT, USA). A value of p<0.05 was accepted as the minimal level of statistical significance.
RESEARCH STUDIES
III. RESEARCH OUTPUTS

Listed below are the peer-reviewed publications that have resulted from this thesis, in addition to the publications currently under review. The published versions of all papers are presented in the Appendix section

**Peer-Reviewed Publications**


Study 1: Activity, Inactivity and Quality of Life among Lebanese Adolescents

INTRODUCTION

During the past decades, studies have found an unprecedented rise in the prevalence of overweight and obesity among children and adolescents in many parts of the world [Kosti et al., 2006; WHO, 2000]. Obesity is caused primarily by a disruption in the delicate homeostasis between energy intake and energy expenditure. Consequently, any parameter that may upset this balance may be considered a risk factor for the development of obesity. PA and inactivity are factors that may influence the prevalence of obesity [Tsiros et al., 2008; Ischander et al., 2007; Ponjee et al., 1996; Ivy, 1997; Raitakari., 1997] especially because they are modifiable.

Numerous studies concerned with young populations have been using the Pediatric Quality of Life Inventory (PedsQL) to assess the HRQOL in children and adolescents. Some studies have shown that obesity is associated with low HRQOL scores among children and adolescents [Schwimmer et al., 2003; Varni et al., 1999; Williams et al., 2005].

Evidence suggests that obesity in the Middle East is following the same trend as in Western countries [Bener et al., 2006; Al-Isa, 2004; Sibai et al., 2003]. To our knowledge, however, there is no existing literature on PA, inactivity, and HRQOL among adolescents in the Middle East.

OBJECTIVE

The aim of the present study is to assess PA, Screen time (sum of time spent in front of TV, computer, and Videogame), and HRQOL among normal, overweight, and obese adolescents in Lebanon.

SUBJECTS and METHODS

982 subjects took part in this study (Refer to phase 1 of the General Methodology).

Statistical analysis

Data are expressed as mean ± SD. Relations between BMI, and variables of PA, inactivity, and PedsQL in boys and girls were analyzed using Kruskal–Wallis one-way analysis of variance on ranks; in the event of significance, all pairwise multiple comparison procedures (Dunn’s method) was performed. All statistical analysis was completed using SIGMA STAT (Jandal Scientific, San Jose, CA, USA). \( P < 0.05 \) was accepted as the minimal level of statistical significance.
RESULTS

Some questionnaires were not included in the study due to incomplete data. Subjects older than 18 years of age and those with chronic physical disabilities were exempted from participation. In all, a total of 18 subjects were excluded from the analysis. The final sample included 982 adolescents, with boys representing 42.9%.

Based on international age- and sex-specific cut-off points [Cole et al., 2000] the present results show that among Lebanese adolescents, 7.8% of boys and 1.75% of girls are obese, and 22.5% of boys and 12.47% of girls are overweight.

Table 1 lists the PA scores of the boys and girls who were assessed in the present study. In boys, scores for PA at health clubs were higher in the normal-weight group compared to the obese group. In contrast, in girls, leisure time PA and total PA scores were significantly lower in the obese group as compared to the normal-weight and overweight group. There was also a trend for lower levels of PA at school \( (P = 0.063) \) and at health clubs \( (P = 0.067) \) in the obese group. The results also show a significant gender difference in that boys reported significantly higher total PA scores than girls for the normal-weight, overweight and obese groups \( (P = 0.0001, P = 0.004, \text{ and } P = 0.0024, \text{ respectively}) \).
Table 1. Physical activity variables per week (MET) vs. BMI grouping (mean ± SD)

<table>
<thead>
<tr>
<th></th>
<th>Boys</th>
<th>Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal n=283</td>
<td>Overweight n=95</td>
</tr>
<tr>
<td>School</td>
<td>7.17 ± 8.7</td>
<td>5.54 ± 4.0</td>
</tr>
<tr>
<td>Health club</td>
<td>16.33 ± 31.9</td>
<td>10.47 ± 22.8</td>
</tr>
<tr>
<td>House</td>
<td>24.00 ± 29.7</td>
<td>25.84 ± 41.5</td>
</tr>
<tr>
<td>Leisure</td>
<td>80.1 ± 85.6</td>
<td>82.16 ± 72.0</td>
</tr>
<tr>
<td>Total PA</td>
<td>126.58 ± 108.9</td>
<td>122.65 ± 99.8</td>
</tr>
</tbody>
</table>

†Statistically significant difference.
BMI, body mass index; MET, metabolic equivalent; PA, physical activity.

Screen time variables are shown in Table 2. Results yielded no significant group differences. Boys in the normal-weight group, however, had significantly higher total screen time than girls in the same group (P = 0.004); this gender difference was not seen across the overweight or obese group.

Table 2. Screen time variables (h) vs. BMI grouping (mean ± SD)

<table>
<thead>
<tr>
<th></th>
<th>Boys</th>
<th>Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal</td>
<td>Overweight</td>
</tr>
<tr>
<td>TV/wkdy</td>
<td>2.53 ± 1.4</td>
<td>2.77 ± 1.4</td>
</tr>
<tr>
<td>TV/wknd</td>
<td>4.85 ± 2.7</td>
<td>5.1 ± 2.6</td>
</tr>
<tr>
<td>Computer/ wkdy</td>
<td>1.20 ± 1.1</td>
<td>1.17 ± 1.1</td>
</tr>
<tr>
<td>Computer/ wknd</td>
<td>3.35 ± 2.4</td>
<td>3.23 ± 2.3</td>
</tr>
<tr>
<td>Videogame/ wkdy</td>
<td>0.41 ± 0.8</td>
<td>0.26 ± 0.5</td>
</tr>
<tr>
<td>Videogame/ wknd</td>
<td>1.31 ± 1.9</td>
<td>1.04 ± 1.5</td>
</tr>
<tr>
<td>Total screen time</td>
<td>29.3 ± 13.6</td>
<td>30.4 ± 13.2</td>
</tr>
</tbody>
</table>

Total screen time: (TV/school day) × 5 + (TV/weekend) + (computer/school day) × 5 + (computer/weekend) + (video game/school day) × 5 + (video game/weekend).
BMI, body mass index.

HRQOL variables are presented in Table 3. In boys, the normal-weight group reported a significantly higher physical functioning score than the obese.
group. In girls, the normal-weight group reported significantly higher physical functioning and average HRQOL scores as compared to the overweight group, and significantly higher social functioning scores as compared to the obese group. Results also show a significant gender difference ($P = 0.001$), in that boys reported higher average HRQOL scores than girls in both the normal and overweight group, this difference was not found in the obese groups.

**Table 3.** Health-related quality of life* vs. BMI grouping

<table>
<thead>
<tr>
<th></th>
<th>Boys</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal</td>
<td>Overweight</td>
<td>Obese</td>
<td>$P$</td>
<td>Normal</td>
<td>Overweight</td>
<td>Obese</td>
<td>$P$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical</td>
<td>84.8 ± 12.7</td>
<td>82.6 ± 13.4</td>
<td>77.1 ± 14.0</td>
<td>0.006†</td>
<td>78.7 ± 13.8</td>
<td>72.3 ± 14.1</td>
<td>76.5 ± 6.5</td>
<td>0.002†</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emotion</td>
<td>69.2 ± 16.0</td>
<td>68.0 ± 16.0</td>
<td>68.5 ± 18.2</td>
<td>0.675</td>
<td>58.8 ± 16.6</td>
<td>53.2 ± 15.7</td>
<td>56 ± 22.3</td>
<td>0.052</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social</td>
<td>85.4 ± 15.5</td>
<td>83.7 ± 15.1</td>
<td>83.3 ± 12.1</td>
<td>0.191</td>
<td>85.4 ± 14.3</td>
<td>80.7 ± 16.5</td>
<td>72.0 ± 6.7</td>
<td>0.0006†</td>
<td></td>
<td></td>
</tr>
<tr>
<td>School</td>
<td>76.6 ± 17.4</td>
<td>77.0 ± 15.1</td>
<td>73.3 ± 19.6</td>
<td>0.767</td>
<td>76.4 ± 16.0</td>
<td>74.4 ± 17.3</td>
<td>74.0 ± 10.2</td>
<td>0.518</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>79.0 ± 11.2</td>
<td>77.8 ± 10.3</td>
<td>75.6 ± 13.1</td>
<td>0.361</td>
<td>74.8 ± 11.0</td>
<td>70.2 ± 10.8</td>
<td>69.6 ± 9.5</td>
<td>0.005†</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Higher scores indicate a better quality of life.
† Statistically significant difference. BMI, body mass index

**DISCUSSION**

To our knowledge this is the first attempt to assess the prevalence of obesity, PA, inactivity, and quality of life, among a population of 982 Lebanese adolescents aged 14–18.

**Prevalence of overweight and obesity**

The present results show that overweight and obesity among Lebanese adolescents is greater in boys than in girls. We used internationally accepted BMI cut-off points [Cole et al., 2000] and found that 7.8% of boys and 1.75% of girls are obese, and 22.5% of boys and 12.47% of girls are overweight. A previous study using the National Health and Examination Survey cutoff points found that 7.7% of boys and 2.9% of girls were obese and 29.9% of boys and 14.7% of girls were overweight [Sibai et al., 2003]. Moreover, another recent study using International Obesity Task Force cutoff points found that 10.1% of boys and 4.2% of girls are obese, and 28.8% of boys and 19.0% of girls are overweight [Chakar et al., 2006]. Since none of the BMI cutoff points have been validated against a direct measure of adiposity in Lebanon, there is a need to define new BMI cut-off points that are specific to the populations of the Middle East.

Obesity prevalence among Lebanese adolescents is lower than that of the USA and England [Baskin et al 2005; The Health and Social Care Information Centre, London 2004] but close to those reported in 11–16-year-old Canadian youth, for whom prevalence rates were greater in boys than in girls [Picket et al.,
With respect to other Mediterranean countries, the present results are comparable to those reported in studies using a similar definition for overweight and obesity. Prevalence rates were very similar to those found in Spain [Serra-Majem et al., 2006] and slightly higher than those reported in Greece [Kosti et al., 2007].

In the Middle East we found that the prevalence of overweight and obesity among Lebanese boys is much higher than those reported among Turkish boys. In contrast, Lebanese girls have a slightly higher prevalence of overweight and a similar prevalence of obesity compared to Turkish girls [Oner et al., 2007]. Compared to other Arabian countries, overweight and obesity prevalence is still much lower than that found in Qatar [Bener, 2006], Bahrain [Al-Sendi et al., 2003] and Saudi Arabia [Al-Almaie, 2005].

Physical activity

The present results show a significant gender difference across all groups, in that boys reported higher PA levels than girls. This is in accordance with other studies [Eck et al., 1992; Gazzaniga and Burns., 1993; McMurray et al., 1995].

The findings show that obese girls have significantly lower leisure time and total PA scores than the normal-weight and overweight groups. This may be partially due to the lack of access to public parks and safe playgrounds, which has been known to negatively affect PA among adolescents [Cohen et al., 2006; Pate et al., 2008]. Moreover, obese girls also reported suppressed social HRQOL functioning scores. This may explain why they shy away from participating in sports activities or even any type of group physical activity. This may well be the reason why obese girls reported no use of gyms or health clubs at all.

Further research is needed to determine if excess bodyweight is reducing the desire and/or interest for physical activity or whether decreased levels of physical activity is the cause of increases in bodyweight. It is in the public health interest to establish physical activity guidelines and provide opportunities for the adolescent community, especially those with excess weight, to increase their levels of physical activity.

Physical Inactivity

Even though some studies show that television viewing, computer use and videogame playing may disrupt the body’s energy balance in many ways [Epstein et al., 2005; Matheson et al., 2004] the present results indicated no significant group differences in screen time variables in boys or in girls. One possible reason may be due to the fact that we assessed only screen time, and subjects might engage in other sedentary activities such as reading, playing cards or listening to music.
Compared with other studies, obese adolescents reported 19.11 ± 8.5 h per week of television viewing whereas US adolescents reported on average 21 h per week [Nielsen Media Research 1998]. Moreover, weekly total screen time reported by obese boys (33.0 ± 15.2 h) and girls (29.6 ± 10.8 h) was higher when compared to that reported among US boys (15.9 ± 0.53 h) and girls (20.3 ± 1.19 h), respectively [Boone et al., 2007]

Health-Related Quality of Life

Poor HRQOL was more pronounced in girls. Indeed, overweight girls reported lower physical functioning and average HRQOL scores than normal-weight girls, and obese girls reported lower social functioning score than normal-weight girls. This may be partially explained with findings from other studies that found that obese adolescent girls have fewer friends [Strauss and Pollack, 2003].

The boys in the normal-weight and overweight group reported higher average HRQOL scores than the girls. This difference was not seen in the obese group. Gender differences in HRQOL seem to disappear as obesity sets in. Thus, obesity among adolescents in Lebanon has similar implications for HRQOL among both boys and girls.

CONCLUSION

Despite certain limitations, the present study is the first to provide data on PA, inactivity, and HRQOL among Lebanese adolescents. Although there is a need for further research, all those concerned with the pediatric population are urged to develop and implement effective strategies to increase physical activity and improve HRQOL among adolescents based on the present findings.
Study 2: Body Mass Index and Body Fat in Lebanese Female Adolescents

INTRODUCTION

The prevalence of overweight and obesity has increased in many parts of the world [Kuczmarski et al., 1994; James, 1992]. An even more shocking phenomenon is the global rise among children and adolescents [Kosti and Panagiotakos, 2006]. The association of obesity with numerous health disorders has amplified the need for accurate assessment techniques of BF. However, these methods are usually complicated, expensive and time consuming, therefore making them inappropriate for population based studies. Therefore, other methods are used to estimate adiposity, among these the most widely used is the BMI. Even though it is a measure of excess weight rather than excess BF, studies have shown a high correlation between BMI and BF [Haslam and James, 2005; Goulding et al., 1996; WHO 2000]. By using appropriate cut-off points, BMI may be used to assess overweight and obesity. Although not as common, some studies have assessed obesity based on BF. These studies suggest a %BF of at least 25% of total body mass for men and 30-33% for women [Wellens et al., 1996; Frankenfield et al., 2001].

Despite the fact that age and sex specific BMI cut-off points have been developed and validated against direct measures of adiposity [Cole et al., 2000], defining overweight and obesity in children is complicated by the fact that weight varies with height as children grow.

Moreover, it has been suggested that the relationship between BMI and BF is affected by factors such as ethnicity and body build [Rush et al., 2004; Deurenberg and Deurenberg-Yap, 2001; Chang et al., 2003; Deurenberg-Yap et al., 2000]. Indeed, these studies have found that universal cut-off points may not be used to accurately assess overweight and obesity in certain Asian populations and therefore they recommend the use of lower BMI cut-off points to define obesity.

OBJECTIVE

In Lebanon and the Middle East, universal BMI cut-off points have been used to assess obesity [Sibai et al., 2003 a]. However, the relation between BMI and BF has never been assessed. Thus the aim of this study is to determine the relation between BMI and BF among Lebanese female adolescents.

SUBJECTS and METHODS

Fifty one adolescent females aged 12 to 18 years took part in the study. Bodyweight and height were measured using standard anthropometric methods. BF was assessed by DXA (refer to phase 2 of the General Methodology)
Statistical analysis

The means and standard deviations were calculated for all clinical data (table 1). Linear regression analysis models were used to test the relationship between fat mass % and BMI, as well as fat mass with BMI and $r^2$ coefficients were reported. Data was analyzed with NCSS (2001). A level of significance of $p < 0.05$ was used.

RESULTS

Descriptive information of the subjects is found in table 2. The participants were classified according to the age and gender specific BMI cut-off points shown in table 1 [Cole et al., 2000] as follows, 16 normal weight, 24 overweight, and 11 obese.

Table 1. Age and sex specific BMI cutoff points (Cole et al., 2000)

<table>
<thead>
<tr>
<th>Age</th>
<th>Overweight</th>
<th>Obese</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>21.68</td>
<td>26.67</td>
</tr>
<tr>
<td>13</td>
<td>22.58</td>
<td>27.76</td>
</tr>
<tr>
<td>14</td>
<td>23.34</td>
<td>28.57</td>
</tr>
<tr>
<td>15</td>
<td>23.94</td>
<td>29.11</td>
</tr>
<tr>
<td>16</td>
<td>24.37</td>
<td>29.43</td>
</tr>
<tr>
<td>17</td>
<td>24.7</td>
<td>29.69</td>
</tr>
<tr>
<td>18</td>
<td>25</td>
<td>30</td>
</tr>
</tbody>
</table>

Cole et al., 2000

Table 2. Descriptive characteristics of the female adolescents (n=51)

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>15.06</td>
<td>1.67</td>
<td>12- 18</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>160.18</td>
<td>5.5</td>
<td>150- 172</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>65.53</td>
<td>13.40</td>
<td>38.00- 97.00</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>25.46</td>
<td>4.64</td>
<td>15.41- 35.69</td>
</tr>
<tr>
<td>Fat-free mass (kg)</td>
<td>39.97</td>
<td>5.63</td>
<td>28.40- 53.82</td>
</tr>
<tr>
<td>BF (kg)</td>
<td>23.58</td>
<td>7.98</td>
<td>8.90- 44.25</td>
</tr>
<tr>
<td>%BF</td>
<td>34.93</td>
<td>6.21</td>
<td>21.00- 46.60</td>
</tr>
</tbody>
</table>

SD: standard deviation; BMI: body mass index; DEXA: Dual Energy X-ray Absorptiometry; BF: body fat; %BF: body fat percent.

Correlation of %BF by DEXA with BMI is 0.82. Correlation of BF by DEXA with BMI is 0.93, both values at $p<0.0001$. Figure 1 shows a scatter diagram of the association between %BF by DEXA and BMI, including best fit lines for the regression of %BF on BMI. On the other hand, figure 2 shows a scatter diagram of the association between BF by DEXA and BMI. The two linear regression formulas are: %BF= 6.89 + (1.1 * BMI) and BF= -0.425 + (1.29 * BMI).
Figure 1. Correlation of %BF by DEXA with BMI in girls (r=0.82, p<0.0001)

%BF: body fat percent; DEXA: Dual Energy X-ray Absorptiometry; BMI: Body Mass Index

Figure 2. Correlation of Body fat by DEXA with BMI in girls (r =0.93, p<0.0001)

BF: body fat (kg); DEXA: Dual Energy X-ray Absorptiometry; BMI: Body Mass Index

DISCUSSION

This study shows that BMI is highly correlated with measures of BF obtained by DEXA. The correlations of BMI with DEXA measurements in this study group were higher with BF (r=0.93) than %BF (r=0.82). These results were similar to that reported in a study conducted in Italian children and adolescents [Pietrobelli et al., 1998].

After checking the correlations, we tried to compare %BF as estimated from the internationally accepted BMI cutoff points, and %BF as found by DEXA measurements. Most studies suggest that %BF cut off values for obesity in adolescent girls is between 30 – 35%. By using the linear regression formula
obtained in our study, a BMI of 30 kg/m² yields a %BF of 39.89. This value falls above the accepted range. Based on the current findings, a %BF of 33 would reflect a BMI of 23 kg/m².

From these results we conclude that even though BMI is correlated with BF and it is used to assess obesity in epidemiological studies and initial screening, its ability to accurately estimate the degree of obesity based on %BF may be affected by several factors. In fact, a number of studies have suggested that the relationship between BMI and %BF may differ between populations. Their findings recommend the development of population specific BMI cut-off points based on age, gender, and ethnicity [WHO 2000; Wellens et al., 1996; Frankenfield et al., 2001]. Because of this, results should be interpreted with caution since the cutoff points currently used cannot detect subjects who have a higher than expected %BF for a given BMI.

One of the limitations of this study is the fact that it was conducted only in adolescent girls. However, our interest was restricted to this group because previous epidemiological studies reported very low prevalence of obesity in this population [Sibai et al., 2003 a]. Nevertheless, future studies should investigate the relation between BMI and %BF in boys.

**CONCLUSION**

Based on the current findings, one can suggest that there is a need to lower BMI cut off point in order to more accurately assess obesity among Lebanese adolescent girls. From a public health perspective, this finding may considerably increase the prevalence of obesity among Lebanese female adolescents.
**Study 3: Taking Physical Activity Level into Account Improves Body Fat Estimation in Adolescents**

**INTRODUCTION**

Obesity has more than doubled in children and adolescents since the 1960s [Kosti et Panagiotakos 2006]. With this growing concern, several accurate measures of BF have been developed. One of these more popular methods is the BMI which is defined as weight (kg)/ height squared (m²). Although it can only detect excess body weight rather than excess fat [Villareal et al. 2005; WHO Expert Consultation 2004], it has shown high correlations with adiposity measurements [Goran et al. 1996; Pietrobelli et al. 1998]. In parallel with this huge increase in the prevalence of obesity, studies have also shown a progressive decline in PA as a result of environmental and behavioral changes over the past fifty years [Haskell 1996; Prentice et Jebb 1995; Weinsier et al. 1998]. There is also consistent evidence that PA tends to decline during adolescence [Kann et al. 1998], especially in girls [Pate et al. 1994]. With this in mind, it is well accepted that PA has an important role in the determination of bodyweight [Obarzanek et al. 1994]. In fact, despite the methodological difficulties of assessing free living PA [Sallis et al. 1992], there is some evidence that BF may be negatively associated to PA levels [Chan et al. 2003; Delany et al. 1998].

In view of the continuous need for improving feasible and convenient measuring techniques, the primary purpose of this study was to assess the relation between BMI and BF among adolescent girls in Lebanon; the secondary purpose was, for the first time, to identify the degree to which PA may improve this relation.

**SUBJECTS and METHODS**

65 adolescent females participated in the study. Body weight and height were determined by standard anthropometric methods. BF was measured by DXA. PA was measured by a self-report questionnaire (Refer to phase 2 of the Research Methodology)

Statistical analysis

The means and standard deviations (SD) were calculated for all the data. Univariate correlations were given as linear regression coefficients (table 2). Multiple linear regression analysis models were used to test the relationship between %BF with BMI and PA (min/week and Met/week), as well as BF with BMI and PA (min/week and Met/week), and $r^2$ coefficients were reported (tables 3 and 4 respectively). Data were analyzed with NCSS (2001). A value of $p < 0.05$ was accepted as the minimal level of significance.
RESULTS

The characteristic of the study sample and assessment of body composition and PA are presented in table 1. According to age and sex, 21 females were classified as normal weight, 25 as overweight and 19 as obese based on BMI [Cole et al. 2000]. DXA whole body scans show that the normal group has an average %BF of 27.95, the overweight group has an average %BF of 37.23, and the obese group has an average %BF of 39.7.

Table1. Descriptive Statistics of the Study Sample (n=65)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean ± SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>15.2 ± 2.0</td>
<td>12 - 18</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.60 ± 0.05</td>
<td>150 - 172</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>65.7 ± 13.9</td>
<td>38 - 97</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>25.5 ± 4.80</td>
<td>15.4 - 35.7</td>
</tr>
<tr>
<td>BF (kg)</td>
<td>39.9 ± 5.54</td>
<td>8.9 - 46.1</td>
</tr>
<tr>
<td>%BF</td>
<td>35.1 ± 6.34</td>
<td>21 - 46.8</td>
</tr>
<tr>
<td>Lean mass (kg)</td>
<td>39.9 ± 5.54</td>
<td>28.4 - 53.8</td>
</tr>
<tr>
<td>PA (min/week)</td>
<td>126.9 ± 64.2</td>
<td>40 - 250</td>
</tr>
<tr>
<td>PA (MET/week)</td>
<td>11 ± 6.61</td>
<td>3 - 27.3</td>
</tr>
</tbody>
</table>

BMI: Body Mass Index; BF: Body Fat; % BF: Percentage Body Fat; PA: Physical Activity

As seen in table 2, separate regression models showed that BMI was positively correlated with BF, %BF and lean mass, and negatively correlated with PA (min/week) and PA (MET/week). Moreover, PA (min/week) was negatively correlated with BF (r = -0.52) and %BF (r = -0.59) and PA (MET/week) was also correlated with BF (r = -0.52) and %BF (r = -0.52). All values were significant at p < 0.001.

Table2. Correlations of BMI Vs. measures of body composition and physical activity in female adolescents

<table>
<thead>
<tr>
<th>Variable</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>BF</td>
<td>0.94 ***</td>
</tr>
<tr>
<td>%BF</td>
<td>0.84 ***</td>
</tr>
<tr>
<td>Lean mass (kg)</td>
<td>0.84 ***</td>
</tr>
<tr>
<td>PA (min/week)</td>
<td>-0.46 ***</td>
</tr>
<tr>
<td>PA (METs/week)</td>
<td>-0.51 ***</td>
</tr>
</tbody>
</table>

BMI: Body Mass Index; BF: Body Fat; % BF: Percentage Body Fat; PA: Physical Activity. ***: P<0.001
Table 3. Multiple Regression Analysis Models with % BF as the dependent variable

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient ± SE</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dependent variable</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>%BF (r² = 0.76)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>14.8 ± 3.25</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>BMI</td>
<td>0.92 ± 0.101</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>PA (min/week)</td>
<td>-0.025 ± 0.007</td>
<td>0.002</td>
</tr>
<tr>
<td><strong>Dependent variable</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>%BF (r² = 0.72)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>10.98 ± 3.66</td>
<td>0.004</td>
</tr>
<tr>
<td>BMI</td>
<td>0.993 ± 0.115</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>PA (METS)</td>
<td>-0.118 ± 0.086</td>
<td>0.18 ns</td>
</tr>
</tbody>
</table>

%BF: Percentage Body Fat; BMI: Body Mass Index; PA: Physical Activity

Table 4. Multiple Regression Analysis Models with BF as the dependent variable

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient ± SE</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dependent variable</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BF (r² = 0.88)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>-13.55 ± 3.15</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>BMI</td>
<td>1.54 ± 0.09</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>PA (min/week)</td>
<td>-0.01 ± 0.00</td>
<td>0.03</td>
</tr>
<tr>
<td><strong>Dependent variable</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BF (r² = 0.87)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>-15.98 ± 3.39</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>BMI</td>
<td>1.58 ± 0.10</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>PA (METS/week)</td>
<td>-0.07 ± 0.08</td>
<td>0.33 ns</td>
</tr>
</tbody>
</table>

BF: Body Fat; BMI: Body Mass Index; PA: Physical Activity

Table 3 shows that BMI and PA (min/week) explained 76% of the %BF variance while table 4 shows that BMI and PA (min/week) explained 88% of the BF variance.
DISCUSSION

As expected, our data show a high correlation between BF and %BF with BMI (r = 0.94 and r = 0.84 respectively). This finding is in accordance with previous studies that reported similar results in adolescent girls [Goulding et al. 1996; Steinberger et al. 2005].

Excess adiposity in adolescents is difficult to define especially because it may vary widely in response to age, gender and pubertal development. Most studies suggest that %BF cut off values for obesity in adolescents girls are between 30 – 35% [Sardinha et al. 1999; Taylor et al. 2002; Weststrate and Deurenberg 1989]. In our study, according to age and sex specific BMI cut off points [Cole et al. 2000], those classified as obese have an average %BF of 40.39% and those classified as overweight have an average %BF of 37.23%. This suggests that even though the relation between BMI and adiposity is highly correlated, it may vary between populations and this variation should be accounted for when assessing obesity in adolescent girls. Moreover, a previous study concluded that the ability of BMI to adequately predict BF may vary widely across youths from different countries [Eckhard et al. 2003].

Studies concerning obesity in Lebanon have suggested that PA levels are low [Sibai et al. 2003], this suggestion is confirmed in this study since our subjects reported very low PA measures. We found that PA (min/week and METs/week) was significantly and inversely associated with %BF and BF. This is in accordance with two other studies. One found that body fatness is related to energy intake and expenditure in both black and white 10 year old girls [Obarzanek et al. 1994]. The other found that percent body fat increased 0.28 percentage points less in girls with a 6.2-minute increase in Moderate to Vigorous Physical Activity (MVPA) than in girls with a 4.5-minute decrease [Stevens et al. 2007]. However, one study found that PA was independently associated with BF in boys only [Ekelund et al. 2005]. But this study used air displacement plethysmography to measure body composition and it has been shown that this technique may underestimate %BF as compared to DXA measurements [Lazzer et al. 2008; Lockner et al. 2000].

Our study was the first, to our knowledge, to investigate the effect of PA on the relation between BMI and BF measurements in Lebanese adolescent girls. Multiple linear regression showed that including PA (min/week) measurements, from the questionnaire we used, significantly improved the relation between BMI and %BF (without PA; $r^2 = 0.70$, with PA; $r^2 = 0.76$).
CONCLUSION

BMI remains the most widely used method to assess obesity. Even though more studies are required to determine the nature of the relation between BMI and %BF in adolescents and its ramifications on health, our findings suggest that by adding a simple validated self report questionnaire for PA, it may be possible to improve the relation between BMI and %BF.
GENERAL DISCUSSION
Excess adiposity is a major health concern among adults worldwide. Its prevalence is also on the rise in children and adolescents [Lobstein et al., 2004]. Of even more concern is the fact that obesity seems to track from adolescence to adulthood [Rolland-Cacher et al., 1987; Whitaker et al., 1997]. Based on this, the prevention and management of obesity during adolescence should be of primary concern.

In Lebanon, as in many other Middle Eastern countries, obesity related research is not yet viewed with the attention it deserves. Nevertheless, in our first study, among a sample of 982 Lebanese adolescents, using widely accepted cut-off points [Cole et al., 2000] we report that the prevalence of overweight and obesity is 22.5% and 7.8% respectively in boys and 12.45% and 1.75% respectively in girls. These figures are approximate to those previously found [Sibai et al., 2003 a; Chakar and Salameh, 2006]. Based on this, it is now well established that in Lebanon, overweight and obesity is more prevalent among boys than girls. This trend is similar to that reported among adolescents in Spain [Serra Majem et al., 2003] and Greece [Tzotzas et al., 2008; Mihas et al., 2009].

Previous research has presented several factors as potential contributors to the prevalence of obesity in Lebanon. In one study, physical inactivity in the form of screen time (television viewing, videogame playing, and computer use) was proposed as a cause [Chakar and Salameh, 2006]. This suggestion was assessed in our first study. In girls, we found no difference in total screen time between the normal weight, overweight, and obese group. In boys, total screen time tended to increase as BMI increased. However, these differences were not significant. Even though many studies have reported significant associations between inactivity, precisely screen time, and obesity [Lajous et al., 2009; Laurson et al 2008], in a recent review, it was suggested that videogames and computers do not represent such a high risk for obesity [Rey-Lopez et al., 2008]. Another study which examined variables of activity, inactivity and nutrition in relation to weight status found that only vigorous physical activity was associated with weight in adolescent boys and girls [Patrick et al., 2004].

In a previous study conducted in Lebanon, lack of physical activity, defined as engaging in three or more days of leisure time physical activity per week, was significantly associated with an increased risk of being obese [Sibai et al., 2003 a]. Based on this, we assessed the relation between BMI and several variables of physical activity. Normal weight boys reported higher physical activity scores at club than the obese group. This finding is important especially since resistance training may serve a protective role against obesity by increasing FFM and decreasing BF [McGuigan et al., 2009].

Although significance was only found in girls, total physical activity tended to decline as BMI increases. This is in accordance with a study which reported that weight status among US high school students is correlated with selected
physical activity behavior [Levin et al., 2003]. In fact, our finding is complemented by the fact that both obese boys and girls reported significantly lower physical functioning scores as assessed by the HRQOL questionnaire.

Obese girls reported significantly lower total and leisure physical activity scores than their normal weight peers. Several factors may explain these findings. It has been suggested that adolescent obesity is associated with low self esteem and body dissatisfaction [Fox and Farrow, 2009; Cornette 2008]. Moreover, previous studies show that obese children may suffer from discrimination by their schoolmates, and this finding is to some degree, connected with their low fitness [Malecka-Tendera et al., 1989]. These factors may possibly cause obese adolescents to shy away from participation in sports activities. In fact this may explain why all the girls in the obese group reported no participation in physical activity at clubs. This hypothesis is further supported by another study which concluded that physical activity was the least common method of losing weight among overweight Lebanese female adolescents [Sibai et al., 2003 b].

In Lebanon, it is a general observation that PA is low. This is due to several factors. For example, only a small number of schools emphasize physical education classes and/or offer extracurricular sports activities. In a country with a high urbanization rate (81%) [WHO 2003], urban planning limits physical activity. In other words public parks and playgrounds are nonexistent. Moreover, fitness clubs are scarce and they may not be accessible to all.

Despite the fact that methodological limitations challenge comparability of physical activity between studies, the results of our first study are consistent with the previously described observation in that Lebanese adolescents and precisely girls, report very low levels of physical activity compared to other countries [Samdal et al., 2007]. This may be explained by several factors. Many developed countries acknowledge the importance of physical activity in promoting health and wellness and therefore physical activity is addressed in public health policies. This is not the case in third world countries. In fact, a recent review on trends in physical activity suggested that PA surveillance must be strongly encouraged in all settings and age groups and that special attention must be paid to low and middle-income countries, where PA surveillance is virtually inexistent [Knuth and Hallal, 2009]

This has led to the paradoxical outcome where the prevalence of overweight and obesity among girls is low despite reporting very low levels of physical activity.

This finding may be partially explained by several factors. First of all, nutritional issues such as lower energy intake and selection of better food choices may have an effect. Second, in today’s society, girls are more conscious of their body image especially during adolescence. Third, as suggested by previous studies, self-report height and weight may be subject to certain biases,
especially among overweight and obese individuals [Shields 2005; Elgar et al., 2005]. Furthermore, we cannot overlook the fact that our results were obtained using BMI which although highly correlated with body fatness, is not a direct measure of adiposity because the components of BMI include both fat mass and fat free mass. Therefore, we speculate that the low prevalence of female obesity reported in our first study may be due to a methodological misinterpretation.

The findings of our second study are in accordance with previous studies that demonstrated that BMI is correlated with body fat [Pietrobelli et al., 1998; Steinberger et al. 2005]. Therefore, BMI may be used as an indicator of obesity. However, if obesity is excess adiposity, then the question remains; how much fat should a person carry in order to be considered as obese? Based on this question, the accuracy of BMI depends on the degree to which the cut-off points can precisely estimate body fat in a given population. Several studies have shown that the relation between BMI and body fat may vary between populations. This has been demonstrated in adults [Rush et al., 2004; He et al., 2001] and in children [Eckhard et al. 2003]. In fact, a recent study conducted among 5 to 16 year old girls of varying ethnicities concluded that BMI may be used as a measure of excess fatness in girls from diverse ethnicities. However its accuracy depends on applying ethnic-specific BMI reference points [Duncan et al., 2009].

Although the BMI cut-off values that would reflect the percent body fat associated with increased risk of obesity related diseases are inconsistent, most studies suggest that percent body fat cut off values for obesity in adolescents girls is between 30 and 35% [Sardinha et al. 1999; Taylor et al. 2002; Weststrate and Deurenberg, 1989]. In our second study, according to age and sex specific BMI cut off points [Cole et al. 2000], those classified as obese have an average percent body fat of 40.39% and those classified as overweight have an average percent body fat of 37.23%. Although this finding may be possibly related to differences in body build and body type [Deurenberg et al., 2002; Deurenberg et al., 1999]. Such a high body fat at low BMI may also be partially explained from a nutritional standpoint, precisely calcium intake. A study from our laboratory reported that 89% of Lebanese female adolescents do not meet the recommended daily calcium intake [El Hage et al., 2009]. This may be related to a high body fat level, especially since it has previously been shown that low calcium intake stimulates the secretion of calciotropic hormones that cause increased intestinal calcium uptake which in turn is known to promote lipogenesis and decrease lipolysis, thus leading to increased fat mass [Zemel 2005].

Our results show that for a given BMI, Lebanese adolescent girls exhibit a higher than expected percent body fat. Therefore, using international cut-off points may lead to a significant underestimation of the prevalence of overweight and obesity among adolescent girls in Lebanon. In fact this may explain why our findings in the first study and that of previous studies reported such a low prevalence of obesity among girls despite their low levels of physical activity.
While our population sample in the second and third study is not large enough to appropriately recommend new cut-off point, our results strongly suggest the need for redefining overweight and obesity based on lower BMI cut-off points. Similar recommendations have been suggested in other studies conducted among Asian [Duncan et al., 2009] and Australian children [Wickramasinghe et al., 2005].

In the absence of other simple and feasible methods to assess body fat in large scale studies, it is highly expected that BMI will remain the most widely used method to assess obesity. Despite its convenience, its relation with body fat has been shown to be affected by factors other than those discussed previously. Physical activity is one of these factors. For example, it has been shown that highly active individuals have a greater proportion of their weight as fat free mass and tend to accumulate less adipose tissue as compared to sedentary individuals of the same weight [Kohrt et al., 1992; Abe et al., 1996; Ode et al., 2007]. Based on this, when using BMI, these individuals may be misclassified as overweight or obese even though their body fat is within normal range. Therefore, we hypothesize that taking physical activity into account may improve the relation between BMI and body fat. In addition to the statistical analysis in the study, Backwards stepwise regression was also performed with %BF as the dependant variable. The model included BMI, age, and PA. The analysis shows that %BF can be predicted from a linear combination of BMI and PA. Moreover, age did not significantly add to the ability of the equation to predict %BF.

Our findings in the third study suggest that by adding a simple validated self report questionnaire for physical activity, it is possible to improve the relation between BMI and body fat. Even though this approach may be criticized for its subjective methodology, the use of a questionnaire to measure physical activity was intended to assess the possibility of using a simple method that may be used in parallel with BMI to more accurately assess obesity.
LIMITATIONS
There are several limitations that need to be acknowledged and addressed. First, we cannot overlook the fact that the BMI scores are based on self-reported weight and height, and therefore may be subjected to recall biases. Second, while the obtained results allow us to check for correlations between the measured variables and weight status, the cross sectional design of the study does not help to establish a cause effect relation between physical activity and obesity. Third, our findings concerning the effect of physical activity could have been reinforced by adding an objective measure of physical activity. Fourth, the studies were conducted on school-based subjects. Therefore, the derived conclusions cannot be generalized to the whole Lebanese adolescent population. Despite these limitations, this thesis includes several strengths such as the large sample size in study 1 and the utilization of validated instruments to measure physical activity and quality of life, in addition to the use of DXA which is considered by many as the current "gold standard" in assessing body composition.
CONCLUSION
In conclusion, based on currently available BMI cut-offs points, the prevalence of overweight and obesity among adolescents in Lebanon is higher for boys than girls. Boys are more active than girls, with girls reporting reduced levels of physical activity.

For a given BMI, girls reflect a higher than expected percent body fat. Based on this, the prevalence of overweight and obesity among adolescent girls is expected to be higher than previously reported. Moreover, taking physical activity into account may possibly improve the relation between BMI and body fat.
PERSPECTIVE
The findings of this thesis provide various opportunities for future research into obesity and physical activity among adolescents in Lebanon. Obviously, periodical screening of the prevalence of overweight and obesity among adolescents is required in order to monitor patterns and trends. Moreover, in parallel to our work, we also suggest that a similar study should be conducted in boys. The results of such an effort would evaluate cut-off points and help compare genders for possible differences. Also, a large scale study that establishes new BMI cut-off points in girls is highly recommended. Such a study would enable researchers to estimate obesity with more accuracy. Furthermore, the cross sectional nature of our study limits our ability to establish a cause effect relation between physical activity and obesity. Therefore, there is a need for a longitudinal study that can further increase our understanding of the relation between physical activity and obesity, possibly by using more objective methods of measuring both parameters.
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PART 3: APPENDIX
APPENDIX A: General Questionnaire

Bonjour, et merci d'être la aujourd'hui pour repondre a ce questionnaire qui va servir a une etude epidemiologique sur l’adolescent libanais. Pour que nos resultats soient fiables, nous vous demandons de prendre votre temps pour repondre aux differentes questions du mieux que vous le pouvez.

Ceci n'est pas un test : Il n'y a pas de reponses fausses ou correctes. Il faut que vos reponses correspondent a votre mode de vie.

Ce questionnaire est totalement anonyme, personne de votre entourage ou de vos ami(e)s n'y aura acces. Le numero qui figure em haut du questionnaire assure votre anonymat. Ceci garanti votre anonymat memes pour les membre de notre equipe qui traiteront les resultats.

DONNEES GENERALES
- Adresse (juste mentionner la ville ou le village ou vous vivez) : _____________________
- Age : ____ ans
- Sexe : ___
- Classe : ______
- Si possible, quelle etait votre moyennes generale de l’anne derniere (/20 ou /100)

DONNEES ANTROPOMETRIQUES
- Taille : ______
- Poids : ______

DONNEES PHYSIOLOGIQUES
- Est-ce que vous etes pubere ?     Oui      Non
  • Est-ce que vous vous raserez ?   Oui      Non
  • Est-ce que vous avez des poils sous les bras ?  Oui      Non
- Pouvez vous si possible indiquer votre poids aux ages suivants (en utilisant votre carnet de sante ou avec l’aide de vos parents) ?
  • A la naissance : _____Kg
  • A 5 ans : __________Kg
  • A 10 ans : __________Kg
  • Avez-vous remarque une prise de poids avec la puberte ?   Oui      Non
  • Si oui pouvez-vous estimer de combien de kilo ? _____Kg

SANTE
- Avez vous une maladie chronique liee a l’obesite (diabetes, cholesterol...) :  Oui      Non
  • Si oui, laquelle : ______________

SITUATION FAMILIALE
- Etes-vous fils unique : Oui      Non
- Etes-vous l’ainee de la famille : Oui      Non
  • Si non quelle est votre place (ex : 2/3 si vous etes le deuxieme sur trois enfants) : ___/___
- Est-ce qu’un de vos freres ou soeurs (si vous en avez) a un exces de poids ?   Oui      Non
VOS HABITUDES

- Avez-vous l'habitude de prendre un petit-déjeuner
  Oui, toujours  Oui, de temps en temps  Non, jamais

- A votre avis, est-ce que votre alimentation est équilibrée ?  Oui  Non

- Avez-vous à la maison :
  • Une télévision :  Oui  Non
    o Combien de temps par jour passez-vous en moyenne à regarder la télévision
      ▪ Les jours d'école : ___h
      ▪ Les jours de vacances et le week-end : ___h
    o Avez-vous une télévision dans votre chambre ?  oui  non

  • Un ordinateur :  Oui  Non
    o Combien de temps par jour passez-vous en moyenne devant l'ordinateur
      ▪ Les jours d'école : ___h
      ▪ Les jours de vacances et le week-end : ___h

  • Des jeux vidéo :  Oui  Non
    o Combien de temps par jour passez-vous en moyenne à jouer
      ▪ Les jours d'école : ___h
      ▪ Les jours de vacances et le week-end : ___h

  • Combien de temps par jour passez-vous assis (lecture, cours de classe, bavardage entre ami(e)s) ? ___h

  - En moyenne combien d'heure dormez-vous par nuit ? ___h
    ▪ Jour avec école le lendemain : ___h par nuit
    ▪ Jour sans école le lendemain : ___h par nuit

  • Sieste (nombre d'heure par semaine) : ___h par semaine

ACTIVITÉS

- Participez-vous aux cours d'éducation physique et sportive (EPS) à l'école ?  Oui  Non
  • Si oui combien d'heure par semaine faites-vous ? ___h

- Participez-vous à une activité sportive régulière hors ou dans l'école ?  Oui  Non
  • Si oui laquelle ? ____________
  • Est-ce une activité de loisir ou de compétition ?  Loisir  Competition

- Allez-vous régulièrement à la piscine, à la patinoire ?  Oui  Non

- Comment venez-vous à l'école :
  A pieds  En velo  En voiture avec vos parents  En bus

- Combien de voiture avez-vous à la maison ? ___  avez-vous une pour vous ?  Oui  Non
QUESTIONS A PROPOS DE VOS PARENTS

- Votre maire vous a-t-elle allaite ?  Oui  Non
- Si oui pendant combien de temps ? ______ mois

- Donnes concernant vos parents :

<table>
<thead>
<tr>
<th>Ages (ans)</th>
<th>Pere</th>
<th>Mere</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taille (m)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poids (Kg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metier</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salaire mensuel (si possible)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Le niveau d’étude de vos parents

Pere : Diplome inferieur au Bac  Bac  Bac +3 (licence)  Bac +5 (master ou plus)
Mere : Diplome inferieur au Bac  Bac  Bac +3 (licence)  Bac +5 (master ou plus)

- Vos parents ont-ils une maladie liée à l’obesité ?  Oui  Non
  • Si oui, laquelle (diabete, cholesterol, hypertension arterielle, maladie cardiaque)… ?

- Pendant votre enfance (aux environs de 5 ans) vous etiez plutot : (demander aux parents)

  Peu actif  Moyennement actif  Tres actif
APPENDIX B : Physical Activity Questionnaire

1. **Sport:** A chaque fois vous précisez, les nombre de séance par semaine, le temps passé et l’intensité (léger/moyen/haute en se réferant à l’essoufflement, la sueur...)

   » » Exemple : 2 fois 1h30 d’éducation physique par semaine à intensité moyenne
   5 fois 15 minutes de foot à la recreation à intensité élevée

   • **A l’école :**

<table>
<thead>
<tr>
<th></th>
<th>Nombre de fois / semaine</th>
<th>Nombre d’heure ou de minutes / seance</th>
<th>Intensité (léger/moyen/haute)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Education physique et sportive</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recreation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Autre</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

• **En dehors de l’école :**

   ➢ **Club**

<table>
<thead>
<tr>
<th>Sport</th>
<th>Nombre de fois / semaine</th>
<th>Nombre d’heure ou de minutes / seance</th>
<th>Intensité (léger/moyen/haute)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

   Competition : Oui Non

   ➢ **A la maison**

<table>
<thead>
<tr>
<th></th>
<th>Sport</th>
<th>Nombre de fois / semaine</th>
<th>Nombre d’heure ou de minutes / seance</th>
<th>Intensité (léger/moyen/haute)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dans la semaine</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Week-end</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

   Renforcement musculaire (minutes par semaine)
   Étirement, assouplissement (minutes par semaine)
Appendix C: Pediatric Quality of Life Questionnaire

Au cours MOIS Dernier, les choses suivantes ont-elles été un problème pour toi

### MA SANTE ET MES ACTIVITES (problèmes avec)

<p>|</p>
<table>
<thead>
<tr>
<th>MA SANTE ET MES ACTIVITES (problèmes avec)</th>
<th>Jamais</th>
<th>Presque jamais</th>
<th>Parfois</th>
<th>Souvent</th>
<th>Presque toujours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1- J’ai des difficultés à marcher plus loin que le coin de la rue</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>2- J’ai des difficultés à courir</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>3- J’ai des difficultés à faire du sport ou de l’exercice</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>4- J’ai des difficultés à soulever un objet lourd</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5- J’ai des difficultés à prendre un bain ou une douche tout(e) seul(e)</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>6- J’ai des difficultés à aider dans la maison</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>7- Je ressens des soulever</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>9- Je manque d’énergie</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

### MES EMOTIONS (problèmes avec…)

<p>|</p>
<table>
<thead>
<tr>
<th>MES EMOTIONS (problèmes avec…)</th>
<th>Jamais</th>
<th>Presque jamais</th>
<th>Parfois</th>
<th>Souvent</th>
<th>Presque toujours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1- J’ai peur</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>2- Je me sens triste ou deprime(e)</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>3- Je me sens en colere ou enerve(e)</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>4- J’ai du mal a dormir</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5- Je m’inquiete de ce qui va m’arriver</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

### MES RELATIONS AVEC LES AUTRES ADOLESCENTS (problèmes avec…)

<p>|</p>
<table>
<thead>
<tr>
<th>MES RELATIONS AVEC LES AUTRES ADOLESCENTS (problèmes avec…)</th>
<th>Jamais</th>
<th>Presque jamais</th>
<th>Parfois</th>
<th>Souvent</th>
<th>Presque toujours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1- J’ai du mal a m’entendre avec les autres</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>2- Les autres ne veulent pas etre amis avec moi</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>3- Les autres se moquent de moi</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>4- Je ne peux pas faire certaines choses que les autres jeunes de mon age peuvent faire</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5- J’ai du mal a suivre les autres</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

### MES RELATIONS AVEC LES AUTRES ADOLESCENTS (problèmes avec…)

<p>|</p>
<table>
<thead>
<tr>
<th>MES RELATIONS AVEC LES AUTRES ADOLESCENTS (problèmes avec…)</th>
<th>Jamais</th>
<th>Presque jamais</th>
<th>Parfois</th>
<th>Souvent</th>
<th>Presque toujours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1- J’ai du mal a m’entendre avec les autres</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>2- Les autres ne veulent pas etre amis avec moi</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>3- Les autres se moquent de moi</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>4- Je ne peux pas faire certaines choses que les autres jeunes de mon age peuvent faire</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5- J’ai du mal a suivre les autres</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>
Appendix D: DXA whole-body scans
<table>
<thead>
<tr>
<th>Region</th>
<th>BMC (grams)</th>
<th>Fat (grams)</th>
<th>Lean (grams)</th>
<th>Lean+BMC (grams)</th>
<th>Total (grams)</th>
<th>% Fat (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L Arm</td>
<td>113.9</td>
<td>1888.8</td>
<td>1541.8</td>
<td>1654.8</td>
<td>2735.6</td>
<td>39.5</td>
</tr>
<tr>
<td>R Arm</td>
<td>129.6</td>
<td>988.6</td>
<td>1829.7</td>
<td>1959.2</td>
<td>2947.8</td>
<td>33.5</td>
</tr>
<tr>
<td>Trunk</td>
<td>497.9</td>
<td>9636.9</td>
<td>17974.9</td>
<td>19472.8</td>
<td>28309.7</td>
<td>34.7</td>
</tr>
<tr>
<td>L Leg</td>
<td>349.5</td>
<td>5394.4</td>
<td>6982.1</td>
<td>7251.6</td>
<td>12646.8</td>
<td>42.7</td>
</tr>
<tr>
<td>R Leg</td>
<td>338.9</td>
<td>5245.8</td>
<td>7283.4</td>
<td>7534.3</td>
<td>12779.3</td>
<td>41.0</td>
</tr>
<tr>
<td>SubTot</td>
<td>1428.0</td>
<td>22054.7</td>
<td>36545.9</td>
<td>36872.7</td>
<td>59418.4</td>
<td>37.9</td>
</tr>
<tr>
<td>Head</td>
<td>487.5</td>
<td>965.7</td>
<td>3667.6</td>
<td>4075.2</td>
<td>5042.9</td>
<td>19.2</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1828.3</td>
<td>23511.4</td>
<td>39119.5</td>
<td>40947.8</td>
<td>64459.3</td>
<td>36.5</td>
</tr>
</tbody>
</table>

*assumes 17.8% brain fat
LBM 73.2% water
Appendix E: Study One

November 27, 2009

Dear Mr. Abdallah Fazah,

We are glad to inform you that your article entitled
MS No.: PED-00365-2008.R1
Author: Abdallah Fazah
Co-Authors: Fazah, Abdallah; Jacob, Christophe; Moussa, Elie; elhage, rawad;
Youssef, Hala; Delamarche, Paul
Activity, Inactivity and Quality of Life among Lebanese Adolescents

was accepted on November 27, 2009 for publication in Pediatrics International,

Address for mailing:
Norikazu Shimizu, M.D., Editor-in-Chief,
Japan Pediatric Society,
4F Daiichi Magami Bldg, 1-1-5 Koraku,
Bunkyo-ku, Tokyo 112-0004, Japan

We appreciate your contribution to the journal.

Sincerely yours

Editor-in-Chief
Norikazu Shimizu
Pediatrics International
Original Article

Activity, inactivity and quality of life among Lebanese adolescents

Abdallah Fazzah,1 Christophe Jacob,1 Elie Moussa,1 Rawad El-Hage,1 Hala Yousef2 and Paul Delamarche2
1Laboratory of Physiology and Biomechanics of Motor Performance, Division of Physical Education, University of
Balmand, Tripoli, Lebanon and 2Laboratory of Physiology and Biomechanics of Muscular Exercise, University of Rennes
2-ENS Cachan, Rennes, France

Abstract

Background: The aim of the present study was to investigate recent overweight and obesity prevalence rates for
Lebanese adolescents, and to examine differences in physical activity, screen time (sum of time spent in front of TV,
computer, and videogames), and health-related quality of life (HRQOL) for the first time among normal, overweight,
and obese adolescents.

Methods: One thousand Lebanese adolescents (14–18 years old) from nine schools participated in the study. Height,
weight, physical activity, screen time, and HRQOL variables were assessed using validated self-report questionnaires.

Results: A total of 7.8% of boys and 1.75% of girls were obese, and 22.5% of boys and 12.47% of girls were overweight.
Normal-weight boys reported higher physical activity scores at school clubs than obese boys. Normal-weight girls
reported higher leisure time and total physical activity scores than obese girls. In the normal-weight group, boys reported
higher total screen time than girls. Normal-weight boys reported higher physical functioning scores than their obese
peers. Normal-weight girls reported higher physical functioning and average HRQOL scores than obese girls. Normal-
weight and overweight boys reported higher average HRQOL scores than girls.

Conclusion: The present study is the first to provide data on physical activity, screen time, and HRQOL among
Lebanese adolescents. Despite the need for further research, all those concerned with the pediatric population are urged
to develop and implement effective strategies to increase physical activity and improve HRQOL among adolescents
based on the present findings.

Key words: adolescence, obesity, physical exercise, quality of life.

During the past decades, studies have found an unprecedented rise in the prevalence of overweight and obesity among children and adolescents in many parts of the world.1-3 Studies have shown that obesity early in life has a definite impact on health associated with many diseases and disorders.4-6 There is also increasing evidence, however, that adolescent obesity may also be linked to psychosocial disorders. All these complications also have a devastating effect on the economy.7 From a public health perspective, obesity-related costs are not confined to the billions of dollars spent on direct medical expenses; it also includes indirect cause of lost productivity.8

Although research in the field of obesity has undertaken a multidimensional approach, the fact still remains that increases in bodyweight that lead to obesity are caused primarily by a disruption in the delicate homeostasis between energy intake and energy expenditure. Consequently, any parameter that may disrupt this balance may be considered a risk factor for the development of obesity. Physical activity and inactivity are factors that may influence the prevalence of obesity.9-11 especially because they are modifiable. Research has shown that physical activity in the form of scheduled exercise has definite acute effects on blood lipids, blood pressure, glucose homeostasis and immunological functions, thus it may improve overall health status in overweight and obese subjects irrespective of weight loss.12 Moreover, evidence suggests that certain forms of physical activity may significantly contribute to psychosocial health and lead to improvement of self-esteem, emotional well-being and self-perception in adolescents.13-17

Numerous studies concerned with young populations have been using the Pediatric Quality of Life Inventory (PedsQL) to assess the health-related quality of life (HRQOL) in children and adolescents. Assessment of HRQOL is a subjective method used to measure one’s physical, emotional and social health. Some studies have shown that obesity is associated with low HRQOL scores among children and adolescents.18-20 Indeed, clinical and population-based studies have shown that the HRQOL of adolescents may be lower in overweight and obese subjects.21-24

In Lebanon, an Asian republic with diverse religious backgrounds located at the east end of the Mediterranean, research on obesity is still in its early stages. Evidence suggests that obesity
FAZAH, Abdallah. Physical activity and obesity in Lebanese adolescents: prevalences, measurements and associations - 2010

Table 1  Variables used in self-report questionnaire

<table>
<thead>
<tr>
<th>Anthropometric measurements</th>
<th>Physical activity scores</th>
<th>Screen time</th>
<th>Pediatric Quality of Life scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age School</td>
<td>TV per weekday and per weekend</td>
<td>Physical functioning</td>
<td></td>
</tr>
<tr>
<td>Sex Health club</td>
<td>Computer per weekday and per weekend</td>
<td>Emotional functioning</td>
<td></td>
</tr>
<tr>
<td>Height Home</td>
<td>Videogame per weekday and per weekend</td>
<td>Social functioning</td>
<td></td>
</tr>
<tr>
<td>Weight Leisure</td>
<td>School functioning</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

in this region is following the same trend as in Western countries. 28-29 To our knowledge, however, there is no existing literature on physical activity, inactivity, and HRQOL among adolescents in the Middle East.

Thus, the aim of the present study is to assess physical activity, screen time (sum of time spent in front of TV, computer, and videogames), and HRQOL among normal, overweight, and obese adolescents in Lebanon.

Methods

The study population consisted of 1600 adolescents (14-18 years old). Participants were randomly selected from nine schools (three public and six private). The survey was presented in French because all the selected schools taught French as a second language. Each school was visited on separate occasions; our team met with the students during the physical education sessions and provided them with a detailed explanation of the whole survey.

The survey consists of four self-report questionnaires. In part 1, general and anthropometric data were collected. In part 2, a validated questionnaire was used to assess different aspects of physical activity. 30 Data in this section were computed using the MET system (1 MET = 3.5 mL oxygen consumed/kg of bodyweight/min) by means of the compendium of physical activity. 31 The results were expressed in MET/week.

In part 3, inactivity is expressed in hours, and defined as an activity that yields an energy expenditure less than or equal to that at rest (1.5 MET). Inactivity includes television viewing, computer usage and video games; playing on an hourly basis, separate timetables were compiled for schooldays and weekends.

Finally, in part 4, to assess HRQOL, we used the PedsQL 4.0 French version. 32 This questionnaire has been validated, with internal consistency reliability >0.7. It is made up of a total of 23 questions divided across four generic scales: physical (eight items), emotional (five items), social (five items), and school functioning (five items), in addition to a total score, which is the sum of all four components of the questionnaire. Scores range from 0 to 100, with higher scores representing a better QOL. A summary of the total questionnaire is provided in Table 1.

All protocols used in the present study were approved by the Ethics committee of the University of Balamand in Lebanon and the Ethics committee of the University of Rennes 2 in France.

Data are expressed as mean ± SD. Relations between body mass index (BMI), and variables of physical activity, inactivity, and PedsQL in boys and girls were analyzed using Kruskal–Wallis one-way analysis of variance on ranks; in the event of significance, all pairwise multiple comparison procedures (Dunn’s method) was performed. All statistical analysis was completed using SIGMA STAT (Jandel Scientific, San Jose, CA, USA). P < 0.05 was accepted as the minimal level of statistical significance.

Results

Some questionnaires were not included in the study due to incomplete data. Subjects older than 18 years of age and those with chronic physical disabilities were exempted from participation. In all, a total of 18 subjects were excluded from the analysis. The final sample included 982 adolescents, with boys representing 42.9%.

Based on international age- and sex-specific cut-off points, 33 the present results show that among Lebanese adolescents, 7.8% of boys and 1.75% of girls are obese, and 22.5% of boys and 12.47% of girls are overweight.

Physical activity among adolescents

Table 2 lists the physical activity scores of the girls who were assessed in the present study. In boys, scores for physical activity at health clubs were higher in the normal-weight group compared to the obese group. In contrast, in girls, leisure time physical activity and total physical activity scores were significantly lower in the obese group compared to the normal-weight and overweight group. There was also a trend for lower levels of physical activity among obese girls.

Table 2  Physical activity variables per week (MET) vs BMI grouping (mean ± SD)

<table>
<thead>
<tr>
<th></th>
<th>Boys</th>
<th>Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal</td>
<td>Obese</td>
</tr>
<tr>
<td>School</td>
<td>7.17 ± 1.7</td>
<td>5.54 ± 1.0</td>
</tr>
<tr>
<td>Health club</td>
<td>16.33 ± 21.9</td>
<td>10.47 ± 22.8</td>
</tr>
<tr>
<td>House</td>
<td>24.03 ± 29.7</td>
<td>28.81 ± 41.5</td>
</tr>
<tr>
<td>Leisure</td>
<td>80.1 ± 85.6</td>
<td>82.16 ± 72.0</td>
</tr>
<tr>
<td>Total PA</td>
<td>126.58 ± 108.9</td>
<td>122.65 ± 99.8</td>
</tr>
</tbody>
</table>

#Statistically significant difference.

BMI, body mass index; MET, metabolic equivalent; PA, physical activity.

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activity at school ($P = 0.063$) and at health clubs ($P = 0.067$) in the obese group. The results also show a significant gender difference in that boys reported significantly higher total physical activity scores than girls for the normal-weight, overweight, and obese groups ($P = 0.0001$, $P = 0.004$, and $P = 0.0024$, respectively).

**Inactivity among adolescents**

Screen time variables are shown in Table 3. Results yielded no significant group difference. Boys in the normal-weight group, however, had significantly higher total screen time than girls in the same group ($P = 0.004$); this gender difference was not seen across the overweight or obese group.

**HRQOL among adolescents**

The HRQOL variables are presented in Table 4. In boys, the normal-weight group reported a significantly higher physical functioning score than the obese group. In girls, the normal-weight group reported significantly higher physical functioning and average HRQOL scores as compared to the overweight group, and significantly higher social functioning scores as compared to the obese group. Results also show a significant gender difference ($P = 0.001$), in that boys reported higher average HRQOL scores than girls in both the normal and overweight group, this difference was not found in the obese group.

**Discussion**

The present results show that overweight and obesity among Lebanese adolescents is greater in boys than in girls. In a sample of 1000 Lebanese adolescents aged 14–18, we used internationally accepted BMI cut-off points, and found that 7.8% of boys and 1.7% of girls are obese, and 22.5% of boys and 12.4% of girls are overweight. A previous study using National Health and Examination Survey cut-off points found that 7.7% of boys and 2.9% of girls were obese and 29.9% of boys and 14.7% of girls were overweight. Moreover, another recent study using International Obesity Task Force cut-off points found that 10.1% of boys and 4.2% of girls are obese, and 28.8% of boys and 19.0% of girls are overweight. Because none of the BMI cut-off points have been validated against a direct measure of adiposity in Lebanon, there is a need to define new BMI cut-off points that are specific to the populations of the Middle East.

Obesity prevalence among Lebanese adolescents is lower than that of the USA and England, but close to those reported in 11–16-year-old Canadian youth, for whom prevalence rates were greater in boys than in girls. With respect to other Mediterranean countries, the present results are comparable to those reported in studies using a similar definition for overweight and obesity. Prevalence rates were very similar to those found in Spain and slightly higher than those reported in Greece. The Middle East we found that the prevalence of overweight and obesity among Lebanese boys is much higher than those reported among Turkish boys. In contrast, Lebanese girls have a slightly higher prevalence of overweight and a similar prevalence of obesity compared to Turkish girls. Compared to other Arabian countries, overweight and obesity prevalence is still much lower than that found in Qatar, Bahrain, and Saudi Arabia.

**Table 3** Screen time variables (h) vs BMI grouping (mean ± SD)

<table>
<thead>
<tr>
<th></th>
<th>Boys</th>
<th>Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal</td>
<td>Overweight</td>
</tr>
<tr>
<td>TV/school day</td>
<td>2.53±.14</td>
<td>2.77±.14</td>
</tr>
<tr>
<td>TV/weekend</td>
<td>4.85±.27</td>
<td>5.1±.26</td>
</tr>
<tr>
<td>Computer/school day</td>
<td>1.20±.11</td>
<td>1.17±.11</td>
</tr>
<tr>
<td>Computer/weekend</td>
<td>3.25±.24</td>
<td>3.23±.23</td>
</tr>
<tr>
<td>Videogame/school day</td>
<td>0.41±.08</td>
<td>0.26±.05</td>
</tr>
<tr>
<td>Videogame/weekend</td>
<td>1.31±.19</td>
<td>1.04±.15</td>
</tr>
<tr>
<td>Total screen time</td>
<td>26.3±13.6</td>
<td>30.4±12.2</td>
</tr>
</tbody>
</table>

Total screen time: (TV/school day) × 5 + (TV/weekend) + (computer/school day) × 5 + (computer/weekend) + (video game/school day) × 5 + (video game/weekend).

BMI, body mass index.

**Table 4** Health-related quality of life vs BMI grouping

<table>
<thead>
<tr>
<th></th>
<th>Boys</th>
<th>Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal</td>
<td>Overweight</td>
</tr>
<tr>
<td>Physical</td>
<td>85.8±12.7</td>
<td>82.6±13.4</td>
</tr>
<tr>
<td>Emotion</td>
<td>69.2±16.0</td>
<td>68.0±16.9</td>
</tr>
<tr>
<td>Social</td>
<td>85.4±15.5</td>
<td>83.7±15.1</td>
</tr>
<tr>
<td>School</td>
<td>76.6±17.4</td>
<td>77.0±15.1</td>
</tr>
<tr>
<td>Average</td>
<td>79.0±11.2</td>
<td>77.8±10.3</td>
</tr>
</tbody>
</table>

*Statistically significant difference.

BMI, body mass index.

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Physical activity

To our knowledge this is the first attempt to seriously assess physical activity, inactivity and pediatric quality of life among an adolescent population in the Middle East. The present results show a significant gender difference across all groups, in that boys reported higher physical activity levels than girls. This is in accordance with other studies. The present findings show that obese girls have significantly lower leisure time and total physical activity scores than the normal-weight and overweight groups. This may be partially due to the lack of access to public parks and safe playgrounds, which has been known to negatively affect physical activity among adolescents. Moreover, obese girls also reported suppressed social HRQOL functioning scores. This may explain why they stay away from participating in sports activities or even any type of group physical activity. This may well be the reason why obese girls reported no use of gyms or health clubs at all.

Further research is needed to determine if excess body fat is reducing the desire and/or interest for physical activity or whether decreased levels of physical activity is the cause of excess body fat. It is in the public health interest to establish physical activity guidelines and provide opportunities for the adolescent community, especially these with excess weight, to increase their levels of physical activity.

Inactivity

Inactivity has been linked to obesity among adolescents. Even though some studies show that television viewing, computer use and videogame playing may disrupt the body’s energy balance in many ways, the present results indicated no significant group differences in screen time variables in boys or in girls. One possible reason may be due to the fact that we assessed only screen time, and subjects might engage in other sedentary activities such as reading, playing cards or listening to music.

Compared with other studies, obese adolescents reported 19.11 ± 8.5 h per week of television viewing whereas US adolescents reported on average 21 h per week. Moreover, total screen time reported by obese boys (33.0 ± 15.2 h) and girls (29.6 ± 10.8 h) was higher when compared to that reported in another study among US boys (15.9 ± 0.53 h) and girls (20.3 ± 1.19 h), respectively.

Health-related quality of life

Numerous studies have demonstrated the impact of obesity on the HRQOL of adolescents. Moreover, there is some evidence that being overweight in childhood or adolescence may also affect future quality of life. Obese boys reported lower physical functioning scores than normal-weight boys. This finding is comparable to studies in adolescents that reported a decrease in physical functioning but not in emotional and school functioning scores. Poor HRQOL was more pronounced in girls. Indeed, overweight girls reported lower physical functioning and average HRQOL scores than normal-weight girls, and obese girls reported lower social functioning score than normal-weight girls. This may be partially explained with findings from other studies that found that obese adolescent girls have fewer friends and are more socially isolated than their normal-weight peers.

The boys in the normal-weight and overweight group reported higher average HRQOL scores than the girls. This difference was not seen in the obese group. Gender differences in HRQOL seem to disappear as obesity sets in. Thus, obesity among adolescents in Lebanon has similar implications for HRQOL among both boys and girls.

Despite certain limitations such as the use of an indirect measure to assess physical activity and the fact that the results are all self-reported, the present study is the first to provide data on physical activity, inactivity, and HRQOL among Lebanese adolescents. Although there is a need for further research, all those concerned with the pediatric population are urged to develop and implement effective strategies to increase physical activity and improve HRQOL among adolescents based on the present findings.

Acknowledgments

The authors would like to thank the schools and participants for their cooperation. This study was funded by a grant from the Projet Cedre.

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Physical activity and obesity in adolescents


6 Fazah et al.


© 2010 Japan Pediatric Society
FROM; Dr ADEL E.BERBARI
TO; Mr ABDALLAH FAZAH
September 25, 2009

I am pleased to inform you that your manuscript titled “BODY MASS INDEX AND BODY FAT IN LEBANESE FEMALE ADOLESCENTS” serial no.2009/4 has been accepted for publication. You will be informed subsequently of the volume and issue in which it will appear.

Sincerely

ADEL E.BERBARI, M.D., FACP, FAHA, FICA
PROFESSOR OF MEDICINE/PHYSIOLOGY
EDITOR IN CHIEF
LEBANESE MEDICAL JOURNAL
ABSTRACT • OBJECTIF : The aim of this study is to investigate the relation between body mass index (BMI) and body fat (BF) among Libyan adolescent females.

METHODS : 51 Libyan adolescent females aged 12 to 18 years participated in this study. BMI was calculated at weight/height². Adiposity was measured by dual energy X-ray absorptiometry (DEXA).

RESULTS : Correlation coefficient of percent body fat (%BF) with BMI is 0.82. Correlation coefficient of fat mass (BF) with BMI is 0.93. The two linear regression formulas are: %BF = 6.89 + (1.1 * BMI) and BF = 0.425 + (1.29 * BMI).

CONCLUSION : Correlations of BMI with DEXA measurements were higher with BF than %BF. For a given BMI, Libyan adolescent females have a higher than expected %BF. Based on the current findings, there may be a need to develop new cutoff points. From a public health perspective, this may considerably increase the prevalence of obesity among Libyan adolescent females.

INTRODUCTION

After being classified as a disease by the World Health Organization (WHO), obesity-related research has expanded widely. By definition, obesity is a pathological condition associated with excess adiposity [1-2]. The prevalence of overweight and obesity has increased in many parts of the world [3-4]. An even more shocking phenomenon is the global rise among children and adolescents [5]. The association of obesity with numerous health disorders has amplified the need for accurate assessment techniques of body fat (BF). However, these methods are usually complicated, expensive and time consuming, therefore making them inappropriate for population-based studies. This led to the development of indirect methods to estimate adiposity, among these, the most widely used is the body mass index (BMI), which is defined as weight (kg)/height squared (m²) [6]. Even though it is a measure of excess weight rather than excess body fat, studies have shown a high correlation between BMI and body fat [7-9]. By using appropriate cutoff points, BMI may be used to assess overweight and obesity. Adults with a BMI 25-30 are classified as overweight, whereas those with BMI >30 are classified as obese [9]. Other studies have also defined obesity based on BF. These studies suggest a body fat percent (%BF) of at least 25% of total body mass for men and 30-33% for women [10-11].
In children, age and sex specific BMI cutoff points have been developed and validated against direct measures of adiposity [12]. However, defining overweight and obesity in children is complicated by the fact that weight varies with height as children grow, this process is best described by Horkick in the title of his article, “Measuring a Moving Target” [13]. Moreover, several studies have suggested that the relationship between BMI and BF is affected by factors such as ethnicity and body build [14-18]. These limitations may become an important issue when assessing obesity in specific populations or when comparing ethnic groups with distinctly different body proportions. Indeed, these studies have suggested that universal cutoff points may not be used to accurately assess overweight and obesity in certain Asian populations and therefore they recommend the use of lower BMI cutoff points to define obesity [16-18].

In Lebanon and the Middle East, universal BMI cutoff points have been used to assess obesity [19]. However, the relation between BMI and BF has never been assessed. Thus the aim of this study is to determine the relation between BMI and BF among Lebanese female adolescents.

METHODS

Subjects

Fifty-one adolescent females aged 12 to 18 years were recruited from different schools to participate in this study. At the time of this study all subjects were at least twelve months ahead of their first menstruation.

Study design

Body weight was measured using an electronic scale (Tanita, Quincy) with a precision of 140 g/100 g. height was measured to the nearest 0.5 cm using a stadiometer (Seca model 222). BF was measured by dual energy X-ray absorptiometry (DEXA, Hologic QDR-4500W, Hologic Inc., Waltham, MA). The coefficient of variation was 0.54% for fat-free mass, and 1.13% for fat mass. Testing took place in a hospital setting under the direct administration of accredited technicians.

| TABLE I
DESCRIPTIVE CHARACTERISTICS OF THE FEMALE ADOLESCENTS (N = 51) |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>15.00</td>
<td>1.67</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>160.18</td>
<td>5.5</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>65.52</td>
<td>12.40</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>25.45</td>
<td>4.64</td>
</tr>
<tr>
<td>Fat free mass (kg)</td>
<td>39.07</td>
<td>5.63</td>
</tr>
<tr>
<td>BF (kg)</td>
<td>23.58</td>
<td>7.98</td>
</tr>
</tbody>
</table>

| % BF | 34.93   | 6.21    | 21.00-46.80 |

SD : standard deviation
BMI : body mass index
BF : body fat
NBF : body fat percent

A written consent was obtained from the subjects and their parents. Participation in the study was voluntary and subjects were free to withdraw at any time.

All procedures used in the study have been approved by both the Ethics committee of the University of Balamand in Lebanon, and that of the University of Rennes in France.

Statistics

The means and standard deviations were calculated for all clinical data (Table I). Linear regression analysis models were used to test the relationship between fat mass percentage and BMI, as well as fat mass with BMI and r² coefficients were reported. Data was analyzed with NCSS (2001). A level of significance of p < 0.05 was used.

RESULTS

Description of study subjects

Descriptive information of the subjects are found in Table I. The participants were classified according to the widely used age and gender specific BMI cutoff points [11] as follows; 16 normal weight, 24 overweight, and 11 obese.

Correlation between DEXA measurements and anthropometric measurements

Correlation of %BF by DEXA with BMI is 0.82. Correlation of BF by DEXA with BMI is 0.93, both values at p < 0.0001. Figure 1 shows a scatter diagram of the association between %BF by DEXA and BMI, including best fit lines for the regression of %BF on BMI. On the other hand, figure 2 shows a scatter diagram of the association between BF by DEXA and BMI.

The two linear regression formulas are:

%BF = 6.80 + (1.1 *BMI) and
BF = 0.425 + (1.29 *BMI).

After checking the correlations, we tried to compare %BF as estimated from the internationally accepted BMI cutoff points, and %BF as found by DEXA measurements in this study. Most studies suggest that %BF cutoff values for obesity in adolescent girls is between 36-37% [20-22]. By using the linear regression formula obtained in our study, a BMI of 30 kg/m² yields a %BF of 39.19. This value falls above the accepted range. In fact, it is even slightly higher than that found in adult female Taiwanese subjects [23]. Based on the current findings, a %BF of 33 would reflect a BMI of 23 kg/m².

DISCUSSION

As mentioned earlier, several studies have suggested that the relationship between BMI and %BF may differ between populations. These findings recommend the development of population specific BMI cutoff points based on age, gender, and ethnicity [8-11].

This study shows that BMI is highly correlated with measures of body fat obtained by DEXA. This finding supports previous research which shows that although
BMI has some flaws, it can be used for the initial screening of obesity [24-25].

The correlations of BMI with DEXA measurements in this study group were higher with FM (r = 0.93) than %BF (r = 0.82). These results were similar to those reported in a study conducted in Italian children adolescents [24].

From these results we conclude that even though BMI is used to assess obesity in epidemiological studies and initial screening, it provides only a limited insight to the degree of obesity based on the percent body fat. Because of this, results should be interpreted with caution since the cutoffs currently used cannot detect subjects who have a higher than expected %BF for a given BMI. Perhaps this may show that the low prevalence of obesity previously reported in adolescent girls [19] may be more due to methodological causes.

One of the limitations of this study is the fact that it is conducted only in adolescent girls. However, our interest was restricted to this group because previous epidemiological studies reported very low prevalence of obesity in this population [19].

Finally, based on the current findings, one can suggest that a BMI cutoff point of 23 may be a more suitable alternative for the assessment of obesity in adolescent girls. From a public health perspective, this finding may considerably increase the prevalence of obesity among Lebanese female adolescents.

ACKNOWLEDGEMENTS

This study was funded by a grant from the University of Balamand Research Committee and the “Projet Cèdre” Committee.

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Appendix G: Study Three

Date: Sep 29, 2010
To: "Abdallah Fazah" abdallah.fazah@balamand.edu.lb
From: "Science & Sports" ppesquies@dbmail.com
Subject: SCISPO - Your Submission

Ms. Ref. No.: SCISPO-D-10-00047R1
Title: Taking physical activity level into account improves body fat estimation in girls
Science & Sports

Dear Mr. Abdallah Fazah,

I am pleased to confirm that your paper "Taking physical activity level into account improves body fat estimation in girls" has been accepted for publication in Science & Sports.

Thank you for submitting your work to this journal.

With kind regards,

Pierre Pesquiès
Editor in Chief / Redacteur en chef
Science & Sports
## Appendix H: Compendium of Physical Activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>Duration</th>
<th>Level of Effort</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking</td>
<td>30 minutes</td>
<td>Light to moderate effort</td>
</tr>
<tr>
<td>Jogging</td>
<td>20 minutes</td>
<td>Moderate effort</td>
</tr>
<tr>
<td>Running</td>
<td>15 minutes</td>
<td>High effort</td>
</tr>
<tr>
<td>Swimming</td>
<td>45 minutes</td>
<td>Moderate effort</td>
</tr>
<tr>
<td>Cycling</td>
<td>60 minutes</td>
<td>Light to moderate effort</td>
</tr>
<tr>
<td>Yoga</td>
<td>60 minutes</td>
<td>Low effort</td>
</tr>
<tr>
<td>Aerobics</td>
<td>45 minutes</td>
<td>Moderate effort</td>
</tr>
<tr>
<td>Cardio</td>
<td>30 minutes</td>
<td>Light to moderate effort</td>
</tr>
<tr>
<td>Elliptical</td>
<td>30 minutes</td>
<td>Moderate effort</td>
</tr>
<tr>
<td>Treadmill</td>
<td>30 minutes</td>
<td>Light to moderate effort</td>
</tr>
</tbody>
</table>

*Note: The table above lists various types of physical activities along with their associated durations and level of effort.*
<table>
<thead>
<tr>
<th>Code</th>
<th>Activity</th>
<th>Duration</th>
<th>Occurrence</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0700</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0720</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0740</td>
<td>Inactivity, quiet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0760</td>
<td>Inactivity, quiet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0780</td>
<td>Inactivity, quiet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0800</td>
<td>Inactivity, quiet</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>0820</td>
<td>Inactivity, quiet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0840</td>
<td>Inactivity, quiet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0860</td>
<td>Inactivity, quiet</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>0880</td>
<td>Inactivity, quiet</td>
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<td></td>
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<tr>
<td>0900</td>
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<tr>
<td>1200</td>
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</tbody>
</table>

FAZAH, Abdallah. Physical activity and obesity in Lebanese adolescents: prevalences, measurements and associations - 2010
<table>
<thead>
<tr>
<th>Code</th>
<th>Activity Description</th>
<th>Calories burned per hour</th>
<th>Running speed (5.5 mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11580</td>
<td>Sitting</td>
<td>13.5</td>
<td>8.0 mph (3.9 min/mile)</td>
</tr>
<tr>
<td>12080</td>
<td>Running</td>
<td>14.0</td>
<td>8.0 mph (3.9 min/mile)</td>
</tr>
<tr>
<td>12190</td>
<td>Running</td>
<td>15.0</td>
<td>8.0 mph (3.9 min/mile)</td>
</tr>
<tr>
<td>12250</td>
<td>Running</td>
<td>16.0</td>
<td>8.0 mph (3.9 min/mile)</td>
</tr>
<tr>
<td>12280</td>
<td>Running</td>
<td>17.0</td>
<td>8.0 mph (3.9 min/mile)</td>
</tr>
<tr>
<td>12300</td>
<td>Running</td>
<td>18.0</td>
<td>8.0 mph (3.9 min/mile)</td>
</tr>
<tr>
<td>12330</td>
<td>Running</td>
<td>19.0</td>
<td>8.0 mph (3.9 min/mile)</td>
</tr>
<tr>
<td>12350</td>
<td>Running</td>
<td>20.0</td>
<td>8.0 mph (3.9 min/mile)</td>
</tr>
</tbody>
</table>

FAAZH, Abdallah. Physical activity and obesity in Lebanese adolescents: prevalences, measurements and associations - 2010

Official Journal of the American College of Sports Medicine
15310 4.0 Sports, Horseback riding, general
15320 3.5 Sports, Horseback riding, saddling horse
15330 3.5 Sports, Horseback riding, trail riding
15400 2.5 Sports, Horseback riding, walking
15410 2.0 Sports, Horseback riding, walking
15420 1.5 Sports, Judo, kaju, karate, kick boxing, tae kwon do
15430 1.0 Sports, Judo, karate, kung fu, karate, kung fu
15440 4.0 Sports, Juggling
15450 7.0 Sports, Kite-flying
15460 8.0 Sports, Lacrosse
15470 4.0 Sports, Motor-cross
15480 9.0 Sports, Orienteering
15490 10.0 Sports, Paddleball, competitive
15500 8.0 Sports, Paddleball, casual, general (T.480)
15510 8.0 Sports, Polo
15520 9.0 Sports, Road bike, competitive
15530 7.0 Sports, Road bike, casual, general (T.470)
15540 11.0 Sports, Rock climbing, crossing rock
15550 8.0 Sports, Rock climbing, repelling
15560 5.5 Sports, Rope jumping, fast
15570 10.0 Sports, Rope jumping, moderate, general
15580 8.0 Sports, Rope jumping, slow
15590 10.0 Sports, Rugby
15600 3.0 Sports, Shuffleboard, lawn bowling
15610 5.0 Sports, Skiing
15620 7.0 Sports, Snorkeling, scuba (T.360)
15630 3.5 Sports, Synchronized swimming, general (T.440)
15640 4.0 Sports, Swimming, scuba diving, general (T.430)
15650 5.0 Sports, Swimming, synchronized, general (T.430)
15660 5.0 Sports, Table tennis, ping pong (T.410)
15670 4.0 Sports, Tai chi
15680 6.0 Sports, Tennis, doubles (T.430)
15690 6.0 Sports, Tennis, singles (T.430)
15700 3.5 Sports, Trap shooting
15710 4.0 Sports, Volleyball, competitive, gymnasium (T.400)
15720 3.0 Sports, Volleyball, noncompetitive, 8-9 members, general
15730 6.0 Sports, Volleyball, beach
15740 6.0 Sports, Water skiing, general
16100 2.0 Transportation, Automobile or light truck (not a semi)
16110 2.0 Transportation, Driving, car (not a semi)
16120 2.0 Transportation, Driving, car (not a semi)
16200 2.0 Transportation, Driving, car (not a semi)
16210 5.0 Transportation, Driving, car (not a semi)
16220 3.0 Transportation, Driving, car (not a semi)
16230 10.0 Transportation, Driving, car (not a semi)
16240 8.0 Transportation, Driving, car (not a semi)
16250 8.0 Transportation, Driving, car (not a semi)
16260 10.0 Transportation, Driving, car (not a semi)
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16280 11.0 Transportation, Driving, car (not a semi)
16290 8.0 Transportation, Driving, car (not a semi)
16300 6.0 Transportation, Driving, car (not a semi)
16310 6.0 Transportation, Driving, car (not a semi)
16320 8.0 Transportation, Driving, car (not a semi)
16330 8.0 Transportation, Driving, car (not a semi)
16340 10.0 Transportation, Driving, car (not a semi)
### APPENDIX 1. Compendium of Physical Activities

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0109</td>
<td>8.5 Bicycling, 10 mph, general, off trail, slow, light effort</td>
</tr>
<tr>
<td>0110</td>
<td>4.0 Bicycling, 10 mph, general, off trail, slow, light effort</td>
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<td>0120</td>
<td>8.0 Bicycling, 10-10 mph, general, off trail, slow, light effort</td>
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<tr>
<td>0130</td>
<td>10.0 Bicycling, 10-10 mph, general, fast, vigorous effort</td>
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<td>0140</td>
<td>12.0 Bicycling, 10-10 mph, general, fast, vigorous effort</td>
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<td>0150</td>
<td>16.0 Bicycling, 10-10 mph, general, fast, vigorous effort</td>
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<tr>
<td>0160</td>
<td>5.0 Bicycling, 10-10 mph, general, fast, vigorous effort</td>
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<tr>
<td>0170</td>
<td>9.0 Bicycling, 10-10 mph, general, fast, vigorous effort</td>
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<tbody>
<tr>
<td>0200</td>
<td>8.0 Conditioning exercise, general, 100 W, very light effort</td>
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<tr>
<td>0260</td>
<td>10.0 Conditioning exercise, general, 400 W, vigorous effort</td>
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### APPENDIX 1. Compendium of Physical Activities - continued

<table>
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<td>10.0 Conditioning exercise, general, 500 W, vigorous effort</td>
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<tr>
<td>0290</td>
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FAZAH, Abdallah. Physical activity and obesity in Lebanese adolescents: prevalences, measurements and associations - 2010
**English Abstract**

Obesity is a pathological excess of body fat. An environment with boundless food availability, and an increasingly sedentary lifestyle coupled with less chances for PA creates the perfect setting for obesity.

Previous studies in Lebanon show that prevalence of obesity in adults is significant. Suggested causes include low physical activity, inactive lifestyle, and nutritional intake. However, in adolescents, research shows that prevalence is low among girls as compared to boys, and as compared to girls in other countries.

The first aim was to assess the prevalence of overweight and obesity among Lebanese adolescents and to examine correlates of physical activity, inactivity, and quality of life with BMI status. The second aim was to determine the relation between Body Mass Index and percent body fat among girls and to investigate the effect of physical activity on this relation.

The work in this thesis was conducted across two phases. In phase one, 1000 participated. They completed a self-report questionnaire made up of several sections. Data from this phase was used in study 1. In phase two, 65 adolescent girls were recruited. Body weight and height were measured by standard anthropometric procedures. DXA whole body scans were performed and subjects completed a physical activity questionnaire. Data from this phase was used in study 2 and 3.

In Study one, based on international BMI cut off points, the prevalence of overweight and obesity is 22.5% and 7.8% in boys respectively, and 12.47% and 1.78% in girls respectively. Boys are more active than girls. Obesity in adolescence impairs quality of life and is more pronounced in girls.

Study two shows that girls demonstrate a higher body fat for a given BMI, based on this, the current prevalence of overweight and obesity is underestimated. Finally, study three suggests that by adding a simple validated self report questionnaire for physical activity, it may be possible to improve the relation between BMI and %BF.

**Keywords:** Adolescents, Body fat, BMI, Physical activity, Quality of life
Résumé en Français

L’obésité est une pathologie définie par un excès de masse grasse. Un environnement caractérisé par une disponibilité illimitée de la nourriture, une augmentation de la sédentarité associée à une baisse de l’activité physique entraîne un état favorable à l’installation de l’obésité.

Les études menées au Liban montrent que la prévalence de l’obésité chez les adultes est importante. Les causes responsables de l’obésité sont nombreuses : le niveau faible d’activité physique, la sédentarité et l’augmentation des apports nutritionnels. Néanmoins, il a été montré que les filles Libanaises sont moins touchées par l’obésité et le surpoids par rapport aux garçons Libanais et aux filles dans d’autres pays.

Le premier but de cette thèse est d’évaluer les prévalences du surpoids et de l’obésité chez les adolescents Libanais et d’explorer les relations entre le niveau d’activité physique, l’inactivité, la qualité de vie et le statut pondéral. Le deuxième but était de déterminer la relation entre l’indice de masse corporelle et le pourcentage de masse grasse chez les adolescentes Libanaises et d’explorer l’influence du niveau d’activité physique sur cette relation.


L’étude 1, se basant sur les valeurs de références mondiales de l’IMC correspondant au surpoids et à l’obésité montre qu’au Liban, 22,5 % et 7,8 % des garçons sont en surpoids et obèses respectivement. Chez les filles, 12,4 % sont en surpoids et 1,7 % sont obèses. Les garçons étant plus actifs que les filles. L’obésité pendant l’adolescence altère la qualité de vie chez les deux sexes et surtout chez les filles.

L’étude 2 montre que pour un IMC donné, les adolescentes libanaises affichent un pourcentage de masse grasse beaucoup plus élevé que prévu. Dès lors, les prévalences d’obésité et du surpoids dans la population Libanaise sont sous-estimées. Enfin, l’étude 3 suggère qu’en ajoutant un simple auto-questionnaire validé, il est possible d’améliorer la relation entre l’indice de masse corporelle et le pourcentage de masse grasse.

Mots clés : Adolescents, Graisse corporelle, IMC, Activité physique, Qualité de vie.