Predictive Factors and Methods of Assessing Physical Activity and Adiposity in Adults

Resource Guide

February 21, 2008

The University of Texas at Austin

Esbelle Jowers, Ph.D.

John Bartholomew, Ph.D.

Rebecca Garza, B. A.

Resource Guide Table of Contents

I. Introduction **5**

II. Overweight & Obesity Risk Factors & Prevalence in Adults **5-10**

a. Psychosocial Factors 6-7

1. Mood and Emotion 6
2. Socioeconomic Status 6-7

b. Environmental and Behavioral Factors 7-10

1. Dietary Intake 7-8
2. Sedentary Behavior 8-9
3. Exercise 9-10

c. Summary 10

III. Adiposity/Body Composition Measurement in Adults **11-26**

a. Field Measures 11-16

1. Body Mass Index 11-12
2. Skinfolds/Anthropometry 13-14
3. Girth/Circumference 14
4. Bioelectrical Impedance Analysis 14-15
5. Adiposity: Field Measures Resource Chart 16

b. Laboratory Measures 17-26

1. Densitometry 17
2. Dual Energy X-ray Absorptiometry 17-18
3. Hydrostatic/Underwater Weighing 18-19
4. Air Displacement Plethysmography 20-21
5. Magnetic Resonance Imaging 21-22
6. Computed Tomography 22
7. Isotopic Dilution 22-24
8. Summary 24
9. Adiposity: Laboratory Measures Resource Chart 25-26

IV. Physical Activity Measurement in Adults 27-38

a. Electronic Devices 27-33

1. Pedometers 27-29
2. Accelerometers 29-30
3. IDEEA 30-31
4. Heart Rate Monitors 31-32
5. Assessing Physical Activity: Electronic Devices Resource Chart 33

b. Other Measures 34-38

1. Self-Report Methods 34-36

2. Direct Observation 36

3. Interviews 36-37

4. Summary 37

5. Assessing Physical Activity: Other Methods

Resource Chart 38

General Summary of Resource Guide 39

V. References 40-45

Introduction

There are two main purposes of this report. First, it can be used to learn about the predictive factors for overweight/adiposity and physical activity in adults. Second, it is to serve as a resource guide in determining what methods are available to measure adiposity and physical activity in adults, identify which methods are most suitable for use in communities and which are more useful in research settings, and provide a discussion of the values and limitations of each of the methods identified.

I. Overweight & Obesity Risk Factors & Prevalence in Adults

According to the 2003-2004 National Health and Nutrition Examination Survey (NHANES), about 66% of adults in the United States are considered either overweight or obese (CDC 2007e). Additional data revealed that the prevalence of obesity among 20-74 year olds in the U.S. has increased from 15% in the 1976-1980 survey to 32.9% in the 2003-2004 survey (CDC 2007c). Standard definitions for overweight and obesity are based on an individual's body mass index (BMI). A BMI between 25 and 29.9 classifies an individual as overweight, and a BMI of 30 or higher classifies the individual as obese (CDC 2007b).

Overweight and obese individuals have a greater risk for the development of specific health consequences such as hypertension, osteoarthritis, dyslipidemia, Type 2 diabetes, coronary heart disease, stroke, gallbladder disease, sleep apnea and respiratory problems, and some cancers (endometrial, breast, and colon) (CDC 2007f). The United States Department of Health & Human Services (USDHHS) states that approximately 300,000 deaths each year are attributed to obesity, and the risk of dying increases as an individual's weight increases

(USDHHS 2007). Additionally, obese individuals are at 50-100% increased risk of dying prematurely when compared to individuals at a healthy weight (USDHHS 2007).

The economic cost of obesity in the United States is huge. In the year 2000, obesity cost the United States about $117 billion where $61 billion was direct costs and $56 billion was indirect (CDC 2007e). It is obvious that obesity is a grave problem in the United States that must be addressed.

Multiple factors exist that influence the likelihood of an adult to become overweight or obese. These factors include psychosocial factors, environmental factors, and behavioral factors.

a. Psychosocial Factors

1. Mood and Emotion

Food is often used as a coping strategy for individuals that are experiencing stress or negative emotions. As stated by Insel & Roth, "eating can provide a powerful distraction from difficult feelings—loneliness, anger, boredom, anxiety, shame, sadness, inadequacy." Additionally, food is used by individuals to fight off decreased mood, energy, or self-esteem. Since food is used to regulate the individual's emotions, binge eating or irregular eating patterns can develop which increases the risk of becoming overweight and developing obesity (Insel & Roth, 2004).

2. Socioeconomic Status

Socioeconomic status (SES) "influences an individual's access to resources, knowledge of nutrition and health, food choices, and physical activity at work and in leisure time." Studies have shown that within industrialized countries, "low-SES groups are more likely to be obese than their high-SES counterparts." Also, research has shown that low-SES

and minority groups within the United States have a higher frequency of obesity (Zhang & Wang, 2004).

At lower income levels, more women tend to be obese than men, and the opposite occurs at higher income levels. Suggested reasons for these gender differences is that higher income women may be more concerned about maintaining a thin appearance, and they have increased access to nutrition information and low-fat/low-calorie foods (Insel & Roth, 2004).

b. Environmental and Behavioral Factors

1. Dietary Intake

An increase in energy intake without a corresponding increase in energy expenditure can lead to the development of obesity. In other words, according to the CDC, weight gain occurs when the calories consumed are greater than the calories used (CDC 2007d). Higher calorie consumption can be attributed to several things. The trend of increasing portion sizes offered by food retailers is a major factor in increasing calorie consumption. Young and Nestle state that, "restaurants are using larger dinner plates, bakers are selling larger muffin tins, pizzerias are using larger pans, and fast-food companies are using larger drink and french fry containers." In addition, the inexpensive "supersizing" of menu items at fast-food restaurants is detrimental to the average American. For example, in 2001, McDonald's supersize weighed almost an ounce more than the 1998 supersize, and their supersize soda was almost one third larger than the large size (Young & Nestle, 2002). If the individual does not burn off these extra calories, an increase in weight will most likely occur.

Increased caloric consumption also results from the convenient access to and availability of fast food and prepackaged food. Although convenient and inexpensive, these types of foods tend to be "high in fat, sugar, and calories" (CDC 2007d). Frequent consumption of convenience

foods paired with physical inactivity may lead to calorie imbalance and weight gain. Additionally, the lifestyles of Americans have become a lot more stressful. Their time is often limited inside the home due to extensive work hours; therefore, less time is spent on preparation and planning of meals. This leads to disordered eating patterns which decrease the occurrence of relaxed home meals (Cummings, Parham & Strain, 2005). A 1999 study revealed that 46% of food expenses in families were spent on food and drinks outside of the home (Nicklas, Baranowski, Cullen & Berenson, 2001). Another study showed that 34% of total food expense was used on fast foods (Nicklas et al., 2001).

2. Sedentary Behavior

Sedentary behavior among U.S. adults is quite common. Technological development has made it easier for individuals to fail to engage in physical activity across all socioeconomic classes (Zhang & Wang, 2004). These types of advancements increase the time spent at a computer or recreational videos games and decrease the time spent exercising, therefore leading to the risk of becoming overweight or obese.

Television watching is another behavior that is associated with a sedentary lifestyle. A 1997 survey revealed that adult males spent about 29 hours weekly watching television, and adult females spent about 34 hours weekly (Hu, Li, Colditz, Willet & Manson, 2003). Television watching was shown to be significantly associated with the risk of the development of obesity among adult women. One potential reason for this association is that watching television reduces the time spent exercising or replaces it altogether. Also, individuals usually eat while watching TV, therefore increasing their caloric consumption (Hu et al., 2003). With a reduction in exercise time and an increase in caloric consumption, the individual will most likely gain weight.

The same study of women also showed that occupations where the individual sits or stands for many hours are significantly related to the risk of obesity (Hu et al., 2003). Again, this is due to the lack of energy expenditure that is required to avoid weight gain. Other contributors to sedentary behavior are the increase in elevators in worksites, apartment buildings, and malls, and the fact that Americans usually drive to work rather than walk (Zhang & Wang, 2004). An individual might decide not to walk to work or a store because of the lack of sidewalks or concerns about crime (CDC 2007d; Zhang & Wang, 2004).

3. Exercise

As revealed by the Behavioral Risk Factor Surveillance System (BRFSS), only 25% of adults in the United States meet the recommended 30 minutes of leisure-time physical activity on most days of the week (Manson, Skerrett, Greenland & VanItallie, 2004). Also, only 15% of U.S. adults get the recommended amount of vigorous activity. On the downside, more than 60% of adults in the United States do not participate in the amount of physical activity that is recommended (Wellman & Friedburg, 2002). The Center for Disease Control states that 25% of American adults do not participate in any physical activity at all (CDC 2007h). Additionally, about 50% of individuals who begin an exercise program end up quitting within six months to a year (Segal, Evans, Johnson, Smith, Colletta & Gayton, 2001). Physical activity burns the calories that are consumed by an individual; therefore, it is important for individuals to engage in activity to maintain a healthy body weight and prevent obesity (CDC 2007d).

There are many health benefits that can be achieved through engagement in physical activity such as a decreased risk of heart disease, stroke, hypertension (high blood pressure), certain cancers, Type 2 diabetes, total and LDL (bad) cholesterol levels, and feelings of depression or anxiety. Physical activity can also help maintain strong bones and muscles,

increase HDL (good) cholesterol levels, promote psychological well-being, and reduce feelings of stress.

It is recommended by the American College of Sports Medicine (ACSM 2007) and the Centers for Disease Control for adults to participate in physical activity of moderate intensity for at least 30 minutes on 5 or more days per week. If participating in vigorous intensity physical activity, the individual should be engaged for at least 20 minutes on 3 or more days per week. A moderate intensity activity is any activity that burns from 3.5-7 calories per minute. Types of moderate intensity activities include brisk walking, dancing, swimming for recreation, or bicycling. Vigorous intensity type activities include jogging, aerobics, and swimming continuous laps where the individual would burn more than seven calories per minute (CDC 2007g).

Summary

Overweight and obesity levels in adults can be attributed to psychosocial, environmental, and behavioral factors. Psychosocial factors such as mood, emotion, and SES can greatly influence an individual's weight category. Environmental factors and behavioral factors such as dietary intake, sedentary behavior, and exercise, are important contributors to adult weight categories.

II. Adiposity/Body Composition Measurement in Adults

Introduction

Integral to the study of overweight in adults are the capabilities to measure adiposity. Methods to determine adiposity may be divided into two types of measures: field measures and laboratory measures. Field measures discussed include Body Mass Index (BMI), Skinfolds, Girth/Circumference, and Bioelectrical Impedence Analysis (BIA). The laboratory measures include Densitometry, Dual Energy X-ray Absorptiometry (DEXA), Hydrostatic/Underwater weighing, Air-displacement Plethysmography, Magnetic Resonance Imaging (MRI), Computed Tomography (CT), and Isotopic Dilution. A description and discussion of strengths and limitations of each type of measurement, as well as resource charts for quick reference follow.

a. Field Measures

1. Body Mass Index

Body Mass Index (BMI) is a number that is calculated by using the height and weight measurements of an individual. The formula used for this calculation is the weight in kg divided by height in meters squared (BMI=weight (kg)/ [height (m)]^2) (CDC 2007a). For an individual 20 years and older, the number that is calculated places him/her within a certain category of weight status. If the BMI is below 18.5, the person is placed into the category of "Underweight." If the BMI is between 18.5 and 24.9, the person is in the "Normal" category. A BMI between 25.0 and 29.9 places the individual within the "Overweight" category, and an individual with a BMI of 30.0 or above is placed into the "Obese" category (CDC 2007a). (See Figure 1).

Figure 1. Body Mass Index.

Body Mass Index	Weight Status
<18.5	Underweight
18.5-24.9	Normal
25.0-29.9	Overweight
≥ 30.0	Obese

BMI has been shown to be a significant predictor of both cardiovascular disease and Type 2 diabetes (Heyward & Wagner, 2004). Because of this relationship, and its simple calculation, BMI is useful when examining large groups of people for assessing risk for overweight or weight status.

There are limitations to using BMI as a tool for the assessment of body fat. There is a strong correlation between BMI and body fat, but there is variation by sex, race, and age. For example, women tend to have more body fat than men, and older adults tend to have more body fat than younger adults. Additionally, BMI can be problematic for highly trained athletes. These individuals often have high BMI's due to their increased amounts of muscle mass, rather than increased body fat (CDC 2007a). Therefore, he/she would be misclassified as "overweight" or "obese." Subjects who receive high BMI measurements should be tested further for percent body fat using other methods. Due to the low sensitivity of BMI, it should be used for screening, and caution should be taken when interpreting results (Heyward, 1996).

2. Skinfolds/Anthropometry

Adiposity (level of fatness) is frequently assessed through measures of skinfold thickness. Skinfold measures are taken with a skinfold caliper, a handheld tool that measures the thickness of skin as it is pinched by the experimenter. This procedure is designed to measure the layers of fat underneath the skin. The standard sites that are used vary depending on gender. For males, measurements are taken from the chest, abdomen, and thigh. For females, measurements are taken from the tricep, suprailiac, and thigh. (See Heyward & Wagner, 2004 for all possible sites). When using the skinfold method, the researcher uses the thumb and forefinger to pinch the skinfold site, pulls the skin away from the body, and places the calipers upon the fold (Wagner & Heyward, 1999). All measurements are taken from the right side of the body, as standard practice in the United States (Heyward & Wagner, 2004), and a minimum of 2 measurements should be taken per site. The resulting numbers are then used to calculate body density and then converted to percent body fat using a conversion formula that is population-specific. (See Heyward & Wagner, 2004 for equations).

Pricing for skinfold calipers can range anywhere from $8.75-$435.00. However, the cheaper the caliper, the less accurate it is in predicting body fat. For example, a plastic skinfold caliper can be purchased for a cheap price, but it is not suitable for professional use due to its lack of accuracy. On the other hand, the Skyndex I ($435.00) is a computerized digital caliper with the formula built into the device for both men and women which makes it more accurate, but it is very expensive.

The skinfold technique is based on two assumptions: thickness of subcutaneous fat (fat just beneath the skin) reflects a constant proportion of total body fat and that the sites used for measurement represent the averaged thickness of subcutaneous fat (Heyward, 1996).

Many factors affect the accuracy of skinfold measurements, including skill of the technician, types of calipers, and the prediction equations used (Heyward & Wagner, 2004). However, accuracy can be increased by following the standardized procedures for using skinfold calipers. In addition, accurate results can be obtained on lean subjects, but it is difficult to maintain this level of accuracy with older adults due to loose connective tissue and obese individuals with larger skinfolds (Wagner & Heyward, 1999).

3. Girth/Circumference

Girth or circumference measurements are field measures designed to estimate body fat by measuring circumference of an individual's waist, hips, chest, arm, and thigh, typically with a tape measure. Equations are then used to estimate body fat.

This is a simple and very cost-effective method that uses tape measure ranging from $3.50-$22.00 which makes it useful for screening large populations. This measurement is also useful in assessing change in fat distribution, which is particularly useful as a motivational tool for those participating in an intervention or weight loss program, and in assessing risk for diabetes (Koh-Baneriee, Wang, Hu, Spiegelman, Willett, & Rimm, 2004). Girth measurements are often used in concert with skinfold measurements to increase accuracy (Goran, 1998). Additionally, waist circumference is a useful measure in predicting insulin resistance, a risk factor for diabetes. Waist circumference is very useful when an individual's BMI is lower than 35, and it is a better predictor of illness risk than BMI in Asian American populations over the age of 65 (Cummings et al., 2005; Bray & York, 1997).

4. Bioelectrical Impedance Analysis

Bioelectrical Impedance Analysis (BIA) is a method in which total body weight is estimated through a low-level electrical current that is passed through the subject's body. The impedance (opposition to the flow of the current) is then measured by the BIA because

electrolytes in an individual's body water are good conductors of electrical current. The current flows more easily in an individual with a large total body weight. There is greater resistance to flow in an individual with higher amounts of body fat because fat is a poor conductor of electrical current. Fat free mass and percent body fat are then calculated from the total body water estimate.

There are many different types of BIA equipment; however, the traditional type is "tetra polar," having four electrodes: two that emit an electrical current and two others that detect the current as it passes through the body. To ensure that the composition of the whole body is accurately determined, electrodes are applied at the hand, wrist, foot, and ankle. A current is applied at the hand and foot, and it is detected by the wrist and ankle.

Other types of BIA include lower-body and upper-body BIA analyzers. A lower-body analyzer requires that the individual stands on electrode plates as it measures the impedance between the legs. The upper-body analyzers are handheld and measure impedance between the arms as the individual holds the machine out in front of him/her (Heyward & Wagner, 2004). These types of analyzers are less accurate; however, they are the cheaper and simpler than tetra polar electrode BIA to achieve body fat percentage estimates. Upper-body analyzers typically cost between $750 and $2000, and handheld lower-body analyzers can be purchased for $50.

The BIA method is considered a good method because it can be easily administered and completed in a short amount of time. In addition, because skinfold measurements are difficult to obtain from overweight or obese subjects, BIA is a preferred field method for measuring body fat in these populations.

Adiposity: Field Measures Resource Chart

	Body Mass Index (BMI)	Calipers	Girth	Bioelectrical Impedance Analysis (BIA)
Description	Determined by measuring height and weight, and calculating a BMI that is then compared to identified numbers. The formula used is: Weight (kg) / Height (m^2).	Skinfold calipers used to measure body fat at select locations on body. Prediction models and equations are then used to estimate body fat mass.	A tape measure is used to measure circumference around waist, hip, chest, arm, and thigh. Equations then used to estimate body fat.	Based on the body's resistance to an electrical current circulated through the body. Estimates total body water, fat-free mass, and body fat percentage.
Type	Field	Field	Field	Field
Age Issues	Older adults tend to have more body fat than younger adults.	Less accurate with older adults due to loose connective tissue.	N/A	N/A
Gender Issues	Women tend to have more body fat than men.	Location of measurements differs by gender.	Different measurements for chest and hips.	N/A
Accessibility	Anyone can use.	Must be trained in usage.	Anyone can use.	Easily transportable.
Accuracy	Low	Dependent upon skill of examiner. Large inter-observer variability. The cheaper the caliper, the less accurate it is.	Low accuracy, especially for individuals very low or very high in fat mass.	Medium Dependent upon machine used and total body water equation used.
Cost	Low $3.50-$22.00 for tape measure, $10-$50 for scale	Low $8.75-$435 for skinfold calipers	Low $3.50-$22.00 for tape measure	Moderate $50-$2,000
Strengths	Fast and easy. Useful for large populations. Retrospective assessment capabilities.	Fast and easy. Useful for screening large populations.	Fast and easy. Useful for large populations. Waist circumference predicts insulin resistance. Waist circumference predicts illness risk in Asian American populations over age 65.	Fast Limited training required. Preferred method over using skinfold caliper for overweight sample.
Limitations	Need for ethnicity and gender-specific charts. Low sensitivity.	Less accurate in overweight populations. Need for ethnicity-specific charts.	Low accuracy.	May be affected by what an individual eats prior to measurement.

b. Laboratory Measures

1. Densitometry

Densitometry involves the measurement of body composition through a combination of different laboratory techniques. Body composition is broken up into the basic components of fat mass, lean (protein) tissue mass, bone (mineral) mass, and water mass. The most thorough assessment, known as the four-compartment model and widely considered to be the "gold standard" of body composition assessment, measures all of these components. The three-compartment model and the two-compartment model divide body composition into the components of 1) fat mass, water, and fat free dry mass; and 2) fat mass and fat free mass, respectively (Wells, Fuller, Dewit, Fewtrell, Elia & Cole, 1999). Methods used to derive these measures include DEXA to measure bone mass, hydrostatic weighing, or Bod Pod, to measure lean body mass and fat mass, and BIA or Isotope Dilution methods to measure total body water content.

Densitometry is expensive. It involves the use of several costly machines requiring skilled technicians to operate, and it is inaccessible to the general population, as these methods are available only in research settings. The need to conduct several tests on each individual makes it impractical for large populations. However, because the four-compartment model is considered to be the most accurate of the body composition assessments, it is useful in cross-validation studies of other measures of body composition (Houtkooper, Going, Lohman, Roche, & Loan, 1992).

2. Dual Energy X-ray Absorptiometry (DEXA)

DEXA is a laboratory measure that is based on a 3 compartment model which divides the body into bone mineral density, lean tissue mass, and fat mass. As the subject lies in a supine

position (on their back) on a scanning bed, a thin beam of low-dose x-rays is sent through the entire body, and the amount of soft tissue and bone in the body is determined. It is a preferred method because it only takes 10-20 minutes, is safe, and does not require much effort from the subject (Heyward, 1996). It is considered to be safe because the DEXA applies a negligible amount of radiation (<1 mSv or<1/100th of the equivalent radiation exposure of a chest x-ray). Another advantage of the DEXA is that it based on a whole-body scan; therefore, it also provides information on regional body composition (Goran, 1998).

For more accurate results from a body scan, adequate training by the manufacturer of the scanner is required. Additionally, several states require X-ray technicians that are licensed to perform a DEXA scan which becomes one limitation to using DEXA. Another limitation of the DEXA is that it should not be used on an individual whose body size is larger than the length or width of the scanning bed (Heyward & Wagner, 2004). A source of error is the variability among different DEXA machines and software; therefore body composition results are different for each manufacturer.

DEXA machines are expensive to purchase (approximately $100,000), and require technician training (usually about $800). Due to its high cost, DEXA is impractical for screening large populations, but due to its high accuracy, has been used extensively in cross-validation studies.

3. Hydrostatic/Underwater Weighing

Hydrostatic, or underwater weighing, is a laboratory method used to measure body density. This is accomplished by total submersion of an individual in a tank of water following the expulsion of all air from the individual's lungs. Underwater weight and water displacement

are measured and compared with the individual's "dry weight" to determine body density through use of a series of calculations. Because fat is less dense than muscle, this technique can provide an accurate estimate of body fat. When underwater weighing is combined with a measure of residual lung volume, a good measure of body volume can be obtained, and body density can be easily determined (Heyward & Wagner, 2004).

A trained operator is required for underwater weighing, and experience is necessary for maximal accuracy. Also, hydrostatic weighing units are expensive and start off at about $30,000. Another limitation associated with underwater weighing involves participant cooperation. Since participants are required to completely exhale as they are fully underwater, this difficult task calls for a lot of cooperation from the participant and cannot be easily applied to the elderly or physically disabled (Heyward, 1996). Additionally, underwater weighing is "impractical to implement in most clinical and research settings, and some patients are incapable of cooperating sufficiently with the water submersion and maximal exhalation" (Ginde, Geliebter, Rubiano, Silva, Wang & Heshka, 2005). The task is repeated until three trials within 100g of each other are attained. The average of these trials is used (Wagner & Heyward, 1999).

The conversion formulas that were previously used for underwater weighing assumed that the density of fat and fat free body density are constant for all individuals. The formulas were based on a study of White male and female cadavers who were representative of only a limited number of populations (Heyward, 1996). Age, gender, ethnicity, body fatness, and physical activity level of individuals can have an effect on fat free body density measurements used in the conversion formulas. Due to this, population-specific formulas are used in order get more accurate measures of fat free body density. This helps to control for error related to the conversion formulas used in earlier years.

4. Air-displacement Plethysmography (ADP)

Established on the idea of determining total body volume for further body composition inferences, air displacement plethysmography has become increasingly popular because of its growing practicality. ADP takes about 5-10 minutes, takes minimal cooperation from the subject, and requires little skill from the technician (Heyward & Wagner, 2004). ADP is one of the more accurate measures of body composition in people of all ages and all ranges of body fatness (Fields & Goran, 2000). This method measures total body volume, and equations are then used to determine body density and body fat percentage.

An individual enters an airtight "podlike" chamber and breathes into a tube connected to the unit. Total body volume is derived by measuring small changes in pressure between the test chamber where the subject sits with that of a reference chamber. In the past, this technique relied heavily on conditions that made it difficult to duplicate testing due to the required maintenance of a constant temperature (Fields, Goran & McCrory, 2002). However, these setbacks have been overcome with the most recent design in ADP known as the "Bod Pod." The Bod Pod is a "large, egg-shaped fiberglass chamber that uses air displacement and pressure-volume relationships to derive body volume" (Heyward & Wagner, 2004).

Following calibration, a subject can step into the test chamber and have his/her raw body volume (Vbraw) and thoracic gas volume (Vtg) measured. Thoracic gas volume is attained by breathing into a tube and filter that connect to the reference chamber in the rear of the Bod Pod. These measurements are then used in an equation to calculate body density. The following is the Lohman equation for calculating body density, which uses age-dependent constants for changes in the density of the fat-free mass and hydration status (Fields & Goran, 2000).

$$Db = M/(Vb\ raw + 0.40Vtg - SAA)$$

Db= body density

M = mass of the subject (Kg)

Vb raw = Raw body volume (L)

Vtg = Thoracic gas volume

SAA = Surface area artifact

Body fat percentage is then estimated from body density:

$$\%\ fat = (C1/Db - C2) \times 100$$

Limitations do exist in regards to the Bod Pod. If the subject has a lot of body hair, results may be affected. Results from clients with beards or exposed scalp hair may be underestimated; therefore, it is important for them shave excess body hair and cover scalp hair with a swim cap (Heyward & Wagner, 2004). Additionally, clothing worn in the Bod Pod must be regulated, as excess clothing can cause underestimation of body volume; thus, individuals should wear tight fitting swimsuits for optimal measurement accuracy. The Bod Pod is expensive, ranging from $30,000-$40,000.

5. Magnetic Resonance Imaging (MRI)

Computer assisted diagnosis (CAD) techniques have made the use of whole body Magnetic Resonance Imaging (MRI) very useful in identifying total body fat and its three-dimensional location in the body. This technique has become increasingly common, with the growing availability of MRI technology. A contributing factor to the increased usage of MRI lies within the decreased usage of CT scans (computed tomography) due to its high radiation

doses (Brennan, Whelan, Robinson, Ghita, O'Brien & Sadlier, 2005). However, availability of MRI and high cost limits its use among the general public (Heyward & Wagner, 2004).

MRI works by scanning the body into a set of overlapping coronal cross sections. A computer-generated image is created from hydrogen nuclei that are emitted from radio frequency signals. An external magnetic field and pulsed radio frequency are applied across a body part which results in nuclei lining up and absorbing energy. These nuclei are able to release the absorbed radio signal to create the image once the radio wave is shut off (Heyward & Wagner, 2004).

6. Computed Tomography (CT or CAT Scan)

Computed tomography is similar to MRI in the way that it scans multiple slices of the body. It has shown to be an accurate technique for measuring soft tissue composition (Snijder, Visser, Dekker, Seidell, Fuerst & Tylavsky, 2001). Multiple x-rays circle the body creating computerized cross-sectional images of body tissues and organs that are used to determine the volume of different body compartments. CT images of the abdomen allow computerized measurement of total fat area and also enable the differentiation of subcutaneous fat from intra-abdominal fat in a cross-section of the body (Borkan, Gerzof, Robbins, Hults, Silbert & Silbert, 1982; Snijder et al., 2001). Because of the radiation exposure and high cost of a CT scan, it is not used for body composition assessment of the whole body. Instead, it is limited to assessment of specific regions of the body (Heyward & Wagner, 2004).

7. Isotopic Dilution

Isotopic dilution measures total body water, which is then used in a series of equations to determine fat-free mass, fat mass, and body fat percentage. Total body water is measured using stable isotopes such as Oxygen 18 or Deuterium Oxide, based on the assumption that isotope

distribution and exchange is similar to that of water. Although Oxygen 18 is typically more accurate, Deuterium Oxide is typically used because of its significantly lower cost.

The procedure requires one of the isotopes to be administered orally or intravenously. Pre and post-dose (at 3-5 hours) measures of plasma, saliva, or urine are taken. A mass spectrometer is then used to determine isotope ratio measurements of the samples. The results are reported as a delta relative to a reference gas:

Delta D = [(Ratio of Sample – Ratio of Reference) / (Ratio of Reference)] x 1000.

Calculation of total body water, according to the back extrapolation method, requires the experimenter to figure out the delta values for the pre-dose (dpre) and post-dose (dpost) samples (Wells, Fewtrell, Davies, Williams, Coward & Cole, 2005). Furthermore, the amount of dose diluted and water used is recorded. The Deuterium content of the tap water (dtap) and diluted dose (ddose) are measured. Total body water in moles is calculated from the dilution of heavy isotopes using the following:

TBW (moles) = ((ddose – dtap) / (dpost – dpre)) x (WA/ 18.02a)

W = amount of water used to dilute the dose

A = amount of dose (g) administered to subject

a = amount of dose (g) diluted for analysis

To convert to TBW in Kg:

TBW (kg) = TBW (moles) x18.02 / 1000g/kg

It has been determined experimentally that Deuterium Oxide overestimates total body water by 4%, while Oxygen 18 overestimates total body water by 1% (Metabolic Solutions 2006). Overestimation occurs because both Deuterium and Oxygen18 binds to acidic amino acids of body proteins or other non-exchangeable sites. Consequently, formulas have been derived to correct these problems:

Deuterium dilution: Corrected TBW (kg) = TBW (kg) / 1.044

Oxygen 18: Corrected TBW (kg) = TBW (kg) / 1.01

(Wells et al., 2005)

Based on the understanding of the percent water in fat-free mass, one is able to determine the total fat-free mass in kilograms. The hydration fraction, however, is known to decrease into adulthood where it seems to level off at around 73% at about 22 years of age (Eckhardt, Adair, Caballero, Avila, Kon & Wang, 2003).

One study showed that age and sex-specific differences in hydration of fat-free mass are rather minor (Eckhardt et al., 2003). The long duration and the added expense, however, have kept this procedure from being used widely in clinical practice.

Summary

There are numerous ways to determine an individual's adiposity level. Field measurements like BMI, skinfolds, girth/circumference, and BIA are most useful in community settings due their simplicity and small cost. The laboratory measurements: DEXA, hydrostatic weighing, ADP, MRI, CT, and isotopic dilution are less accessible to the general population and more useful in research type settings. In addition, they are more expensive and usually require a skilled technician.

Adiposity: Laboratory Measures Resource Chart

	Densitometry	Dual Energy X-Ray Absorptiometry (DEXA)	Underwater Weighing	ADP/Bod Pod
Description	Combined usage of various lab techniques to formulate the most accurate assessment of body composition. Usage of DXA, underwater weighing or ADP/Bod Pod, BIA, or DH20.	Machine that performs an X-ray scan of body and then technician uses computer software to determine fat mass, lean tissue mass, and mineral mass.	Individual is submerged in a tank of water. Underwater weight is measured and used to calculate body density and then body fat percentage.	Involves an airtight chamber that measures body volume relative to pressure changes. Body density and body fat are then calculated.
Type	Lab	Lab	Lab	Lab
Age Issues	N/A	N/A	Difficult to perform on the elderly or with individuals uncomfortable in water.	Useful for all age groups.
Gender Issues	See DXA, BIA, and Isotope Methods.	N/A	N/A	N/A
Accessibility	Requires use of several machines/methods. Available only in research settings.	Available in research facilities. Requires skilled technicians.	Available in research facilities. Requires skilled technicians.	Available in research facilities.
Accuracy	Highest four-compartment model considered the "gold standard."	High	High	High
Cost	High	High $100,000+ for DEXA machine, $800 for technician training	High $30,000 +	High $30,000-$40,000
Strengths	Highest accuracy. Provides measurement of fat mass, lean tissue mass, and mineral mass.	Provides measurements of fat mass, lean tissue mass, and mineral mass.	Accuracy	Accuracy Fast measurement time.
Limitations	Time consuming. Impractical for screening large populations.	Cannot be used on individuals whose body size is larger than the length or width of the scanning bed.	Impractical for large populations. Population-specific formulas needed for calculations. Not easily applied to the physically disabled.	Small, enclosed space. Excessive body hair affects results. Must wear tight fitting swimsuits for optimal accuracy.

Adiposity: Laboratory Measures (continued)

	Isotopic Dilution	Magnetic Resonance Imaging (MRI)	Computed Tomography (CT, CAT Scan)
Description	Involves the ingestion of a stable isotope in conjunction with pre-dose and post-dose urine, saliva, or plasma samples. An estimate of total body water is derived and used to calculate fat-free mass, fat mass, and body fat percentage.	Whole body scans or compartment scans can determine the location and volume of total fat.	Scans body to create a computerized image that can be used to determine total fat area. Shows soft tissue composition.
Type	Lab	Lab	Lab
Age Issues	Minor differences in hydration of fat-free mass with age.	N/A	N/A
Gender Issues	Minor differences in hydration of fat-free mass with gender.	N/A	N/A
Accessibility	Requires lab work to process samples.	Available in research and healthcare facilities. Requires skilled technicians.	Available in research and healthcare facilities. Requires skilled technicians.
Accuracy	High	High	High
Cost	Moderate	High	High
Strengths	Accuracy	Accuracy Measures adiposity location.	Accuracy
Limitations	Requires extensive lab work. Time consuming. Impractical for large populations.	Small, enclosed space is loud and cold. Impractical for large populations.	Not used for body composition assessment of whole body due to radiation exposure.

III. Physical Activity Measurement in Adults

Introduction

The measurement of physical activity can be broken down into two groups, electronic devices and other methods. Each group can be broken into further subcategories of measurement apparatuses and techniques. The electronic devices discussed include pedometers, accelerometers, the IDEEA device, and heart rate monitors. The other available types of measurement include self-report methods, direct observation, and interviews. Advantages and disadvantages will be discussed for each type of measurement, and a description of available features as well as which features should be considered when selecting a device will be discussed for the electronic devices.

a. Electronic Devices

1. Pedometers

A pedometer is a small device worn at the waist or on the ankle that counts the steps an individual takes (Zhang, Werner, Sun, Pi-Sunyer & Boozer, 2003). Pedometers are inexpensive ($10-$50 each) and can detect steps with reasonable accuracy; however, they are unable to measure the physical activity type, pattern, or intensity (Tudor-Locke, Ainsworth, Thompson & Matthews, 2002). Most pedometers consist of a sensor that moves up and down as the individual walks. The total step count is displayed on an LCD screen (BioTrainer 2007).

Pedometers usually have a sensitivity switch that can be adjusted for accurate counting of steps. For example, the Omron Pedometer (Model HJ-105) sensitivity switch adjustment is based on the individual walking 100 steps. If the screen displays 105 steps or more, the switch should be moved towards the minus (-) direction. Additionally, if the screen reads 95 steps or

less, the switch should be moved in the plus (+) direction (Omron Healthcare 2007). "Improper adjustment will seriously affect the accuracy of the device producing significant over-counts or under-counts (BioTrainer 2007). Pedometers are not sensitive to stride length that can vary from person to person among different activities (Tudor-Locke et al., 2002).

Researchers have recommended the pedometer as a sufficient method of measurement for physical activity when walking is the principal behavior (Tudor-Locke & Myers, 2001a). Pedometers instantly give the individual a display of how many steps he/she has achieved during the day (BioTrainer 2007; Tudor-Locke & Myers, 2001b). This information can cause an increase in confidence and motivation to take a specific number of steps per day (Basset, 2000; BioTrainer 2007). In addition, a Swiss study showed pedometers to be a good method of measurement in large populations. In this study, 500 participants successfully used pedometers for seven days (Sequeira, Rickenbach, Wietlisbach, Tullen, & Schutz, 1995). Pedometers can be used to monitor individual activity as well as in community programs or research projects to monitor physical activity.

Popular brands of pedometers include: Digi-Walker, Omron, Acumen, Bodytrend, Oregon Scientific, Sportline, Freestyle, Brookstone, and Accustep (BioTrainer 2007). Yamax is a highly regarded brand by researchers and has the data to back up its claims. In a comparison between some less expensive models, Yamax performed with 1% error of the true distance walked while the other models were within 11%. Yamax was the only pedometer to perform well at slow (walking) speeds while all brands performed similarly at fast speeds (Bassett, Ainsworth, Leggett, Mathien, Main & Hunter, 1996). Le Masurier, Lee, & Tudor-Locke (2004) make the claim that Yamax is the most accurate under controlled and free-living conditions.

There are several limitations that are associated with pedometers. First, pedometers usually undercount the number of steps during activities of higher intensity and "consistently show more errors during slow walking" (BioTrainer 2007; Bassett et al., 1996). Another disadvantage of pedometers is that many cannot store or recall single-day step counts over a period of many days (BioTrainer 2007). Some do have a 7-day memory, but it can be deleted if the device is reset. Therefore, the daily step count must be recorded manually if the pedometer is reset (BioTrainer 2007). In addition, in using pedometers for research, the addition of a physical activity log is helpful to determine at which times of the day the participant is active and to estimate intensity of activity (walking/running; light to vigorous, etc.).

2. Accelerometers

Accelerometers are small devices that can be worn at the waist, hip, or lower back. Just like pedometers, accelerometers count the number of steps taken; however, unlike pedometers, they also measure the intensity with which the steps are taken. As a result, accelerometers can distinguish between light, moderate, and vigorous physical activity across the time span it is worn. Accelerometers measure movement in uniaxial or triaxial planes and record activity based on the product of the frequency and intensity of the movement (Tudor-Locke & Myers, 2001a). Uniaxial accelerometers measure activity in a single plane, and triaxial accelerometers measure activity in three planes: vertical, horizontal, and medio-lateral (Freedson & Miller 2000). The main function of accelerometers is that "the sensor converts physical movements into electrical signals that are proportional to the muscular force producing motion" (BioTrainer 2007; Melanson & Freedson 1996). The electrical signals are sent to a converter and downloaded onto a computer for analysis. Information can be stored in accelerometers in specific time intervals such as 2, 15, 30, 60, or 120 seconds (BioTrainer 2007). In addition, an individual's energy

expenditure can be estimated based on his/her age, gender, height, and body mass (Tudor-Locke & Myers, 2001a).

The Actigraph, a popular brand of accelerometer, is considered the "gold standard." Another popular brand of accelerometer, the BioTrainer, measures both vertical and horizontal acceleration, is able to "capture activity from subtle movements (about .05-.2g) to moderate activity (about .2-1.0g) to vigorous walking and jogging (about 1.0-4.0g)" (BioTrainer 2007). Accelerometers are most useful in research settings where intensity is as important as quantity of physical activity.

Several limitations can be associated with accelerometers. Accelerometers are expensive, ranging from about $50-$600 each. Tritrac, the most commonly used brand of triaxial accelerometer, is priced at about $550 (Freedson & Miller, 2000). Also, some accelerometers need technical expertise and specific computer software, as well as a computer, to analyze the data (Tudor-Locke & Myers, 2001a).

3. IDEEA

The Intelligent Device for Energy Expenditure and Activity (IDEEA) is a microcomputer-based portable device that measures the type, duration, frequency, and intensity of physical activity with an accuracy of more than 98% (Zhang et al., 2003). Compared to other types of physical activity measurement devices, "IDEEA can provide the concurrent quantification of basic gait variables and human daily physical activity, including the accurate estimation of energy expenditure" (Maffiulett, Gorelick, Kramers-de Quervain, Bizzini, Munzinger & Tomasetti, 2007). This device monitors the individual through a recorder and five small sensors that are attached to the chest, thighs, and feet with hypoallergenic medical tape. Different physical activities are represented by a combination of signals from the five sensors.

IDEEA is able to identify and measure more than 40 types of activities (Zhang et al., 2003; MiniSun 2007).

The IDEEA device is costly, ranging from $1,000 to several thousand dollars, depending on the order quantity, but shows the most accurate results for true daily living energy expenditure (Zhang, Pi-Sunyer & Boozer, 2004; Zhang et al., 2003). Also, the software that comes with this device allows the researcher to view an animation of what actually happened for the subject at any given time (MiniSun 2007). IDEEA is currently the only device of its kind (made by MiniSun); therefore, no features can be noted between competing companies.

A limitation associated with IDEEA includes the inconvenience of wearing multiple sensors on the body. In addition, arm movements cannot be directly measured by the IDEEA. For example, physical activity where arm motion plays a major part like rowing or swinging a bat would be incorrectly identified by the IDEEA (Zhang et al. 2003).

4. Heart Rate Monitors

Heart Rate monitors are made up of a transmitter that is attached to the chest and a receiver watch (Freedson & Miller, 2000). The watch displays a flashing heart icon for each heart beat that is detected and the heart rate is displayed on the small LCD screen (BioTrainer 2007). Heart rate monitors often have internal clocks that allow the storage of data for several days. This device is unobtrusive to the individual and can distinguish activity by frequency, duration, and intensity (Freedson & Miller, 2000).

Using a heart rate monitor for measuring physical activity also has its limitations. Heart rate monitors can be expensive. Priced similarly to accelerometers, heart rate monitors range from $50-$500, depending upon the features (Freedson & Miller, 2000). Heart rate monitors are useful during exercise sessions; however, they are not useful in measuring activities of daily

living (BioTrainer 2007; Welk, Corbin & Dale, 2000). An increase in heart rate can occur due to high temperatures, humidity, or stress in the individual (Freedson & Miller, 2000) which would inaccurately represent the individual as being more physically active. The heart rate tends to remain elevated after bouts of exercise as well, longer for obese people, providing a possible false increased length of time for the physical activity event (Crouter, Albright & Bassett, 2004; Rice & Howell, 2000; Sirard & Pate, 2001; Trost, 2001; Weston, Petosa & Pate, 1997). Additionally, an individual who is less trained would have a higher heart rate than the better trained individual at a given level of intensity (Freedson & Miller, 2000). Heart rate monitors would also give a false representation of the level of physical activity when comparing the two types of individuals.

	Pedometers	Accelerometers	IDEEA	Heart Rate Monitors
Description	Small device worn at the waist or on the ankle that counts the steps an individual takes.	Small device that can be worn at the waist, hip, or lower back that count the number of steps taken and also the intensity with which steps are taken.	A microcomputer-based portable device that measures the type, duration, frequency, and intensity of physical activity.	Monitor composed of a transmitter that is attached to chest and a receiver watch. Flashing heart icon for each heart beat detected is displayed on watch and heart rate is displayed on LCD screen.
Type	Field	Field	Lab	Field
Age Issues	N/A	N/A	N/A	N/A
Gender Issues	N/A	N/A	N/A	N/A
Accessibility	Anyone can use.	Must have specific computer software and a computer to analyze the data. Some require technical expertise.	Available in research settings.	Available in sporting goods stores and/or stores selling fitness equipment.
Accuracy	Detect steps with reasonable accuracy; however, they are unable to measure the physical activity type, pattern or intensity.	More accurate than a pedometer for counting steps and can measure acceleration as well.	High, > 98%	Depends on type and quality of heart rate monitor purchased.
Cost	Low $10-$50 for pedometer	High $50-$600 for an accelerometer	High $1,000- Several thousand	High $50-$500 for heart rate monitor
Strengths	Instantly gives the individual a visual display of how many steps he/she has achieved during the day. This can cause an increase in confidence and motivation. Great for consistent monitoring of activity.	Distinguishes between light, moderate, and vigorous physical activity across the time span it is worn. Measures movement in uniaxial or triaxial planes and records activity based on frequency and intensity.	Able to identify and measure more than 40 types of physical activities.	Unobtrusive to the individual and can distinguish activity by frequency, duration and intensity.
Limitations	Usually undercount the number of steps during activities of higher intensity and show more errors during slow walking. Cannot be used with water-based activities.	Some need technical expertise, certain computer software, and specific computers to analyze the data.	Inconvenience of wearing multiple sensors on the body. Arm movements cannot be directly measured.	Not useful in measuring activities of daily living. Can be expensive.

b. Other Methods

1. Self-Report Methods

Detailed information can be provided through daily activities and logs (Ainsworth, Bassett, Strath, Swartz, O'Brien & Thompson, 2000). Additionally, diaries and logs can be easily administered to different populations (Tudor-Locke & Myers, 2001). Self-report methods can be useful in conjunction with pedometers or accelerometers where it can be indicated by the individual what time(s) of day he/she is active.

One self-report method of physical activity measurement is the Previous Day Physical Activity Recall (PDPAR). The PDPAR is a pencil and paper exam that contains a time-based grid. Time is measured in 30 minute increments with participants rating activity using a three level intensity rating (very light, moderate, and vigorous). Individuals describe their physical activity from the previous day for each 30 minute increment and use it much like a physical activity log (Anderson, Hagstromer & Yngve, 2005).

This type of measurement of physical activity also has specific categories which help the user choose what kind of activity and at what level they are performing at, such as, type, intensity and duration of the activity. In addition, the PDPAR has a relatively low cost (photo copying); making it one of the most inexpensive assessment tests.

Another type of self-report method is the Stages of Change Questionnaire (Marcus, Selby, Niaura & Ross, 1992). The Transtheoretical model stipulates that individuals when acquiring a new behavior change, progress through a series of stages in reaching their desired behavior. The stages of change are precontemplation, contemplation, preparation, action, and maintenance (Marcus et al., 1992). In the first stage, the precontemplation stage, the individual has no desire to exercise within the next six months. In the preparation stage, individuals are

taking steps to facilitate their behavior change, and in the maintenance stage, the individual has been regularly engaging in the behavior (exercise) for more than 6 months (Lox, Martin & Petruzello, 2003).

There are two versions of this questionnaire that can be used: short form and continuous measure. The short form consists of one question with choices for how long the individual has been exercising at least 3-5 times per week for 20-60 minutes. The answer choice places the individual within a certain category or "stage of change." The continuous measure for stages of change consists of 24 questions that the individual must answer in order to be placed within a specific stage of change. The individual must answer each question with a number from 1 to 5, based on a scale where 1 is "strongly disagree" and 5 is "strongly agree." The responses are then scored, and the individual is categorized within a specific stage of change (Cancer Prevention 2007). The stages of change questionnaires are very useful for exercise research because interventions and tools can be matched to individuals within a specific stage (Marcus et al. 1992; Lox et al. 2003). Interventions involving exercise have proven to be most effective when they are matched to the individual's specific stage of change (Lox et al. 2003).

Limitations exist among self-report methods. For example, they often don't consider routine light to moderate activities like household chores and family care as modes of physical activity. Also, at this time, there is no self-report method that can capture small bouts of physical activity or the "lower end of the continuum of physical activity." For example, the 7-day Physical Activity Recall does not count any physical activity that occurs for less than 10 minutes or has an intensity that is lower than for brisk walking (Tudor-Locke & Myers, 2001). Response bias is another issue that comes up with self-report methods. This is where the individual will

respond to a questionnaire or survey in ways he/she thinks the researcher wants him/her to respond instead of responding according to his/her true beliefs.

2. Direct Observation

Direct observation is defined as the witnessing of exercise behavior in person. This type of measurement allows the researcher to take notes on the physical activity that individuals participate in which removes the threat of memory recall or response bias that is associated with self-report methods (Lox et al., 2003). Direct observation is most commonly used with children and has been shown to be very useful (Mckenzie, Marshall, Sallis & Conway, 2000). In one type of direct observation, SOPLAY, the researcher codes the type and intensity of physical activity for an individual during a short span of time, and he/she documents more about the behavior or setting (BioTrainer 2007).

Limitations of direct observation include the time and expense involved. A lot of time must be spent when directly observing the individuals, and this becomes a very expensive task. Also, due to the individuals' awareness of being observed, they might behave differently (Lox et al., 2003).

3. Interviews

Interviews can also be used when assessing physical activity. One type of interview is the semi-structured interview which is usually face-to-face and audio recorded. The purpose of the audio recording is for the researcher to be able to listen to it when he/she is examining the information provided in the interview. When an interview is conducted, the interviewer is provided with instructions and standard questions to be used in the interview (Patten, 2007).

Since the interviews are semi-structured, the interviewer can ask additional questions to the standardized ones. The interviewer can rephrase a question when it is unclear to the

interviewee. Additionally, the interviewer can ask more questions when the interviewee is too brief or to further investigate an important topic (Patten, 2007).

The Lifetime Physical Activity Questionnaire is administered to individuals by interview. This interview type questionnaire asks questions about exercise and physical activity engaged at work and in the household. The frequency, intensity, and duration of the physical activity or exercise are assessed during the interview. Frequency of household/work physical activity is reported in months/year, days/week, and time/day, and duration is reported in years. The individuals are also asked to report the frequency of exercise and the amount of time spent during each exercise session. Additionally, the interviewer asks the individual to rate the intensity of the physical activity/exercise as sedentary, light, moderate, or heavy, according to specific definitions (Friedenreich,, Courneya & Bryant, 1998).

Summary

Physical activity can be assessed using electronic devices like pedometers, accelerometers, IDEEA, and heart rate monitors and paper form type measurements like self-report methods, direct observation, and interviews. The electronic devices all have their pros and cons to usage as well as appropriateness in specific settings. The paper form measurements are also great ways to measure physical activity and can be extremely useful in combination with electronic devices.

Assessing Physical Activity: Other Methods

	Self-Report Methods	Direct Observation	Interviews
Description	Detailed information provided through survey instruments and physical activity logs.	The witnessing of exercise behavior in person.	Semi-structured interview, which is usually face-to-face and audio recorded. Interviewer is provided with instructions and standard questions to be used in the interview in order to assess physical activity.
Type	Field	Field	Field
Age Issues	N/A	N/A	N/A
Gender Issues	N/A	N/A	N/A
Accessibility	Anyone can perform.	Anyone can perform.	Anyone can perform.
Accuracy	Possibility of responder bias in recording level and type of activity performed.	Behavior that is observed may change merely due to observer's presence.	Responder bias possible.
Cost	Variable, depends on survey or log used, number of participants, and resulting copy costs.	Variable, depends on distance traveled to observe, total observation time needed, and on fee rate of observer(s).	Variable, depends on fee rate for interviewer(s)' time, any travel costs, and any incentives paid to participants.
Strengths	Can be useful in conjunction with pedometers or accelerometers where the individual can indicate what time(s) of day he/she is active.	Type of measurement allows the researcher to take notes on the physical activity that individuals participate in which removes the threat of memory recall or response bias that is associated with self- report methods.	Since interviews are semi-structured, the interviewer can ask more questions or rephrase questions, if necessary. Audio recording makes it possible for the researcher to listen to it when he/she is examining the information provided in the interview.
Limitations	Completion rate for all questions on all instruments may be problematic (participants may not complete log as instructed).	A considerable amount of time must be invested in the individuals when directly observing, which becomes expensive. Due to the individuals' awareness of being observed, they may behave differently.	Time consuming and possibly costly if conducted on a large group of participants or with many interviewers.

Summary of Resource Guide

Various factors must be examined in order to predict and explain adiposity and physical activity among adults. Psychosocial, environmental, and behavioral factors must be addressed in order to most accurately determine the causes of overweight and inactivity in adults. Coupled with the predictive factors discussed, the measurement of both adiposity and physical activity in adults is a complex issue. In order to determine the best method(s) to use for a prospective project or study, one must take into account the research evidence available for each type of assessment. By examining all potential assessments, health professional/educators can make more informed decisions as to which methodology will produce the best assessment within the confines of the type of setting and budget available.

References

American College of Sports Medicine (2007). Physical activity and public health guidelines. Retrieved September 7, 2007 from http://www.acsm.org/AM/Template.cfm?Section=Home_Page&TEMPLATE=/CM/HTMLDisplay.cfm&CONTENTID=7764

Anderson, C.B., Hagstromer, M., & Yngve, A. (2005). Validation of the pdpar as an adolescent diary: effect of accelerometer cut points. *Medicine & Science in Sports & Exercise, 37,* (1224-1230).

Ainsworth, B.E., Bassett, D.R., Strath, S.J., Swartz, A.M., O'Brien, W.L., Thompson, R.W., Jones, D.A., Macera, C.A., & Kimsey, C.D. (2000). Comparison of three methods for measuring the time spent in physical activity. *Medicine & Science in Sports & Exercise, 32* ,(S457-S464).

Bassett, D.R. (2000). Validity and reliability issues in objective monitoring of physical activity. *Research Quarterly for Exercise and Sport, 71,* (30-36).

Bassett, D. R., Ainsworth, B. E., Leggett, S. R., Mathien, C. A., Main, J. A., Hunter, D.C., & Duncan, G.E. (1996). Accuracy of five electronic pedometers for measuring distance walked. *Medicine and Science in Sports and Exercise, 28,* (1071-1077).

BioTrainer Weight Loss System (2007). *BioTrainer clinical studies.* Retrieved July 16, 2007 from http://www.biotrainerusa.com/clinical.asp

Borkan, G.A., Gerzof, S.G., Robbins, A.H., Hults, D.E., Silbert, C.K., & Silbert, J.E. (1982). Assessment of abdominal fat content by computed tomography. *American Journal of Clinical Nutrition*, *36*, (172-177).

Bray, G.A., & York, D.A. (1997). Leptin and clinical medicine: a new piece in the puzzle of obesity. *Journal of Clinical Endocrinology & Metabolism, 82,* (2771-2776).

Brennan, D., Whelan, P.F., Robinson, K., Ghita, O., O'Brien, J., Sadlier, R., & Eustace, S. (2005). Rapid automated measurement of body fat distribution from whole-body mri. *American Journal of Roentgenology*, *185*, (418-423).

Cancer Prevention Research Center (2007). *Exercise-Stages of Change.* Retrieved August 6, 2007 from http://www.uri.edu/research/cprc/Measures/Exercise01.htm

Center for Disease Control and Prevention (2007)a. *BMI-body mass index.* Retrieved June 7, 2007, from http://www.cdc.gov/nccdphp/dnpa/bmi/adult_BMI/about_adult_BMI.htm

Center for Disease Control and Prevention. (2007)b. *Defining overweight and obesity.* Retrieved July 21, 2007, from http://www.cdc.gov/nccdphp/dnpa/obesity/defining.htm

Center for Disease Control and Prevention. (2007)c. *Obesity and overweight: introduction.* Retrieved July 21, 2007, from http://www.cdc.gov/nccdphp/dnpa/obesity/index.htm

Center for Disease Control and Prevention. (2007)d. *Overweight and obesity: contributing factors.* Retrieved July 21, 2007, from http://www.cdc.gov/nccdphp/dnpa/obesity/contributing_factors.htm

Center for Disease Control and Prevention. (2007)e. *Overweight and obesity: frequently asked questions (faqs).* Retrieved July 21, 2007, from http://www.cdc.gov/nccdphp/dnpa/obesity/faq.htm

Center for Disease Control and Prevention. (2007)f. *Overweight and obesity: health consequences.* Retrieved July 21, 2007, from http://www.cdc.gov/nccdphp/dnpa/obesity/consequences.htm

Center for Disease Control and Prevention. (2007)g. *Physical activity for everyone: how active do adults need to be to gain some benefit.* Retrieved February 13, 2008, from http://www.cdc.gov/nccdphp/dnpa/physical/recommendations/adults.htm

Center for Disease Control and Prevention. (2007)h. *Physical activity for everyone: the importance of physical activity.* Retrieved July 21, 2007, from http: http://www.cdc.gov/nccdphp/dnpa/physical/importance/index.htm

Crouter, S. E., Albright, C., & Bassett, D. R., Jr. (2004). Accuracy of polar s410 heart rate monitor to estimate energy cost of exercise. *Medicine and Science in Sports and Exercise, 36,*(1433-1439).

Cummings, S., Parham, E.S., & Strain, G.W. (2005). Weight management. *American Dietetic Association,* (1-22).

Eckhardt, C.L., Adair, L.S., Caballero, B., Avila, J., Kon, I.Y., Wang, J., & Popkin, B.M. (2003). Estimating body fat from anthropometry and isotopic dilution: a four-country comparison. *Obesity Research*, *11*, (1553-1562).

Fields, D.A., & Goran, M.L. (2000). Body composition techniques and the four compartment model in children. *Journal of Applied Physiology*, *89*, (613-620).

Fields, D.A., Goran, M.L., & McCrory, M.A. (2002). Body-composition assessment via air-displacement plethysmography in adults and children: a review. *American Journal of Clinical Nutrition*, *75*, (453-467).

Freedson, P.S. & Miller, K. (2000). Objective monitoring of physical activity using motion sensors and heart rate. *American Alliance for Health, Physical Education, Recreation, and Dance, 71,* (S21-29).

Friedenreich, C.M., Courneya, K.S., & Bryant, H.E. (1998). The lifetime total physical activity questionnaire: development and reliability. *Medicine & Science in Sports & Exercise, 30,* (266-274).

Ginde, S.R., Geliebter, A., Rubiano, F., Silva, A.M., Wang, J., Heshka, S., & Heymsfield, S.B. (2005). Air displacement plethysmography: validation in overweight and obese subjects. *Obesity Research, 13,* (1232-1237).

Goran, M.I. (1998). Measurement issues related to studies of childhood obesity: assessment of body composition, body fat distribution, physical activity, and food intake. *Pediatrics, 101,* (505-518).

Heyward, V.H. (1996). Evaluation of body composition: current issues. *Sports Medicine, 22,* (146-156)

Heyward, V.H. & Wagner, D.R. (2004). *Applied body composition assessment (2nd ed.);* Weight Management; p.33, 58-59; Champaign: Human Kinetics.

Houtkooper, L.B., Going, S.B., Lohman,T.G., Roche, A.F., & Loan, M.V. (1992). Bioelectrical impedance estimation of fat-free body mass in children and youth: A cross validation study. *Journal of Applied Physiology*, *72*, (366-373).

Hu, F.B., Li, T.Y., Colditz, G.A., Willett, W.C., & Manson, J.E. (2003). Television watching and other sedentary behaviors in relation to risk of obesity and type 2 diabetes mellitus in women. *Journal of the American Medical Association, 289,* (1785-1791).

Insel, P.M. & Roth, W.T. (2004). *Core Concepts in Health;* Body Composition Reference Methods, p. 243; New York: McGraw Hill.

Koh-Baneriee, P, Wang, Y., Hu, F.B., Spiegelman, D., Willett, W.C., & Rimm, E.B. (2004). Chanages in body weight and body fat distribution as risk factors for clinical diabetes in U.S. men. *American Journal of Epidemiology, 159(12):*1150-1159.

Le Masurier, G. C., Lee, S. M., & Tudor-Locke, C. (2004). Motion sensor accuracy undercontrolled and free-living conditions. *Medicine and Science in Sports and Exercise, 36,* (905-910).

Lox, C.L., Martin, K.A., & Petruzello, S.J. (2003). *The psychology of exercise: integrating theory into practice.* Scottsdale, Holcomb Hathaway.

Maffiuletti, N.A., Gorelick, M., Kramers-de Quervain, I., Bizzini, M., Munzinger, J.P. Tomasetti, S., & Stacoff, A. (2007). Concurrent validity and intrasession reliability of the

idea accelerometry system for the quantification of spatiotemporal gait parameters. *Gait Posture,* (1-4).

Manson, J.E., Skerrett, P.J., Greenland, P., & VanItallie, T.B. (2004). The escalating pandemics of obesity and sedentary lifestyle: a call to action for clinicians. *Archives of Internal Medicine, 164,* (249-258).

Marcus, B.H., Selby, V.C., Niaura, R.S., & Rossi, J.S. (1992). Self-efficacy and the stages of exercise behavior change. *Research Quarterly for Exercise and Sport, 63,* (60-66).

McKenzie, T.L., Marshall, S.J., Sallis, J.F., & Conway, T.L. (2000). Leisure-time physical activity in school environments: an observational studying using soplay. *Preventive Medicine, 30,* (70-77).

Melanson, E.L. & Freedson, P.S. (1996). Physical activity assessment: A review of methods. *Critical Reviews in Food Science Nutrition, 36,* (385-396).

Metabolic Solutions Inc. *Total body water measurements.* Retrieved April 7, 2006 from: http://www.metsol.com/body_composition.htm

MiniSun (2007). *Ideea overview: a device for analyzing body motion.* Retrieved July 20, 2007 from http://www.minisun.com/IDEEA_Overview.asp

Nicklas, T.A., Baranowski, T., Cullen, K.W., & Berenson, G. (2001). Eating patterns, dietary quality, and obesity. *Journal of the American College of Nutrition, 20,* (599-608).

Omron HealthCare (2007). *Frequently asked questions: for pedometers.* Retrieved July 16, 2007 from http://omronhealthcare.com/enTouchCMS/app/viewCategory?catgId=12&catgFilter=34

Patten, M.L. (2007). *Understanding research methods: An overview of the essentials (6th ed.).* Glendale: Pyrczak Publishing.

Rice, M. H., & Howell, C. C. (2000). Measurement of physical activity, exercise, and physical fitness in children: Issues and concerns. *Journal of Pediatric Nursing, 15,* (148-156).

Segal, R., Evans, W., Johnson, D., Smith, J., Colletta, S., Gayton, J., Woodard, S., Wells, G., & Reid, R. (2001). Structured exercise improves physical functioning in women with stages I and II breast cancer: Results of a randomized controlled trial. *Journal of Clinical Oncology, 19,* (657-665).

Sequeira, M.M., Rickenbach, M., Wietlisbach, V., Tullen, B., & Schutz, Y. (1995). Physical activity assessment using a pedometer and its comparison with a questionnaire in a large population survey. *American Journal of Epidemiology, 142,* (989-999).

Sirard, J.R., & Pate, R.R. (2001). Physical activity assessment in children and adolescents. *Sports Medicine, 31,* (439-454).

Snijder, M.B., Visser, M., Dekker, J.M., Seidell, J.C., Fuerst, T., Tylavsky, F., Cauley, J., Lang, T., Nevitt, M., & Harris, T.B. (2001). The prediction of visceral fat by dual-energy x-ray absorptiometry in the elderly: a comparison with computed tomography and anthropometry. *International Journal of Obesity, 26,* (984-993).

Trost, S. G. (2001). Objective measurement of physical activity in youth: Current issues, future directions. *Exercise and Sport Science Reviews, 29,* (32-36).

Tudor-Locke, C., Ainsworth, B.E., Thompson, R.W., & Matthews, C.E. (2002). Comparison of pedometer and accelerometer measures of free-living physical activity. *Medicine & Science in Sports & Exercise, 34,* (2045-2051).

Tudor-Locke, C.E. & Myers, A.M. (2001)a. Challenges and opportunities for measuring physical activity in sedentary adults. *Sports Medicine, 31,* (91-100).

Tudor-Locke, C.E. & Myers, A.M. (2001)b. Methodological considerations for researchers and practitioners using pedometers to measure physical (ambulatory) activity. *Research Quarterly for Exercise & Sport, 72,* (1-12).

United States Department of Health & Human Services. (2007). *Overweight and obesity: health consequences.* Retrieved July 21, 2007, from http://www.surgeongeneral.gov/topics/obesity/calltoaction/fact_consequences.htm

Wagner, D.R. & Heyward, V.H. (1999). Techniques of body composition assessment: A review of laboratory and field methods. *Research Quarterly for Exercise and Sport, 70,* (135-149).

Welk, G.J., Corbin, C.B., & Dale, D. (2000). Measurement issues in the assessment of physical activity in children. *Research Quarterly for Exercise and Sport, 71,* (59-73).

Wellman, N.S. & Friedberg, B. (2002). Causes and consequences of adult obesity: health, social and economic impacts in the united states. *Asia Pacific Journal of Clinical Nutrition, 11,* (S705-S709).

Wells, C.K., Fewtrell, M.S., Davies, P.S.W., Williams, J.E., Coward, W.A., & Cole T.J. (2005).Prediction of total body water in infants and children. *Archives of Disease in Childhood*, *90*, (965-971).

Wells, J.C., Fuller, N.J., Dewit, O., Fewtrell, M.S., Elia, M., & Cole, T.J. (1999). Four-component model of body composition in children: density and hydration of fat-free mass and comparison with simpler models. *American Journal Clinical Nutrition*, *69*, (904-912).

Weston, A.T., Petosa, R. & Pate, R.R. (1997). Validation of an instrument for measurement of physical activity in youth. *Medicine & Science in Sports & Exercise, 29,* (138-143).

Young, L.R. & Nestle, M. (2002). The contribution of expanding portion sizes to the us obesity epidemic. *American Journal of Public Health, 92,* (246-249).

Zhang, Q. & Wang, Y. (2004). Trends in the association between obesity and socioeconomic status in u.s. adults: 1971 to 2000. *Obesity Research, 12,* (1622-1632).

Zhang, K., Pi-Sunyer, F. X., & Boozer, C. N. (2004). Improving energy expenditure estimation for physical activity. *Medicine and Science in Sports and Exercise, 36,* (883-889).

Zhang, K., Werner, P., Sun, M., Pi-Sunyer, F.X., & Boozer, C.N. (2003). Measurement of human daily physical activity. *Obesity Research, 11,* (33-40).